

INHERITANCE PECULIARITIES

of resistance to *Septoria* leaf spot on sunflower in F_1 hybrids

Goal. To find out the peculiarities of inheritance of the resistance level to *Septoria* leaf spot by sunflower hybrids of the first generation obtained from crossing the lines with different disease resistance. **Methods.** Field assessment of resistance to pathogen of sunflower breeding lines and F_1 hybrids obtained from crossing the lines. **Results.** Differences in *Septoria* leaf spot resistance in sunflower breeding lines on a stationary infectious background were found. Among the lines, the most affected by *Septoria* leaf spot was the line ZL58A and had from 88.8% to 97.9% of plants with symptoms of the disease. ZL70A and ZL78A lines were significantly less affected by disease than the previous line. Healthy plants for two years of research in these samples were from 73.3% to 87.5%. The HAR7 line was close to the previous two lines, the number of diseased plants varied in different years from 16.7% to 40%, and without lesions from 60% to 83.3%. This line had some differences in the intensity of the disease during the two experimental years. As a result of the study, it was found that the hybrid ZL58A × HAR7 was most affected by *Septoria* leaf spot. The number of affected plants in both years of research ranged from 80.8% to 90.3%. This sample was susceptible to the disease, as well as the maternal line ZL58A. Hybrids of the first generation of the combinations ZL70A × HAR7 and ZL78A × HAR7 were the least affected. In two years of research, these hybrids had between 60% and 79% of healthy plants and 21% to 40% with symptoms of the disease, respectively. These hybrids are relatively resistant to the disease, as well as their maternal and paternal components. **Conclusions.** The type of inheritance of resistance to *Septoria* leaf spot by sunflower hybrids is revealed implies the presence of cytoplasmic effects or

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control of this trait by nuclear genes where susceptibility to the disease is the dominant feature and resistance is recessive.

***Septoria helianthi*; lines; F_1 hybrids; lesions; susceptibility; domination; recessiveness**

Sunflower is one of the main agricultural crops in Ukraine. The leading zones of sunflower cultivation are Dnipropetrovsk, Zaporizhzhia, Kharkiv, Odesa, Kirovograd and Mykolaiivska regions [1].

However, pathogens are the limiting factor in sunflower production on all continents where it is grown. It is bring to significant crop losses.

The most effective method of protection against diseases is the breeding of resistant sunflower genotypes [2].

The most harmful sunflower diseases are caused by pathogenic fungi. The main diseases include pathogens of rust, downy mildew, verticillium, stem and basket rot, coal rot, late blight and leaf spot, such as *Septoria* leaf spot and *Alternaria* leaf spot [3].

The pathogen of sunflower *Septoria* disease is the imperfect fungus *Septoria helianthi* Ellis & Kellerm, there is widespread prevalence in Europe, Africa, North and South America, and Asia. The pathogen causes the greatest damage of sunflower in Brazil, India, and Pakistan [3, 4].

The characteristic symptoms of pathogen damage are the appearance on the lower leaves of small, from brown to dark brown, irregularly shaped spots, gradually spreading to the upper tiers of the plant. In under wet conditions, in the center of the spots small pycnidia with pycnosporae are formed. Then the spots merge and the leaves wither. The pathogen *S. helianthi* mainly infects sunflower leaves, but can damage stems and heads [3].



Photo1: *Septoria* leaf spot on cotyledon leaves of sunflower

The pathogen develops in warm and wet weather. The spores of the pathogen dissemination spread by raindrops. The defeat of *Septoria* leaf spot leads to a decrease in the content of chlorophyll in the leaf and a violation of the basic physiological functions of the plant organism. Under favorable weather conditions, it can pose a threat to sunflower crops and bring to significant crop losses [5].

In recent years, *Septoria* leaf spot is one of the economically important diseases in sunflower. Plant pathologists and breeders give it the same attention as rust and powdery mildew. Despite the widespread prevalence of the pathogen on sunflowers throughout the world, there are not resistant sunflower samples to the pathogen *S. helianthi* [6].

To protect sunflowers from this pathogen, the most promising is the creation of stable samples [7].

The aim of the work was to find out the features of the inheritance of the level of resistance to *S. helianthi* by the sunflower hybrids of the first generation obtained by

crossing lines with different resistance.

Materials and methods. In 2019–2020 in the field on a stationary infectious background of the Institute of Oilseed Crops of NAAS an assessment of the resistance of breeding lines, as well as their hybrids to *Septoria* leaf spot was made. The self-pollinating sunflower lines ZL58A, ZL78A, ZL70A of the Institute of Oilseeds Crops of the National Academy of Sciences (IOC), and the HAR7 line (originating from the USA) and hybrids F₁ from crossing these lines served as the material.

Sunflower samples were sown manually according to the 70 × 70 scheme in 2019, two seeds per hole, two plants per nest in four-row plots for hybrids and two-row plots for lines. In 2020, hybrids and lines were sown in two-row plots, two plants per hole, following the sowing scheme as in the previous year for F₁ hybrids, and for breeding lines according to the 35 × 70 scheme.

The degree of plant damage (the degree of manifestation of the disease) was determined in the early flowering phase. It was performed by visually inspection of all leaves against a modified (Table 1).

As a base scale, we used the «Scale for estimating wheat resistance to the causative agent of *Septoria* leaf spot (*S. tritici*)» [8].

Statistical processing of the obtained data was performed using the Microsoft Excel 2010 software package [9].

The percentage error was determined by the formula:

$$S_p = \sqrt{\frac{P \times (100 - P)}{n}},$$

where S_p is the percentage error; P is the percentage of affected plants; n — the total number of plants analyzed [10].

Results and discussion. The analysis showed that the breeding lines had differences in resistance during two years of research (Fig.).

During the two years of research, the line ZL58A was the most affected by the pathogen *S. helianthi* (Fig.). The number of affected plants varied from 88.8 to 97.9%, and unaffected — from 11.2 to 2.2% in different years. This line had varying degrees of damage — from minor, ie affected only the leaves of the lower tier, to severe — the defeat of the whole plant.

Lines ZL70A and ZL78A were significantly less affected by the pathogen than previous ZL58A. In 2019, they had from 73.3 to 82.0% of healthy plants, and in 2020 there were 87.1 and 87.7%, respectively.

The degree of damage to these samples was close. In 2020, both lines were affected only on the lower leaves, and in the previous year the symptoms of the lesion were recorded on both the lower and middle tiers of the leaves. In addition, the ZL70A line in 2019 had 9% of severely affected plants.

The HAR7 line was close to the ZL70A and ZL78A lines in terms of



Photo 2: Infection's pathogen on true leaves of sunflower

1. The scale for assessing the degree of damage of sunflower plants by the pathogen *Septoria helianthi*

Gradation according to degree of plant damage			Characteristics of phenotype	Level resistance of plant
-	missing	no lesions on all leaves	all plants of sample are not affected	highly resistant
±	minor	only lower leaves are affected	most of plants of sample are not affected, leaves of lower tier are affected on some of them	resistant
+	average	leaves of lower and middle parts of plant are affected	most of plants of specimen are not affected, on some of them leaves of middle tier or whole plant are affected	relatively resistant
++	severe	lesions present on all leaves	leaves of lower tier are affected in most plants	relatively susceptible
			leaves of middle tier are affected in most plants	susceptible
			all leaves are affected in most plants	highly susceptible

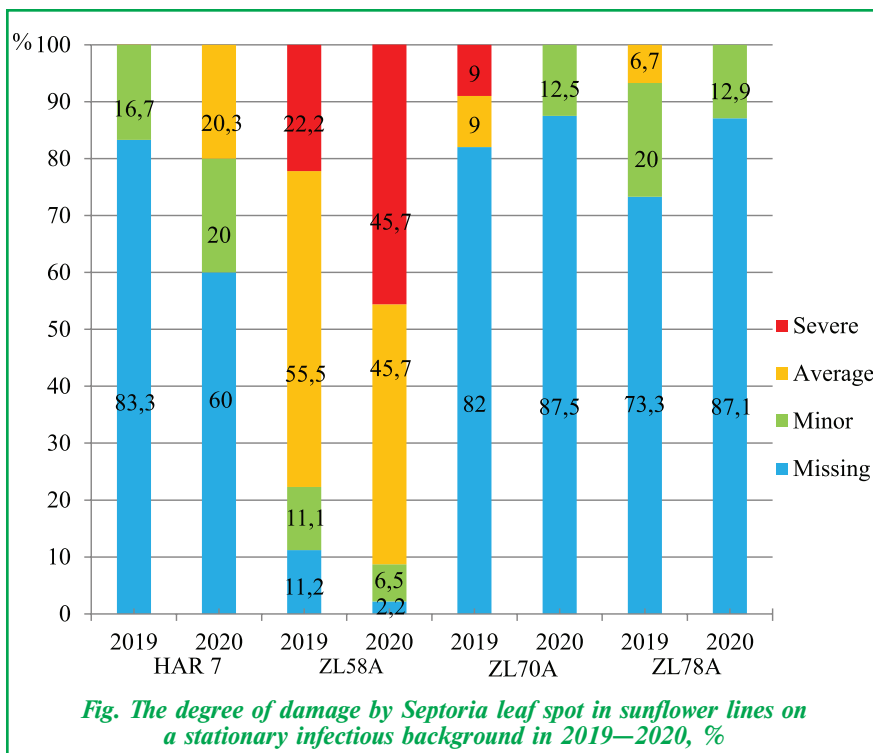


Fig. The degree of damage by *Septoria* leaf spot in sunflower lines on a stationary infectious background in 2019–2020, %

pathogen infestation, although it had certain differences over two years of research. The number of diseased plants varied in different years from 16.7% to 40%, and without damage from 60% to 83.3%. The degree of damage was insignificant in these plants, and 20% of plants had an average damage in 2020.

The results of the assessment of *Septoria* leaf spot lesions in first-generation hybrids from the crossing of IOC breeding lines with the HAR7 line are shown in Table 2.

It is established that the hybrids of the first generation differ in terms of resistance to *Septoria* leaf spot. Hybrids of crossing combinations ZL70A × HAR7 and ZL78A × HAR7 were the least affected.

The hybrid which maternal component was the ZL70A line had from 69.1 to 79% of healthy plants. Plants of this genotype affected by the disease were from 21 to 30.9% in different years of research. The degree of damage varied from slight to severe, however, more plants were affected leaves of the lower and middle part of the plant.

The hybrid of the first generation ZL78A × HAR7 had insignificant differences in resistance to *Septoria* leaf spot during two years of study. Healthy plants were 60% in 2020, and 75.9% in 2019. Most of the plants of this sample had a lesion on the lower leaves for two years of the study.

The hybrid ZL58A × HAR7

from the three hybrids was affected by *Septoria* leaf spot the most strongly and significantly differed from the other two hybrids in level of resistance in both years of research. 80.8% of affected plants with varying degrees of damage were noted in 2020. 90.3% of plants were affected by the pathogen in 2019. At the same time, more than 70% of the plants were with an average and severe degree of damage.

After comparing the results obtained in 2019 and 2020, where there was a difference in the amount of precipitation during the growing season, F₁ hybrids within the same crossing combination had insignificant differences in the intensity of pathogen damage.

Consequently, the F₁ hybrids with the participation of the three lines of IOC breeding were characterized by different degrees of resistance to *Septoria* leaf spot. The F₁ 3L58A × HAR7 hybrid, despite the significantly greater resistance of the HAR7 parental line in this crossing combination, inherited this trait as the ZL58A line, which turned out

2. Damage of sunflower hybrids of the first generation by the pathogen *Septoria helianthi*, %

Combination of crossing	Year of research	Number of plants, pcs.	Total affected plants, %	Distribution by degree damage of plants, %			
				missing	minor	average	severe
F ₁ ZL58A×HAR7	2019	93	90.3±3.0	9.7±3.1	17.2±4	54.8±5.1	18.3±4
	2020	26	80.7±7.7	19.2±7.7	57.7±9.6	19.2±7.7	3.8±3.7
F ₁ ZL78A×HAR7	2019	87	24.1±4.5***	75.9±4.5	17.2±4	2.3±1.7	4.6±2.2
	2020	20	40.0±10.9**	60±10.9	35±10.6	5.0±4.8	0
F ₁ ZL70A×HAR7	2019	76	21.0±4.7***	79.0±4.6	6.6±2.8	13.1±3.8	1.3±1.4
	2020	42	30.9±7.1**	69.1±7.1	28.6±6.9	0	2.3±2.3

Notes: 1. ** — differences from hybrid ZL58 × HAR7 are significant at the 0.01 level of significance in 2020;
2.*** — differences from hybrid ZL58 × HAR7 are significant at the 0.001 level of significance in 2019.



Photo 3. Lesions at the phase of the beginning sunflower flowering

to be susceptible to the disease. The other two hybrids were relatively resistant to the disease, as were their maternal and parental components.

At first glance, it can be assumed that resistance to *Septoria* leaf spot was inherited by hybrids according to the maternal type. However, given that the IOC breeding lines acted only as maternal components of hybrids, it is currently impossible to confirm or refute the presence of cytoplasmic effects in the inheritance of resistance to *Septoria* leaf spot. On the other hand, the discovered type of inheritance may be due to the fact that resistance to the disease is controlled by nuclear genes, where susceptibility is a dominant trait, and resistance is recessive one.

According to C. Block, the genetic nature and inheritance of resistance to *Septoria* leaf spot in sunflower is unknown. However, the author noted that the wild sunflower *Helianthus annuus* contains potentially useful pathogen resistance genes [11]. The presence of resistance genes to *Septoria* leaf spot in wild *H. annuus* was also indicated by other researchers [12]. M. Car-

son briefly reported the variation in resistance among sunflower inbred lines [7].

There is more information in the literature about resistance to *Septoria* leaf spot in other plant species. The samples both with the lowest susceptibility and with a high level of infection with *Septoria melissae* Desmat were found. According to the authors, weather conditions during the growing season can have a significant impact on the development of the disease [13].

Some scientists argue that modern varieties of spring wheat of different origin do not have complete immunity to *Septoria* leaf spot and are characterized only by resistance to the disease. Some varieties show relative resistance to leaf infection with severe ear damage, while others, on the contrary, are resistant to ear damage with significant damage of the leaf apparatus. Based on these data, there is an assumption about the different genetic resistance of spring wheat to *Septoria* leaf and ear spot [14].

H. Toubia-Rahme and B.J. Stephenson were engaged in identifying the sources of barley resistance to *Septoria passerinii* under different growing conditions. The authors observed differences in the trait of stability in field and greenhouse conditions within the same sample. At the same time, they noted that samples that were resistant to the disease at the stage of seedlings and adult plants come from different geographical regions [15].

The genetics of resistance to *Septoria* leaf spot in the Portuguese wheat breeding line TE 9111 is also reported. This line is the most resistant line known in Europe and combines non-specific, partial resistance with somewhat pathogen-specific resistance. Scientists believe that this line may be a valuable source of resistance to *Septoria* leaf spot [16].

Information about the genetic nature of sunflower resistance to the pathogen *S. helianthi* is almost absent in literature sources, despite the wide prevalence of this pathogen on sunflower worldwide. It is only known that there is variation in resistance among sunflower inbred

lines, and that high resistance to this pathogen has been observed in wild sunflower.

CONCLUSIONS

It was found that sunflower hybrids of the first generation over two years of research had differences in terms of resistance to *Septoria* leaf spot. The hybrid of the crossing combination ZL58A × HAR7 was susceptible to the disease and inherited the characteristic resistance by the type of maternal line ZL58A, despite the significantly greater resistance of the parental line. Hybrids ZL70A × HAR7 and ZL78A × HAR7 were relatively resistant to the disease, respectively, as were their maternal and parental forms. The revealed type of inheritance of resistance to *Septoria* leaf spot in sunflower hybrids implies the presence of cytoplasmic effects or control of this trait by nuclear genes where susceptibility to the disease is the dominant feature and resistance is recessive one.

It was established that the weather conditions of the growing seasons of two years of research did not affect the manifestation of the trait of resistance to *Septoria* leaf spot in F₁ sunflower hybrids.

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Photo 4. Lesions of the leaves of adult sunflower plants (fruit formation phase)

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Особливості успадкування стійкості до збудника септоріозу соняшнику гібридами F₁

Мета. З'ясувати особливості успадкування рівня стійкості до збудника *S. helianthi* гібридами соняшнику першого покоління, одержаними від схрещування ліній з різною стійкістю. **Методи.** Польова оцінка стійкості до збудника септоріозу селекційних ліній соняшнику та гібридів F₁. **Результати.** Встановлено відмінності за показником стійкості до септоріозу у селекційних ліній соняшнику на стаціонарному інфекційному фоні. Серед ліній найбільш ураженою була лінія ЗЛ58А, у якої від 88,8 до 97,9% рослин мали

симптоми хвороби. Лінії ЗЛ70А та ЗЛ78А уражувались патогеном значно менше. Здорових рослин за два роки досліджень у даних зразках було 73,3–87,5%. У лінії НАР7 було ураження на листі нижньої та середньої частин, кількість хворих рослин варіювала у різні роки від 16,7 до 40%, а без ураження — від 60 до 83,3%. Дана лінія мала певні відмінності за інтенсивністю ураження хворобою впродовж двох експериментальних років. За результатами дослідження виявлено, що гібрид ЗЛ58А × НАР7 мав найсильніше ураження. Кількість уражених рослин варіювала від 80,8 до 90,3%. Даний зразок є чутливим до хвороби, як і материнська лінія ЗЛ58А. Найменш ураженими збудником септоріозу були гібриди першого покоління комбінацій ЗЛ70А × НАР7 та ЗЛ78А × НАР7. Рослин без ознак ураження (імунних рослин до патогену) за два роки досліджень серед цих гібридів було від 60 до 79%, а з симптомами хвороби — від 21 до 40%, відповідно. Дані гібриди є відносно стійкими до хвороби, як і їх материнські та батьківські форми. **Висновки.** Виявлений тип успадкування стійкості до септоріозу гібридами соняшнику передбачає наявність цитоплазматичних ефектів або контроль вказаної ознаки ядерними генами, де сприйнятливість контролюється домінантним геном або генами, а стійкість — рецесивними генами.

Septoria helianthi; лінії; гібриди F₁ соняшнику; ураження; сприйнятливість

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