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EVALUATION OF MAIZE HYBRIDS FOR RESISTANCE TO MAJOR DISEASES AND PESTS IN THE CONDITIONS OF THE SOUTHWESTERN FOREST-STEPPE OF UKRAINE

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Topicality*. The results of phytopathological evaluation of maize breeding material (Zea mays* L.*) against the natural background of the main diseases such as Fusarium blight (Fusarium moniliforme J. Sheld), ear bacterial disease (Bacillus mesentericus vulgatus Flugge), silk-cut (non-parasitic disease), boil smut (Ustilago zeae (Beckm.) Unger) are given. The maize hybrids were damaged by the European corn borer (Ostrinia nubilalis Hb).* ***Purpose.*** *Our research was aimed to conduct a comprehensive evaluation of new maize hybrids for resistance to major diseases and pests in the conditions of the southwestern Forest-Steppe of Ukraine.* ***Methods****. The studies was conducted on the fields at Bukovyna State Agricultural Experimental Station of Institute of Agriculture in the Carpathian region of NAAS in selective crop rotation of NAAS according to generally accepted methods of field experiments, methodical recommendations and handbooks. The resistance of 299 maize hybrids, including 125 hybrids in the competitive variety trial and 174 in the preliminary variety trial, was evaluated. Pochayivskyi 190 MV and DB Lada hybrids were used as a standard for comparing the early-ripening hybrids, Orzhytsia 237 MV and DB Khotyn hybrids were used as a standard for comparing the mid-early hybrids. Early-ripening hybrids are classified as the FAO 180–199, and mid-early hybrids – in the FAO 200–299.* ***Results****. Effectiveness of sampling based on resistance of hybrids to major diseases and damage by European corn borer was established. This allowed us to improve grain quality and productivity of newly developed maize hybrids. Highly resistant, resistant and moderately resistant hybrids to diseases were identified and recommended for state variety testing: to Fusarium pathogen – 52, 97 and 92 (80.5 %) hybrids, ear bacterial disease – 143, 106, 38 (95.9 %), white smut – 190, 59, 34 (94.8 %), boil smut – 279, 8, 10 (99.3 %), respectively, and to damage by European corn borer: the highest resistance (damage of 0–5 %) – 172, high resistance (6–15 %) – 75, and medium resistance (16–25 %) – 35 (94.3 %) hybrids.* ***Conclusion****. As a result of multi-year research, the Bukovyna State Agricultural Research Station of the Institute of Agriculture of the Carpathian region of NAAS, in collaboration with breeders of State Enterprise Institute of Grain Crops of NAAS were identified a number of maize hybrids with high yield properties (9,2 t/ha) and resistance to major diseases and pests. Thus, 77 maize hybrids have high resistance to damage by European corn borer, 8 hybrids were distinguished by high resistance to the pathogen of boil smut. In addition, 97 maize hybrids were resistant to Fusarium pathogen. The implementation of these hybrids in production will significantly improve the maize cultivation in the south-western Forest-Steppe of Ukraine. For the second year, the state variety testing of the early-ripening hybrid DB Tyras (FAO 180), bred in collaboration with State Enterprise Institute of Grain Crops of NAAS, is undergoing. The hybrid is highly resistant to Fusarium pathogens, boil smut, its potential yield is 13.5 t/ha.*

Key words: *hybrid, maize, natural background, disease, pest, resistance, injury, damage*

Introduction. The southwestern Forest-Steppe, in particular Bukovyna, is one of the traditional maize growing areas.

Maize (Zea mays L.) is one of the most important food, fodder and industrial crops on the globe in terms of its distribution, versatility and energy content. Therefore, it is called the Queen of the Fields. The largest maize producers are the United States, China, Brazil, the EU and Argentina. According to the USDA, Ukraine ranks sixth in the world's top maize producers [1].

Maize is in high demand in Ukraine as it is considered the most productive grain for farmers.

In recent years, corn has taken a strategically important place in the grain balance along with other grain crops, increasing its share in the overall structure of total grain production to 50 %. According to national statistics on the

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dynamics of planted areas and yields, maize is the leader among all crops [2].

Over the past five years, the area under maize in Ukraine has been growing steadily. For example, in 2016–2020, the harvested area under this crop increased from 4.2 to 5.4 million hectares, or by 1.3 times [3]. It should also be noted that maize grain exports are constantly growing. For Ukraine, this crop is export-oriented. The domestic market demand for food and fodder maize accounts for about a third of its total production. Therefore, most of the maize yield is sold on the foreign market [4].

The constant growth of maize acreage in Ukraine is increasing the need for new high-yielding domestic maize hybrids with stable yield and high resistance to diseases and pests.

Modern maize hybrids have high yield potential, however, it is not fully realised in production due to their insufficient resistance to diseases.

The development and use of resistant maize hybrids in production is the most cost-effective method of disease and pest control.

In breeding programmes, there is an urgent need to address the problem of combining plant productivity and resistance to various environmental stressors, i.e. to increase the adaptive potential of crops [5].

Breeding research is aimed at deepening knowledge about the nature of inheritance of economically valuable traits in order to purposefully develop and select source material for the synthesis of highly productive maize hybrids.

In agricultural production, maize, which is planted as a single crop, contributes to the accumulation of pathogens in the soil.

Global losses of maize grain due to the harmful effects of phytopathogens average 9.4 %, and in Ukraine this indicator ranges from 19–25 % and more [6].

Yield losses from diseases and pests vary significantly over the years, and depend on soil and climatic conditions that facilitate or inhibit the spread of the harmful organisms [7].

Purpose. To investigate the manifestation degree of the main diseases and maize damage by European corn borer, in particular in hybrids of preliminary and competitive variety trials in the southwestern part of the Forest-Steppe zone. of damage [10].

Damage to maize samples by European

Materials and Methods. In 2017–2021, 299 maize hybrids were evaluated for resistance to boil smut, ear diseases, and European corn borer against a natural background. In the competitive variety trial, 125 hybrids were analysed, including 39 early ripening and 89 mid-early hybrids. The preliminary variety trial included 174 maize hybrids. The early-ripening group included 62 hybrids and the mid-early group – 112 ones. The Pochaivskyi 190 MV and DB Lada standards were used to compare the early ripening hybrids, and the Orzhytsia 237 MV and DB Khotyn standards were used to compare the mid-early hybrids. Early ripening hybrids are included in the FAO 180–199 group, and mid-early hybrids are included in the FAO 200–299 group. The research was conducted in breeding nurseries of the Bukovyna State Agricultural Research Station of the Institute of Agriculture in the Carpathian region of NAAS in a selective crop rotation.

The soil is a heavy loamy meadow chernozem. The humus content in the topsoil is 3.5 %, and content of nutrients in available form (mobile phosphorus, exchangeable potassium, and nitrogen) is average.

Maize was sown manually using the single-seed method (70 x 35 cm) in the optimal dates for the zone. Variety testing nurseries were sown with a given plant density of 70 thousand/ha for early ripening forms, 60 thousand/ha – for mid-early forms and 55 thousand/ha for mid-ripening forms. In the variety testing trials, each block included up to 20 samples. In the preliminary variety testing, the accounting area was 9.8 m^2, in the competitive variety testing – 14.7 m^2, experiment was replicated three times. Harvesting was carried out manually.

Agricultural practices for growing maize are common for the zone. The study was conducted according to the guidelines [8, 9].

Hybrids were evaluated for resistance to major diseases under natural background conditions. The disease development, pest abundance and resistance to them were evaluated under different moisture supply and temperature conditions. The share of ears affected by the most common diseases was determined during the harvesting period. The studied hybrids were divided into groups of resistance (high, medium and low) to diseases according to the percentage corn borer was evaluated before harvesting according to the Descriptor - Reference Book for

Zea mays L. species [10].

The research was conducted under peculiar meteorological conditions that differed significantly from the long-term average that allowed to differentiate maize samples by disease resistance.

During 2017–2021, the average daily air temperature was 19.6 ºC (with a norm of 16.8 ºC), which was 2.8 ºC higher than the long-term average (Table 1).

Table 1. Basic meteorological data of average daily air temperature and precipitation for the growing season by year (2017–2021)

Years	Average daily air temperature, °C					Precipitation, mm				
	month									
	V	VI	VII	VIII	IX	V	VI	VII	VIII	IX
2017	15.4	19.8	21.1	22.0	16.0	54.8	105.1	73.1	24.2	93.1
2018	19.4	20.9	22.1	23.4	17.5	63.8	210.5	87.0	3.8	11.2
2019	15.7	23.3	21.5	22.4	17.2	126.5	111.3	90.2	22.5	27.9
2020	13.8	20.7	21.3	22.8	17.9	150.7	112.4	49.4	36.5	113.9
2021	15.2	20.5	24.0	20.6	15.0	88.8	75.9	98.2	99.7	29.4
Long-term average	14.5	17.5	19.2	18.6	14.2	73.0	89.0	94.0	74.0	57.0

The hottest year was 2018, when the difference between the daily average and the long-term average was 3.9 °C.

In the 2017 growing season, there was 350.3 mm of precipitation, compared to the normal 387 mm. The overall precipitation deficit for this period was the largest and amounted to 9.5 %.

In 2018, precipitation amounted to 10.7 mm less, which was 97.2 % of the long-term average. During the growing season in 2019, 378.4 mm of precipitation fell, compared to the normal 387.0 mm. The precipitation deficit for the period was only 2.2 %.

The 2020–2021 growing seasons were characterised by uneven distribution of precipitation. During the growing season of 2020, 462.9 mm of precipitation fell (119.6 % of the long-term average), and in 2021 – 392 mm (101.3 % of the norm). June in 2017–2020 and September in 2017, 2020 were characterised by significant waterlogging.

In particular, in June 2018, precipitation was 210.5 mm, while the norm was 89.0 mm, which is 2.4 times higher than the long-term average. In September 2017 and 2020, there was 36.1 and 56.9 mm more precipitation, respectively, than the long-term average.

These weather conditions proved to be stressful for both the spread of diseases and plant development, which allowed us to objectively evaluate their resistance to harmful pathogens.

Results and Discussion. Over five years of testing maize hybrids, we found that the spread and intensity of diseases over the years depends mainly on the meteorological conditions of the second half of the growing season and on the resistance of specific hybrids.

According to the average resistance data for 2017–2021, the study found that against the natural background, maize ears in the competitive and preliminary variety testing were affected by Fusarium blight, ear bacterial disease, silk-cut and boil smut. The average disease incidence ranged from 6.7 to 82.5 % (Table 2).

After the formation of maize ears (during the period of milk ripeness), they are affected by blister smut, bacteriosis, pain, and later by fusarium and other diseases.

In 2017–2018 and the wet conditions of 2020–2021, Fusarium blight was the most common harmful fungal disease. The percentage of cultivars affected by this disease was 4-80%. The disease is caused by spores spread by insects, wind and rain from the affected vegetative organs of maize and plant residues. Injured ears by pests or silk-cut are the most commonly affected. Outbreaks of European corn borer also contribute to the spread of Fusarium blight. Fusarium fungi develop in a wide temperature range +3...+30 ºC (optimum +20...+22 ºC). Disease spread is facilitated by high temperature and humidity [11–15].

In the dry and warm autumn of 2017–2019, an incidence of ear bacterial disease was 4.0–32.0 %. This disease manifests during milk-wax ripeness on the uncovered kernels in the upper part of the ear. The pathogen is a gram-positive, spore-bearing, rod-shaped aerobic bac-

Table 2. Average indicators of maize hybrids damage by major diseases and pests on the natural background (2017–2021), %

Nursery	Number of samples analysed	Boil smut			Ear diseases				European corn borer	
		unaffected	affected		unaffected	affected			undamaged ears	ears damaged
			vegetative organs	ears		Fusarium blight	ear bacterial disease	silk-cut		
			limits (min/max)			limits (min/max)				limits (min/max)
			<5/ >50			<10/ >25		<5/ >10		<5/ >50
Competition test	125	82.4	12.0	5.6	0	4–80	4–28	4–16	36.0	64.0
Preliminary test	174	75.3	17.2	7.5	0	4–60	4–32	4–24	27.6	72.4
Total	299	234	45	20	-	-	-	-	95	204
Average indicator of disease and pest damage	-	78.2	15.1	6.7	100	82.5	52.2	36.6	31.8	68.2

terium transmitted from a diseased plant to a healthy one by the sunn pest (*Eurygaster integriceps* Put.). Kernels are infected when the bug damages the seed coat. The main infection source is the sunn pest, inside whose body the bacteria overwinter. Ear bacterial disease develops at a temperature range of +5...+55 ºC, with an optimum of +25...+30 ºC [6, 12–13].

The repeated change of dry and excessively wet weather in 2017 and 2020 contributed to the development of the silk-cut (4.0–24.0 %). Silk-cut of maize ears is a non-parasitic disease that manifests at the end of milk ripeness and at the beginning of dough stage of maize kernels in the form of cracks of different configurations and depths. Cracking is caused by uneven water supply to plants during grain ripening. Cracks in the kernels are formed as a result of the discrepancy between the endosperm formation rate and the growth of the seed coat during sudden changes in air and soil moisture. Fusarium blight and mould fungi develop more rapidly on ears affected by the silk-cut in the field [12–13].

On the natural background, 21.8 % of hybrids were affected by boil smut, including vegetative organs from 4.0 to 20.0 % and ears from 4.0 to 16.0 %. On average, 78.2 % of the samples resistant to this disease were identified over the years of study. The development of boil smut is influenced by climatic factors, such as high air temperatures and insufficient rainfall, especially during the stages of silking and grain filling.

High temperatures and sharp fluctuations in moisture supply are more favourable than systematic sufficient wetting for the development of boil smut. Boil smut is very common in years with uneven rainfall during the growing season, but prolonged droughts inhibit its development.

Maize plants are most affected by boil smut from stage of 4–6 leaves to the beginning of milk maturity. The first signs of primary disease damage appear on young leaves and sheaths. In the stage of 5–8 leaves, leaf sheaths and stems are affected, then tassels, and at the beginning of flowering – ears. At the end of the growing season, tumours appear on the reproductive buds.

The number, size and location of blisters on one plant affect the amount of yield loss. Large galls cause yield losses of about 60% or more, medium-sized galls – 25 %, and small galls – 10 % [18].

The fungus infects all plant organs except the roots: leaves, stems, internodes, leaf sheaths, ears, tassels, and aerial roots. Primary infection occurs via teliospores spread by the wind from galls left on the field and destroyed by tillage. The spread of boil smut is also caused by damage to plants by the European corn borer, Oscinella frit and other pests [12–17].

During 2017–2021, the lowest damage to ears of maize hybrids by the Fusarium pathogen (*Fusarium moniliforme J. Sheld*) was found in 2019 (54.9 %), and the highest – in 2021 (96.7 %). In 2017–2018, 2020, the disease incidence was in the range of 84.2–89.8 % (Fig. 1).

The highest incidence of ear bacterial disease was observed in 2017 – 65.6 %, and the lowest – in 2020 – 39.0 %.

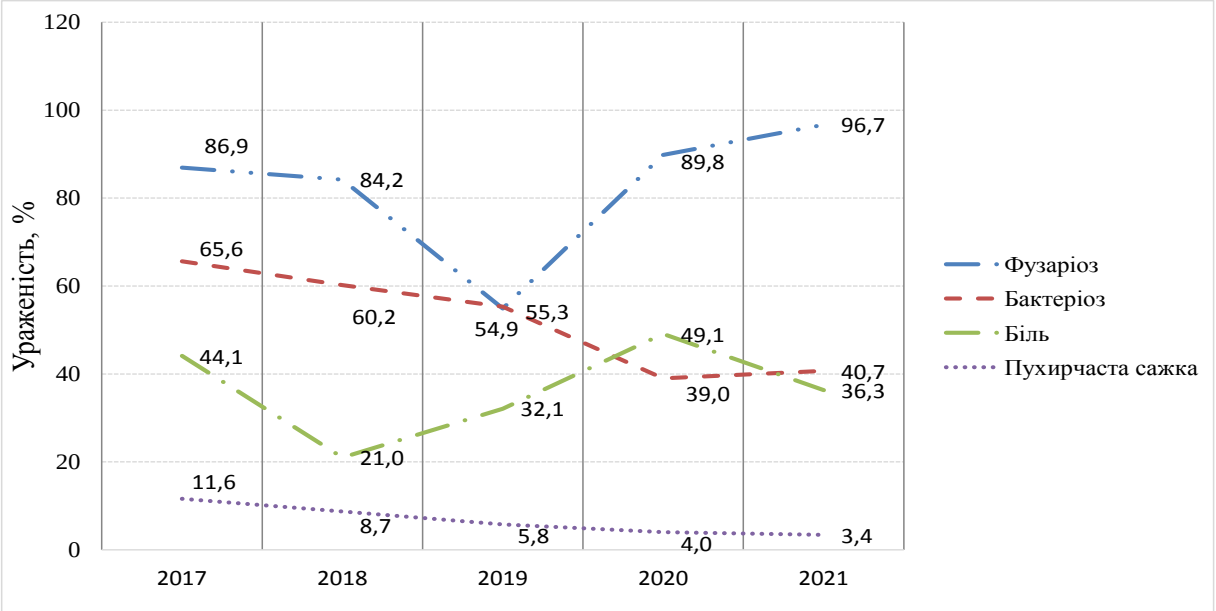

Fig. 1. Indicators of damage by the main diseases of maize ears (2017–2021).

Ears affected by silk-cut ranged from 21.0 % in 2018 to 49.1 % in 2020.

The development of boil smut was less intense. Ears of maize hybrids were affected by the pathogen from 3.4 % in 2021 to 11.6 % in 2017.

When studying the disease resistance of maize ears, we identified three groups with high, medium and low resistance (Fig. 2).

Evaluation of maize ear resistance to Fusa-

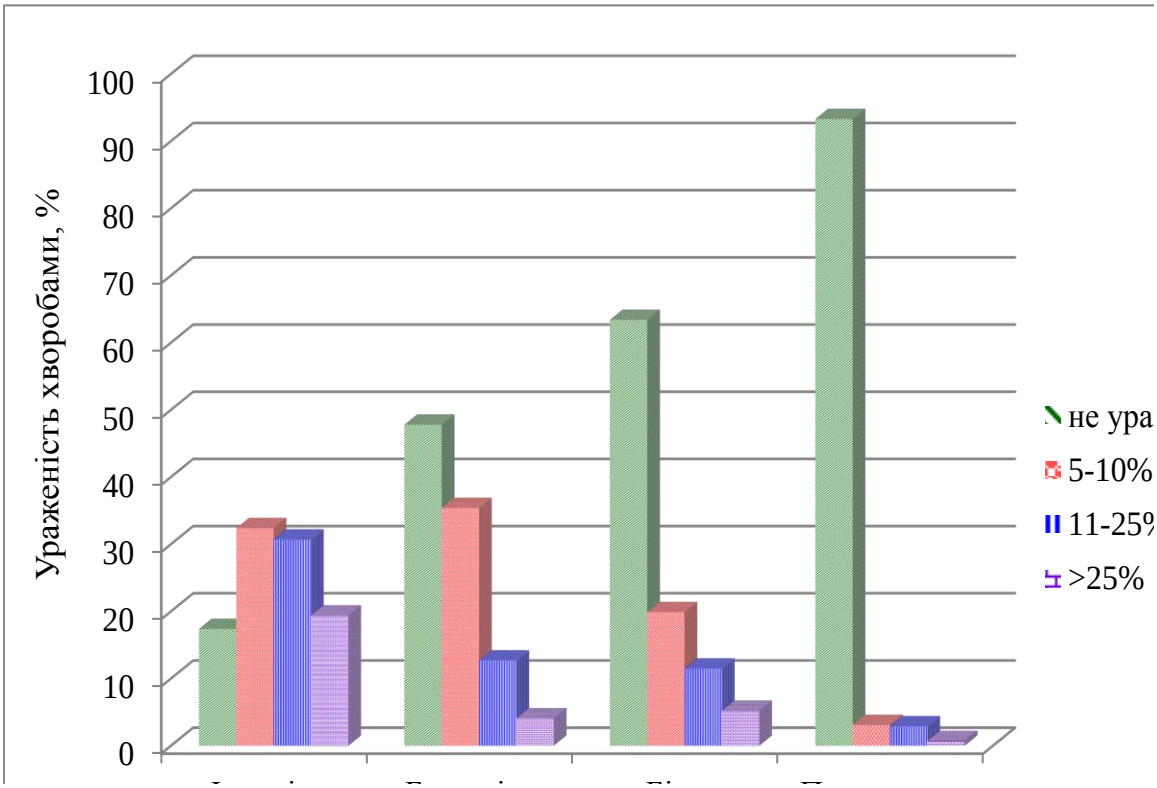

Fig. 2. Distribution of hybrids (ears) by resistance groups (average for 2017–2021).

rium pathogen revealed that 52 (17.4 %) hybrids were unaffected. The high resistance group (up to 10 % affected ears) and the medium resistance group (11–25 %) included 97 (32.4 %) and 92 (30.7 %) hybrids, respectively, and the low resistance group (>25 %) included 58 (19.4 %) hybrids.

The number of hybrids unaffected by ear bacterial disease was 143 (47.8%), with high resistance to this disease was 106 (35.3 %), medium resistance – 38 (12.8%), and low resistance – 12 (4.1 %).

There were 190 (63.4 %) hybrids with ears unaffected by silk-cut. The high resistance group included 59 (19.9 %) hybrids, the medium resistance group included 34 (11.5 %) hybrids, and the low resistance group included 16 (5.2 %) hybrids.

There were 279 (93.3 %) hybrids unaffected by boil smut. The groups with high (damage up to 5 %) and medium (6–10 %) resistance of ears included 8 (2.7 %) and 10 (3.3 %) hybrids, respectively, and low resistance (damage of 11–25 %) was shown by 2 (0.7 %) hybrids.

The most common pest in the southwestern Forest-Steppe of Ukraine is the European corn borer, which is a highly harmful pest. Favourable conditions for the development of the borer are in areas with temperatures above 20 ºC in June–August and precipitation of more than 200 mm at this time [14].

The moth flight coincides with the beginning of tasseling, in June. The caterpillars of this borer are polyphagous, damaging leaves, stems, tassels, ears and grain. Places of damage by the pest serve as a gateway for the infection. Ears damaged by caterpillars reduce the seed yield and deteriorate its quality, increasing the risk of Fusarium and other diseases [18].

Pest infestation reduction requires the use of resistant maize hybrids in addition to a set of protective practices, including agronomic and chemical methods [19].

Evaluation of maize ear damage by European corn borer showed that on average for 2017–2021, 95 hybrids were undamaged, which is 31.8 % (Table 2).

The highest damage to maize ears by the borer was observed in 2018 – 249 hybrids (83.2 %), and the lowest damage in 2019 – 140 hybrids (46.8 %). Very high resistance (damage up to 5.0%) was observed in 77 hybrids (25.8 %) and high resistance (6–15 %) was observed in 75 hybrids (25.0 %). The medium resistance group (16–25% damage) included 35 hybrids (11.7 %) and the low resistance group (26–50%) included 17 hybrids (5.7 %).

As a result of the research, we have identified the highly resistant, resistant and moderately resistant hybrids to Fusarium pathogen – 52, 97 and 92 (80.5 %) hybrids, respectively, to ear bacterial disease – 143, 106, 38 (95.9 %), silk-cut – 190, 59, 34 (94.8 %), boil smut – 279, 8, 10 (99.3 %), and to damage by European corn borer: very high resistance (0–5 % damage) – 172, high resistance (6–15 %) – 75 and medium resistance (16–25 % damage) – 35 (94.3 %) hybrids. We recommend these hybrids for state variety testing.

Conclusions. Many years of research at the Bukovyna State Agricultural Research Station of the Institute of Agriculture in the Carpathian region of NAAS in collaboration with breeders of the SE Institute of Grain Crops of NAAS have resulted in the identification of a number of maize hybrids with high yield properties (9.2 t/ha) and resistance to major diseases and pests. In particular, 77 maize hybrids are highly resistant to damage by the European corn borer, and 8 hybrids are highly resistant to the boil smut pathogen. A total of 97 maize hybrids were resistant to Fusarium blight. The introduction of these hybrids into production will significantly improve maize cultivation in the southwestern Forest-Steppe of Ukraine.

An early-ripening hybrid DB Tyras (FAO 180), which is characterised by high resistance to Fusarium pathogens and boil smut and has a potential yield of 13.5 t/ha, has been undergoing state variety testing for two years. This hybrid was developed in collaboration with SE Institute of Grain Crops of NAAS.

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Томаш Л. В., Микуляк І. С., Лінська М. І., Козак Г. В. Результати оцінки гібридів кукурудзи на стійкість до основних хвороб і шкідників в умовах південно-західного Лісостепу України. *Зернові культури. 2022. 6 (2). 43–50.*

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Актуальність. Наведено результати досліджень по фітопатологічній оцінці селекційного матеріалу (гібриди кукурудзи Zea mays L.) на природному фоні основних хвороб: фузаріоз (Fusarium (F. moniliforme J. Sheld)), бактеріоз (Bacillus mesentericus-vulgatus Flugge), біль (непаразитарне захворювання), пухирчаста сажка (Ustilago zeae (Beskm.) Unger). Визначено пошкодженість гібридів кукурудзи стебловим метеликом (Ostrinia nubilalis Hb). **Метою** наших досліджень було проведення комплексної оцінки нових гібридів кукурудзи на стійкість до основних хвороб і шкідників в умовах південно-західного Лісостепу України. **Методи.** Дослідження проводили на полях Буковинської державної сільськогосподарської дослідної станції Інституту сільського господарства Карпатського регіону в селекційній сівозміні НААН згідно із загальноприйнятими методиками проведення польового досліду та методичними рекомендаціями. Оцінку стійкості проведено на 299 гібридах кукурудзи. В конкурсному сортовипробуванні проаналізовано 125 гібридів, в попередньому сортовипробуванні – 174. Для порівняння ранньостиглих гібридів використовували стандарти – Почаївський 190 МВ та ДБ Лада, а середньоранні гібриди порівнювали зі стандартами Оржиця 237 МВ та ДБ Хотин. Ранньостиглі гібриди входять у групу ФАО 180–199, а середньоранні – в групу ФАО 200–299. **Результати.** Встановлено ефективність відбору зразків за стійкістю до основних хвороб та пошкодження гібридів стебловим кукурудзяним метеликом, що сприятиме покращенню якості зерна та продуктивності новостворених гібридів кукурудзи. Виділено

високостійкі, стійкі та середньостійкі до хвороб гібриди, які можна рекомендувати до державного сортовипробування: до збудника фузаріозу – 52, 97 та 92 (80,5 %) гібридів, бактеріозу – 143, 106, 38 (95,9 %), біллі – 190, 59, 34 (94,8 %), пухирчастої сажки – 279, 8, 10 (99,3 %) гібридів, відповідно та до пошкодження стебловим кукурудзяним метеликом: дуже високе (пошкодження 0–5 %) – 172, високе (6–15 %) – 75, та середнє (пошкодження 16–25 %) – 35 (94,3 %) гібридів. **Висновки.** Підсумком багаторічних досліджень на Буковинській державній сільськогосподарській дослідній станції Інституту сільського господарства Карпатського регіону НААН, у співавторстві з селекціонерами ДУ Інституту зернових культур НААН виділено ряд гібридів кукурудзи, які при високих урожайних властивостях (9,2 т/га) характеризуються стійкістю до основних хвороб та шкідників так 77 гібридів кукурудзи мають високу стійкість до пошкодження кукурудзяним метеликом, 8 гібридів відзначилися високою стійкістю до збудника пухирчастої сажки. Стійкими до збудника фузаріозу виявилось 97 гібридів кукурудзи. Впровадження цих гібридів у виробництво дасть змогу значно поліпшити вирощування кукурудзи в умовах південно-західного Лісостепу України. Другий рік проходить державне сортовипробування ранньостиглий гібрид (ФАО 180) ДБ Тирас, характеризується високою стійкістю до збудників фузаріозу, пухирчастої сажки, потенційна врожайність якого 13,5 т/га. Створений в співавторстві з ДУ Інституту зернових культур НААН.

Ключові слова: *гібрид, кукурудза, природний фон, хвороба, шкідник, стійкість, ураженість, пошкоджуваність*