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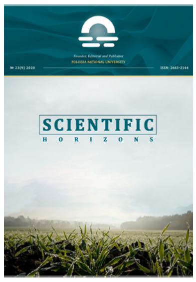

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Study of the world collection of oilseed flax as a source material for selection in the conditions of Northern Kazakhstan

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Abstract. According to the modern requirements of cultivation, new varieties of oilseed flax are being created, differing in a complex of useful features. The basis of the selection of oilseed flax is the study, selection, and creation of new varieties based on the world collection and suitable for the agro-climatic conditions of Northern Kazakhstan. The purpose of the study is to investigate the collection samples of oilseed flax in the conditions of the Kostanay region of Northern Kazakhstan and to select the most promising pedigree material according to economically valuable characteristics in the conditions of a moisture deficit zone. The following methods were used: biological, phenological, laboratory, statistical, and information analysis of the adaptive capabilities of individual varieties of oilseed flax. An assessment of economically valuable traits was carried out for 14 varieties of oilseed flax from the world collection of various ecological and geographical origin for the period in 2020-2022. As a result of the research, samples characterised by high yield were identified:

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Linol – 82 g/m^2, Sibirskaya 38854 – 71 g/m^2, Antares – 78.3 g/m^2. Samples of the varieties Biryuza, Krokus, Kustanayskiy – 8.2 g, Iceberg – 8.1 g were distinguished by high indicators of the weight of 1000 seeds. A valuable and plastic source material for selection with the main valuable and economic characteristics was identified: the growing season for 85-92 days, with a seed yield of more than 47.5-82.2 g/m^2, a weight of 1000 seeds of 6.9-8.1 g, oil content in seeds of 43.7-47.5%, plant height of 45-60 cm. The selected samples are recommended for cultivation in Northern Kazakhstan: by precocity – Sibirskaya 38854 and Iceberg; productivity – Linol, Antares; weight of 1000 grains – Nebesniy, Biryuza, Linol, Krokus; oil content in seeds – Kostanayskiy-11, Iceberg; resistance to fusarium – Kostanayskiy-11, Sibirskaya 38854, Antares, Iceberg. The effectiveness of the breeding programme depends on the patterns of inheritance of economically valuable traits operating in a hybrid population, reducing the loss of valuable genotypes and reducing costs by culling less valuable traits

Keywords: productivity; adaptive abilities; yield; oil content; genotype; fusarium

INTRODUCTION

Oilseed flax (*Linum usitatissimum* L.*)* is a widely used food culture, a source of high-grade inexpensive vegetable protein for animal husbandry, and technical raw materials in industrial sectors, including paint, soap, and leather. The development of various industries has led to an increase in demand for vegetable oils of various quality. The greater the variety of technical products and food products, the more diverse the raw materials needed for their production should be. In search of promising additional sources for the production of oils and fats, producers are turning to an increasing number of cultivated crops, considering valuable morphological, biological, and economic characteristics. K.A. Akshalov *et al.* (2023) note that whole oilseed flax seeds are used as a popular additive in many types of bread. They are one of the richest sources of substances with a powerful antioxidant effect – lignans, valuable raw materials for the production of organic compounds such as esters, acetals, urethanes, and amides, from which various coatings, fibres, insulating foams, plasticisers, high-pressure lubricants can be produced.

In Kazakhstan, oilseed flax is a promising crop, and its acreage is increasing from year to year, reaching 1.5 million hectares. The main flax-growing regions are the North Kazakhstan, Kostanay and Akmola regions. The agro-climatic conditions of Northern Kazakhstan meet the requirements for growing oilseed flax, from which both oilseeds and livestock feed are obtained. As noted by A. Suleimenova (2019), oilseed flax seeds are relatively resistant to cold and begin to germinate at a soil temperature of 3-5°C. Lower temperatures and increased soil moisture can cause rotting. With optimal humidity and an average daily soil temperature of 7-8°C, seedlings appear after 5-7 days, and at a lower temperature, germination is delayed up to 15 days.

Since flax is an early sowing crop, there is a risk of damage and death of plants due to low temperatures, and the creation of varieties resistant to hypothermia is an urgent direction in flax breeding. G.S. Kaliakparova and Y.Y. Gridneva (2019) evaluate the most important varieties in the technology of growing and breeding oilseed crops adapted to specific agro-climatic conditions, ensuring sustainable yield and product quality. The new gene pool of oilseed flax is based on hybridisation methods using varieties from the VIR World Collection of Plant Genetic Resources (Vavilov All-Russian Institute of Plant Industry). Hybridisation when crossing varieties of different ecological and geographical origin is the most common way toп create a starting material for the selection of agricultural crops. As noted in the studies by A. Nogaev *et al.* (2021), before the cultivation of oilseed flax, the following tasks are to develop modern high-yielding varieties suitable for food and technical use, with high oil content in seeds of about 55%, crude protein – 35%, resistant to biotic and abiotic environmental factors. Y. Lan *et al.* (2020) note that oilseed flax seeds, due to the high content of polyunsaturated fatty acids, have a high iodine number – 170-200 units, forming a strong, stable film when dried.

According to the Food and Agriculture Organisation (FAO), in terms of linolenic acid content, linseed oil can be divided into four categories: more than 50% – high oil, suitable mainly for technical use; within 36-49% – medium oil, suitable for technical use in pharmaceuticals and perfumes; within 10-35% – low, mainly for food purposes; less than 10% – very low, only for food purposes (Bureau of National Statistics..., 2023). According to C. Qiu *et al.* (2020), linseed oil contains fatty acids such as: palmitic 5-7%, stearic 3-4%, oleic 16-20%, linoleic 14-17% and linolenic 50-60%. The selection of oilseed flax is aimed at creating technical varieties with a high content of linolenic acid >65%, food varieties with a low content of linolenic acid <40%, and medical varieties >40%.

According to J. Yang *et al.* (2021), flax cake is a product of the secondary processing of flax seeds and by biochemical composition contains 6-12% crude fat, 33-38% crude protein, 7% crude ash, and 9% crude fibre, and by nutritional value, 1 kg has 1.15 fodder units and contains 260 g of digestible protein. 1 kg of flax meal contains 1.12 fodder units and 285 g of digestible protein. I.V. Goudar *et al.* (2021) characterised the composition of flax fibres and their application. Oilseed flax stalks contain 12-18% crude fibre, which is used in the production of pressing material, coarse fabrics, rope, twine, gaskets, packaging, and insulation. In addition, flax straw contains up to 50% pure cellulose, so it is suitable for the production of thin paper and cardboard by pressing. The flax husk obtained after threshing and cleaning of seeds is a valuable feed raw material for pigs, according to its nutritional value, 1 kg contains 0.27 fodder units and 20 g of digestible protein.

The right choice of varieties is important for the successful cultivation of oilseed flax, therefore, due to the efforts of breeders, the potential yield, quality, adaptability to local conditions, resistance to pests and diseases and tolerance to stress factors are improving. In view of the above, studying the characteristics of different flax varieties and hybrids is not only of theoretical but also of practical interest. The purpose of the study is to identify the most promising material for the selection of oilseed flax in the conditions of the zone of insufficient moisture in the Kostanay region of the Republic of Kazakhstan (RK).

MATERIALS AND METHODS

The research work was carried out in the Karabalyk Agricultural Experimental Station during 2020-2022. The object of the study was 14 varieties of oilseed flax of various ecological and geographical origin. Meteorological conditions during the years of research were diverse and reflected quite widely the features of the Kostanay region, located in Northern Kazakhstan, divided into three natural and climatic zones. The test site of the Karabalyk Station is located in the 1 natural and climatic zone. During the years of the research, there were no significant deviations from the climatic conditions of Northern Kazakhstan, as they were relatively favourable for the growth of oilseed flax. The following methods were used in experimental studies: biological, determining the parameters of environmental conditions and comprehensive analysis of the qualitative characteristics of the yield of oilseed flax varieties; phenological, monitoring the stages of plant development; laboratory, monitoring the biochemical composition of plant material; statistical, data analysis, and assessment of adaptive capabilities. The selection of oilseed flax was carried out considering specific conditions and was aimed at creating high-yielding medium-ripened varieties with high oil content in seeds, resistant to drought, diseases and pests, equally maturing, and suitable for double use. The solution to this problem was facilitated by the use of the world collection of oilseed flax.

The area of each plot was 10 m^2, in four repetitions, with a consistent systematic arrangement, the seeding rate was 7 million pcs./ha. Sowing was carried out using a low-volume system with an SN-10C seeder: in 2020 – May 6, in 2021 – May 13, in 2022 – May 19. Harvesting was carried out manually, using a frame method, flax threshing was carried out using a Heqe-125 breeding combine, and cleaning and sorting of seeds was carried out manually. Vegetation of plants proceeded in 2020 in conditions of moderate moisture (hydrothermal coefficient (HTC) – 1.24), in 2021 – insufficient moisture (HTC – 0.92), in 2022 – insufficient moisture (HTC – 0.87). The average duration of the growing seasons in 2020, 2021, 2022 was 97, 101 and 111 days, respectively. At the early stages of breeding, more than 4000 samples were studied. According to the complex of economically valuable features, 15 cultivars were identified, which were involved in the competitive variety testing: Kostanayskiy-1, Nebesniy, Biryuza, Linol, Severniy, Surpriz, Sokol, Triumf, Krokus, Sibirskaya 38854, Isilkulsky, Kustanayskiy yantar, Antares, Iceberg.

The temperature regime in the area of operation of the station was characterised by sharp fluctuations observed not only monthly, but also daily throughout the year, the average temperature is 2.8°C. In spring, there was a big difference between daytime and nighttime temperatures, sunny weather prevailed in summer, followed by an autumn cold snap and the first frosts at the end of September. Data on average daily air temperature are indicated in Table 1.

Table 1. *Average daily air temperature in the Karabalyk agricultural station, °C*

Years	**2020**	**2021**	**2022**
May	18.2	21.5	13.5
June	19.2	22.3	18.9
July	25.2	22.8	23.4
August	21.3	24.4	22.2
Total for May-August	20.9	22.7	19.5

Source: *compiled by the authors*

For the periods 2020, 2021, 2022, the sum of active temperatures was – 1977, 2055.5, and 2030°C, respectively. The average annual precipitation over the past 80 years is 328.3 m, June and especially July are the wettest and warmest months, but the intake of moisture and heat varies significantly from year to year. In general, there is more precipitation in the warmer months than in the colder ones. During the periods 2020, 2021, 2022, precipitation fell 273, 240, and 156.6 mm, respectively (Table 2).

Table 2. *Precipitation totals for 2020-2022 in the Karabalyk agricultural station, mm*

Year	2020	2021	2022
May	41.8	6.7	40.6
June	22.4	8.4	20.9
July	12.7	51.9	17.7
August	41.5	21.7	10.5
Total for May-August	118.4	88.7	89.7

Source: *compiled by the authors*

In 2020, precipitation in Karabalyk amounted to 41.8 mm in May, 28 mm in the summer months, and 118.4 mm in the entire growing season. In 2021, in May-June, there was a low amount of precipitation on average – 7.5 mm, in July – 51.9 mm, in August, when the vegetation is almost complete – 21.7 mm, on average for the entire growing season – 88.7 mm. In the conditions of May 2022, precipitation amounted to 40.6 mm, on average for the summer months – 16.4 mm, for the entire growing season – 89.7 mm. The soils of the Karabalyk agricultural zone belong to medium-humus chernozem soils, which are genetically typical for this zone, the humus content is 5.2-6%. According to the mechanical composition, it is a heavy loamy soil with a very high nitrogen content >5 mg/100 g according to Tyurin, with a potassium content >20 mg/100 g. The soil is characterised by good agrochemical properties: humus content – 4.6%, easily hydrolysable forms of nitrogen – average, mobile phosphorus – high, exchangeable potassium – increased. The degree of acidity of the soil according to the pH is slightly acidic – 4.2. Statistical processing of field experiment data was carried out by the method of variance analysis based on the study by L. Quillian *et al.* (2019). The study complied with the requirements of the Convention on Biological Diversity (1992).

RESULTS

The high demand for oilseed flax has made its cultivation highly profitable. In world agricultural production, flax occupies more than 3.5 million hectares, and the total seed yield ranges from 2.2 to 2.7 billion tonnes. According to the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan (2023), in 2020, the main flax grain-producing countries are Kazakhstan – 158.4 thousand tonnes, Canada – 578 thousand tonnes, China – 330 thousand tonnes, USA – 145 thousand tonnes, India – 112 thousand tonnes. Sunflower and oilseed flax are the leaders in the market of oilseeds in the Republic of Kazakhstan, both in terms of acreage and production, and export potential. Over the past six years, the total acreage of oilseeds in the Republic of Kazakhstan has increased by more than 1 million hectares and according to the data of 2020-2022 will exceed 3 million hectares, which is noted in detail in Table 3.

Table 3. *Areas of oilseed crops in the Republic of Kazakhstan, thousand hectares*

Cultures	2020/21	2021/22
Rapeseed	127.4	121.9
Flax	1526.4	1496.1
Sunflower	756.1	958.5
Corn	327.7	381.9
Soy	127.8	113.3
Other	32.9	21.9

Source: *Development strategy of the joint-stock company "National Company". Food contract corporation for 2021-2030 (2020)*

The most significant growth occurred in the oilseed flax cultivation sector, where the acreage in 2020-2021 amounted to 1526.4 hectares, and in 2021-2022 – 1496 hectares, which compared to the total oilseed crops amounted to 53 and 48%, respectively. Unlike sunflower, rapeseed and soybeans, the trend of growth in the volume of oilseed flax harvest in the Republic of Kazakhstan is due to the expansion of acreage, given the almost unstable yield in the wide range of 2-12 metric centners/ha. According to Kazakh Grain Union estimates, the production of oilseed flax in the Republic of Kazakhstan in 2021-2022 amounted to 744 thousand tonnes compared to 1.06 million tonnes in the previous year. The achievement of optimal production volumes of sparsely distributed oilseeds in the Republic of Kazakhstan was achieved by increasing yields and significant investments, which will continue to be obtained with the effective use of oilseed flax. Significant achievements in breeding, seed production and technology of growing sparsely distributed oilseeds give grounds to increase the production of their seeds to 1.2 million tonnes by 2025, as noted in Table 4.

***Table 4**. Projected production of oilseed flax seeds in Kazakhstan until 2025*

Indicators	2020/2021	2021/2022	2024/2025
Acreage, thousand hectares	1526.4	1496.1	1650
Gross harvest, thousand tonnes	1058.4	744.1	1200
Yield, t/ha	0.79	0.59	1.1

Source: *Development strategy of the joint-stock company "National Company". Food contract corporation for 2021-2030 (2020)*

Due to the severe drought during the growing season of flax and the unusually high level of pests and diseases for this crop, some acreage of oilseeds turned out to be unsuitable for harvesting, and producers did not consider it advisable to carry out harvesting on such areas. As a result, more than 200 thousand hectares of flax acreage were lost. In addition, the drought has had an extremely negative impact on the yield of oilseeds. As a result, even after significant losses, the total yield of this crop has significantly decreased despite the fact that it ranks second in the area of harvesting oilseeds. The leaders in the cultivation of oilseed flax in the Republic of Kazakhstan are the North Kazakhstan, Kostanay and Akmola regions with a sown area of 605, 282, 186 thousand hectares, respectively. It is previously known that in order to increase the productivity of oilseed flax cultivation, it is necessary to develop new high-yielding varieties that are adapted to local conditions, have a high oil content of seeds, are resistant to major diseases and adverse environmental factors. The growing season and the formation of the yield of the studied samples of oilseed flax are important biological signs in the natural and climatic conditions of the Karabalyk agricultural complex, noted in detail in Table 5.

***Table 5.** Duration of the growing season and the height of oilseed flax plants for the period 2020-2022*

Variety	Growing season, days				Plant height, cm			
	2020	2021	2022	Average	2020	2021	2022	Average
Kostanayskiy-11	88	91	93	90	55	58	50	54
Nebesniy	84	92	85	87	55	56	54	55
Biryuza	88	92	93	91	54	58	53	55
Linol	86	90	85	87	55	53	49	52
Severniy	89	94	93	92	54	48	45	49
Surpriz	87	90	91	89	53	51	44	49
Sokol	85	92	89	88	46	47	40	44
Triumf	88	93	93	91	44	49	40	44
Krokus	84	91	87	87	53	54	46	51
Sibirskaya 38854	82	90	87	86	54	58	50	54
Isilkulsky	87	90	89	88	58	55	50	54
Kustanayskiy yantar	86	93	89	89	54	55	52	53
Antares	85	90	91	88	49	50	45	48
Iceberg	81	90	85	85	52	56	50	52

Source: *compiled by the authors*

The growth period of the varieties ranged from 85-92 days, but in most samples, this indicator strongly depended on the conditions of the year. Despite very different climatic conditions, some varieties cultivated in the Karabalyk agricultural complex had a stable growth period throughout the year: Kostanayskiy – 91-93 days, Isilkulsky – 87-90 days, Surpriz – 87-91 days. In general, according to the results of a three-year study, two early-ripening varieties were identified that grew 5-6 days earlier than the standard variety, namely, Sibirskaya 38854 and Isilkulsky, which ripened on 86 and 85 days, respectively. In addition, eight varieties ripened earlier than the standard varieties Nebesniy, Linol, and Krokus – 87 days; Sokol, Isilkulsky, and Antares – 88 days; Surpriz and Kustanayskiy yantar – 89 days. According to the duration of the growing season, the varieties – Biryuza, Triumf, and Severniy, ripened 1-2 days later, in comparison with the standard.

When cultivating flax for oilseeds, an average plant height of 45-60 cm is sufficient. With double use, for seeds and fibre, it is necessary to create flax varieties with a plant height of 65 cm and above. For this purpose, it is necessary to involve tall varieties in crossing. The height of plants in the varieties under study largely depended on the weather conditions prevailing during the growing season, and varied between 44-54 cm with an average value of 51 cm. Three groups of plants were identified: with a height within 44-49 cm, 49-52 cm, and 52-58 cm. The standard plant height was 54 cm in the Karabalyk agricultural complex, Surpriz and Triumf varieties were marked below the standard – 44 cm, and the tallest were the Nebesniy and Biryuza varieties – 54 cm. Given the characteristic stunting of the varieties of oilseed flax, it can be emphasised that the varieties included in the crosses for spinning purposes are not suitable. Seed productivity is an important indicator of oilseed flax and includes related features, namely: the number of productive pods on the plant, the number of seeds in the box, the weight of 1000 g of seeds, which is described in detail in Table 6.

Table 6. *Seed productivity of oilseed flax for the period 2020-2022*

Variety	Number of productive boxes, pcs.			Number of seeds in a box, pcs.			Weight of 1000 seeds, g		
	2020	2021	2022	2020	2021	2022	2020	2021	2022
Kostanayskiy-11	23	29	21	9	10	8	6.5	7.1	6.2
Nebesniy	20	28	26	9	9	8	6.5	7.7	6.8
Biryuza	31	34	33	9	10	10	6.6	7.6	6.8
Linol	21	26	22	9	8	8	7	7.4	6.6
Severniy	19	23	18	8	9	8	6.6	7.2	6.4
Surpriz	22	27	20	8	8	7	6.5	7.4	6.4
Sokol	21	29	24	7	8	7	6.8	7	6.2
Triumf	23	25	19	10	10	9	6.4	7	6.2
Krokus	25	29	21	9	10	10	6.6	7.7	6.8
Sibirskaya 38854	24	28	22	9	9	8	6.5	7	6.2
Isilkulsky	26	30	24	9	10	9	6.3	7.2	6.4
Kustanayskiy yantar	27	32	25	9	10	10	6.7	7.2	6.4
Antares	24	27	19	10	10	9	6.7	7	6.2
Iceberg	21	30	25	9	10	10	6.3	7.5	6.6

Source: *compiled by the authors*

The number of productive pods per plant is an important feature closely related to the seed productivity of oilseed flax; according to this feature, the varieties Biryuza – 32.7 and Kustanayskiy yantar – 28 are distinguished in the experimental farm. Severniy and Kaiser had the lowest productivity rates of 20 and 22 boxes, respectively. The number of seeds in the box varied between 7.1-7.3 pcs. Varieties Nebesniy, Linol, Severniy, Sibirskaya 38854 were slightly inferior to the standard – 8.3-8.8 pcs., the remaining varieties showed results at the level of the Kostanayskiy-11 variety. Achieving a high yield is ensured by the availability of complete information about the processes of photosynthesis, growth and development, air, water and heat regimes, mineral nutrition, plant structure, sowing quality. The main chemical component of flax seeds is oil, the amount of which, in terms of crude fat, averages from 27 to 48%, therefore, in terms of the content of biologically valuable components, linseed oil ranks first among other edible vegetable oils. Data on the yield and oil content of flax seeds are indicated in Table 7.

Table 7. *Indicators of flax yield and oil content for the period 2020-2022*

Variety	Oil content, %			Yield, g/m^2		
	2020	2021	2022	2020	2021	2022
Kostanayskiy-11	42.5	44.3	40.9	59	52	53
Nebesniy	40.2	40.8	39.3	78	75	56
Biryuza	41.5	43.7	41.1	73	71	60
Linol	42.4	42.3	42.7	84	90	72
Severniy	42.1	41.8	42.9	65	60	45

Table 7, Continued

Variety	Oil content, %			Yield, g/m²		
	2020	2021	2022	2020	2021	2022
Surpriz	41.9	43	41.3	57	52	39
Sokol	40.7	42.7	39.6	64	65	36
Triumf	41.6	43	41.5	59	50	35
Krokus	42.3	41.8	42	53	48	42
Sibirskaya 38854	42.8	43.4	41.8	84	81	48
Isilkulsky	43	43.9	38.8	76	71	44
Kustanayskiy yantar	42.9	43.1	42.3	68	65	47
Antares	41.9	42.5	42.1	89	90	56
Iceberg	43.2	44.2	43.7	44	39	59

Source: *compiled by the authors*

The average yield of oilseed flax in a three-year trial of the standard Kostanayskiy-11 variety was 54.2 g/m^2. At the same time, the yield of the tested varieties varied from 47.5 to 82.2 g/m^2. During the three-year research period, some samples consistently exceeded the standard in seed yield: Linol – 82 g/m^2, Antares – 78.3 g/m^2, and Sibirskaya 38854 – 71.2 g/m^2, consistently exceeding the standard by 28, 24 and 17 g/m^2. The varieties Nebesniy, Biryuza, Isilkulsky, and Kustanaiskiy yantar also exceeded the standard for these samples by 60-69.7 g/m^2. Surpriz, Triumf, Krokus, and Iceberg varieties were below standard with a productivity of 47.5-49.3 g/m^2. As a result of the research, a high oil content in seeds of all varieties was revealed in the range of 38.8-44.3%. In the standard variety Kostanayskiy-11, the oil content averaged 42.6% over three years, in the varieties Biryuza, Linol, Triumf, Krokus, Sibirskaya 38854, Isilkulsky, Kustanayskiy yantar, Iceberg oil content varied at the same level. The oil content of the standard Kostanayskiy-11 variety averaged 42.6% over three years, and also, in the varieties Biryuza, Linol, Triumf, Krokus, Sibirskaya 38854, Isilkulsky, Kustanayskiy yantar, and Iceberg, it varied at the same level. On the artificial complex infectious background of single-row plots of 0.4 m^2, the stability of ecological variety testing of oilseed flax was studied. 2 varieties were used as controls: Kostanaysliy-11, resistant to fusarium, and the unstable Isilkulsky variety. Stability was determined by counting plants after germination and before harvesting. Gathering was carried out when 75% of the plot area matured (Table 8).

Table 8. *Resistance to fusarium wilting of varieties of ecological variety testing*

Variety	Resistance to fusarium, %, pcs.			
	2020	2021	2022	Average
Kostanayskiy-11	96	95	97	96
Nebesniy	92	95	98	95
Biryuza	92	91	97	93.3
Linol	95	92	89	92
Severniy	96	92	94	94
Surpriz	96	90	92	92.7
Sokol	98	96	90	94.7
Triumf	94	95	87	92
Krokus	92	94	93	93
Sibirskaya 38854	93	95	96	94.7
Isilkulsky	92	91	89	90.7
Kustanayskiy yantar	92	95	93	93.3
Antares	93	94	95	94
Iceberg	96	94	92	94

Source: *compiled by the authors*

In addition to high yield, oil content of seeds and early maturation, the selection of oilseed flax should have high resistance to the most common and harmful linseed fungus *Fusarium oxysporum* v. The spread of the disease and the degree of damage to the crop depends on the presence of the pathogen and environmental conditions (temperature, humidity, precipitation) and the degree of resistance of cultivated flax varieties.

DISCUSSION

In the current economic conditions, the production of oilseed flax is based on the cultivation of high-yielding varieties with high oil content, resistant to major pathogens and producing a marketable product that meets international quality standards. The reserve for increasing the productivity of the oilseed flax crop is the creation of new highly productive varieties adapted to local conditions, with high seed oil content and oil quality, resistant to major diseases and adverse environmental factors. The effectiveness of the breeding programme largely depends on the patterns of inheritance of economically valuable traits operating in the hybrid population of oilseed flax, allowing for more efficient selection, reducing the loss of valuable genotypes, saving costs by culling less valuable traits at an early stage of breeding. According to the study by G. Silska *et al.* (2022), interspecific crosses of oilseed flax can be used to breed varieties with greater plasticity and resistance to individual pathogens and complex diseases.

The reproductive success of oilseed flax cultivation includes the selection of flax samples from ecologically and geographically diverse world collections, and the development of methods for selecting parent pairs during crosses that determine the prospects for the future. The appearance of valuable traits in hybrids is associated with the possibility of combining the qualities of different parental forms. As a direction of breeding work, it is quite appropriate to attract wild species that can be significantly diversified in many ways due to interspecific crosses. As reported by A. Hoque *et al.* (2020), chromosomes of breeding traits of the genus *Linum* are important and valuable carriers of hereditary information, such as increased lateral branching and an increase in the number of pods on the plant, in addition to low content of crude fat, brittle pods, and small seeds. As noted by Z. Behzadi *et al.* (2022), a number of breeding methods are used to create new flax varieties, including microgametophytic selection, induced mutation, interspecific and intraspecific hybridisation, and electrophoresis of reserve seed proteins.

The creation of new crops is based on the theoretical development of models of varieties with specific characteristics and characteristics corresponding to high levels of yield and quality in specific environmental conditions. The diversity of genetic materials is an important characteristic for a sustainable breeding programme, as it provides the breeder with the best opportunities to select lines based on needs. BJ. Soto-Cerda *et al.* (2022) report that morphometric diversity is labour-intensive, often leads to false predictions, depends on the stage of development of plants sensitive to the environment, and diversity based on molecular markers is more accurate and economical since it allows breeders to select unrelated individuals among thousands of genotypes in a short period of time, which, in turn, reduces the workload in the field by evaluating only unrelated genotypes. The use of molecular biological methods and markers for the study of various cultivated plants has increased significantly. M. Yaşar (2023) describes various types of molecular markers and microsatellites for assessing the genetic diversity of the germ plasma of oilseed flax, such as: Random Amplified Polymorphic DNA (RAPD); Amplified Fragment Length Polymorphism (AFLP); Inter-Simple Sequence Repeat (ISSR); Simple Sequence Repeat (SSR); Inter-Retrotransposon Amplified Polymorphism (IRAP).

In breeding, a wide list of criteria reflecting different aspects of the process is used to assess the homeostaticity of oilseed flax culture, such as: ecological stability of varieties according to statistical indicators, and general, specific, and relative adaptive capacity. The general adaptive capacity describes the average value of a useful feature over the entire range of environmental conditions. Specific adaptive capacity is determined by differences in specific environmental conditions. Relative stability allows comparing different sets of features. According to A. Akrami *et al.* (2020), the ecological plasticity of the variety is a biological ability to adapt to growing conditions with the establishment of consistently high values of useful traits in various natural and climatic conditions. Varieties of oilseed flax with higher plasticity have greater stability of characteristics under fluctuations in environmental conditions, providing higher productivity under both favourable and unfavourable conditions.

Individual varieties of oilseed flax showed adaptive abilities in 2022 under sufficiently arid weather conditions, while new genetic sources of resistance were noted. This valuable source material distinguished the varieties of oilseed flax Biryuza, Linol, Iceberg with a significant, adaptive to drought potential, according to yield estimates. The productivity of agricultural crops depends on the moisture availability of crops. As noted by L. Ghobadi-Namin *et al.* (2022), in arid zones, growth conditions and crop formation will be determined by the provision of crops with moisture. Oilseed flax reacts less sensitively to moisture with the presence of a developed root system, but at the same time, moisture supply fundamentally reflects the level of yield.

The main economically valuable signs are: early maturity – recommended for cultivation in the northern and western regions of the Republic of Kazakhstan; tallness – for dual production use for vegetable oil and fibre; large-seeded and small-seeded; high yield. The varieties distinguished themselves by high yield: Linol – 82 g/m^2, Sibirskaya 38854 – 71 g/m^2, Antares – 78.3 g/m^2. The yield of oilseed flax is determined by the cultivation technology – the timing of sowing, the seeding rate, the provision of plants with nutrients, and varietal characteristics. According to K.K. Bharatya *et al.* (2022), crop yield is an integrated indicator reflecting the effectiveness of all elements in the technology of crop formation of individual plants and the biosphere as a whole, while the highest genetic potential of oilseed flax is to obtain a yield of 2 t/ha or more.

Flaxseed oil ranks first among other edible oils in terms of biological value. The content and composition of the oil are genetically fixed traits, but natural and climatic conditions can affect its accumulation and fatty acid composition. According to biochemical indicators, varieties with a high oil content in seeds were identified: Kostanayskiy-11 – 44.3%, Iceberg – 44.2%, Isikulsky – 43.9%, Biryuza – 43.7%, respectively, are characterised as medium-oil. M.Z. Koçak *et al.* (2022) noted that as the oilseed flax matures, the crude fat content in the seeds continuously increases, at first more intensively, and then the process slows down. Thus, the highest oil content is observed in seeds that have reached full ripeness and, on average, is in the range of 42-48%.

Since flax is an early sowing crop, there is a risk of damage and death of plants due to low temperatures, therefore, the creation of varieties resistant to hypothermia is an urgent direction in flax breeding. At low temperatures, the risk of fungal diseases of oilseed flax increases, the main ones are: fusarium, anthracnose, ascochytosis, polysporosis. The intensity of diseases depends on the characteristics of the pathogen, soil conditions, agricultural technology and susceptibility of the variety. A high coefficient of adaptation of oilseed flax was noted in the varieties Kostanayskiy-11, Sibirskaya 38854, Antares, Iceberg. As noted by S. Zare *et al.* (2023), the spread of oilseed flax diseases and the intensity of damage depends on the presence of the pathogen and its virulence, depending on environmental conditions, such as temperature, humidity, precipitation, the degree of resistance of the cultivated variety, therefore, flax breeding requires high resistance to the most common and harmful flax disease – fusarium. As reported by M. Walkowiak *et al.* (2022), excessively early crops of oilseed flax suffer from fusarium wilt, flax rust. Processing of oilseed flax crops, during the budding phase, has a stimulating effect on the culture, increasing the coefficient of plant adaptability to abiotic and biotic conditions.

With regard to oilseeds and flax, it is important to apply appropriate cultivation techniques and technologies. Observing the basic rules of compatibility and crop rotation, irrigation, seed quality, and temperature regime – can provide high results. The importance of Kazakh oilseed flax increases annually, which indicates its further prospects for cultivation and expansion of the selection range.

CONCLUSIONS

Based on the data obtained, the genetic potential of oilseed flax was determined by identifying the optimal parameters of cultivation technology in the conditions of Northern Kazakhstan. As a result of the conducted research, the patterns of the impact of various meteorological conditions in 2022-2023 have been established. In 2020, the weather conditions for the growing season were favourable for the growth and development of oilseed flax. The agro-climatic conditions of 2021 differed somewhat from the average annual ones, and June and July were marked by lower air temperatures, affecting the development of culture. The weather conditions of 2022 in the region were characterised as abnormally dry, while creating extreme conditions for growth and development.

As a starting material for breeding, economically valuable signs of oilseed flax were identified: the growing season – 85-92 days, seed yield – 47.5-82.2 g/m^2, seed weight – 6.9-8.1 g, seed oil content – 43.7-47.5%, and plant height – 45-60 cm. Assessment of the resistance of modern oilseed flax genotypes to plant diseases of the genus *Fusarium*. Based on the assessment of the signs of biological and economic value of the three-year period 2020-2022, the following parameters can be recommended for the creation of varieties for use in the zone of moisture deficiency in the Kostanay region in the conditions of the Karabalyk agricultural complex: early maturity – Sibirskaya 38854 and Iceberg; productivity – Linol, Antares, and Sibirskaya 38854; weight of 1000 grains – Nebesniy, Biryuza, Linol, and Krokus; oil content in seeds – Kostanayskiy-11, Iceberg; resistance to fusarium – Kostanayskiy-11, Sibirskaya 38854, Antares, Iceberg. Moreover, flax indicators, distinguished by the height of plants, the number of productive boxes, and the number of seeds in the box, are recognised as promising for inclusion in the breeding process. High-yielding varieties were noted: Linol – 82 g/m^2, Sibirskaya 38854 – 71 g/m^2, Antares – 78.3 g/m^2. A high productivity index was shown in terms of the weight of 1000 grains in the varieties Biryuza, Krokus, and Kostanaysky – 8.2 g, and Iceberg – 8.1 g.

Theoretical developments are used to create new varieties with appropriate yield indicators and the quality of products grown in specific environmental conditions. To ensure the profitability of agricultural production, especially in the oil and fat industry, pest resistance, especially to the meadow moth, must be included in research. The low yield of flax is explained by its biological features, i.e., slow growth in the early stages, and the need to create a highly effective system of herbicidal protection to prevent the growth of crops such as chamomile, knotweed, and sow thistle, which compete for nutrients and water.

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CONFLICT OF INTEREST

None.

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Вивчення світової колекції льону олійного як вихідного матеріалу для селекції в умовах Північного Казахстану

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Анотація. За сучасними вимогами вирощування, створюються нові сорти олійного льону, що відрізняються за комплексом корисних ознак. Основою селекції льону є вивчення, відбір, створення нових сортів на основі світової колекції та придатних для агрокліматичних умов Північного Казахстану. Мета дослідження – вивчення колекційних зразків льону олійного в умовах Костанайської області Північного Казахстану та відбір найбільш перспективного селекційного матеріалу за господарсько-цінними ознаками в умовах зони дефіциту вологи. У роботі використовувалися методи: біологічні, фенологічні, лабораторні, статистичні, аналіз інформації адаптивних можливостей окремих сортів льону олійного. Проведено оцінку господарсько-цінних ознак за 14 зразками льону олійного світової колекції різного еколого-географічного походження за період 2020-2022 рр. В результаті досліджень виділено зразки, що характеризуються високою врожайністю: Лінол – 82,0 г/м^2, Сибірська 38854 – 71,0 г/м^2, Антарес – 78,3 г/м^2. Високими показниками маси 1000 насінин відрізнялися зразки сортів Бірюза, Крокус, Кустанайський – 8,2 г, Айсберг – 8,1 г. Виявлено цінний та пластичний вихідний матеріал для селекційної роботи з основними цінно-господарськими ознаками: вегетаційний період протягом 85-92 днів більше 47,5-82,2 г/м^2, масою 1000 насінин 6,9-8,1 г, вмістом олії в насінні 43,7-47,5 % рослин заввишки 45-60 см. Виділені зразки рекомендуються до обробки в Північному Казахстані: за скоростиглістю – Сибірський 38854 та Айсберг; продуктивності – Лінол, Антарес; масі 1000 насінин – Небесний, Бірюза, Лінол, Крокус; вмісту олії в насінні – Костанайський-11, Айсберг; стійкості до фузаріозу – Костанайський-11, Сибірський 38854, Антарес, Айсберг. Ефективність селекційної програми залежить від закономірностей успадкування економічно цінних ознак, які діють у гібридної популяції, скорочуючи втрати цінних генотипів і знижуючи витрати за допомогою відбраковування менш цінних ознак

Ключові слова: продуктивність; адаптивні здібності; врожайність; олійність; генотип; фузаріоз