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MYCOBIOTA OF WINTER WHEAT (*TRITICUM* L.) SEEDS DEPENDING ON PROTECTIVE MEASURES

Spychak Yurii
PhD student
Sumy National Agrarian University, Sumy, Ukraine
ORCID: 0000-0003-2677-0284
yuriispychak@gmail.com

The study aimed to investigate the interaction of winter wheat seed mycobiota with various protective systems, including chemical and organic, to improve winter wheat cultivation technologies. Particular attention was paid to establishing the relationship between the use of protective systems and changes in the seed mycobiota composition that affect wheat quality and yield. The research was conducted during 2022–2023 on two varieties of winter wheat: Aliot and Emil.

Protective measures were taken at different stages of plant development. Pre-sowing treatment was carried out one day before sowing, and spraying was carried out at the stages of growth according to the BBCH scale (Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie): 21–29 (tillering), 37–39 (flag leaf), and 71-77 (milky ripeness). The seed microbiota was analyzed using a biological method with potato glucose agar to detect external and internal infections. For the statistical analysis of the crop data, the Data Analysis tool in Microsoft Excel was used, in particular, the analysis method of variance, which allowed us to determine the influence of various factors on the study's results.

The results of the study showed that the weight of 1000 seeds depended more on varietal characteristics than on the use of protective systems. However, it was found that the composition of the microbiota of winter wheat seeds significantly depends on the type of protection system used. In particular, the chemical protection system had the greatest impact on the microbiota composition. It was found that under the conditions of dominance of the fungus Alternaria tenuissima, the use of protective systems leads to a significant decrease in its number and changes in the composition of the fungal complex. At the same time, a significant spread of Penicillium spp. is associated with a significant slowdown in the growth of winter wheat seedlings and inhibition of other fungal species.

It was also found that there is a moderate to significant correlation between the number of Fusarium oxysporum colonies and the weight of 1000 seeds. This indicates the negative impact of this fungus on seed filling, which is especially intensified under conditions that favor its development, in particular during favorable weather conditions. Based on the results of the study, the importance of controlling F. oxysporum populations to ensure high quality and yield of winter wheat was established. The results emphasize the need for further research to better understand the factors that influence the interaction between microbiota and defense systems, especially in the context of organic farming, which is considered a promising alternative to pesticides.

Key words: *winter wheat, organic protection system, chemical protection system, mycobiota, Fusarium oxysporum.*

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Introduction. The study of the microorganisms influence on plant development is currently attracting significant attention from the scientific community. A key aspect of this issue is the investigation of mycobiota and its interaction with plants, especially considering the use of protection systems. Seeds, as the foundation of the plant life cycle, possess a unique microbiota that determines their resilience, yield, and ability to adapt to environmental changes.

Selecting a protective system for winter wheat ensures high yields and improves crop quality (Spychak & Butenko, 2023). A starting point for addressing this issue is the thorough investigation of seed mycobiota, as it has great potential to influence plant health and productivity.

The aim of the research was to determine the relationship between protection systems and the mycobiota of winter wheat seeds, which offers prospects for improving winter wheat production.

The composition of seed mycobiota includes a variety of fungi that can contaminate agricultural products with mycotoxins. Among such fungi are *Fusarium* sp., *Penicillium* sp., *Aspergillus* sp., *Alternaria* sp., *Cladosporium* sp., *Cochliobolus* sp., and others. It is noted that 20–25% of food crops worldwide contain mycotoxins in their structure. (Eskola et al., 2020)

Research on the mycobiota of winter wheat seeds in Ukraine over recent years has shown that the most commonly isolated and identified genera include *Aspergillus* sp., *Curvularia* sp., *Fusarium* sp., *Nigrospora* sp., *Epicoccum* sp., *Cladosporium* sp., *Stemphylium* sp., *Cochliobolus* sp., *Alternaria* sp., *Phoma* sp., *Mucor* sp., *Penicillium* sp., *Acremoniella* sp., and *Sordaria* sp. A study of 70 wheat grain samples from the 2016 and 2017 harvests collected in different regions of Ukraine revealed that one gram of wheat grain contains between 1.12×10^3 and 6.5×10^4 CFU (colony-forming units), with an average of $3.3\times10^4 \pm 3.2\times10^4$ CFU. Inside the seeds, 11 fungal species were found. The most prevalent were *Alternaria* spp. (67% of samples), *Aspergillus* spp. (37%), and *Phoma exiqua* (30%). Less frequently, fungi from the genera *Fusarium* spp. and *Mucor* spp. were detected (in 19% of samples). (Ostrovsky et al., 2018)

Today, the use of chemical preparations is a crucial element in growing winter wheat under traditional technology. This approach to production enhances plant protection, leading to reduced crop losses and increased production efficiency (Ons et al., 2020). Chemical products have undeniably proven their effectiveness in preventing the spread and development of pathogens such as fungi, bacteria, and other harmful agents that affect the plant during its growing season (Siroshtan et al., 2019; Klipakova & Bilousova, 2018). In study of Zaima O. and Derhachova O. (2019), a correlation was demonstrated between use of various active substances and yield growth during the vegetation period of winter wheat. The application of *Tilt Turbo 575 EC*, *Amistar Trio 255 EC*, and *Vareon 520* contributed to improving grain quality and increasing yields by 0.16–0.75 t/ha (Zaima & Dergacheva, 2019).

According to Shvartau V. (2019) and others, the positive impact of using various fungicides for the control of *Fusarium* head blight is also noted. The use of these substances for pathogen control resulted in 47-59% control effectiveness and an average yield increase of 1.5 t/ha. (Schwartau et al., 2019)

Despite the many positive aspects of pesticide use, there are also negative factors to consider. Seed treatment has a significant impact on laboratory germination, early embryo development, and the subsequent growth of plants. An increase in the number of active substances negatively affects seed germination compared to treatments based on a single active ingredient (Bilousova et al., 2020).

The negative aspects of pesticide use manifest through their impact on ecosystems and human health (Narayanan et al., 2022; Upadhayay et al., 2020). Continuous pesticide use can lead to the development of resistance in harmful organisms, which requires the application of more toxic chemicals (Hawkins et al., 2019). Pesticides pollute soil and water, adversely affecting non-target organisms, including beneficial insects and soil microorganisms (Syafrudin et al., 2021; Wołejko et al., 2020). Additionally, the accumulation of pesticides in food products can cause health issues in humans, such as endocrine disorders and cancer (Liu, Q. et al., 2021). Pesticide emissions into the atmosphere also contribute to air pollution and climate change (Zaller et al., 2022).

As an alternative to pesticide use, organic farming is gaining prominence by offering effective plant protection methods. Organic farming systems meet the key criteria for sustainable production by using significantly fewer resources, such as fertilizers and plant protection agents, while still achieving high-quality wheat yields. In the long term, this contributes to the efficient use of resources and reduces the negative impact on the environment. Organic farming has the potential to make a significant contribution to addressing issues related to the high externalities of conventional agriculture. (Mäder et al., 2007)

With the popularity growth of organic production, Ukrainian scientists are actively searching for and developing of new methods, models, and other means of improvement this direction. For example, researchers have demonstrated high effectiveness of using plant extracts to fight the pathogen of *Alternaria tenuissima*. Specifically, extracts from sage, annual wormwood, and field poppy showed significant fungistatic action, reducing infection levels ranging from 84.3% to 99.5% (on the fifth day of inoculation). These results indicate the potential importance of plant extracts in modern strategies of plant disease control. (Shevchuk et al., 2021)

Scientists recommend to elaborate systems that combine different agents and implement advanced achievements, for enhancing effectiveness in various crop rotations and winter wheat protection systems. This approach has the potential to increase winter wheat yield, expand the application area of these technologies, and reduce the need of pesticides. (Zayets et al., 2020; Chugrii, 2020)

Materials and methods. The research was conducted during 2022-2023 years with two varieties of winter wheat: Aliot and Emil (State Register of Plant Varieties Suitable for Distribution in Ukraine, 2023). The experiment was carried out at the educational-scientific-production complex of Sumy National Agrarian University (SNAU), located in the North-Eastern Forest-Steppe of Ukraine.

The trial plot area was 216 m², and the soil was typical deep medium-humus black soil. The plot arrangement was sequential. There were six variants, with three replications. It was used seed-driller Klen -1.5C for sowing. Spraying was carried out with an OP-2.0 LUX sprayer.

The fieldwork part of the experiment was conducted according to Yeshchenko, V. (Yeshchenko et al., 2005). Experiment conditions: 1. Sowing term: late September−mid-October (depending on weather); 2. Protective measures. Pre-sowing treatment was done the day before sowing. Spraying (on the spike of plant) was carried out in phases according to the BBCH scale: 21–29, 37–39, 71–77. The preparations used in the experiment are presented in Table 1. 3. Fertilization was done in spring after the physical maturity of the soil (application in rows).

The analysis of the mycobiota was carried out using a biological method with potato-glucose agar to assess both external and internal infections (Zhukova et al., 2023). For each variant, 100 seeds were randomly selected. The analyzing procedure of seeds included the following steps: 1. plating on potato-glucose agar (PGA); seeds were placed on Petri dishes with medium. Each seed was spaced to avoid contact with others, ensuring individual growth and identification of colonies; 2. incubation – the Petri dishes were incubated at 22-25°C for 7 days in the dark to promote fungal growth. Regular observations were made to assess the development of fungal colonies; 3. identification of fungal species; after incubation period, the emerging fungal colonies were examined and identified based on their morphological characteristics. Identification was carried out with microscope and reference guides for fungal taxonomy.

During 2021-2022 growing season of winter wheat, weather conditions were characterized by a relatively mild autumn and cold winter. In the autumn period of 2021, the average temperature gradually decreased from September to November, creating favorable conditions for the initial development of plants. A moderate amount of rainfall in the autumn (44.80 mm in September and 48.70 mm in November) provided sufficient soil moisture, promoting good root establishment. The winter months of 2021-2022 were relatively cold, with minimum temperatures lowing to -7.58°C in January, but with significant snow cover (up to 1476 mm). In spring of 2022, temperatures gradually rose,

Table 1

Experimental design

Variant	Preparations	Treatment method
Control	Spraying with pure water	Seed soaking in water and spraying
Chemical system	1. Fungicides: a. Maxim 025 FS, TH (fludioxonil 25 g/l); b. Aviator Xpro 225 EC, KE (prothioconazole 150 g/l, Bixafen 75 g/l); 2. Herbicides: Granstar Gold 75, WG (tribenuron-methyl 750 g/kg, Thifensulfuron-methyl 187.5 g/kg); 3. Insecticides: Fas, KS (alpha-cypermethrin 100 g/l); 4. Fertilizer: ammonium nitrate	Seed treatment, fertilization, spraying
Organic system	Mulching, 20% garlic solution	Seed treatment, spraying

and the amount of rainfall, particularly in April (66.20 mm), provided sufficient moisture for plants to actively growth resume.

During 2022–2023 growing season, favorable conditions for the initial development of winter wheat were fixed in autumn. The average temperature in September was moderate (11.77°C), and the rainfall (106.60 mm) ensured good level of soil moisture. The winter of 2022-2023 was milder compare with previous year, with less snow cover, but minimum temperatures of -6.08°C in February, reducing the risk of crop freezing. Spring of 2023 was warmer, and the amount of rainfall in April (63.40 mm) and May (10 mm) was sufficient to support active plant growth in the final stages of plant development, contributing to better conditions for yield formation.

Statistical data processing on yield was done with Microsoft Excel's "Data Analysis" tool, utilizing the analysis of variance method (Tsarenko et al., 2000).

Results. Studying the impact of protection systems on plants and their interaction is a crucial factor in agronomy. Analyzing the influence of different systems on mycobiota composition needs consideration of a large seed number, as the application of protection systems affects plant productivity directly (stress on plants during the application of chemical agents) and indirectly (protection against pathogens). The results of measuring the weight of 1000 seeds for two years are presented in Table 2.

The analysis of the results showed that the protection systems had a more significant impact on the weight of 1000 seeds than the year conditions. In 2023, there was a significant increase in the weight of 1000 seeds by 18.5% compared to 2022. Data analysis for 2022 showed a negative impact of protection systems on the weight of 1000 seeds. For the Aliot variety, the difference between the control and organic systems was 8.5%, and with chemical protection, it was 20.7%. For the Emil variety, the difference was 3.6% between the control and chemical systems, but there was an increase in seed weight by 6.8% in the organic one. Based on the data of 2022, it is not possible to confirm a relationship between the application of protection systems and the weight of 1000 seeds weight.

As the result of data processing for 2023 year ambiguous results were got. For Emil variety indicators growth were determined, by 7.5% in particular, in variant with chemical protection, while deviations from the control were insignificant: less than 1%, in the organic system. Conversely, for Aliot variety increasing of 1000 seed weight was fixed in protection systems: 8.7% for organic and 13.2% for chemical systems.

During the 2021-2022 growing season, a relatively cold winter and moderate spring precipitation may have caused the negative impact of protection system on 1000 seed weight. Low temperatures and different levels of humidity could create additional stress for plants, especially in combination with the use of chemicals. In contrast, the 2022-2023 growing season was characterized by a milder winter and warmer spring with favorable moisture conditions, which likely contributed to seed weight growth. More favorable weather conditions of 2023, especially for critical stages of plant growth may have decreased

Table 2

The influence of protection system on the weight of 1000 seeds

Variety	Variant	Weight of 1000 seeds, g	
		2022	2023
Aliot	Control	49.72	50.77
	Organic system	45.48	55.63
	Chemical system	39.45	58.50
$LSD_{0.5}$		0.06	
Emil	Control	41.34	49.49
	Organic system	44.24	49.42
	Chemical system	39.84	45.81
$LSD_{0.5}$		0.07	

the stress caused by protection systems, and promote in productivity increasing.

Determination the mycobiota of winter wheat seeds (2022-2023 harvest) was done. The following fungi species were identified: *Fusarium oxysporum, Fusarium oxysporum* (with pink mycelium) (Fig. 1b), *Fusarium sporotrichoides, Alternaria tenuissima* (Fig. 1a, b), *Alternaria infectoria, Penicillium spp.* (Fig. 1c), *Mucor spp., Monilia sitophila, Curvularia spp., Aspergillus oryzae, Cladosporium spp., Aureobasidium pullulans, Arthrinium arundinis, Humicola spp., Trichoderma spp.*

The results of the mycobiota analysis are presented in Table 3 and Table 4. The percentage of colonies and the average number of colonies for 2022-2023 were showed.

Certain tendencies can be noted in distribution of genera/species of fungi on the winter wheat varieties of Aliot and Emil. In 2023, the Aliot variety demonstrated a significant increase in the percentage of *A. tenuissima* colonies till 83.05%, the highest number among all species. This indicates that favorable conditions have been formed for the development of the fungus. At the same time, there was a decrease in the percentage of *Penicillium spp.* colonies to 1.69%, which may indicate an improvement in the variety's resistance of this species.

In contrast, the Emil variety decreased the percentage of *A. tenuissima* colonies from 73.9% in 2022 to 71.79% in 2023, which may indicate the variety stability in conditions unfavorable for development of this fungal species. However, the increase in the percentage of other colonies from 4.08% to 8.33% may point to increase in the biodiversity of micromycetes on this variety. It will be positive and

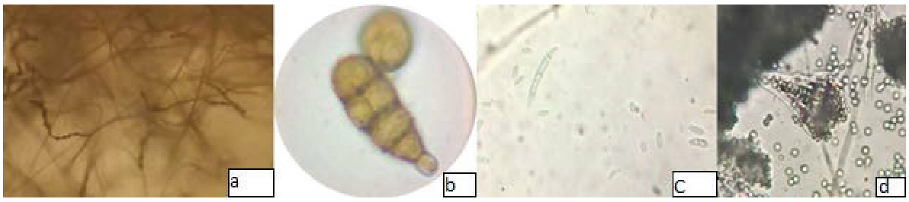

Fig. 1. a, b – *A. tenuissima*; c – *F. oxysporum* (with pink mycelium); d – *Penicillium* spp. (Photo by Spychak Y.)

Table 3

Percentage of the total and average colony number on the seeds of Aliot variety

Variant	**Percentage of the total number of colonies, %**		
	Genera/species	**2022**	**2023**
Control	*F. oxysporum* (pink mycelium)	5.5	3.03
	A. tenuissima	69.6	78.8
	Penicillium spp.	8.4	1.21
	F. oxysporum	10.5	4.85
	M. sitophila	5.9	-
	A. pullulans	-	0.61
	Mucor spp.	-	0.61
	Other colonies	-	10.91
Organic system	*F. oxysporum* (pink mycelium)	6	1.32
	A. tenuissima	64	70.4
	Penicillium spp.	20.5	12.5
	F. oxysporum	7	3.29
	Curvularia spp.	0.5	-
	A. pullulans	-	1.32
	A. infectoria	-	1.32
	Mucor spp.	-	2.63
	Other colonies	2	6.85
Chemical system	*F. oxysporum* (pink mycelium)	7.4	3.95
	A. tenuissima	57.6	83.05
	Penicillium spp.	10.6	1.69
	F. oxysporum	7.4	1.69
	F. sporotrichoides	9.2	-
	Aspergillus oryzae	0.9	-
	A. arundinis	-	0.56
	Mucor spp.	-	0.56
	Trichodérma spp.	-	0.56
	Other colonies	6	7.91
$LSD_{0.05}$ for *A. tenuissima*		0.55	0.3

Table 4

Percentage of total and average colony number on the seeds of Emil variety

Variant	Percentage of the total number of colonies, %		
	Genera/species	**2022**	**2023**
Control	*F. oxysporum* (pink mycelium)	11.6	0.64
	A. tenuissima	73.9	71.79
	Penicillium spp.	1.6	1.92
	F. oxysporum	6.4	7.05
	Mucor spp.	0.4	4.49
	A. oryzae	1.2	-
	A. pullulans	-	0.61
	A. infectoria	-	1.28
	A. arundinis	-	0.64
	Trichodérma spp.	-	3.21
	Other colonies	4.08	8.33
Organic system	*Fusarium oxysporum* (pink mycelium)	11.5	10.76
	A. tenuissima	72.5	63.29
	Penicillium spp.	3.5	5.7
	F. oxysporum	7	6.33
	Mucor spp.	0.5	1.9
	A. oryzae	2	-
	A. infectoria	-	3.16
	Trichodérma spp.	-	2.53
	Other colonies	0.5	6.33
Chemical system	*F. oxysporum* (pink mycelium)	12.7	4.83
	A. tenuissima	32.7	79.31
	Penicillium spp.	39.6	0.69
	F. oxysporum	1.9	2.07
	Mucor spp.	0.8	2.07
	F. sporotrichoides	3.1	-
	Humicola spp.	-	0.69
	Trichodérma spp.	-	0.69
	Other colonies	-	9.66
$LSD_{0.05}$ for *A. tenuissima*		0.72	0.67

negative for yield and its quality. Overall, both varieties demonstrate different response to micromycetes colonization, which could be important to select variety depending on specific growing conditions.

For both years, the dominant characteristic was the prevalence of *A. tenuissima*. In protection systems positive results in reducing the overall species number were noted, although the organic system was less effective than the chemical one.

The comparison of research years revealed that the effects of the protection systems on the microbiota varied significantly. In 2022, with the decrease of *A. tenuissima* in protection system variant, there was a noticeable increase of *Penicillium spp.*, especially in the variant with chemical protection. In 2023, the dominant species was *A. tenuissima* as well, but its total number was lower compare with previous year, with a particularly obvious reduction in organic system. Increase in the dominant species was observed in the chemical protection system, which, in turn, reduced the number of other species, besides *F. oxysporum.*

Plant shoot growth was suppressed by severe infection of *Penicillium spp.* compared to the control. The average length of severely damaged shoots by *Penicillium* spp. were 0.9 cm, whereas, in control samples, it was 2.7 cm. This indicates that the presence of *Penicillium spp.* adversely affected the early growth of winter wheat and delayed its development. Other species were virtually absent or grow very slowly because of abundant presence of *Penicillium* spp. It may be result of competition between species for nutrients, and where there is strong dominance, other species cannot develop under normal conditions.

Additionally, it should be noted that protection systems leading to decrease in the total number species, contributes to the emergence of new pathogen and increase in existing ones. Such dynamics can be observed in both years, as protection systems disrupt the balance of microbiota around plants, diminishing the dominance of certain species and creating more favorable conditions for the emergence and propagation of others. This, in turn, fosters the spread of new pathogens and exacerbates existing ones. In organic protection system, species such as *Curvularia spp.* was revealed in 2022, and *Cladosporium* spp., *Alternaria infectoria* – in 2023. With traditional protection technology *F. sambucinum* was fixed in 2022 and *Humicola spp.* – in 2023.

F. oxysporum is one of the widespread phytopathogenic fungi causing diseases of many plant species, including winter wheat. Its ability to induce seedling blight is particularly problematic because of great impact on quality and yield of crops. Calculations were conducted to establish the relationship between the number of fungal colonies and seed weight to better understand the influence of *F. oxysporum* on this indicator of winter wheat. The Pearson correlation coefficient was used complete this task, The obtained data are presented in Table 5.

On the base analysis it was found that most correlation coefficients exceed 0.5, except for the cases with the use of organic protection. system in 2022.This result indicates a moderate/strong positive linear relationship between the colony number of *F. oxysporum* and the 1000 seed weight, suggesting a negative impact of the fungus on the quality of winter wheat seeds. However, in the variant of organic protection, a less significant relationship between the quantity of *F. oxysporum* and the seed weight was observed, which may indicate a lesser impact of the fungus in organic farming system.

The obtained data confirm the importance of controlling the population of *F. oxysporum* to ensure high quality and yield of winter wheat. Further research is needed to understand the factors influencing this relationship, especially in organic farming systems.

It is also important to analyze the weather conditions for better understanding of reasons for increase of *F. oxysporum* in winter wheat seeds. During the period of possible seed contamination – the flowering-heading stage of winter wheat – favorable weather conditions were observed. Moisture was at optimal level, reaching 64% in 2022 and 67% in 2023, while the amount of precipitation was sufficient for fungi development and propagation: to 89.6 mm in 2022 and 110.9 mm in 2023.

Discussion. Today, the development of more effective strategies for fungal disease protection has become especially important. The need for new approaches has become critical, as they can ensure the resilience of winter wheat and increase its yield.

In the studies of Rozhkova et al. (2021) of 2018-2020 it was found that the use of fungicides has a significant effect on the microflora of wheat seeds. This impact was noticeable both in the quantitative indicators of species and genera of fungi, as well as in the overall composition of microorganisms. Spraying with fungicides affected the mycocomplex, reducing the number of dominant *Alternaria* fungi compared to biological preparations. Regarding the mass of 1000 seeds, there was a tendency for increasing it under influence of fungicides, (except 2018), when the presence of fungi of the genus Mucor was observed in the seed microflora. (Rozhkova & Spychak, 2021) The data coincide previous results, except for the 1000 seed weight in the Emil variety, in protection system.

Studying aqueous extracts of *Allium* genus revealed the significant effect on the development of fungal which were common mycoflora representatives of winter wheat seeds. The results confirm that treating seeds with aqueous extracts of *A. sativum* (10% and 20% solutions) is an effective method to prevent the development of dangerous mycoflora species and promote the stimulation of seedling growth. It is worth noting that the 20% solution completely inhibits the development of *F. poae*. (T. Rozhkova, 2020)

Our studies confirm the effectiveness of *Allium* extract in a biological system. We observed reduction in the dominant fungus *A. tenuissima* and other species, including *F. oxysporum* and *Penicillium* spp.

Under traditional cultivation technology, a significant number of conidia were observed, reaching 2.9 million units per milliliter. This contributes to the rapid spread of *F. oxysporum* in winter wheat agrocenoses and increases the level of biological contamination. (Beznosko et al. 2023) Our research also revealed that the use of traditional technology led to an increase of *F. oxysporum*.

In study of Rozhkova (2022), it was found that presence of *Fusarium* genus negatively affects the germination and development of winter wheat plants. The presence of these fungi resulted in a reduction of seedling length, loss of growth activity, and the formation of necrotic areas. The roots were also characterized by stunted growth and necrosis, which prevented normal plant development. Some species, particularly *F. poae and F. sporotrichioides*, could progress without visible symptoms, but *F. poae* had a significant impact, reducing the average seedling length by 51.3%. (Rozhkova, 2022)

In our study, the relationship between the number of *F. oxysporum* colonies and the 1000 seeds weight was analyzed. The results showed that there is a moderate to strong linear correlation between these indicators, confirming the negative impact of this pathogen on the quality of winter wheat seeds.

In the study of scientists from Henan University of Technology and the School of Resources, Environmental and Chemical Engineering, it is noted that with an increase

Table 5

The impact of *F. oxysporum* on the 1000 seed weight

Variety	Variant	Correlation coefficient	
		2022 year	2023 year
Aliot	Control	0.73	0.52
	Organic system	-0.02	0.65
	Chemical system	0.6	-0.74
Emil	Control	-0.52	0.68
	Organic system	0.2	-0.64
	Chemical system	0.54	-0.63

number of mold fungi, including *Penicillium spp.,* and high level of moisture, the microstructure of the endosperm and embryo of wheat seeds is disrupted, which in turn leads to impaired growth and development. (Ruolan, et al. 2020) The inhibition of other species is also noted in the study of Prange A. et al. (2005). Their research highlights that for the 12th week of wheat grain storage, the number of *Penicillium spp*. colonies increase by 72%, while other colonies hardly develop. (Prange, et al. 2005)

Data obtained from the research results of various scientific groups coincide with our conclusions regarding the impact of *Penicillium* spp. on wheat shoot growth, which manifested in its significant retardation.

Conclusions. It was found the 1000 seeds weight was determined by varietal characteristics more than the use of protection systems. The seed mycobiota of winter wheat depends on the protection system. The chemical protection system made the most significant impact. In the case of the dominance of a single species of *A. tenuissima*, the application of protection systems leads to its significant reduction and changes in the composition of the fungal complex. Significant spread of *Penicillium spp.* leads to a significant slowing down of seedling growth and suppression of other species. In most cases, there is a moderate or significant correlation between the number of colonies of the fungus *F. oxysporum* and the mass of 1000 seeds of winter wheat, indicating a negative impact of this fungus on seed fill. The weather conditions during the study positively affected the development *of F. oxysporum.*

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Спичак Ю. І., *аспірант, Сумський національний аграрний університету, м. Суми, Україна*

Мікобіота насіння озимої пшениці (Triticum L.) залежно від заходів захисту

Метою дослідження було вивчення взаємодії мікобіоти насіння озимої пшениці з різними захисними системами, зокрема хімічними та органічними, для вдосконалення технологій вирощування пшениці озимої. Особливу увагу приділено встановленню залежностей між використанням захисних систем та змінами в складі мікобіоти насіння, що впливають на якість і врожайність пшениці. Дослідження проводилося протягом 2022–2023 років на двох сортах озимої пшениці: Aliot та Emil.

Захисні заходи здійснювалися на різних етапах розвитку рослин. Передпосівна обробка проводилася за один день до сівби, а обприскування виконувалося на етапах росту за шкалою BBCH (Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie): 21–29 (кущіння), 37–39 (прапорцевий листок), та 71–77 (молочна стиглість). Мікробіота насіння аналізувалася за допомогою біологічного методу із використанням картопляно-глюкозного агару для виявлення як зовнішніх, так і внутрішніх інфекцій. Для статистичного аналізу даних врожаю застосовувався інструмент "Аналіз даних" в Microsoft Excel, зокрема метод дисперсійного аналізу, що дозволив визначити вплив різних факторів на результати дослідження.

Результати дослідження показали, що маса 1000 насінин значною мірою залежала від сортових характеристик, ніж від застосування захисних систем. Однак було виявлено, що склад мікробіоти насіння озимої пшениці значно залежить від типу захисної системи, яка використовується. Зокрема, хімічна система захисту мала найбільший вплив на склад мікробіоти. Було встановлено, що за умов домінування гриба Alternaria tenuissima застосування захисних систем призводить до значного зменшення його чисельності та змін у складі грибкового комплексу. Водночас, значне поширення Penicillium spp. асоціюється зі значним уповільненням росту сіянців озимої пшениці та пригніченням інших видів грибів.

Також було виявлено, що існує помірна або значна кореляція між кількістю колоній гриба Fusarium oxysporum та масою 1000 насінин озимої пшениці. Це свідчить про негативний вплив цього гриба на наповнення насіння, що особливо посилюється в умовах, які сприяють його розвитку, зокрема під час сприятливих погодних умов. Виходячи з результатів дослідження, встановлено важливість контролю за популяціями F. oxysporum для *забезпечення високої якості та врожайності озимої пшениці. Результати підкреслюють необхідність подальших досліджень для кращого розуміння факторів, які впливають на взаємодію мікробіоти та захисних систем, особливо в контексті органічного землеробства, яке розглядається як перспективна альтернатива пестицидам.*

Ключові слова: *озима пшениця, органічна система захисту, хімічна система захисту, мікобіота, Fusarium oxysporum.*