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Resistance of the soft winter wheat varieties to pests and their productivity in the northern forest-steppe zone

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Abstract. There are highlighted the results of research in order to determine the field and laboratory resistance of the winter wheat varieties in a competitive variety testing at the National Scientific Centre Institute of Agriculture of NAAS (2016–2020) against pests, and the level of their productivity is assessed. Among the studied varieties of winter wheat, varieties with complex resistance were found: to cereal aphids, wheat thrips powdery mildew and brown leaf rust - variety *Efektna*; to cereal aphids, wheat thrips and leaf rust - varieties *Polisianka, Pyriatynka, Krasunia Poliska, Vodohrai, Kesariia Poliska, Myroliubna, Romanivna, Pamiati Hirka*, and standard *Lisova Pisnia St.* When varieties were grown without the use of fungicides, insecticides and growth regulators, their yield varied over the years from 2.99 t ha^{-1} to 10.71 t ha^{-1}. The best varieties of soft winter wheat in terms of their productivity were identified in the northern Forest - Steppe zone, which are included in the State Register of the plant varieties, suitable for distribution in Ukraine - *Kesariia Poliska* (7.67 t ha^{-1}), *Pyriatynka* (7.10 t ha^{-1}), *Myroliubna* (7.08 t ha^{-1}), *Merezhka* (6.77 t ha^{-1}), Kraeivyd (6.71 t ha^{-1}), *Pamiati Hirka* (6.61 t ha^{-1}), *Polisianka* (6.51 t ha^{-1}) and *Efektna* (6.36 t ha^{-1}). Consequently, with proper selection of the winter wheat varieties, it is possible to significantly limit the harmfulness of pests and diseases, to reduce the amount of the used pesticides, to increase the grain productivity, and to improve its commercial and seed quality.

Key words: allelic state of a gene, diseases, pests, productivity, resistant varieties, winter wheat.

INTRODUCTION

Wheat is the main food crop, which plays the leading role. As the demand for grain increases year on year, it is vital to increase its productivity (MAPU, 2022).

Stable specialization has developed in the world's grain market: the grain production is concentrated mainly in the developed countries of the world, while the developing countries are often unable to solve their grain problems; in the countries where the population is such that they are not able to satisfy the domestic demand, using only their own potential, and grain is imported.

The main consumers of the Ukrainian wheat are Asian countries (China, Israel, Thailand), North Africa (Egypt, Tunisia, Morocco), the EU (Spain, Netherlands, Italy).

The Ukrainian agricultural market feeds not only Ukraine's 40 million population, but also 190 countries around the world, while the trend towards increasing the production volumes remains. Ukraine has strong potential for the production growth, and there is dynamically growing demand in the world markets (Borukh, 2019).

In 2023, 22.4 million tons of wheat were harvested in Ukraine. with an average yield of 4.76 t ha^{-1}. This year's harvest exceeded the last year by 1,679 thousand tons (Superagronom, 2023).

The main limiting factor for the implementation of the potential productivity of varieties and hybrids is the leading role, played by harmful organisms (pests and diseases). The losses of the yield due to them, on average, according to FAO data, amount to 34%. In the years of outbreaks of phytophagous reproduction and epiphytotic development of pathogens they reached 50%, or more. It is known that in Ukraine the incomplete annual crop yields because of the harmful pathogens and pests make 12–14%, which is equal to the cost of the winter wheat grain from an area of 1 million hectares (Murashko et al., 2021; Murashko et al., 2022; Morgun et al., 2022).

Analysis of the phytosanitary condition of agricultural crops in recent years indicates its catastrophic aggravation. This situation is largely due to the fact that the well - functioning plant protection system is disrupted and is mostly of episodic nature. This has also been caused by recent weather and climate changes. Intense climate warming in Ukraine has been clearly visible since 1988, and is more noticeable in the winter months. Temperatures increase uniformly during the summer months. Over 100 years of meteorological observations, the warmest was the last decade, when the average annual air temperature exceeded the annual norm by 0.8 to 2.1 °C. The average annual air temperature in the Forest - Steppe has increased by 0.7 °C over the past 15 years. Based on agricultural monitoring, indicators of the numbers and distribution of pests and diseases affecting agricultural crops have consistently increased year on year (Kalenska et al., 2019; Kovalyshina et al., 2020; Murashko et al., 2022).

To reduce losses of the crop and to increase gross grain yields, varieties with complex resistance against pests should be more intensively introduced into production (Trybel, 2004).

Selection for complex resistance of varieties to pests is one of the most promising, environmentally safe and economically profitable ways to improve integrated systems for the protection of field crops (Mukha et al., 2020). To date the share of the variety in the growth of wheat ranges from30 to 70%. Introduction into production of varieties with group resistance against diseases is equivalent to an increase in the sown areas by15–20% (Mukha et al., 2020). With a complete transition to the use of pest - resistant varieties of the grain crops, the increase in the yield will correspond to an increase in the sown areas by 20–25%.

Therefore, selection for the immunity of agricultural plants to harmful organisms should become the basis of integrated plant protection (Fedorenko, 2014). This will significantly facilitate the technology of growing the grain crops by avoiding additional costs for the plant protection products, increasing their productivity by 0.7–1.0 t ha^{-1}, and will improve the commercial quality of grain. Contemporary varieties of the intensive type are characterized by increased productivity and high quality, but often they do not have field resistance to diseases, which leads to the accumulation of pathogens in agrobiocenoses, and with prolonged use of one variety for more than 7 years, the racial composition of pathogens and their virulence changes, i.e., the level of their resistance. Therefore, in addition to breeding varieties with complex resistance, one should also monitor their impact on the state of pest populations and promptly carry out variety replacement. In addition, the process of selection for resistance must be continuous, and the duration of using a resistant variety and its cultivation must be comprehensively justified (Retman, 2013). The creation and introduction into production of the winter wheat varieties with complex resistance against diseases and pests, high productivity at the present stage and in the future will be of great relevance and significance.

The purpose of research to identify the winter wheat varieties that are resistant to the most common and dangerous types of pests and pathogens and evaluate their productivity in the northern Forest - Steppe zone of Ukraine.

MATERIALS AND METHODS

An assessment of the field resistance of 17 varieties of winter wheat to pests and diseases was made in 2016–2020 in the zone of the northern Forest - Steppe of Ukraine, at the competitive variety testing department of the selection and seed production of the grain crops by the department of plant protection from pests and diseases of the NSC ‘Institute of Agriculture’ in Kyiv Region in partnership with the Latvia University of Life Sciences and Technologies. The originator of the varieties *Kraeivyd, Pamiati Hirka, Kesariia Poliska, Romanivna, Myroliubna, Vodohrai, Spivanka Poliska, Prestyzhna, Rusiava, Krasunia Poliska, Mokosha, Pyriatynka, Efektna NSC* is the ‘Institute of Agriculture of NAAN’; *Namysto, Polisianka, Merezhka NSC* ‘Institute of Agriculture NAAS’ and Cherkassy State Agricultural Academy NSC ‘Institute of Agriculture NAAS’.

The varieties were sown on typical chernozems in 2016, 2017, 2019, 2020 and in gray podzolized soil - in 2018. The area of the accounting plot is 10 m^2, quadruple repetition. Soil cultivation included disking, ploughing, followed by cultivation. The fertilization system and crop care were at the level of energy - saving and resource - saving technologies. In particular, 30 kg ha^{-1} nitrogen, 30 kg ha^{-1} phosphorus and 30 kg ha^{-1} potassium were added for the main treatment, and 30 kg ha^{-1} nitrogen for spring feeding of crops. Sowing was carried out during the period (September 25 – October 7) with mandatory pre- sowing treatment against diseases with Vitavax 200 FF. The productivity, resistance and disease susceptibility were assessed using the winter wheat standard *Lisova Pisnia St*. Accounts and observations of the complex of harmful organisms made according to generally accepted methods of entomological and phytopathological research: visual inspection of the accounting plots - a method of collecting the plant samples (Mukha et al., 2020). Determination of the varietal resistance against diseases and damage by the dominant species of winter wheat phytophages was performed according to methods, indicated in the manual (Trybel et al., 2010; Kovalishyna, 2014).

The statistical processing of the data obtained was carried out in accordance with the methodology used in previous studies (Topchyi, 2009; Trybel et al., 2010).

In addition to the field studies, PCR analysis was performed under laboratory conditions, using GenPak® PCR Core kits according to the recommendations. The results of the PCR analysis were visualized by electrophoresis in a 2.0–2.5% agarose gel with 1 × TBE buffer and staining with ethidium bromide TM. The markers of the molecular mass were GeneRuler 50 bp DNA Ladder ready - to - use (the Fermentas company).

RESULTS AND DISCUSSION

One of the ways how to enhance the biological factor in the plant protection systems is the selection and use of varieties that exhibit resistance to the most common and dangerous types of harmful organisms. Application of resistant varieties is the most cost-efficient and radical means of controlling most diseases and pests of winter wheat. The advantages of using resistant varieties are obvious.

Under field conditions the soft winter wheat varieties were assessed for resistance against the main phytophages (cereal aphids and wheat thrips) and pathogens (powdery mildew and leaf rust).

Differentiation of the winter wheat varieties, based on the presence and number of phytophages on plants, was carried out in the milky ripeness phase when the number reaches its maximum. Field assessment of the resistance of varieties against cereal aphids and wheat thrips occurs through antixenosis (avoidance of plants by phytophages when trying to use them for nutrition or laying eggs) and elimination (divergence of vulnerable phases of crop development from the harmful phase of the phytophage); antixenosis can be partially overcome (Topchyi, 2014; Kyrychenko et al., 2021).

The most numerous and harmful species in Ukraine that damage the above - ground organs of winter wheat are the large cereal aphid (*Sitobion avenae* F.), the common cereal aphid (*Schizaphis graminum Rond.*) and the bird cherry - cereal aphid (*Rhopalosiphum padi* L.) from the aphid family. At the beginning of the growing season aphids feed and reproduce on the leaves; later winged female migrants fly from the leaves of cereals to the ears in the flowering - filling phases of the grains, where they can form numerous colonies. Mass reproduction of aphids in the milky ripeness phase leads mainly to stunting and a decrease in the grain weight, as a result of which the crop productivity actually decreases by 5–10%.

In the zone of the northern Forest- Steppe the dominant species of cereal aphids was the large cereal aphid (*Sitobion avenae* F.), the share of which was 60%, the share of the common cereal aphid (*Schizaphis graminum Rond.*) and the bird cherry - grass aphid (*Rhopalosiphum padi* L.) was 3–4 of the dominant kind.

According to the results of a field evaluation of the winter wheat varieties, the highest abundance of the phytophage was noted in the milky ripeness phase of the grain. On average, over the years of research the population of the crop plants did not exceed 2–10% (this indicator shows the attractiveness of the variety for winged females), and reached from 0.3 to 6.2 specimens/spike (the indicator is the result of the level of female fertility, the survival of larvae, which indicates the feeding suitability). The evaluation of the winter wheat varieties against cereal aphids was made according to the scale, given in Table 1.

Table 1. Scale for field evaluation of the resistance of the wheat varieties against large cereal aphids (Fedorenko, 2014)

Plant population			Sustainability
Degree	Distinctive mark	Score	Degree
Absent and hardly noticeable	Infested single ears < 5%	9–8	High sustainability
Weak	Poorly infested 5–20% of ears	7–6	Sustainable
Medium	Infested 21–50%	5–4	Medium sustainability
Strong	Heavily populated 51–70% of ears	3–2	Weak sustainability
Very strong	Heavily populated all the ears	1	No sustainability

The results of the performed investigations indicate that the least attractive for population and highly resistant in accordance with the scale, where the degree of habitation of plants by aphids is barely noticeable (resistance score 9–8), are the following varieties. *Spivanka Poliska*, *Kesariia Poliska*, *Myroliubna*, *Krasunia Poliska*, *Pamiati Hirka*, *Polisianka*, *Rusiava*, *Prestyzhna*, *Pyriatynka*, *Efektna*, *Mokosha* and standard *Lisova Pisnia, St*. Among the resistant varieties (resistance score 7–6) against aphids were found: *Vodohrai*, *Namysto*, *Merezhka*, their number was 1–5 specimens/ear. The highest number of 6.2 specimens/ear was on the *Kraeivyd* variety, the degree of population was weak, 5–10% of ears.

A common species in the winter wheat crops is wheat thrips - Haplothrips tritici Kurjumov (phleothrips family - *Phloeothripidae*, ciliated family - *Thysanoptera*). Adult thrips appear in the tube phase - at the beginning of earing of the winter cereals (from late April to early May) and are concentrated in the sheaths of the leaves, closest to the ear. At the stage of milky ripeness of grains, the larvae penetrate under the shell and suck out reserve nutrients from the grains. Damage to the grain by thrips causes deterioration in the sowing properties of the seeds (Fedorenko et al., 2013).

Resistance of the varieties against wheat thrips was assessed by the infestment of the plants with larvae in specimens/ear, when they acquire a scarlet colour. The resistance of the winter wheat varieties against wheat thrips was assessed according to the scale given in Table 2.

Table 2. Modified scale for evaluation of the resistance of the winter wheat varieties against wheat thrips (Retman, 2013)

Intensity	Population of wheat thrips larvae		Sustainability	
	pieces/ear	degree	score	degree
1	< 20	Weak	8–9	High sustainability
2–3	20–40	Moderately weak	7–6	Sustainable
4–5	41–60	Medium	5–4	Medium sustainability
6–7	61–80	Heavy	3–2	Weak sustainability
8–9	> 80	Heavily populated	1	No sustainability

The background number of the phytophage in the field conditions was low, this was affected by abiotic factors, morphological characteristics of the ear and ripeness of the variety; therefore all varieties were highly resistant with 8–9 scores.

On average, over the years of research, the grain damage by the wheat thrips larvae was at the level of 10–20% with a larval density of 0.9–10.4 specim./ear. According to the results of the field evaluation, among the studied varieties, the early ripening variety

Romanovna (0.9 specim./ear) was least infected by the phytophage larvae. Among the mid- season group of varieties *Kesariia Poliska*, *Pamiati Hirka*, *Polisianka*, *Krasunia Poliska*, *Mokosha, Pyriatynka*, *Myroliubna*, *Merezhka* and the standard *Lisova Pisnia St*, the density of wheat thrips larvae was 0.9–5.0 specim./ear. On the other varieties *Kraeivyd*, *Vodohrai*, *Spivanka Poliska*, *Rusiava*, *Prestyzhna* and *Namysto* the phytophage density was in the range of 5.5–8.2 specim./ear. The highest density of 10.4 specim./ear was noted on the variety *Efektna*.

Abiotic factors significantly influenced the restriction of the development of aphids and thrips; with HTC < 0.9 and HTC > 2.5, the number and harmfulness of phytophages sharply decreased during the period of tubing - milky ripeness of the grain. Excessive amount of moisture in the form of torrential rains restrained the number of phytophages (Kyrychenko et al., 2021).

Under field conditions the winter soft wheat varieties were assessed for resistance against two main diseases: powdery mildew and brown leaf rust. The indicators of the damage, caused by diseases are reflected during the period of the highest disease development.

One of the most common diseases of the winter wheat in the northern Forest - Steppe zone is powdery mildew - *Blumeria graminis (DC) Speer. (BLUMGR)*. The pathogen has a fairly short development cycle, and it forms the first generation of spores within 7 days, under favourable weather conditions, mass destruction occurs very quickly. It looks impressive when the entire above - ground part of the plant gets covered with a white cobweb - like coating. Later it thickens and acquires a mealy appearance, forming cotton wool - like pads. The pathogen passes winter on winter crops and the plant residues. The harm of powdery mildew manifests itself primarily in a decrease in the assimilation surface of the leaves and the destruction of the chlorophyll pigment. It is intensive when high unbalanced rates of nitrogen fertilizers are used. If the plants are severely damaged, the process of growing in tufts slows down significantly and the ear - forming phase is delayed. The losses of the yield may reach 10–15%, and in the years of epiphytoty - up to 35% of the grain (Murashko et al., 2022).

According to the results of a field evaluation of the winter wheat varieties, the highest development of the disease was noted in the phase of milky - waxy grain ripeness. Accounting was performed visually, using the *E.E. Heschele* scale as a percentage of the leaf surface covered by mycelium and was taken into account according to the modified BER scale (2010) (Table 3).

By years of research of the varieties of winter wheat, the development of powdery mildew varied from 1.3% to 10.0% on the scale.

The development of the powdery mildew on the winter wheat variety *Effectnaya* amounted to 1.3% on average over the years of research 2016–2020. That is, by the degree of resistance to the disease, it has 8–9 points (highly resistant). Resistance (2–5% or 7–6 scores) was demonstrated by the varieties *Polisianka*, *Pyriatynka*, *Merezhka*, *Prestyzhna*, *Krasunia Poliska*, *Vodohrai*, *Kesariia Poliska*, *Rusiava*, *Spivanka Poliska*, *Myroliubna*, *Mokosha*, *Romanivna* and the standard *Lisova Pisnia*, St. The development of the disease in these varieties was in the range of 2.6–5.0%. The varieties *Namysto*, *Pamiati Hirka* and *Kraeivyd* belonged to the moderately resistant (6.0–10.0% or 5 points), the disease development was 7.2%, 9.2% and 10.0%, respectively.

Table 3. Scale for the assessment the resistance of the wheat samples against powdery mildew (*Blumeria graminis* (*DC.*) *Speer*. (*BLUMGR*)) (Fedorenko et al., 2013)

Score	Affected surfaces of the leaves and stems, %	Degree of durability of receptivity	Signs of the disease
9–8	< 1	Highly receptive	There are no signs of disease or there are separate chlorotic and necrotic spots on the leaves, a very rare single coating of conidia.
7–6	2–5	Receptive	Only the lower leaves are affected: there are single small pads, chlorotic and necrotic elongated spots are possible.
5	6–10	Medium receptive	The plant is affected up to the pre– flag leaf: the lower leaves are heavily, the higher ones are moderately affected.
4–3	11–25	Weekly receptive	The plant is affected up to the pre- flag leaf: the leaves of the lower level (lower third) are significantly affected, the lower leaves have died; middle level - moderately, the appearance of traces of infection on the pre- flag sheet is noticeable and weakly on the flag sheet.
2	26–50	Receptive	The whole plant is affected: the flag leaf is moderate, the lower and middle leaves have died, infection on the scales and awns.
1	> 50	Very receptive	The entire plant is affected: the leaves die, there are infections on the scales and awns and stems.

The development of powdery mildew is enhanced by the alternation of the dry and wet weather in April–May, but the hot and dry weather of June inhibits the development of powdery mildew. The year 2018 was characterized by favourable conditions for pathogens when the hydrothermal coefficient (HTC) was equal to 1.8, and the amount of precipitation was 1.5 times higher than in other years. It should be noted that unfavourable conditions for pathogens developed in 2016; 2017; 2019 and 2020 due to the lack of optimal humidity for their development (70–85%), HTC - 0.2–0.6 (weak level) and increased air temperatures; therefore their harmfulness decreased.

Infection of the winter wheat plants by brown leaf rust *Puccinia triticina Erikss*. (PUCCTR) = P. recondita Roberge: *Desm.f.sp.tritici* (PUCCRE) is observed on the entire territory of Ukraine. But it causes the greatest damage in the Polesie and Forest - steppe zones. It appears mainly on the leaves on the upper side in the form of rusty - brown, oval uredinia, which, with severe damage, densely cover the entire surface of the leaf. The pathogen is located on the remains of the stubble, carrion or wild cereal grasses.

The degree of severity of the rust depends on the stage of development of the plant. The seedlings, affected in the autumn, die during the winter, which causes thinned winter crops. When the leaves of the upper level are affected, they lag behind in growth, and the assimilation surface decreases, the quality of the seed material and baking performance deteriorate. Excessive nitrogen rates, early sowing dates, susceptible varieties, and tumours contribute to the damage. The losses of the yield will be 12–20% (Topchyi, 2009).

The examination of crops took place in dynamics, starting from the resumption of the winter wheat growing season and until the phase of milky– wax ripeness. During the milky ripeness phase the disease reaches its maximum development; currently, basic registration made. Damage to the plants was assessed visually. Assessment of the degree of damage of each leaf by the scale of *R.F. Peterson* and the integral scale of stability of *L.T. Babayants* (Table 4).

Table 4. Integral scale for assessment of the resistance of the eary grain crops against *Puccinia triticina Erikss. (PUCCTR) = P.recondita Roberge: Desm.f.sp.tritici (PUCCRE)* (*Babayants* L.T.) (Kovalishyna, 2014)

Sustainability score	Degree of durability, receptivity	Nature of the disease manifestation
9	Very high sustainability	There are no signs of disease.
8	High sustainability	On the leaf there are single chlorotic and necrotic spots with very small uredopustules and an intensity of 1–5%.
7–6	Sustainable	Small and medium uredopustules are possible in chlorotic and necrotic spots with an intensity of 6–10 and 11–15%.
5	Moderately receptive	The intensity of uredopustules is 16–25%, mild chlorosis and necrosis are possible.
4–3	Receptive	Medium, large uredopustules, intensity from 26–40%, mild chlorosis up to 41–65% is possible.
2	Highly receptive	Large uredopustules, intensity 66–90%.
1	Very high receptivity	Large fused uredopustules, intensity 91–100%.

The development of brown leaf rust, depending on the variety, fluctuated between 0.3–10.2%. The highly resistant varieties (1–5%, or 8 scores) included the varieties *Efektna, Vodohrai, Kraeivyd, Mokosha, Pyriatynka, Pamiati Hirka, Kesariia Poliska, Myroliubna, Merezhka, Krasunia Poliska, Polisianka, Romanivna* and the standard *Lisova Pisnia St*. The development of the disease was within 0.3–4.5%. Resistance (6–10%, or 7–6 scores) was observed on the varieties - *Rusiava, Spivanka Poliska, Prestyzhna,* and *Namysto*; the disease development was in the range of 5.3–10.2%, respectively.

The development of the brown leaf rust is facilitated by the presence of an optimal temperature of 15–25 °C and air humidity in late April and early May. At high temperatures in June of 30 °C, infection does not occur.

According to the weather station of the NSC ‘Institute of Agriculture of the National Academy of Sciences’, the weather conditions for 2016–2020 in the northern Forest - Steppe zone were characterized by increased temperatures and a significant deficit of precipitation, compared to the long- term average indicators. These characteristics influenced the growth and development of the plant, the reproduction and spreading of harmful organisms (Kyrychenko et al., 2021).

According to average indicators, April was warmer by 2.6 °C, compared to the norm. In 2016 and 2017 the air temperature was by 3.9° and 4.6 °C higher than the long - term indicators. Precipitation above normal was determined in 2016, its amount exceeded 1.1 times (GTC 1.9). The year 2018 was dry, almost without precipitation, the amount of precipitation was 5.6 mm (11% of the norm, HTC 0.1).

The weather conditions in May were marked by an increased air temperature by 0.9 °C. The average monthly air temperature in 2020 was 2.6°C below normal, and in absolute terms it amounted to 12.5 °C (normal 15.1 °C). In 2016–2017 the air temperature indicators were almost consistent with long - term averages. The year 2018 turned out to be a hot year with very little precipitation (3 times below the norm), the air temperature exceeded the norm by 4.5 °C (HTC 0.3), the sum of active temperatures above 100 was 599. In May 2020 the rains were torrential by their nature, 104.8 mm fell (2 monthly norms), which created conditions for plant In May 2020, the rains were torrential in nature, 104.8 mm fell (2 monthly norms), which created conditions for beating down the plants and the development of diseases (GTC 4.1).

Average monthly air temperatures in June were by 1.1 degrees higher; 0.9; 2.7; 5.9 and 4.4°C (2016; 2017; 2018; 2019 and 2020) (Fig. 1), compared to the long - term averages; the weather with a deficit of precipitation (GTC - 0.3; 0.2; 1.8; 0.5 and 0.6), respectively. In 2018 the weather was different, precipitation exceeded the norm by 1.5 times (GTC 1.8). The weather conditions in June were not favourable for the development of phytophages, due to the hot weather with a lack of precipitation or excessive amounts of moisture that fell in the form of torrential rains.

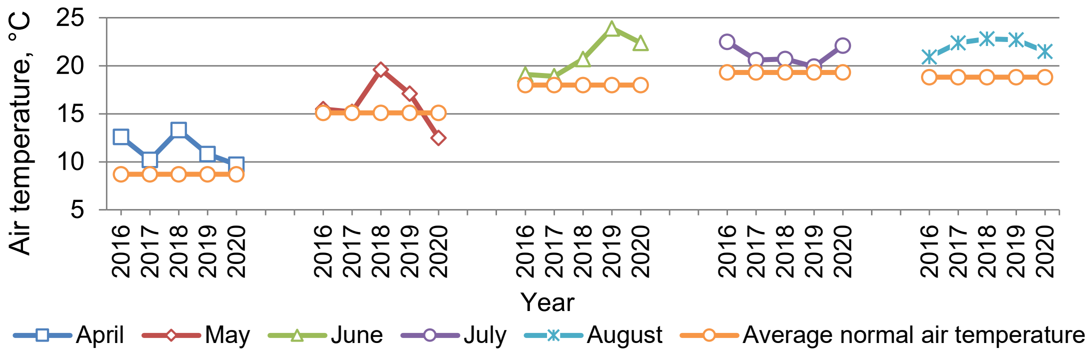

Figure 1. The air temperature by years during the spring - summer growing season of the winter wheat.

In July, on average over the years of research, the air temperature exceeded the norm by 1.7 °C. The year 2016 was hot (the air temperature 3.2 °C above the normal) with little precipitation (2.6 times below the normal) (Fig. 2). The amount of precipitation in 2018 was almost consistent with many years. The driest month was July 2019, the amount of precipitation was 19.4 mm (21% of normal).

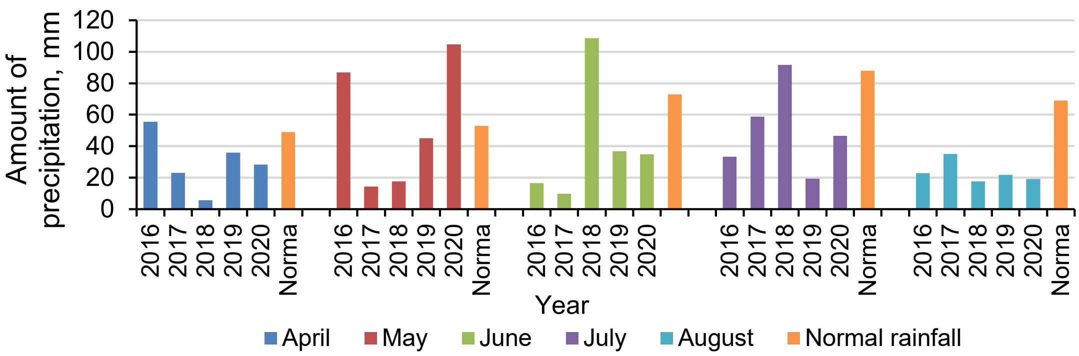

Figure 2. Amount of precipitation by year during the spring– summer growing season of the winter wheat.

August was hot and dry, on average, with air temperatures exceeding the norm by 3.2 °C. In all years there was a deficit of precipitation, its amount was 2–4 times lower than the norm (GTC for the years of research 0.3; 0.4; 0.6).

Abnormally dry conditions for the summer growing season of the winter wheat led to an acceleration of the development phases of the winter wheat, to a reduction in the development period of sucking pests and the period of damage, caused by them. Taking into account abiotic factors, the timing of the appearance of pests should be closely monitored in order to apply effective plant protection products, if necessary. Such a need may arise for individual varieties which in those years contributed to the mass reproduction and spread of certain types of pests and diseases in the varieties with an insufficient level of resistance. The industrial crops, affected by powdery mildew above the average, must be protected with chemicals, if necessary, with preparations from the list of pesticides and agrochemicals, approved for use in Ukraine (MEPNR, 2018).

Stability in the yield indicators during the years of research is determined by one winter wheat variety that is highly resistant against aphids *Myroliubna* - the coefficient of variation was $V = 28.5\%$ and two stands - *Kraeiv Krasunia Poliska, Vodohrai, Kesariia Poliska, Romanivna, Spivanka Poliska*, the coefficient of variation in the yield increased by V = 31.9 – 38.1%. As almost unstable by productivity were noted the aphid - resistant varieties *Prestyzhna* V = 45.6% and *Rusiava*, 58.1% (Table 5).

Table 5. Productivity of the soft varieties of winter wheat, NSC 'Institute of Agriculture NAAS' 2016–2020

No.	Variety	Productivity of the soft varieties of winter wheat, (t·ha^{-1})			
		Medium	Min	Max	*V*, (%)
1	*Lisova Pisnia St.*	5.97	3.58	7.27	25.2
2	*Kraeivyd*	6.71	4.50	8.56	25.2
3	*Pamiati Hirka*	6.61	3.41	8.38	31.7
4	*Kesariia Poliska*	7.67	4.12	10.71	32.6
5	*Romanivna*	5.65	2.99	7.94	34.8
6	*Myroliubna*	7.08	4.40	9.14	28.5
7	*Vodohrai*	6.94	3.74	9.43	32.2
8	*Spivanka Poliska*	6.82	3.70	9.64	38.1
9	*Namysto*	6.15	3.81	8.82	34.2
10	*Polisianka,*	6.51	3.03	9.34	44.3
11	*Merezhka*	6.77	3.65	9.85	42.4
12	*Rusiava* [1]	5.72	2.20	8.80	58.1
13	*Prestyzhna* [1]	6.16	3.73	8.86	45.6
14	*Krasunia Poliska*	6.95	4.15	9.14	31.9
15	*Mokosha*	6.27	3.66	7.77	26.9
16	*Pyriatynka*	7.10	3.67	8.59	29.3
17	*Efektna* [1]	6.36	4.08	8.14	32.6
	HCP_{05}, t ha^{-1}	0.38	0.64	0.50	1.4

[1]Varieties *Rusiava* and *Prestyzhna* were not studied in the competitive variety testing in 2016 and *Efektna* - in 2016–2017.

The best years by the productivity were 2016, 2017, 2019 with a variation of 7.77 t ha^{-1} (*Mokosha*) - 10.71 t ha^{-1} (*Kesariia Poliska*). The selection of productivity was noted in 2018 during the downtime when grain harvesting, due to heavy rainfall in the period of wheat ripening and, accordingly, grain shedding and germination. Under such conditions, among the high - quality varieties against cereal aphids, the highest productivity showed the winter wheat *Myroliubna* 4.40 t ha^{-1}, *Krasunia Poliska* 4.15 t ha^{-1}, *Kesariia Poliska* 4.12 t ha^{-1} and the resistant ones - *Kraeivyd* 4.50 t ha^{-1}. In the snowless year of 2020, when cereal aphids 'dominated' the field from spring until harvest, high yields were observed in the varieties *Kesariia Poliska* 6.59 t ha^{-1} and *Pyriatynka* 6.56 t ha^{-1}.

The average productivity among the highly resistant varieties against cereal aphids varied from 5.65 t ha^{-1} (early ripening *Romanivna*) to 7.67 t ha^{-1} (mid ripening *Kesariia, Poliska*) and resistant from 5.72 t ha^{-1} (mid ripening *Rusiava*) to 7.10 t ha^{-1} (mid - season *Pyriatynka*). Consequently, among the highly resistant and resistant to cereal aphids *Kesariia Poliska* (X = 7.67 t ha^{-1}, V = 32.6%) had better productivity; *Pyriatynka* (X = 7.10 t ha^{-1}, V = 29.3%); *Myroliubna* (X = 7.08 t ha^{-1}, V = 28.5%).

The average productivity among the varieties of winter wheat varied from 5.65 t ha^{-1} to 7.67 t ha^{-1}, respectively, the *Lisova Pisnia* standard is 5.79 t ha^{-1}.

During the investigation various weather factors influenced the yield variability. The variability of the average yield and coefficient of variation among the varieties was by year of research: 2016 (varieties included in the State Register from 2013 to 2019: the average productivity X = 7.82 t ha^{-1}, the coefficient of variation V = 9.26%); 2017 (X = 7.82 t ha^{-1}, V = 9.77%); 2018 (X = 3.51 t ha^{-1}, V = 20.27%); 2019 (X = 8.75 t ha^{-1}, V = 13.22%); 2020 (X= 4.74 t ha^{-1}, V = 21.45%).

Highly resistant, according to the scale (resistance 9–8 scores) were the varieties *Pyriatynka* (the 2016–2020 research) and *Efektna* (the 2018–2020 research), the development of the disease was at the level of 5.0 and 8.3%. Over five years of research of the variety *Pyriatynka* (powdery mildew coefficient of variation V = 81.3%, leaf rust - V = 112.7%), made it possible to classify it as highly resistant (respectively, resistance 9 scores) and obtain an average productivity of 7.10 t ha^{-1}. Accordingly, for three years *Efektna* (powdery mildew and the leaf rust coefficient of variation was V = 173.2%); however, resistance against two diseases is 8 scores, and the average productivity is 6.36 t ha^{-1}. The difference in productivity can be explained by the fact that there are other characteristics (the winter - frost resistance, the drought resistance, resistance to falling of the corn as a result of heavy wind and rain, and the impact of other diseases) that must be taken into account during the research.

During five years of research the best varieties in terms of productivity were noted: *Kesariia Poliska* (7.67 t ha^{-1}); *Pyriatynka* (7.10 t ha^{-1}); *Myroliubna* (7.08 t ha^{-1}); *Krasunia Poliska* (6.95 t ha^{-1}); *Vodohrai* (6.94 t ha^{-1}); *Spivanka Poliska* (6.82 t ha^{-1}); *Merezhka* (6.77 t ha^{-1}); *Kraeivyd* (6.71 t ha^{-1}); *Pamiati Hirka*, (6.61 t ha^{-1}); *Polisianka* (6.51 t ha^{-1}); three years - *Efektna* (6.36 t ha^{-1}).

Under laboratory conditions there was analyzed the effect of the allelic state of the Lr34/Yr18/Pm38 gene upon the disease resistance in the varieties of winter wheat. For this variety they were divided into three groups depending on the allelic state of the gene: The first group - with a stable allelic state of the gene (conditionally - Lr34+); the second group combined heterogeneous genotypes for alleles of the Lr34/Yr18/Pm38 locus (Lr34+/−). The third group are genotypes in which there is no stable allelic state of the Lr34/Yr18/Pm38 gene (Lr34−).

Under field conditions the *Effectna* variety showed the group high resistance to aphids, thrips, powdery mildew and brown leaf rust. In the laboratory studies this variety belonged to the 3rd group with the absence of a stable allelic state of the Lr34/Yr18/Pm38 (Lr34−) gene.

Under field conditions the varieties are highly resistant to aphids, thrips and brown leaf rust; resistant to powdery mildew - *Myroliubna*, *Spivanka Poliska*, *Polisianka*. In the laboratory to the 1st group with a stable allelic state of the gene (conditionally - Lr34+); *Kesariia Poliska* belonged to the 2nd group, which combined loci, heterogeneous in alleles (polymorphism for this marker). *Pyriatynka* referred to the 3rd group with the missing stable allelic state of the Lr34/Yr18/Pm38 gene (Lr34−); *Krasunia Poliska* was not studied under laboratory conditions.

Under field conditions, the varieties are highly resistant to thrips and brown leaf rust; resistant to aphids and powdery mildew - *Vodohrai* to the 1st group with a stable allelic state of the gene (conditionally - Lr34+) and *Network (Setj)* to the 3rd group with the absence of a stable allelic state of the gene Lr34/Yr18/Pm38 (Lr34−).

Highly resistant to thrips and brown leaf rust; moderately resistant to aphids and powdery mildew variety *Kraeivyd* up to group 3 with a missing stable allelic state of the Lr34/Yr18/Pm38 gene (Lr34−). Highly resistant to aphids, thrips and brown leaf rust; a variety moderately resistant to powdery mildew - *Pamiati Hirka* to the 1st group with a stable allelic state of the gene (conditionally - Lr34+).

The results of our investigations are aimed at deepening and improving the breeding processes to increase the resistance of plants against disease and pest damage, to achieve better yields and adaptability to the growing conditions, to gain distinguished environmental plasticity and ensure the formation of more stable yields every year.

CONCLUSIONS

In the northern Forest - Steppe zone of Ukraine, the most common pests of the soft winter wheat are cereal aphids and wheat thrips. The main diseases are powdery mildew and brown leaf rust. The number of phytophages and disease incidence were significantly influenced by abiotic factors, the phenological state of plants and the ripeness of varieties.

Based on the results of assessing the field resistance to phytophages, the varieties of winter wheat showed high resistance (resistance score 9–8) to several pests (cereal aphids and wheat thrips) - *Spivanka Poliska*, *Kesariia Poliska*, *Myroliubna*, *Krasunia Poliska*, *Pamiati Hirka*, *Romanivna, Polisianka*, *Rusiava*, *Prestyzhna*, *Pyriatynka*, *Efektna*, *Mokosha* and standard *Lisova Pisnia St*.

During the growing season only one variety among the range of varieties, *Efektna*, showed consistently high resistance to the pathogens of powdery mildew and brown leaf rust. All the other varieties had a resistance of 7–6 scores.

It has been established that the 1st group with a persistent allelic state of the gene (conditionally Lr34+) includes the following varieties of winter wheat: *Pamiati Hirka*, *Myroliubna*, *Romanivna*, *Vodohrai*, *Spivanka Poliska*, *Namysto*, *Polisianka*, *Osiaina, Prestyzhna*, *Rusiava*. To the 2nd group, which combine the winter wheat variety heterogeneous in locus alleles (polymorphism at a preset marker): *Kesariia Poliska*. To the 3rd group with absent *Efektna*, *Pyriatynka* and *Fortetsia Poliska*.

The indicated varieties belong to the mid– season group, except for one variety - *Romanovna*. They have high winter hardiness (8–9 scores), resistance to the crop falling in heavy wind and rain (8–9 scores) and drought (9 scores). The field resistance to diseases and pests is another strong point of these wheat varieties. Almost 9–8 and 7–6 scores were received by varieties for resistance to aphids, thrips, powdery mildew and leaf rust, except for the varieties *Namysto*, *Pamiati Hirka* and *Kraeivyd* (5 scores) to powdery mildew and (5–4 scores) to cereal aphids. At the same time the productivity of the *Kraeivyd* variety is 6.71 t ha^{-1}, which is 0.74 t ha^{-1} more than the standard.

The investigated varieties *Kesariia Poliska* (7.67 t ha^{-1}); *Pyriatynka* (7.10 t ha^{-1}); *Myroliubna* (7.08 t ha^{-1}); *Krasunia Poliska* (6.95 t ha^{-1}); *Vodograi* (6.94 t ha^{-1}); *Spivanka Poliska* (6.82 t ha^{-1}); *Merezhka* (6.77 t ha^{-1}); *Kraeivyd* (6.71 t ha^{-1}); *Pamiati Hirka* (6.61 t ha^{-1}); *Polisianka* (6.51 t ha^{-1}); *Efektna* (6.36 t ha^{-1}) are characterized by better productivity and adaptability to growing conditions. They are more flexible in relation to the times of sowing, grow more in tufts in the autumn, even at late sowing dates, and regenerate better in the spring. They are distinguished by their ecological plasticity and ensure the formation of more stable yields over the years. Considering abiotic factors, namely increased temperatures, which have been observed in recent decades, preference should be given to varieties with high resistance to drought and disease damage.

In the northern Forest-Steppe zone of Ukraine the winter wheat varieties, recommended for cultivation, are *Kesariya Polesskaya, Piryatinka, Mirolyubnaya, Krasavitsa Polesskaya, Vodogray, Spivanka Polesskaya, Pamyati Girka, Romanovna, Polisyanka* and *Effectnaya*, which are characterized by better productivity and adaptability against damage by pests.

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