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ORIGINAL ARTICLE

Adaptive properties of maize forms for improvement in the ecological status of fields

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The conducted research has become the basis for the development of practical recommendations and the improvement in the methods for determining the resistance of maize plants to pathogens of head and boil smut. In terms of monoculture, susceptible lines are significantly affected by head smut, and what is more, maize cobs are characterized by heavy infestation that significantly influences the harvest of these lines. To improve the effectiveness of assessing the resistance of lines and hybrids to this disease in the conditions of Right-Bank Forest-Steppe of Ukraine, where the disease is not widespread, it is expedient to use an artificial provocative background.
Keywords: Maize; self-pollinated lines; boil and head smut; resistance assessment; ripeness group; breeding

Introduction

Maize is a dominant crop in the world's total grain production. Approximately 850 million tons of maize, with an average yield of 5.2 t/ha, are produced on the total area of 162 million hectares. In more recent times, the production of this crop grain has increased at a record pace up to 850 million tons in the world, and 39.0-46.2% of it is harvested in the United States, the high gross yield is observed in China and Brazil as well (Riabchun, 2007).

In Ukraine, 4.5-5.0 million hectares are occupied by maize that is almost a quarter of all grain crops. Grain maize is grown on 4.0-4.5 million hectares, maize for silage and green fodder - on 0.2-0.4 million hectares (Palamarchuk, 2018; Kolisnyk, 2007). The introduction of intensive technology and new high-performance hybrids into production has significantly increased the yield of maize on large areas. Many of the best farms obtain 9-10 t/ha or more, including in new maize-growing areas (Polissia of Ukraine). In some regions of Ukraine, the yield is amounted to 4.5-6.0 t/ha, but in general in Ukraine the volume of maize yield remains low, including as a consequence of entomopathogens and phytopathogens (Palamarchuk, 2018).

According to the long-term data (Palamarchuk, 2010), the total shortfall in maize grain production caused by stem rot, smut, kernel rot and European com borer is estimated at an average of 30.9%.

This a reason that the search for sources of resistance to these diseases and pests is particularly relevant, and the creation of maize hybrids with a group character of resistance to major diseases and pests remain one of the main practical tasks of the breeding of maize plant.

An increase in maize grain production is possible primarily due to the limitation of losses during harvesting. Annual losses of grain yield from the lodging of maize plants reach 20%, and in some cases, especially with stem breakage, up to 20-40% of the crop (Zozulia, 1983; Palamarchuk, 2009; Kolisnyk, 2016).

Materials and methods

In 2015, the 64 simple hybrids were obtained based on the dedicated lines by crossbreeding under insulators. The assessment of the obtained hybrids and self-pollinated lines was carried out during 2015-2017. The crossbreeding and reproduction were carried out under parchment insulators. In this case, the pollen was gathered in the parchment insulator, and then applied to the cob silks, which had been previously under the polyethylene insulator. The gathering was carried out manually.

For self-pollinated lines, which significantly differed in the date of cob flowering and were used in direct and back crosses of a diallel scheme, the synchronization of flowering was achieved by their being planted at different times, thereby reducing the divergence in flowering to 3-5 days.

The field and laboratory methods of studying the breeding material were used in the research. The records and observations were made in accordance with the "Guidelines for Field and Laboratory Study of Genetic Maize Resources" (Kolisnyk, 2007,2010; Kravtsov, 2000).

The field methods were used for individual selection in the breeding nursery, phenological observations and sampling; the laboratory methods - for the analysis of plants by morphological characters, genetic - for the identification of the breeding and genetic characteristics of maize lines in the creation of hybrids of different ripeness groups when using monoculture in combination of valuable economic characters with resistance to diseases and pests; statistical - for the establishment of patterns of variability of characters and the degree of reliability between the variants of experience; comparative-calculated - for the determination of economic efficiency.
Soil is grey forest, coarse silt and moderately-loamy on the experimental plots. According to the results of the last comprehensive agrochemical analysis (2015), the humus content in the arable layer is 2.4%. The reaction of soil solution that is pH (salt) is 5.8; average weighted namely hydrolytic acidity, is 4.1 mg-eq., and the amount of absorbed bases is equal to 15.3 mg-eq. per 100 g of soil, the degree of saturation with bases is 78.9%; the content of nitrogen available for plants (by Chyrykov) is 8.8 mg, mobile phosphorus and potassium exchange (by Chyrykov) are respectively, 21.2 and 9.2 mg per 100 g of soil. The leaching of colloids of organic and mineral origin out of the arable soil layer and low humus content lead to the deterioration in the physical and chemical properties of these soils. Their fertility potential is assessed as satisfactory.
On the territory of Vinnytsia region, where the research area is located, the climate is moderately warm. Winter begins in the second or third decade of November. Snow cover occurs on average in the third decade of December and melts in the third decade of March. Its height in the western and southern parts of the zone ranges from 13 to 20 cm, and in the eastern part - 26-35 cm. The average monthly air temperature in January and February varies from -4 to -8.0 °C. This zone is characterized by long thaw periods, during which the air temperature in some years rises to +12 to +14 °C.
Spring lasts from 65 to 75 days. The transition of air temperature with +5 °C is observed in the first decade of April. Summer is characterized by high and stable temperatures. In July, the average monthly air temperature varies from + 10 °C in the west to -20 °C in the east. The absolute maximum temperature reaches +39-49 °C.
The duration of vegetation period is 150-170 days. At the same time, dry periods and dry winds are often observed. According to the average long-term data, the maize in the research area undergoes the main stages of its development on the following calendar dates: sprouting stage - May 20; the third leaf appearance stage - May 26; comfrey appearance stage - July 14; cob flowering stage- July 20; kernel milk stage - August 22; kernel dough stage - September 11 (Palamarchuk, 2009; Nadtochaev, 2000).
Thus, the most favorable for the maize growth and development by weather indicators were 2015 and 2016. They have contributed to the resistance of maize to disease and pests and the intensive growth and development of plants. In 2017, there was a significant deterioration in climatic conditions due to a long dry period, which fell on the stages of comfrey and cob flowering and the formation of grain.

Results and discussion

The goal of our research is to determine the effectiveness of the use of maize lines various in genetic basis and resistance to diseases and pests.
The selection of parents for the generation of heterosis is crucial in the breeding of hybrid vigor. The maximum effect of heterosis is achieved only by the hybridization of specially selected lines.
Zozulia O. L. states that one of the most significant reserves for increasing the production of maize grain is the creation and put into production of highly productive hybrids, which are characterized by the stability of output yield under variable environmental conditions, resistance to lodging, diseases and pests, intensive moisture return of grain, that is, fully comply with the requirements of industrial technology of cultivation and harvesting (Zozulia, 1983). For breeding of this type of hybrids, it is expedient to have genetically diverse material that is new self-pollinated lines of maize adapted to the soil and climatic characteristics of the region, and the appropriate methodology for their evaluation and use.
The relevant material was used and the principles of choosing self-pollinated lines for the selection of hybrids in this direction were developed in order to create high-yielding maize hybrids resistant to diseases and pests (Palamarchuk, 2018; Orlianskyi, 2005).
The 125 forms resistant to boil smut, of which only 9.2% were characterized by the stability of this character, were distinguished from the studied self-pollinated maize lines. The variation in the resistance of lines and hybrids by years is explained by the different distribution of climatic factors during the period of the greatest susceptibility of plants.
Based on the results of our research, it was found that among the diseases, the greatest harm to the maize breeding material was caused by boil and head smut in the experimental areas. The results of studying the resistance of self-pollinated lines of different origin to the infestation with boil smut (Table 1) indicate that the breeding material studied in the conditions of natural infectious background, regardless of the ripeness group, is highly resistant to this disease.

Table 1. Resistance of self-pollinated lines of maize to the infestation with boil smut (2015-2017).

Resistance	Ripeness	Self-pollinated lines
High, less than 10%	Early ripening	FS 200, MA 17, PLS 61, HLG 81, HLG 224, HLG 272, HLG 1128, SM 7 (St).
	Middle-early	SM 5-1-1, SO 91, F 502, K 210, KL 13, MA 22, MA 23C, Oh 43H.t, HLG 163, HLG 189, HLG 294, HLG 386, HLG 489, HLG 1216, P7(St).
	Mid-ripening	AS 77-4-1, B 37, SO 108, K 212, MA61A37, S 35, S 38, DK 44-1, UH 405, UHK 409, HLG 33, HLG 42, HLG 85, HLG 562, HLG 1278, HLG 1339, W 401 (St).

Medium, 10-15%	Early ripening	F 101, MAIL
	Middle-early	-
	Mid-ripening	UHK411.
Low, more than 15%	Early ripening	-
	Middle-early	SO 255, UHK 372, HLG 293, HLG 998.
	Mid-ripening	SO 113, KL 17, HLG45.

However, the early ripening lines F 101, MA 11 and mid-ripening lines UHK 411 had a high level of resistance, and the mid-early lines SO 255, UHK 372, HLG 293, HLG 998 and mid-ripening lines SO 113, KL 17, HLG 45 were characterized by low resistance to the infestation with boil smut.

The resistance of simple maize hybrids to the infestation with boil smut depended on the parent components which took part in the crossing, and a heterosis effect.

The following samples characterized by high resistance to the disease were selected among the hybrid combinations of different ripeness groups:

early ripening - HLG 81 × HLG 272, HLG 272 × HLG 81, PLS 61 × HLG 562;

mid-early - HLG 1278 × HLG 1216, KL 13 × UHK 411, HLG 33 × HLG 163, SO 108 × MA 22, UHK 409 × MA 22, SM5-1-1 × KL 17, UHK 411 × KL 13, HLG 1216 × HLG 1278, UHK 409 × F 502, MA 22 × F 502, SM 5-1-1 × SO 108, UHK 409 × SM 5-1-1, F 502 × SO 108, SO 108 × F 502, HLG 1339 × HLG 1128, F 502 × MA 22, F 502 × SM 5-1-1, UH 405 × F 502, HLG 1128 × HLG 1339, HLG 562 × PLS 61, HLG 294 × HLG 293, UH 405 × SM 5-1-1.

mid-ripening - SO 108 × UH 405, DK 44-1 × HLG 42, F 502 × UHK 409, UH 405 × SO 108, HLG 42 × DK 44-1, UHK 409 × UH 405, KL 17 × UH 405, UHK 409 × SO 108, SO 113 × AS 77-4-1, MA 22 × UH 405, UH 405 × UHK 409, SM 5-1-1 × UH 405, B 37 × MA61A37, F 502 × UH 405.

Other simple hybrids were characterized by medium and low resistance to the infestation with boil smut. It should be noted that if such lines as SO 255 and KL 17 took part in crossing, the resistance of hybrid combinations was low.

In support of these statements, a number of researchers (Palamarchuk, 2010; Palamarchuk, 2009; Azurkin, 2002) note that the resistance of maize to U. Zeae is a rather complicated feature, which is determined by the anatomical and morphological, and physiological and biochemical characters of plants that are controlled by genetic factors in the system of plant- host - pathogen - environment. Many authors point to the significant variability of immunological properties of lines and hybrids to boil smut depending on the year and place of testing. Most of them explain this fact by the difference in environmental conditions. Among the 540 studied self-pollinated maize lines, Yurku A. I. (Yurku, 1990) and Lazu M. N. (Lazu, 1986) distinguished the 125 forms resistant to boil smut, of which only 9.2% were characterized by the stability of this character. They explain the variation in the resistance of lines and hybrids by years by the different distribution of climatic factors during the period of the greatest susceptibility of plants.

On the other hand, the stability of resistance of lines and hybrids to U. zeae depends heavily on the ability of the parasite to change its pathogenicity under the influence of various factors (Palamarchuk, 2009; Ponurenko, 2005). The submitted statements are confirmed in our studies as well. The characteristics of self-pollinated lines of maize by resistance to boil smut are given in Table 2.

Table 2. Assessment of the resistance ofself-pollinated lines of maize to the infestation with boil smut (average values for 2015-2017). Note * - for years of observations.

Resistance (by infestation, %)	**Ripeness group**	**Self-pollinated lines**	**R*, %**	**V, %**	$X + S\bar{x}$
High, 0.0-10.0% (resistant)	Early ripening	FS 200, MA 17, PLS 61, HLG 81, HLG 224, HLG 272, HLG 1128, SM	0.8 - 6.2	53	3.1 ± 0.33
	Mid-early	SM 5-1-1, SO 91, F 502, K 210, KL 13, MA 22, MA 23C, Oh 43H.t, HLG 163, HLG 189, HLG 294, HLG 386, HLG 489, HLG 1216, F 7(St)	0.2 - 13.0	63	5.6 ± 0.50
	Mid-ripening	AS 77-4-1, B 37, SO 108, K 212, MA61A37, S 35, S 38, DK 44-1, UH 405, UHK 409, HLG 33, HLG 42, HLG 85, HLG 562, HLG 1278, HLG 1339, W401 (St)	0.0 - 10.7	71.1	3.9 ± 0.39

Medium, 10.0-15.0% (mid-resistant)	Early ripening	F 101, MA 11	7.9 - 13.1	26.3	11.5 ± 0.77
	Mid-early	-	-	-	-
	Mid-ripening	UHK 411	8.6 - 13.9	16.3	10.7 ± 1.63
Low (favorable) 15.1 - 30.0 %	Early ripening	-	-	-	-
	Mid-early	SO 255, UHK 372, HLG 293, HLG 998	15.2 - 45.1	35.5	29.9 ± 3.07
	Mid-ripening	SO 113,KL17, HLG 45	11.9 - 40.9	36.2	24.2 ± 2.92
On average for yankee maize subspecies			0.0 - 21.6	48.9	7.20 ± 1.27
On average for dent maize subspecies			0.5 - 45.1	52.8	8.24 ± 1.06
The average value for early ripening lines			0.8 - 13.1	80.3	4.74 ± 0.70
The average value for mid-early lines			0.5 - 45.1	75.4	10.6 ± 1.61
The average value for mid-ripening lines			0.0 - 40.9	89.5	7.09 ± 1.03

The results of studying the resistance of self-pollinated lines to the infestation with boil smut indicate that the breeding material studied in the conditions of natural infectious background, regardless of the ripeness group, is highly resistant to this disease (Table 2).

Thus, we recommend to use such lines as SO 255, KL 17, SO 113, HLG 45 for the breeding of maize resistant to head smut. During the test years, the infestation of maize plants with head smut under the field conditions was not found. Against the provocative background the plants infested with Sorosporium reilianum were found in 2017. In the hybrid combination of S0255 × KL 17, the infestation was equal to 9.5%. In 2017, the maize lines and hybrids were infested with head smut to a greater extent on the breeding plot. This was obviously facilitated by the accumulation of infection in the soil and the weather conditions favorable for the spread of the disease (Figure 1).

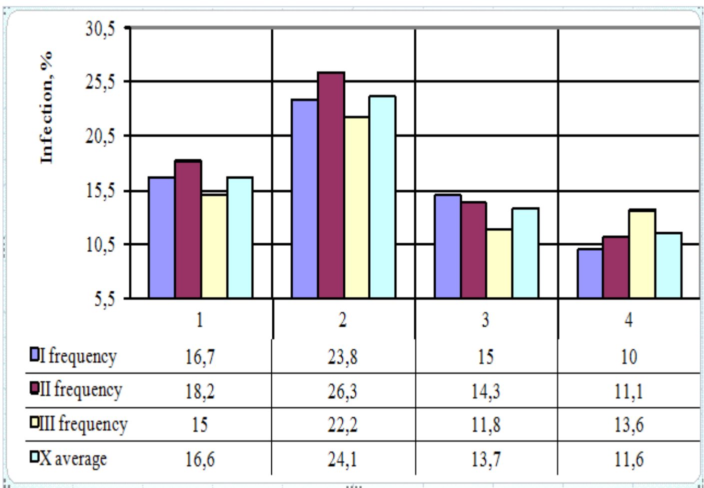

Figure 1. Infestation of susceptible lines of maize with head smut in terms of monoculture for 2015-2017.

Conclusion

The genotypic differences in resistance to diseases and pests in self-pollinated lines open the potential for the effective selection of forms with integrated resistance, and their use in hybridization will enable to obtain hybrids resistant to a set of diseases and pests.

The authors have distinguished the self-pollinated lines with integrated resistance to major pests and diseases, namely: HLG 81, HLG 224, F 502, K 210, HLG 163, HLG 189, HLG 1216, HLG 562, K 212, HLG 1278, UH 405, HLG 1339.Their resistance to the infestation with smut diseases amounts to 0.0-5.0%. These are the lines that may be effectively studied and used to create resistant to entomophagous and phytophagous hybrids and in further breeding study.
Therefore, the significant infestation of susceptible lines with head smut was observed in terms of monoculture, and the maize cobs were characterized by heavy infestation that significantly influenced the harvest of these lines. In connection with this, the assessment of lines and hybrids for resistance to head smut against the enhanced provocative background is a very important step in breeding the hybrids resistant to diseases. The improvement in the effectiveness of assessing the resistance of lines and hybrids to this disease in the Right-Bank Forest-Steppe of Ukraine, where the disease is not widespread, requires the use of artificial provocative background.

References

Ryabchun, V. K., & Gurieva, I. A. (2007). Maize genetic resources in Ukraine (Monograph). Kharkiv. Plant Research Institute named after V. Ya. Yurieva.

Palamarchuk, V., & Telekalo, N. (2018). The effect of seed size and seeding depth on the components of maize yield structure. Bulgarian Journal of Agricultural Science, 24(5), 783-790.

Palamarchuk, V. D., Klimchuk, O. V., Polishchuk, I. S., Kolesnyk, O. M., & Borivskyi, A. F. (2010). Ecological and biological and technological principles of cultivation of field crops: textbook. Vinnytsa.

Zozulia, A. L. (1983). Anatomical and morphological methods of evaluation of maize breeding material. Maize Selection and Seed Production.- K.: Urozhai, 55, 27-30.

Palamarchuk, V. D., Mazur, V. A., & Zozulia, O. L. (2009). Com, selection and cultivation of hybrids. Vinnytsa: [Monograph].

Kolisnyk, O. M. (2016). Resistance of self-pollinated maize lines to ustilagozeae I sphacelothecareilina. Selection and Genetic Science and Education, Materials of the International Conference March 16-18, 2016, pp: 134-137.

Kolisnyk, O. M., & Liubar, V. A. (2007). Resistance of the initial maize material to boil smut. Feed and Feed Production, 61, 40-45.

Kolisnyk, O. M., & Vatamaniuk, O. V. (2010). Resistance of self-pollinated maize lines to UstilagozeaeBeck Grain Storage and Processing. Scientific and Practical Journal, 8(134), 28-30.

Yurku, A. I. (1990). The head smut of com. - Kishinev: Stiintsa.

Lazu, M. N. (1986). Genetic aspects of resistance of com to boil smut and donors of immunity to the disease in Moldavia: extended abstract of dissertation for a candidate degree in Biological Sciences: 06.01.11. - Kishinev.

Kravtsov, I. A., & Fedotkin, I. V. (2000). Productivity of parent forms of maize hybrids and their cultivation for grain. Com and Sorghum, 4, 11-12.

Nadtochaev, N. F., Meleshkevych, M. A., Davydenko, A. S., & Shymanskyi, L. P. (2000). Density of stand of parental forms of com in the conditions of Belarus. Com and Sorghum, 5, 15-19.

Orlianskyi, N. A. (2005). Behavior of maize under conditions of artificial stress caused by overcrowding. Com and Sorghum, 4, 5-8.

Azurin, V. O. (2002). Number of flowers on the maize cob and its seed production. Collection of Scientific Papers of the Institute of Agriculture of the Southern Region of UAAN. - Kherson.

Ponurenko, S. H., Hurieva, I. A., & Panchenko I. A. (2005). Phenotype effect and environmental plasticity of samples of gene pool of maize grain by characteristics of grain quality and productivity. Scientific works of Poltava State Agrarian Academy. Agricultural Sciences. - Poltava, 4(23), 64-66.

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