Agronomy Research **22**(1), 96–109, 2024
https://doi.org/10.15159/AR.24.013

Breeding and genetic screening of F_1 hybrids of soft winter wheat (*Triticum aestivum* L.) by manifestation of resistance to *Fusarium graminearum* Schwabe

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Received: august 12th, 2023; Accepted: February 24th, 2024; Published: March 19th, 2024

Abstract Diseases of field crops significantly reduce yield and the quality of agricultural products. Developing resistant varieties is one of the tasks for enhancing agroecosystem resilience. The creation of infectious material for the background pathogen and heterosis analysis of F_1 hybrids of soft winter wheat for resistance against *Fusarium graminearum* Schwabe (*F. graminearum*) and elements of spike productivity was the goal of the conducted research. The analysis of F_1 genotypes of wheat for resistance against *F. graminearum* was carried out in field infections and natural nurseries of the wheat breeding laboratory of The V.M. Remeslo Myronivka Institute of Wheat of the NAAS of Ukraine (located in the northern part of the Right-Bank Forest-Steppe of Ukraine) during 2021 and 2022. The most aggressive isolates of the *F. graminearum* fungus were identified for developing inoculum and creating an artificial infection background in field conditions. In terms of the inheritance of resistance and spike productivity traits, 29.4% of hybrid populations of the first generation were selected. Positive dominance for the complex of investigated traits was found in hybrid combinations where sources of resistance against *Fusarium graminearum* (MV 20-88 × Smuhlianka, (Mikon × ALMA) × Lehenda Myronivska and local winter wheat varieties MIP Knyazhna, MIP Vyshyvanka were involved in the crossbreeding. It was established that cytoplasmic genes enhance the dominance of genes for complex resistance in one crossbreeding group. The best combinations with positive dominance in resistance to fusarium can be utilized in the development of highly resistant varieties.

Key words: soft winter wheat (*Triticum aestivum* L.), variety, hybrid, spike, heterosis, fusarium.

INTRODUCTION

Soft winter wheat plays a major role in food security. In modern conditions, with a rapid change in climatic scenarios (Liu et al., 2021) and an increase in the phytopathogenic pressure of the variety, a special role is assigned to the biological factor of wheat and agricultural intensification (Lozinskiy et al., 2021). Cereals are damaged by a wide range of pathogens during the growing season, among which fungi of the genus *Fusarium* Link occupy a significant niche (Ward et al., 2008, Gao et al., 2023).

The causative agents of numerous diseases and pests annually affect significant losses of the wheat harvest and decrease in grain quality. The antidote to this effect is an integrated system of plant protection, which includes various measures that affect the final result - obtaining a high yield in terms of quantity and quality. The key direction of this system is the creation and introduction into the production of varieties resistant and tolerant to common pathogens (Pagán & García-Arenal 2018; Mazurenko et al., 2020; Mikaberidze & McDonald, 2020). The variety is a reliable and economically beneficial factor in increasing crop yield under any growing technology. Wheat varieties created by breeders have productivity potential that has not yet been realized in production, the limit of which is not only not reached, but has not even been established and is growing as varieties are selectively improved and growing conditions are optimized (Kovalyshyna et al., 2020; Moisienko et al., 2020).

Creation of primary material in Ukraine for breeding winter wheat with group resistance against *Erysiphe graminis* DC. f. sp. *tritici* Em. Marchal, *Puccinia recondita* Rob. et Desm., *Septoria tritici* Rob. et Desm., *F. graminearum* Shwabe, *Tilletia caries* Tul., *Cercosporella herpotrichoides* Fron are successfully researched at the Institute of Plant Protection of the National Academy of Agrarian Sciences of Ukraine, The V.M. Remeslo Myronivka Institute of Wheat of the National Academy of Agrarian Sciences of Ukraine (MIP), The Plant Breeding and Genetics Institute - National Center of Seed and Cultivar Investigation of the National Academy of Agricultural Sciences of Ukraine (SGI) and others (Kovalyshyna et al., 2018).

It is known that grain crops can be affected by more than 300–350 species of various organisms, but the main threat to crop loss, especially in the initial phases of development, in the autumn and winter period, are pathogens of fungal infections, among which one of the leading places is occupied by micromycetes of the genus *Fusarium* Link (Ryabovol et al., 2019; Diakite et al., 2022). They cause damage at all stages of the organogenesis of winter wheat plants. Infection of wheat grain with pathogenic fungal species of this genus reduces the energy of its germination and germination, deteriorates gluten density and baking properties of flour (Hysing & Wiik, 2014; El Chami at el., 2023). Mycotoxins (fusariotoxins) accumulate in grain, among which fumonisin B1 (FB1), deoxynivalenol (DON) and zearalenone (ZEA) are the largest (Klyszejko et al., 2005; Tančić, 2013; Obradović et al., 2022). The greatest harmfulness of micromycetes of the genus *Fusarium* Link is detected when infecting the spike of plants, including one of the most dangerous diseases of cereals - Fusarium head blight. The danger of the latter lies not only in the reduction of grain yield, but also in the contamination of grain with fusariotoxins, this disease is of a hidden nature, and therefore the cause of the weakening of plants during their development, it can be detected by mycological analysis (Muthomi et al., 2008; Kovalyshyna et al., 2016).

The problem of grain fusarium infection has now reached international significance. The widespread distribution of fusarium fungi, their variability, as well as indisputable evidence of the danger posed by mycotoxins to human and animal health, determine the interest that the scientific community shows in *Fusarium* (Muthomi et al., 2008; Foroud et al., 2014; Ostrovskyi et al., 2017; Shikur Gebremariam et al., 2018). A complex of fungi of this genus takes part in the intensity of damage to plants, which differ in biology and adaptation to the conditions of the biocenosis in different zones of grain cultivation (Champeil et al., 2004; Panwar et al., 2016). Significant efforts of scientists are aimed at researching the morphological features, biology, biochemistry, physiology and genetics of fungi of the genus Fusarium Link, as well as finding ways to limit their number in agrobiocenoses and reduce their number (Mostovyiak et al., 2020). The solution to this important scientific problem determines the relevance of the topic of our research, which consisted of identifying sources of resistance among winter wheat varieties that were studied for a certain time on an artificial infectious background of fusarium head blight and involving them in breeding studies.

The purpose of the research is to create infectious material for the background of the pathogen and heterosis analysis of F_1 hybrids of soft winter wheat for resistance to the pathogen *Fusarium graminearum* Schwabe (*F. graminearum*) and spike productivity elements.

MATERIALS AND METHODS

The research was conducted in the field of infectious and natural nurseries (Tribel et al., 2010) of the winter wheat breeding laboratory of The V.M. Remeslo Myronivka Institute of Wheat of the National Academy of Agrarian Sciences of Ukraine (MIP), during 2021 and 2022.

The relief of the territory is a broad plateau, the microrelief is shallow depressions of 0.2–1 ha. Groundwater lies at a depth of 50–60 m. The soil is low-humus, slightly leached, medium loamy chernozem. The thickness of the humus horizon is 38–40 cm. The carbonate layer lies at a depth of 45–65 cm. Soil structure according to the scale of S.P. Dolgov is good, aggregates 0.25–10 mm in the range of 60–80% of the total mass are air-dry, and 55–70% are waterproof. The content of humus in the 0–20 cm layer of the soil is 3.7–4.0%, easily hydrolyzed nitrogen – 12 (11.6–13.0) mg per 100 g of soil, mobile phosphorus is 23 (21–25) mg per 100 g of soil and exchangeable potassium is 11 (10–16) mg per 100 g of soil. Hydrolytic acidity is 1.7–2.2 mg. equiv. per 100 g of soil, pH_{KCl} - 5.4–6.0.

Climate conditions

The meteorological conditions of the 2020/2021 growing season were favorable for the development of the pathogen *Fusarium graminearum* Schwabe. In the spring-summer period of wheat vegetation, average monthly temperatures were observed to be higher than long-term ones: in March and June by 1.0 °C and 1.5 °C, respectively, and in April and May, a decrease in air temperature was noted in comparison with long-term data (–1.4 °C and –0.8 °C respectively). The hydrothermal coefficient (HTC) for May, June, and July 2021 corresponded to 3.1; 2.7; and 2.6, overmoistening contributed to the manifestation and intensity of development of the causative agent of fusarium head blight.

The meteorological conditions of the 2021/2022 vegetation year were very unfavorable for the development of the pathogen *F. graminearum*. The average air temperature in July 2021 and August 2022 recorded 9.3 °C, which is 0.4 °C more than the long-term average (Table 1). In the spring-summer wheat growing season, average monthly temperatures were determined to be lower than the long-term norms by 0.1–1.5 °C, only in June they were noted to increase by 1.4 °C. From August 2021 to July 2022, 663 mm of precipitation fell (108% of the long-term average). Precipitation in August (109 mm, 198% of the annual amount) contributed to obtaining uniform wheat shoots.

Table 1. Hydrothermal conditions at 2020/2021 and 2021/2022 vegetative period[1]

Year	Month	Air temperature			Precipitation, mm			
		Fact	Multi-annual	±**	Fact	Multi-annual	±, mm**	±, %**
2020/2021	August	21.1/20.5*	20.4	1.6/0.1	11.4/109	55	-46.6/54	19.7/198
	September	18.5/13.2	14.9	4.0/-1.7	33.8/27	58	-24.2/-31	58.3/46
	October	13.2/7.6	8.7	5.0/-1.1	67/26	43	27.0/-17	167.5/60
	November	3.8/4.8	2.4	1.6/2.4	39.8/41	40	-1.2/1	97.1/101
	December	-0.3/-1.1	-1.8	1.9/0.7	49.6/94	42	7,6/52	118.1/223
2021/2022*	January	-2.3/-1.2	-3.7	2.3/2.5	83.7/33	39	48,7/-6	239.1/86
	February	-4.7/1.7	-2.5	-1.2/4.2	73.9/10	33	42.9/-23	238.4/32
	March	2.3/2.3	2.4	1.0/-0.1	39.3/13	39	2.3/-26	106.2/32
	April	7.7/8.3	9.8	-1.4/-1.5	58.6/143	41	16.6/102	139.5/349
	May	14.5/14.7	15.7	-0.8/-1.0	117.9/42	61	58.9/-19	199.8/70
	June	20.1/20.7	19.3	1.5/1.4	157.9/58	87	70.9/-30	181.5/66
	Jule	23.3/20.4	21.1	3.0/-0.7	172.1/68	75	98.1/-7	232.6/91
Per Year		**9.8/9.3**	**8.9**	**1.6/0.4**	**905/663**	**615**	**302/48**	**150.1/108**

[1] Data according to meteostation Myronivka, #33466; *First number - 2020–2021 vegetative period, second - 2021–2022 vegetative period; ** ± according to multi-annual means.

In the spring-summer period of winter wheat vegetation, a sufficient amount of moisture was observed, at least the amount of precipitation was lower than the multi-annual amount by 7–30 mm, and only in April 349% of the average multi-annual amount of precipitation fall. The duration of the period from germination to the end of autumn vegetation in 2021 was on par with long-term data (59 days), the period of rest was shorter by 8 days. According to the indicator of moisture supply, this year was characterized by a weak drought (HTC = 0.9), and in the spring-summer period of winter wheat vegetation, insufficient moisture (HTC = 0.8).

Sampling and methods

The research material included 34 F_1 hybrids resulted from direct (×) and backcrossing (↔) in 2020 with the involvement of soft winter wheat sources of resistance to *F. graminearum* (MV 20-88 × Smuhlianka, BILINMEVEN-49 × Natalka, Donskoy prostor × Slavna, Myronivska rannostyhla × CATALON, and (Mikon × ALMA) × Lehenda Myronivska) and new soft winter varieties (MIP Kniazna, MIP Fortuna, MIP Vyshyvanka, Avrora Myronivska, Podolianka).

In the study, plant protection chemicals and fertilizers were not used. The seeds were sown untreated in standard sowing periods (2nd decade of September). The sowing rate was 133 plants per 1 m^2.

The seeds of the hybrids were sown by hand, according to the scheme: mother form, hybrid, father form (pollinator). Threshing of spikes was carried out manually. For the maximum implementation of the program, a sparse sowing method was used: the distance between plants in a row is up to 5 cm, and between rows is 15–30 cm. During the growing season, phenological observations were made, and upon the onset of full maturity, a structural analysis of the elements of the spike productivity of parental components and crossing combinations (F_1 – 25 plants) was carried out (Perepelytsia et al., 2022).

The intensity of damage against *Fusarium graminearum* of wheat was carried out according to the methods of scientists (Babayants et al., 1988; Shelepov et al., 2005; Babayants & Babayants, 2014; Kyrylenko et al., 2017). The intensity was determined by the ratio of affected plants to the total sample.

The degree of phenotypic dominance in hybrid combinations for this quantitative trait was calculated according to the formula of B. Griffing (1950):

$$hp = (F_1 - MP) / (BP - MP),$$

where hp – degree of dominance; F_1 – the average arithmetic value of the indicator in the hybrid; MP – the average arithmetic value of the indicator of both parent forms; BP – the average arithmetic value of the parental component with a stronger development of the symptom (the lowest proportion (%) of the intensity of the infection).

The range in which the degree of dominance (hp) lies covers any values from $-\infty$ to $+\infty$ (Zhupina et al., 2022). Data were grouped according to the methodise of Beil & Atkins (Table 2).

Phytopathological analysis of grain samples in laboratory conditions was used to isolate pathogens of *Fusarium* fungi in pure culture. The studied grain of the hybrid populations was surface sterilized, by passing it over the flame of an alcohol still and soaking it in the Domestos solution. Sterile grain was laid out in Petri dishes on a nutrient medium of potato-glucose agar (PGA), ten seeds in ten cups (100 seeds). Isolates were examined for 5–7 days, recording the presence or absence of microconidia. The final identification of pathogens was carried out by microscopic examination, taking into account the morphological features of macroconidia characteristic of F. graminearum (spindle-sickle, ellipsoidal curved, with a gradually and evenly narrowed conical, elongated upper cell, with a distinct stalk at the base, usually with five septa, whitish-pink, golden-yellow, carmine-purple in mass), the presence or absence of chlamydospores. As a result of the research, the most aggressive isolates of the causative agent of the fungus *F. graminearum* were selected for inoculum development and the creation of an artificial infectious background in field conditions (Mukha & Murashko, 2019).

Table 2. Classification of dominance (Beil & Atkins, 1965)

Type of dominance	hp range
Positive overdominance (heterosis) (POD)	$hp > +1$
Positive dominance (PD)	$+0.5 < hp \leq +1$
Intermediate inheritance (II)	$-0.5 \leq hp \leq +0.5$
Negative dominance (ND)	$-1 \leq hp < -0.5$
Negative overdominance (depression) (D)	$hp < -1$

RESULTS AND DISCUSSION

The impact of climate change on the contamination of agricultural crops by *Aspergillus* and toxigenic *Fusarium* species may lead to a sharp increase in morbidity worldwide with higher food safety risks for humans and animals due to high levels of mycotoxin contamination in the final product (Sarrocco & Vannacci, 2018; Moretti et al., 2019; Thanushree et al., 2019). Recent decades have been characterized by extraordinary changes in weather conditions, which negatively affect not only cultivated plants but also their development by pathogens (Juroszek & von Tiedemann, 2015; Vozhegova, 2020; Miedaner & Juroszek, 2021).

In the conducted studies, the development of winter wheat diseases and appearance in crops was primarily influenced by the weather conditions of the year, namely the sum of the effective air temperatures and the amount of precipitation. Cereal crops can significantly alter the expression of certain phenotypic dominance depending on the yearly conditions (Spriazhka et al., 2022).

In 2021, overdominance (heterosis) in terms of resistance to the causative agent of Fusarium head blight was established in four (11.76%) hybrid combinations (Fig. 1, A), namely, MIP Kniazna × (Donskoy prostor × Slavna); [(Mykon × ALMA) × Lehenda Myronivska] × Podolianka; MIP Vyshyvanka × (MV 20-88 × Smuhlianka); MIP Vyshyvanka × (BILINMEVEN-49 × Natalka). In 2022, overdominance (heterosis) was found in nine (26.47%) hybrid combinations, namely, (BILINMEVEN-49 × Natalka) × MIP Kniazhna, (Myronivska rannostyhla × CATALON) × MIP Kniazhna, Podolianka × (Donskoy prostor × Slavna), Podolianka × [(Mikon × ALMA) × Lehenda Myronivska], MIP Fortuna × (BILINMEVEN-49 × Natalka), (BILINMEVEN-49 × Natalka) × MIP Fortuna, MIP Fortuna × (Donskoy prostor × Slavna), (Donskoy prostor × Slavna) × MIP Fortuna (Fig. 1, B).

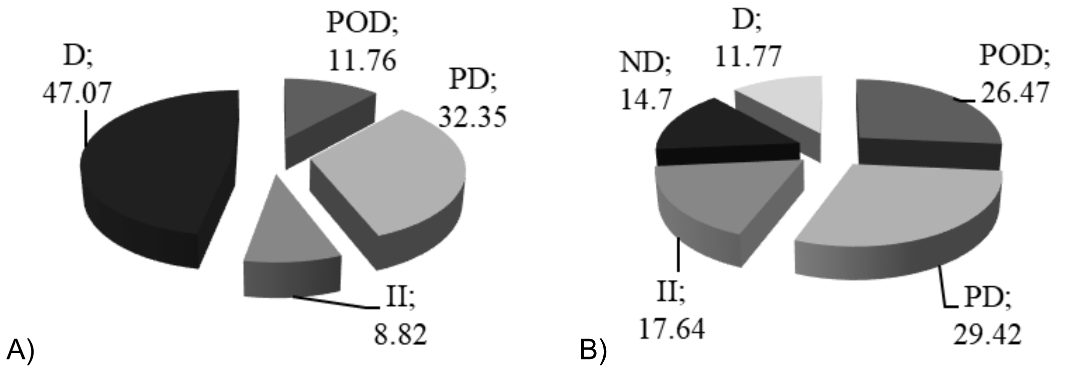

Figure 1. Distribution of phenotypic dominance indicators by the intensity of infection with F. graminearum in F_1 of soft winter wheat. (POD – heterosis; PD – positive dominance; II – intermediate inheritance; ND – negative dominance; D – depression (A – 2021, B – 2022)).

The transmission of resistance to the pathogen *Fusarium graminearum* was observed in the varieties MIP Knyazna, MIP Vyshivanka, MIP Podolyanka, MIP Fortuna, which were involved in crossing as the mother form and the pollinator variety of the source of resistance. Agostinelli et al. (2012) indicate that breeders often use phenotypic selection to develop fusarium-resistant soft winter wheat cultivars.

In the studies of Jin et al. (2013) resistance to Fusarium wilt in wheat is determined either by gene products that contribute to plant defense (active resistance factors) or by plant properties that indirectly affect susceptibility reduction, such as morphological characters and developmental features (passive resistance factors). In F_1, resistance to fusarium wilt was mostly at the level of one of the parental forms, partially positive inheritance was present in 11 (32.35%) hybrids, in 2022 was 10 hybrids (29.42%). Three hybrids (8.8%) and six (17.64%) hybrids had intermediate inheritance, respectively. In the 2022 studies, five (14.7%) hybrid combinations had partial negative inheritance. Depression was identified in 16 hybrids of the first generation, which is (47.07%) and four (11.77%), respectively. It is worth noting that this provision complements the general principle of the formative process (Miedaner, 1997; Motsnyy et al. 2017; Khalikulov et al., 2022) as a result of which such a proportion of the probability of selection of new resistant genotypes for a given pathogen is formed.

Grain yield is a complex feature and the result of multiplicative interaction of components (Slafer et al., 1996). Previous studies of wheat have identified some quantitative trait loci affecting grain yield that are co-located with those associated with its components, suggesting partially shared genetic control of these traits (Kuchel et al., 2007; Cuthbert et al., 2008; Sukumaran et al., 2015; Schulthess et al., 2017). Wheat yield components are multifaceted Slafer et al. (2014) and cover two main parameters: grain yield per area and grain yield per spike. The output of grain from the area includes grains in the spike, mass of grain and spikes from the area; while grain yield per spike consists of the number of spikes per ear, the number of grains and the size of grains per spikes and/or spike. There are numerous interactions and compensation mechanisms between different yield components, depending on genotype x environment x agronomy interactions (Gegas et al., 2010).

Therefore, studies of the nature of the variability of this trait in the parent-offspring system were conducted based on biometric analysis, and the degree of dominance of this trait in the first-generation hybrids was determined. Motsnyy et al. (2017) note that the interaction is characterized by partial or complete dominance or even overdominance of the trait and low or medium heritability. Khalikulov et al. (2022) add that alleles that have a weaker direct negative effect or do not have such an effect prevail over alleles that contribute to a more pronounced decrease. During the research period of 2021, 2022, heterosis for the trait 'grain number per the main spike' was noted in the group of crosses 29 (85.29%) hybrids F_1 (Fig. 2, A) and 19 (55.88%) (Fig. 2, B), respectively; partial positive dominance was noted in four (11.77%) and 12 (35.29%) hybrids F_1, respectively. In 2021, intermediate inheritance was noted only in the hybrid combination (BILINMEVEVN-49 × Natalka) × Podolianka.

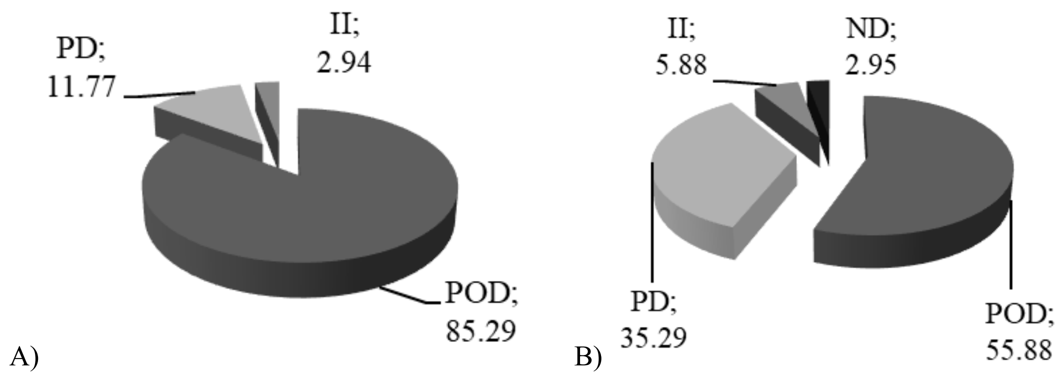

Figure 2. Distribution of phenotypic dominance indicators by the grain number per spike in F_1 of soft winter wheat. (POD – heterosis; PD – positive dominance; II – intermediate inheritance; ND – negative dominance (A – 2021, B – 2022)).

In 2022, intermediate inheritance for this trait was observed in hybrid combinations ntermediate inheritance for this trait was observed in two hybrid combinations (BILINMEVEN-49 × Natalka) × MIP Fortuna, (Donskoy prostor × Slavna) × MIP Fortuna, and negative dominance (ND was found in the combination Svitanok Myronivskyi × (Myronivska rannostyhla × CATALON).

Grain weight from the main spike is one of the important elements of productivity (Zhou et al., 2007; Zheng et al., 2011; Xiao et al., 2012; Feng et al., 2018). The results of research by Zhang et al. (2022) showed that a significant increase in grain yield over the past 60 years was mainly due to an increase in the number of grains in spike and grain weight, while the number of spikes per m^2 did not change significantly. According to the grain weight per the main spike, heterosis (superdominance) was revealed in 82.35% (2021) (Fig. 3, A) and 61.77% of new genotypes (2022) (Fig. 3, B). Positive dominance was found in three (8.82%) and ten (29.41%) hybrid combinations, respectively.

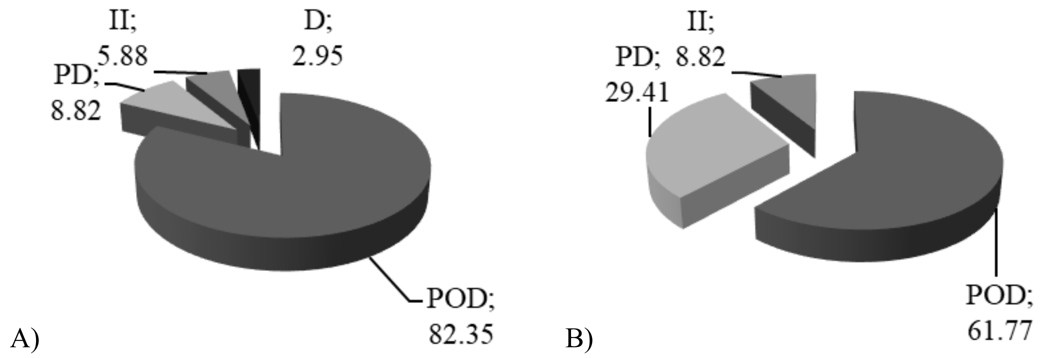

Figure 3. Distribution of phenotypic dominance indicators by the grain weight per main spike in F1 of soft winter wheat. (POD – heterosis; PD – positive dominance; II – intermediate inheritance; ND – negative dominance (A – 2021, B – 2022)).

In 2021, in two (5.88%) hybrid combinations (BILINMEVEN-49 × Natalka) × Podolianka, [(Mikon × ALMA) × Lehenda Myronivska] × MIP Fortuna; and in 2022, in three (8.82%) MIP Kniazna × (MV 20-88 × Smuhlianka), MIP Fortuna × (BILINMEVEN-49 × Natalka), (Donskoy prostor × Slavna) × MIP Fortuna intermediate inheritance of grain weight per main spike was noted. An expression of depression was recorded in one hybrid combination (in 2021) MIP Fortuna × (Donskoy prostor × Slavna).

Ten (29.41%) hybrid populations of the first generation were identified according to the nature of inheritance of resistance and yield components of the main spike (Table 3). In 2021, the following direct hybrid combinations [(Mikon × ALMA) × Lehenda Myronivska] × Podolianka, MIP Vyshyvanka × (MV 20-88 × Smuhlianka) were singled out for resistance to Fusarium head blight with heterosis (overdominance), and in 2022, they were Podolianka × [(Mikon × ALMA) × Lehenda Myronivska] and the reverse hybrid combination MIP Fortuna ↔ (BILINMEVEN-49 × Natalka).

According to the yield components of the main spike in eight F_1, the most expression of heterosis was observed in the conditions of 2021, positive dominance was found in two reverse hybrids Podolianka ↔ [(Mikon × ALMA) × Lehenda Myronivska]. In the conditions of 2022, heterosis is established in direct hybrid combinations:

MIP Kniazna × (MV 20-88 × Smuhlianka), (MV 20-88 × Smuhlianka) × MIP Kniazna, (BILINMEVEN-49 × Natalka) × MIP Fortuna and the reverse combination Podolianka ↔ [(Mikon × ALMA) × Lehenda Myronivska].

Table 3. Degree of phenotypic dominance for resistance against *F. graminearum* and main spike productivity traits in F_1 winter wheat, 2021–2022.

Hybrid combination	Degree of phenotypic dominance*					
	2021			2022		
	Resistance to *F. graminearum*	Grain number per spike	Grain weight per spike	Resistance to *F. graminearum*	Grain number per spike	Grain weight per spike
MIP Kniazhna × (MV 20-88	PD	POD	POD	PD	POD	II
× Smuhlianka)	0.51	3.76	17.61	0.80	7.40	0.45
(MV 20-88 × Smuhlianka)	PD	POD	POD	PD	POD	POD
× MIP Knyazhna	0.52	5.34	24.65	0.80	13.70	17.61
Podolianka × [(Mykon × ALMA)	II	PD	POD	POD	POD	POD
× Lehenda Myronivska]	0.43	0.92	1.12	1.40	3.90	1.12
[(Mykon × ALMA) × Lehenda	POD	PD	PD	II	POD	POD
Myronivska] × Podolianka	2.41	0.53	0.64	0.40	2.30	1.64
MIP Vyshyvanka × (MV 20-88	POD	POD	POD	PD	PD	PD
× Smuhlianka)	3.17	2.43	24.63	0.94	0.87	0.94
(MV 20-88 × Smuhlianka)	PD	POD	POD	PD	PD	PD
× MIP Vyshyvanka	0.76	8.50	23.37	0.71	0.52	0.71
MIP Vyshyvanka × [(Mykon × ALMA)	PD	POD	POD	PD	PD	PD
× Lehenda Myronivska]	0.87	1.61	1.98	0.83	0.96	0.50
[(Mykon × ALMA) × Lehenda	PD	POD	POD	PD	PD	PD
Myronivska] × MIP Vyshyvanka	0.51	2.29	2.57	0.50	0.51	0.73
MIP Fortuna × (BILINMEVEN-49	II	POD	POD	POD	PD	II
× Natalka)	0.45	1.81	2.23	1.30	0.73	0.27
(BILINMEVEN-49 × Natalka)	PD	POD	POD	POD	II	POD
× MIP Fortuna	0.52	2.86	8.0	1.60	0.35	3.04

*Degree of phenotypic dominance: POD – heterosis; PD – positive dominance; II – intermediate inheritance.

Positive dominance of the set of investigated traits was found in hybrid combinations in which sources of resistance to the pathogen *Fusarium graminearum* (MV 20-88 × Smuhlianka, (Mikon × ALMA) × Lehenda Myronivska) and local varieties of winter wheat (MIP Kniazhna, MIP Vyshyvanka) were involved in crossing.

The obtained results give grounds for asserting that cytoplasmic genes strengthened the dominance of complex resistance genes in the crossbreeding group: (MV 20-88 × Smuhlianka) × MIP Kniazna; [(Mikon × ALMA) × Lehenda Myronivska] × Podolianka; (MV 20-88 × Smuhlianka) × MIP Vyshyvanka; [(Mikon × ALMA) × Lehenda Myronivska] × MIP Vyshyvanka; (BILINMEVEN-49 × Natalka) × MIP Fortuna. The dependence of the level of resistance to *Fusarium graminearum* of the progeny of winter wheat on the level of resistance of the parental forms is visible in hybrids: MIP Kniazna

× (MV 20-88 × Smuhlianka); Podolianka × [(Mikon × ALMA) × Lehenda Myronivska]; MIP Vyshyvanka × (MV 20-88 × Smuhlyanka); MIP Vyshyvanka × [(Mikon × ALMA) × Lehenda Myronivska]; MIP Fortuna × (BILINMEVEN-49 × Natalka).

It should be noted that in order to increase the percentage of selectively valuable new forms, it is necessary to have as few negative signs and properties as possible or to detect them as early as possible at the initial stages of selection. The selection of transgressive forms for resistance to pathogens in combination with elements of productivity in the second, third and fourth generation of hybrids can be effective. Selection for ecologically stable resistance must be carried out in multiple environments with a maximal range of different infection levels (Miedaner, 1997; Agostinelli et al., 2012).

CONCLUSIONS

To improve the efficiency of winter wheat breeding for immunity, it is promising to create a qualitatively new source material that is maximally adapted to zonal conditions. When developing new varieties, selection plays a central role, regardless of the method used to create the source material. At the same time, it is important for the breeder to determine the characteristics of the nature of inheritance of traits. 10 combinations of F_1 crosses out of 34 studied combine in one genotype resistance to *Fusarium graminearum* and main spike yield components that exceed the parental components for these traits. These genotypes are recommended for further breeding work to develop high-yielding winter bread wheat varieties resistant to *Fusarium graminearum*, as these hybrid combinations are potentially highly transgressive.

In 2021, overdominance (heterosis) in terms of resistance to the causative agent of Fusarium head was found in four (11.76%) hybrid combinations (MIP Kniazhna × (Donskoy prostor × Slavna); [(Mikon × ALMA) × Lehenda Myronivska] × Podolianka; MIP Vyshyvanka × (MV 20-88 × Smuhlianka); MIP Vyshyvanka × (BILINMEVEN-49 × Natalka)); in 2022, overdominance (heterosis) was found in nine (26.47%) hybrid combinations (BILINMEVEN-49 × Natalka) × MIP Kniazhna, (Myronivska rannostyhla × CATALON) × MIP Kniazhna, Podolianka × (Donskoy prostor × Slavna), Podolianka × [(Mikon × ALMA) × Lehenda Myronivska], MIP Fortuna × (BILINMEVEN-49 × Natalka), (BILINMEVEN-49 × Natalka) × MIP Fortuna, MIP Fortuna × (Donskoy prostor × Slavna), (Donskoy prostor × Slavna) × MIP Fortuna).

29.4% of hybrid populations of the first generation were distinguished by the nature of inheritance of resistance and productivity elements of the main ear. Positive dominance of the set of investigated traits was found in hybrid combinations in which sources of resistance against the pathogen *Fusarium graminearum* (MV 20-88 × Smuhlianka, (Mikon × ALMA) × Lehenda Myronivska) and local varieties of winter wheat MIP Knyazhna, MIP Vyshivanka were involved in crossing.

The obtained results give reason to assert that cytoplasmic genes strengthened the dominance of genes of complex resistance in one crossing group, and the dependence of the level of resistance against *Fusarium graminearum* of winter wheat offspring on the level of resistance of parental forms in other hybrids was observed.

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