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Evaluation of fiber flax varieties in the Central region of non-chernozem zone of Russia

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Abstract. Long-fiber flax (Linum usitatissimum L. var. elongata) is a specialized industrial crop valued for its high-quality bast fibers, essential for the textile and composite materials sectors. At the core of this investigation lies a comprehensive evaluation of nine accessions of long-fiber flax germplasm, conducted in the pedoclimatic conditions of the Central Non-Chernozem Zone of Russia. The research presented in this paper aims to identify genotypes with optimal agronomic and quality traits for sustainable cultivar selection in this temperate region. Key morphological, yield, and fiber quality parameters were quantified during the 2024 growing season, including plant height, stem diameter, fiber yield, fiber content, and seed production. The analysis of the experimental data revealed significant varietal diversity. The cultivar 'Vesta' demonstrated superior fiber yield (30.94 q/ha) and fiber content (26.05%), while 'Nadezhda' excelled in stalk fineness (a critical parameter for textile quality) and seed set per plant. A comparative analysis with historical varieties revealed genetic progress achieved through breeding, particularly in improving yield components and morphological structure suitable for high-quality fiber production. The results provide a scientific basis for selecting adapted long-fiber flax varieties to optimize sustainable cultivation systems, maintain agricultural biodiversity, and stimulate the production of climate-resilient plant materials for the bioeconomy.

1 Introduction

Flax (Linumusitatissimum L.) was one of the key agricultural crops in ancient civilizations, including India, China, Egypt, and Transcaucasia, where its cultivation dates back to the 4th–5th millennia BCE. In the territory of modern Russia, flax has also been cultivated since ancient times, with its products (fabrics and other goods) used not only for domestic consumption but also as trade commodities. Until the late 18th century, flax fiber held a leading position in the structure of Russian exports [1,2]. Fiber flax is one of the primary spinning crops in temperate climates. Its cultivation yields three types of valuable products: fiber, seeds, and shives [3, 4].

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Flax fiber is a strategically important raw material for the textile industry due to its technical characteristics, including high strength, flexibility, and fineness. It is used to produce a wide range of goods, such as clothing, bed and table linens, wallpaper and technical fabrics (burlap, canvas, tarpaulin), as well as high-quality materials (linen, batiste, etc.).

Household fabrics made from flax possess several unique properties: high hygroscopicity, rapid moisture exchange, wear resistance, durability, and lightfastness.In modern conditions, amid the growing production of synthetic fibers, flax is actively used in composite materials (e.g., cotton-linen blends). The incorporation of synthetic fibers significantly improves the resistance of flax fabrics to bending deformations [5].

Shives (the woody part of the stem) are used in the production of shive boards, which are applied in construction and furniture manufacturing. Additionally, shives serve as raw material for high-quality paper.

Flaxseeds contain 37–40% or more of high-quality oil and about 25% protein compounds. The oil is used in the food industry, as well as in the production of drying oil, varnishes, paints, and linoleum. Moreover, flax oil is in demand in the perfumery and pharmaceutical industries due to its bactericidal mucilaginous components and the high biological activity of polyunsaturated fatty acids.By-products of oil extraction (flaxseed cake and meal) are valuable concentrated feed for livestock. The nutritional value of 1 kg of flaxseed cake is 1.15 feed units, containing 285 g of digestible protein [2].

One of the key factors determining the technological value of flax fiber is its varietal characteristics. Therefore, the introduction of new varieties with genetically fixed high spinning qualities and increased yield is a priority in flax breeding.

Research Objective – To evaluate and identify the best fiber flax varieties based on fiber and retted straw quality.

2 Materials and methods

Conditions, Materials, and Methods. The study used nine fiber flax varieties from the VIR collection, representing different ecological and geographical origins. The research was conducted in 2024 on the experimental field of the Russian State Agrarian University (RSAU-MTAA) following standard methodological guidelines [3]. Meteorological conditions during the study period were characterized by elevated temperatures (June–July: 2.1–2.4°C above average; August: 1.2°C above average), excess precipitation (40% above average in June–July, with a deficit in August), and increased sunlight duration (20–25% above average).Weather conditions of the growing season from May to August are provided by the V.A. Mikhelson Meteorological Observatory of the Russian State Agricultural Academy named after K.A. Timiryazev (Figures 1, 2).

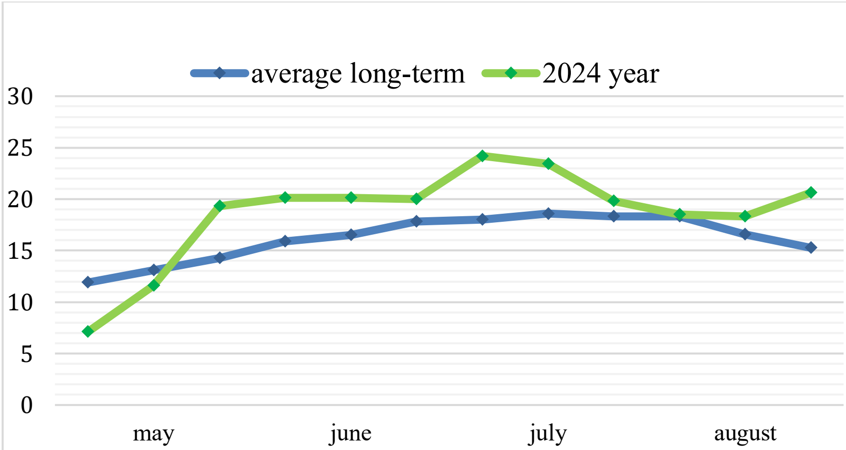

Fig. 1. 2024 temperature regime

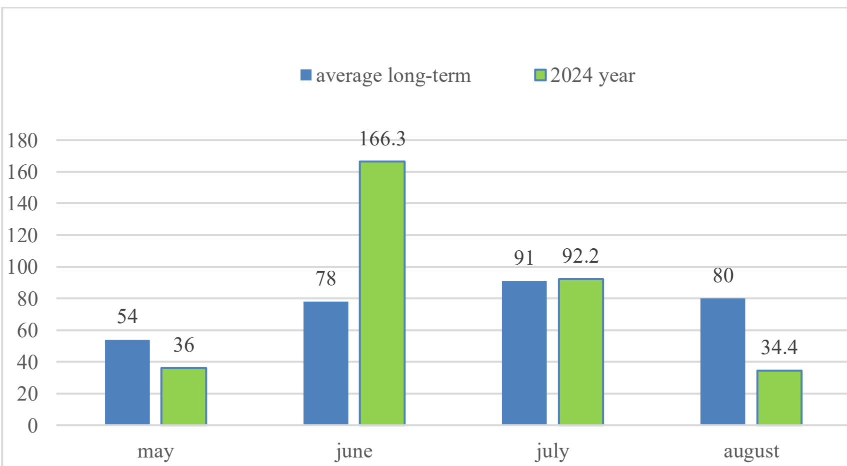

Fig. 2. Precipitation in 2024

During the analysis, the fiber yield, the yield of stems, the number of seeds from the plant, the height of the plants, and the diameter of the stem were evaluated.Yield structure analysis was performed using a ruler, scales, calipers, and manual or automated seed counting (SLY-C Plus seed counter).In the spring, fiber was isolated from the trusts of the studied varieties for further evaluation of fiber yield, as well as for calculating yield values.The study included 6 varieties from the collection of flax. A comparison in terms of characteristics was also carried out with old flax varieties.

3 Results

In 2024, climatic conditions showed a strong influence on the vegetative period. The main flowering of flax began earlier than in previous years, which may be due to changes in precipitation and air temperature. Since the flowering phase is influenced by both precipitation and temperature conditions, such an early flowering may indicate systemic changes in the environment that require additional attention from researchers.To evaluate the varieties based on agronomic and quality traits, yield structure analysis was conducted, including the following parameters: number of productive stems, plant height, technical length, base diameter, inflorescence diameter, fiber fineness, tapering, number of bolls per plant, number of seeds per plant, and seed weight (Table 1).

Table 1. Yield Structure Analysis

Variety	Stems analysis					Inflorescence analysis		
	Productive Stems (count)	Height (cm)	Technical Length (cm)	Fiber Fineness	Tapering	Boll Count per Plant	Seed Count per Plant	Avg. Seeds per Boll
Vesta	1	79,60	65,80	410,6	0,80	4,60	36,6	7,70
Krepysh	1	73,08	63,30	460,93	1,04	3,50	28,10	8,11
Atlant	1	85,29	72,75	450,30	0,98	5,02	41,23	8,17
Rosinka	1	86,07	71,91	415,22	1,15	4,82	40,05	8,51
Tomich 2	1	80,26	66,47	457,80	0,82	6,00	47,00	7,86
Nadezhda	1	77,67	74,82	502,60	1,01	6,53	54,97	8,53
Novotorzhsky	1	75,91	63,72	415,20	0,81	5,62	45,00	7,73
Torzhokskiy 4	1	75,27	62,16	402,52	0,82	5,27	37,00	6,82
LSD05	-	6,50	8,10	68,82	0,12	1,43	12,48	0,78

Fiber yield and productivity were also assessed (Table 2).

Table 2. Yield Assessment

Variety	Retted Straw Weight (g)	Fiber Weight (g)	Fiber Yield (%)	Straw Yield (t/ha)	Fiber Yield (t/ha)
Vesta	11,9	3,1	26,05	119	30,94
Krepysh	8,4	1,7	20,2	84	16,80
Atlant	7,2	1,6	22	72	15,84
Rosinka	11,5	1,9	16,5	115	18,98
Tomich 2	11,2	2,4	21,4	112	23,97
Nadezhda	10,5	2,6	24,8	105	26,04

Novotorzhsky	13,1	2,2	16,8	131	22,01
Torzhokskiy 4	6,9	1,4	29,3	69	20,22

Based on the analysis of experimental data from evaluations and assessments of the yield structure, fiber output, and productivity of flax, as well as the analysis of seed set in the studied varieties, several key conclusions can be drawn, highlighting the characteristics and advantages of the tested samples.The Nadezhda variety proved to be the most productive in terms of stalk fineness (502.60). Stalk fineness is an important indicator, determined by the ratio of stem length to its width. A high value of this trait implies good fiber quality and its ability to twist, affecting not only strength but also the decorative properties of the fiber. High stalk fineness allows for the production of superior textile products. The Nadezhda variety significantly outperformed older varieties such as Novotorzhsky and Torzhoksky 4 (415.2 and 402.52, respectively) as well as some modern varieties (Vesta with 410.6 and Rosinka with 415.22).The Vesta variety performed best in terms of tapering. Tapering reflects the plant's ability to produce lateral shoots and increase yield. This indicator is determined by the difference in diameter at the base and the diameter at the inflorescence. At the same time, the values for older varieties fall within the same range as Vesta.The Nadezhda variety was the most productive in terms of seed quantity (54.97 seeds per plant). This indicates that the sample is well-adapted to producing the maximum number of seeds under favorable conditions in our region. The seed yield of Nadezhda significantly exceeded that of the older variety Torzhoksky 4 (37 seeds on average) and all modern varieties except for Tomich 2.The Vesta variety stood out in fiber output (26.05%). This variety also demonstrated the highest fiber yield (30.94 q/ha). Among the older varieties, Torzhoksky 4 had the best fiber output (29.3%), but its relatively low straw yield prevented it from surpassing Vesta in fiber productivity.The Krepysh and Vesta varieties proved to be the best maternal lines based on crossing results and seed set (avg. 84%). Among all studied varieties, they exhibited the highest percentage of successful hybridization with different varieties. However, Krepysh had the best hybrid seed yield, provided that full fertilization resulted in 10 seeds per boll. The Rosinka sample performed the worst as a maternal plant.

4 Conclusion

Based on the studies described in this paper, it has been revealed that for many decades, flax varieties have undergone significant improvements due to careful breeding work. As a result of focused research and long-term experiments, breeders and scientists have achieved significant increases in yields, resistance to diseases and pests, improved lodging resistance, and improved crop quality. The introduction of genetic markers and molecular breeding methods made it possible to accelerate the breeding of new varieties with improved parameters.

Modern flax varieties not only significantly exceed the previously existing ones in their qualitative and quantitative characteristics, but also meet the increased requirements of industrial production and processing. For example, the Vesta and Nadezhda samples proved to be the best varieties for cultivation in the conditions of the Central Region of the non-Chernozem zone. The Rosinka variety has the highest seed yield values.

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