

Assessment of the resistance of varieties and collection samples of flax to fusarium wilt

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Abstract. The purpose of the work is to identify samples of flax, resistant to fusarium wilt. The assessment of resistance to fusarium wilting of varieties and samples of flax-long-lived (*Linum ussitatissimum* L.) from the "Collection of Russian flax" of the Flax Research Institute (NIIL, Torzhok) was carried out. The experiment was conducted for three years from 2019 to 2021. Most of the samples showed average resistance to the disease. The greatest degree of resistance to fusarium wilting (87.5-100%) was shown by the the variety Sursky (86.9%) of the selection of the Flax Research Institute. The lowest resistance to the disease was shown by varieties B-100 (40.4%) and Peresvet (37.1%), their resistance indicators were lower than the susceptibility of the AR-5 standard variety (45.6%), which allows them to be classified as highly susceptible.

1 Introduction

Fungal diseases of flax (*Linum usitatissimum* L. var. *elongata*) are one of the main factors in reducing the profitability of growing this crop [2]. Among the flax diseases caused by fungal pathogens, the most harmful are: fusarium wilt (*Fusarium oxysporum* Schlecht. emend. Snyder et. Hansen), anthracnose (*Colletotrichum lini* Pethybr.), pasmo (*Septoria linicola* (Speg.) Garass.), and rust (*Melampsora lini* (Ehrenb.) Lév.) [5].

Fusarium wilt is a complex fungal disease caused by the imperfect fungus (*Fusarium oxysporum* Schlecht. f. *lini* (Bolley) Snyd. et Hans) from the department of ascomycetes, as well as other pathogens, but fusarium prevails among them. The main organs through which fusarium penetrates into flax plants are the root system and root neck. The sources of infection may be plant residues of affected plants. The pathogen is well preserved in seeds and soil. The monoculture of flax, as well as the lack of crop rotation, contribute to the accumulation of fusarium in the soil.

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Symptoms of fusarium, as a disease, are detected throughout the entire growing season of flax, but the pathogen causes the greatest harm to young plants in the phase of 5-6 real leaves, also known as "herringbone", causing serious damage and complete death of plants [1]. The external manifestation of the disease is characterized, first of all, by the drooping of the top of the plant, and in the future the plant turns yellow and withers (Fig. 1 (A)), at the same time the pathogen penetrates into the root system, causing its destruction [6, 9]. Plants that are affected in the flowering phase are very lagging in growth and development, they have browning of leaves and stems, they most often do not proceed to fruiting. Such plants rarely tie seeds, and if the seeds are tied, then they are formed puny. The same symptoms appear on plants when infected at a later stage – "green ripeness". The only difference is only a high probability of low-quality seeds being set, and at the same time they will be a source of primary infection in the next season.

Fusarium flax has a focal nature of manifestation. With severe damage to crops, fiber yield can decrease by 90-97%; seed yield by 43-65%. With severe damage to crops, a complete loss of seed yields is possible [6, 7, 8].



A

B

Fig. 1. A plant with symptoms of fusarium wilt (A) and provocative infectious nursery for fusarium wilt, 2021 (B)

2 Materials and methods

11 varieties and samples of the "Collection of Russian flax" of the NIIL (Flax Research Institute) of Torzhok were studied in the experiment. A provocative infectious nursery to test the resistance of flax crops to fusarium wilt is organized in a "vegetative house", due to the aggressiveness of the pathogen and the peculiarities of its preservation in the soil. Infectious background in the box sowing was created by adding 30-70 grams of flax straw and 200-300 grams of pure culture of fusarium into the soil jointly. Nutrition area of each plant was 2,5×2,5 cm. Three rows of safety lines were sowed by edges of the trial plot. The experiment was duplicated three times (Fig. 1 (A)) [3].

A pure culture of the pathogen was isolated by sowing plant residues with signs of fungal plaque on an agarized nutrient medium. A small amount of mycelium was collected with a needle, then the lid of the Petri dish was lifted and a piece of mycelium was applied to the surface of the agarized medium. After the appearance of the mycelium, its

identification was carried out using a microscope. By repeated replanting, a "pure culture" of fusarium was obtained, then visual identification of pathogens was carried out [6].

On a nutrient medium at an average temperature of +25°C, *F. oxysporum* forms fluffy felt colonies of medium density. The color of colonies varies from white to pink (Fig. 2 (A)). The average size of colonies is 2-10 mm. Conidiophores are simple or branched. Each conidium contains from 2 to 6 partitions. Macroconidia predominate over microconidia (mostly unicellular) (Fig. 2 (B)) [10, 11].

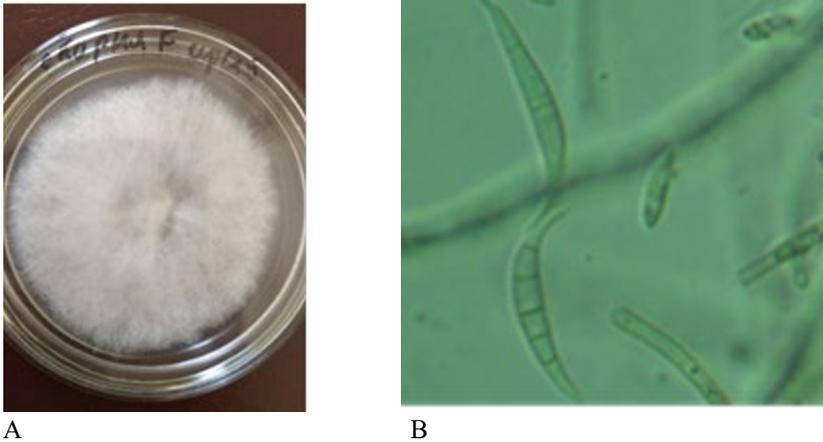


Fig. 2. *Fusarium oxysporum* colony (A) and conidia *Fusarium oxysporum* (B)

During the growing season of 2019, favorable temperature conditions were formed for the development of the causative agent of fusarium wilt (Fig. 3). At the time of sowing, and this is the first decade of May, the air temperature reached 18 °C, which is favorable conditions for the development of fusarium. High humidity also had a positive effect on the development of the disease (Fig. 4). The maximum amount of precipitation fell in the last decade of July and the first decade of August, which could affect the appearance of signs of fusarium browning (Fig. 5).

During the sowing in 2020, the air temperature was lower (13.2 °C) than in 2019 (18 °C), with an optimal temperature for infection of 15-17°C, which could play a role in the infection of plants. But throughout the rest of the growing season, there was a favorable temperature background for the development of fusarium, since more precipitation fell than in other years of the experiment (Fig. 3, 4, 5).

In 2021, during experimental sowing, a temperature above 16 °C was noted, which positively affected the infection of flax plants with fusarium. In July, the highest temperatures in three years of research were observed, while the overall temperature background was favorable for the development of fusarium (Fig. 3).

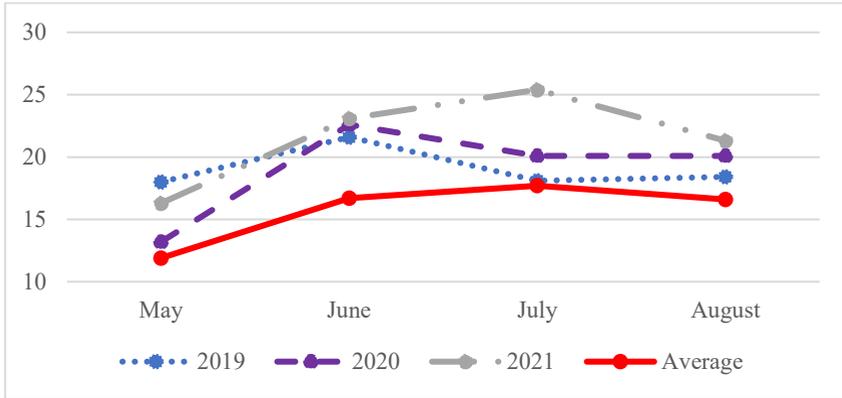


Fig. 3. Average monthly temperatures during the growing season (°C), 2019-2021

The average humidity of the air and the amount of precipitation were lower than in other years of testing, while in August the highest humidity was recorded for all three years (Fig. 4, 5).

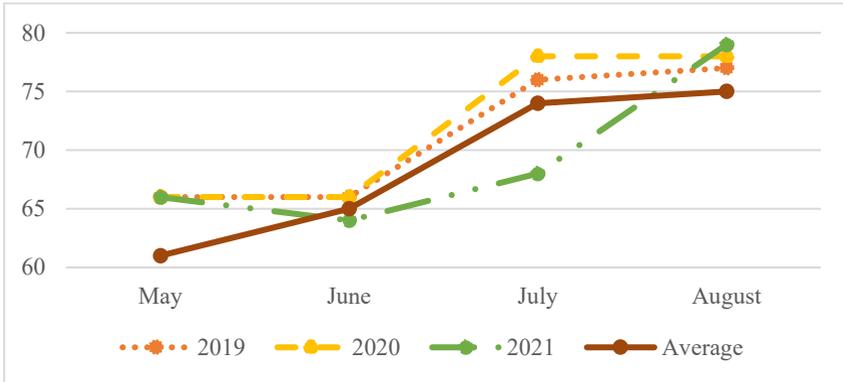


Fig. 4. Average monthly humidity during the growing season (%), 2019-2021

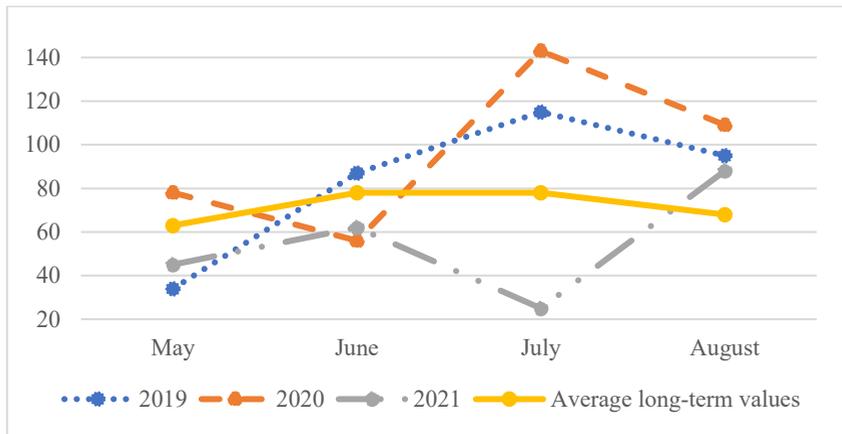


Fig. 5. Average monthly precipitation during the growing seasons (mm), 2019-2021

Low humidity in June and July 2021 probably had a negative impact on the development of fusarium.

Data were obtained on the resistance of 11 collection samples of flax, in comparison with 2 control varieties (standard) to fusarium wilt. To assess the reliability of the results obtained, the collected data (from 2019 to 2021) were processed using variance analysis and presented in Table 01.

Table 1. The results of the resistance of flax longseed varieties to fusarium wilt (%), average for 2019-2021

Variety/Sample	The average degree of resistance to fusarium wilt by repetition, %			Average for 3 years, %
	2019	2020	2021	
Fakel	81.5	84	64.3	76.6
Peresvet	50	22.9	38.5	37.1
Borets	90	86.7	68.8	81.8
Start	90	58.6	93.3	80.6
Orshansky	88.4	73.3	93.3	85
Rhythm	90.8	80	73.3	81.4
Phoenix	89.8	75.6	76.9	80.8
Sursky	91.7	94.1	75	86.9
B-100	28.6	44.6	47.9	40.4
Melina	70	68.9	46.7	61.9
Lirica	88.8	61	86.7	78.8
Standards (Control)				
A-29 (resistant)	87.9	86.8	87.9	87.2
AP-5 (receptive)	46.2	48.6	42	45.6

Due to the fact that the calculated actual Fisher criterion turned out to be equal to 5.91, and the tabular Fisher criterion is equal to 1.8, significant differences between the results obtained have been reliably proven.

3 Results and discussion

As a result of comparing 11 flax samples by the degree of resistance to fusarium wilt in comparison with the indicators of resistance of standard varieties, it was found that most of the studied varieties are medium-resistant.

Assessment of flax resistance to fusarium wilt is of strategic importance in the conditions of modern flax growing. The cultivation area of this crop has decreased significantly over the past 20 years, so the question of cultivating the most productive and most resistant to fungal diseases varieties is acute. The samples with a strong manifestation of this disease did not form seeds, and the fiber was brittle.

When the disease manifested by 50-65%, the yield of long fiber flax straw decreased by 70%. When the disease manifested by 80-96%, the long fiber was not formed, and the short fiber was brittle.

4 Conclusion

Varieties B-100 (40.4%) and Peresvet (37.1%) showed very low resistance, which allows them to be classified as highly susceptible to this disease. Both of these varieties showed

resistance to fusarium wilt lower than that of the susceptible variety-standard AR-5 (45.6%).

The greatest resistance to fusarium wilting was shown by the Sursky variety (86.9%) of the NIIL selection.

Most of the samples studied by us showed average resistance to fusarium wilt. Thus samples whose resistance is at the level of 70% and above can be recommended as parent components for breeding for resistance to fusarium wilt.

The most resistant was the Sursky variety (86.9%), which showed resistance higher than that of the A-29 standard (45.6%). The least resistance to fusarium wilt was shown by varieties B-100 (40.4%) and Peresvet (37.1%), their resistance indicators were lower than those of the susceptible variety of the AR-5 standard (45.6%), which allows them to be classified as highly susceptible.

In the future, it is planned to conduct a hybridological analysis of the best samples to assess the ability to be donors of resistance to fusarium wilt of longseed flax.

References

1. A. Boba, K. Kostyn, B. Kozak, et al. *Planta*, **251**, 50 (2020) <https://doi.org/10.1007/s00425-020-03339-9>
2. N.A. Kudryavtsev, L.M. Zakharova, L.A. Zaitseva, Vladimirsky husbandman, **2 (84)** 32-37 (2018)
3. N. I. Loshakova, T. V. Krylova, L. P. Kudryavtseva, *Methodological guidelines for the phytopathological assessment of the resistance of flax to diseases* (Moscow: Publishing House of RASKHN, 2000) 22-26.
4. N.I. Loshakova, *Protection and quarantine of plants*, **9**, 43-44 (2011)
5. J. Moyse, S. Lecomte, S. Marcou, G. Mongelard, L. Gutierrez, M. Höfte, *Plants*, **12**, 2811 (2023) <https://doi.org/10.3390/plants12152811>
6. V.F. Peresyphkin, *Diseases of industrial crops and potatoes* **2**, 248 (1990)
7. A.R. Rogash, *Flax growing* (M., 1967) 583.
8. L.M. Sokolova, *System of selection and immunological methods for creating varieties and hybrids of table carrots with group resistance to Alternaria sp. and Fusarium sp. with a complex of economically valuable features*: dis. ... doctor of agricultural sciences: spec. 06.01.05 (VNIIO is a branch of FGBNU FNTSO. Odintsovo, 2021) 321.
9. Tatyana Rozhmina, Anastasia Samsonova, Alexander Kanapin, Maria Samsonova, *Data in Brief*, **41**, 107869, (2022) ISSN 2352-3409, <https://doi.org/10.1016/j.dib.2022.107869>
10. Tsutomu Arie, *Journal of Pesticide Science*, **44 (4)**, 275-281 (2019) <https://doi.org/10.1584/jpestics.J19-03>
11. V. Edel-Hermann, C. Lecomte, *Phytopathology*, **109 (4)**, 512-530 (2019) <https://doi.org/10.1094/PHYTO-08-18-0320-RVW>