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EVALUATION OF SUNFLOWER STARTING MATERIAL FOR BREEDING-VALUABLE TRAITS

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Data of a four-year study (2018−2021) were evaluated for breeding-valuable traits of sunflower starting material (pollen fertility restorers, sterility fixers and sterile analogues of self-pollinated lines). Genotypes with optimal values of head productivity, 1000-seed weight and oil content were identified. Fertile lines that had the best pollen viability were identified and selected.

Key words: *sunflower, lines, breeding, productivity, pollen viability, leaf surface index*

Introduction. To create modern sunflower hybrids, breeding requires starting material of good quality, videlicet self-pollinated lines, which will have a set of economically useful features, including high yield, good seed quality, optimal height and growing period, ability to form a well-developed photosynthetic surface, and high pollen viability.

Literature review problem articulation. Today, agriculture is important for the economic development of Ukraine and ensures the food security of populations in many European countries. Among major crops, sunflower is a leading one in agriculture, justifying its large sown areas. Sunflower breeding, like any other crop breeding, constantly evolves and cannot be stopped because of climatic changes or due to new races of pathogens and pests.

Leading research institutions of the National Academy of Agrarian Sciences of Ukraine create sunflower hybrids and starting material. In particular, the main registrars of sunflower hybrids are the Plant Production Institute named after V.Ya. Yuriev (PPI nd.a. V.Ya. Yuriev) and the Institute of Oil Crops, whose shares in the State Register of Varieties for 2022 are 3.9-3.3% according to the General Register of Hybrids [1]. Since the sunflower breeding onset, there has been a transition from seed quantity to its quality. Self-pollinated lines should have increased seed productivity, seed quality, combining ability, improved architectonics and markers, which will simplify culling [2, 3]. Chemical and physical mutageneses have been widely used to obtain marker traits in sunflower breeding, but hybridization remains the main method for creating sunflower starting material [4, 5]. Sunflower is constantly bred to create inbred germplasm that would be resistant to major diseases and pests, such as red sunflower weevil, broomrape, downy mildew, phomopsis stem canker, etc. [6–9]. Sunflower is also drought-resistant and can withstand temporary wilting due to a well-developed root system and grow under insufficient rainfall [10, 11]. In particular, it was noted that droughts and temperature shifts exerted the greatest effects on the plant height and the stem and head diameters [12]. This explains that these characteristics can be considerably variable in inbred sunflower lines from year to year.

Pollen viability is an important feature for breeding and seed production, which allows for rapid reproduction of new sunflower hybrids and their implementation into production. Scientists emphasized that, in addition to inbred depression, environmental conditions were the main factors influencing the pollen viability [13−16].

Purpose and objectives. To evaluate self-pollinated sunflower lines for major breeding-valuable traits: performance, growth and development, and pollen viability; to select the best genotypes for further breeding in the Eastern Forest-Steppe of Ukraine.

Materials and methods. The study was conducted in the experimental field of the Chair of Genetics, Breeding and Seed Production of Kharkiv National Agrarian University named after V.V. Dokuchaev (KhNAU nd.a. V.V. Dokuchaev; now it is the State Biotechnological University) in 2018−2021. Ten self-pollinated sunflower lines bred at the PPI nd.a. V.Ya. Yuriev and four mutant lines obtained at KhNAU nd.a. V.V. Dokuchaev were studied. Genotypes were represented by lines - pollen fertility restorers (Kh06135V, Kh06134V, Kh785V, KhNAU1133V, KhNAU63V, KhNAU488V, and KhNAU505V), sterility fixers (Kh1010B and Kh1012B) and sterile analogues of self-pollinated sunflower lines (Skh808A, Skh808A/Kh1002B, Skh1010A, Skh1012A, and Skh1002A). Planning, experiments, surveys and records were carried out in compliance with traditional methods [17, 18]. There were four replications; winter wheat was the forecrop; the sowing arrangement was 70 × 25 cm. Plants were not additionally fertilized. To control weeds, soil herbicide Kratos at a dose of 2.0–2.5 L/ha was applied; weeds were also eradicated manually. Data were statistically processed in Statistica 10 and Microsoft Excel.

Biometric measurements were performed on day 30 after anthesis. The total number of leaves and the number of dry leaves were determined by cutting and counting. To determine the leaf surface index (hereinafter − LSI), we first calculated the average leaf area using the following formula (LP Osipova, PP Litun) [19]:

$$S = -0.1063 - 15.6618 \times L + 17.4572 \times H + 0.574 \times L^2 + 0.0617 \times H^2,$$

where S is the leaf blade area; L is the leaf length; H is the leaf width.

Then the obtained figures were multiplied by the average total number of leaves per plant and the plant density per square meter.

The weather in the study years was characterized by uneven distribution of precipitation and high average daily temperatures, which was manifested by droughts in the main periods of sunflower development. The average daily temperatures exceeded the multi-year averages to various degrees depending on the year and month: from insignificant 0.2°C in July 2019 and August 2020 and to significant 4.8−6.5°C in July 2021 and August 2018.

The precipitation amounts during the sunflower growing period in the study years were lower than the long-term average. Over the period of 2018–2021, August (0.0-11.8 mm; the long-term average is 51.0 mm) and September (0.0−10.7 mm; the long-term average is 45.4 mm) were unusually arid. However, in general, the environmental conditions were favorable for the growth and development of sunflower.

The pollen viability was determined by P. Diakon’s method, which is based on the dehydrogenase reaction with 1% tetrazole in live pollen grains [20]. Pollen was collected in the morning: five anthers from 10 plants during three days. Microscopic slides were prepared and left in a dark place at room temperature for 30 min; then the slides were photographed at 10-fold magnification with a microscope MICRO-med XS-3330 LED and a digital camera.

Results and discussion. The field experiments showed that the sterile analogues of self-pollinated lines had shorter “shooting-anthesis” periods (60 ± 2.0 – 66 ± 1.5 days) than the pollen fertility restorers and sterility fixers (65 ± 2.0 – 75 ± 2.1 days). It was noted that this parameter was moderately correlated with the total number of leaves per plant (r =0.50) and negatively correlated with the plant height (r = -0.40). Other researchers found that the vegetative surface of sunflower was weakly correlated with the anthesis length [2]. At the same time, we noted no correlation (r = 0.00).

The number of leaves per plant and their death during the growing period are important for breeding and agronomy. Foliage is the main indicator of the photosynthetic potential of the plant and is controlled by a large number of recessive genes, which produce totally 27−32 leaves per plant under optimal environmental conditions according Marinković and Škorić’s data [21]. It was found that the total number of leaves varied within 25 ± 1.2 – 29 ± 2.4 leaves in the studied self-pollinated sunflower lines bred at the PPI nd.a. V.Ya. Yuriev, while the sunflower lines obtained via chemical and physical mutageneses at KhNAU nd.a. V.V. Dokuchaev had significantly smaller numbers of leaves (21 ± 1.6 – 24 ± 2.2, except for KhNAU1133V line (33 ± 3.1 leaves), which had a branched stem. The total number of leaves per plant was moderately correlated with the number of dry leaves on day 30 after anthesis (r = 0.48), stem height (r = 0.46), and LSI (r = 0.58) (Tables 1 and 2).

Table 1

Economic features of the self-pollinated sunflower lines, average for 2018–2021

Line	"Shooting-anthesis" period, days	Total number of leaves per plant	Number of dry leaves per plant	LSI, m^2	Height, cm	Head productivity, g	1000-seed weight, g	Oil content, %
Sterile analogues of self-pollinated lines								
Skh808A	60 ±2.0	27 ±2.6	10 ±0.3	2.9 ±0.3	182 ±15.8	57.8	58.3	51.3
Skh808A/X1002B	65 ±1.7	28 ±1.6	16 ±1.7	3.0 ±1.0	182 ±28.5	53.5	54.6	48.9
Skh1010A	66 ±1.5	27 ±1.8	20 ±2.2	1.8 ±0.6	119 ±14.5	17.0	51.8	34.1
Skh1012A	64 ±2.5	25 ±1.5	15 ±1.0	1.9 ±0.9	114 ±20.3	20.1	39.2	40.9
Skh1002A	62 ±2.1	26 ±1.4	17 ±2.0	2.3 ±0.7	150 ±27.5	15.5	37.8	33.8
LSD_{05}	3.4	3.5	3.0	–	11.4	12.7	9.0	7.7
Lines – pollen fertility restorers and fertility fixers								
Kh06135V	70 ±3.0	29 ±2.4	14 ±2.0	3.0 ±0.6	126 ±10.8	38.8	46.1	39.0
Kh06134V	68 ±1.5	26 ±1.1	14 ±2.8	1.9 ±0.7	124 ±17.6	13.9	31.9	43.6
Kh785V	68 ±2.0	29 ±1.5	19 ±2.3	1.9 ±0.7	140 ±27.6	30.0	45.8	43.2
KhNAU1133V	75 ±2.1	33 ±3.1	16 ±4.3	2.5 ±0.5	122 ±25.0	9.0	35.1	40.4
KhNAU63V	65 ±2.0	21 ±1.6	10 ±1.9	1.3 ±0.7	90 ±19.1	9.5	50.0	43.0
KhNAU488V	67 ±1.8	24 ±2.2	15 ±1.3	1.8 ±0.6	124 ±15.2	8.7	32.5	41.1
KhNAU505V	66 ±1.6	22 ±1.3	11 ±2.0	1.8 ±0.5	114 ±14.5	8.5	30.0	41.6
Kh1010B	67 ±1.5	27 ±1.7	19 ±2.2	1.6 ±0.7	122 ±14.6	14.7	50.8	34.0
Kh1012B	67 ±2.1	25 ±1.2	15 ±1.8	2.2 ±0.5	106 ±17.1	18.9	34.0	35.7
LSD_{05}	4.3	3.6	4.4	–	12.6	10.2	10.3	7.9

The number of dry leaves per plant is important for breeding and agronomy and can be used as a marker. It was found that the number of dry leaves was not correlated with the height (r = 0.05), LSI (r = -0.11), productivity (r = -0.13), or with 1000-seed weight (r = 0.07) in the self-pollinated sunflower lines, which is in agreement with K.M. Makliak et al.'s results [22]. However, there was a positive correlation (r = 0.50) between the number of dry leaves per plant and the total number of leaves per plant and a negative correlation (r = -0.57) between the number of dry leaves per plant and oil content. Of the studied sunflower genotypes, Kh785V, Kh1010V and its sterile analogue Skh1010A were distinguished, as they had the highest percentages of dry leaves related to the total number of leaves: 66%, 71% and 74%, respectively. It was noted that in 2018-2021 the sterile analogue of the Skh808A self-pollinated line showed the lowest rate of post-anthesis leaf death (37% or 10 ± 0.3 leaves) related to the total number.

The plant height was closely correlated with the LSI (r = 0.71), productivity (r = 0.81), 1000-seed weight (r = 0.48), and oil content in seeds (r = 0.55). It was found that the KhNAU63V line had the shortest plants (90 ± 19.1 cm), and Skh808A and simple sterile hybrid Skh808A/Kh002B – the tallest ones (182 ± 15.8 cm and 182 ± 28.5 cm, respectively).

The LSI indicates the photosynthetic potential of the plant on which depends the accumulation of fats and lipids in the plant and is described in more detail in our previous publication [23]. Of the sterile analogues, high LSI values were recorded for Skh808A, Skh808A/Kh1002V, and Skh1002A: 2.9 ± 0.3, 3.0 ± 1.0, 2.3 ± 0.7 m^2, respectively. Of the pollen fertility restorers and sterility fixers, Kh06135V, KhNAU1133V, and Kh1012B had the highest LSI values: 3.0 ± 0.6, 2.5 ± 0.5, 2.2 ± 0.5 m^2, respectively. The rest of the studied self-pollinated sunflower lines had significantly a lower LSI of 1.3–1.9 m^2.

Table 2

Correlations between the studied traits in the self-pollinated lines

	Trait	1	2	3	4	5	6	7	8
1	"Shooting-anthesis" period, days	1							
2	Total number of leaves per plant	0.50*	1						
3	Number of dry leaves per plant	0.28	0.48*	1					
4	Height, cm	-0.40	0.46*	0.05	1				
5	LSI, m^2	0.00	0.58*	-0.11	0.71**	1			
6	Head productivity, g	-0.37	0.36	-0.13	0.81**	0.77**	1		
7	1000-seed weight, g	-0.39	0.22	0.07	0.48*	0.26	0.68**	1	
8	Oil content, %	-0.23	0.06	-0.57*	0.55*	0.38	0.62**	0.31	1

Note: * the value is probable at P> 0.05, ** the value is probable at P> 0.01

Seed yield and seed quality are the main indicators of the value of self-pollinated lines. Thus, of the sterile analogues of self-pollinated lines, Skh808A was singled out: its head productivity was 57.8 g (3.3 t/ha); the 1000-seed weight was 58.3 g; the oil content was 51.3%. The simple sterile hybrid originated from this line, Skh808A/Kh1002B also had high indicators: its head productivity was 53.5 g (3.0 t/ha); the 1000-seed weight was 54.6 g; the oil content was 48.9%. The pollen fertility restorers and sterility fixers had lower seed productivity and quality. The best lines were Kh06135V (the head productivity was 38.8 g (2.2 t/ha); 1000- seed weight – 46.1 g; oil content – 39.0%) and Kh785V (the head productivity was 30.0 g (1.7 t/ha; 1000-seed weight – 45.8 g, oil content – 43.2%) on average for 2018-2021 (all values are significant at P<0.05).

In other studied lines of sunflower bred at the PPI nd.a. V.Ya. Yuriev, the head productivity was 13.9-20.1 g (0.8-1.1 t/ha). It was noted that the lines obtained via chemical and physical mutageneses, KhNAU1133V, KhNAU63V, KhNAU488V, and KhNAU505V, had a low head productivity of 8.5–9.5 g corresponding a yield of 0.5 t/ha. Features of low productivity of mutant lines are also noted by other scientists, who argue about the difficulty of obtaining high-yielding sunflower lines by chemical mutagenesis [2]. The head productivity was strongly correlated with the 1000-seed weight (r = 0.68) and the oil content in seeds (r = 0.62), which is confirmed by our previous studies on other genotypes [24].

Investigating the pollen viability in the fertile sunflower lines, we established different gradations according to the pollen grain color: red - viable, pink - weakly viable and gray - not viable (Fig. 1).

It was revealed that of the studied lines the highest viability of pollen was inherent to Kh06134V (64.5%); 17.8% of pollen grains were weakly viable; and 17.7% − non-viable. In Kh785V and Kh06135V, the pollen viability averaged similarly over the study years (2018−2020): 54.5% and 54.0%, respectively. The percentages of weakly viable and non-viable pollen grains did not exceed 26.5% and 25.6%, respectively. In the Kh1010B sterility fixer, a high percentage of non-viable pollen grains was noted (39.3%) and the share of viable pollen grains was low (43.2%) (Fig. 2).

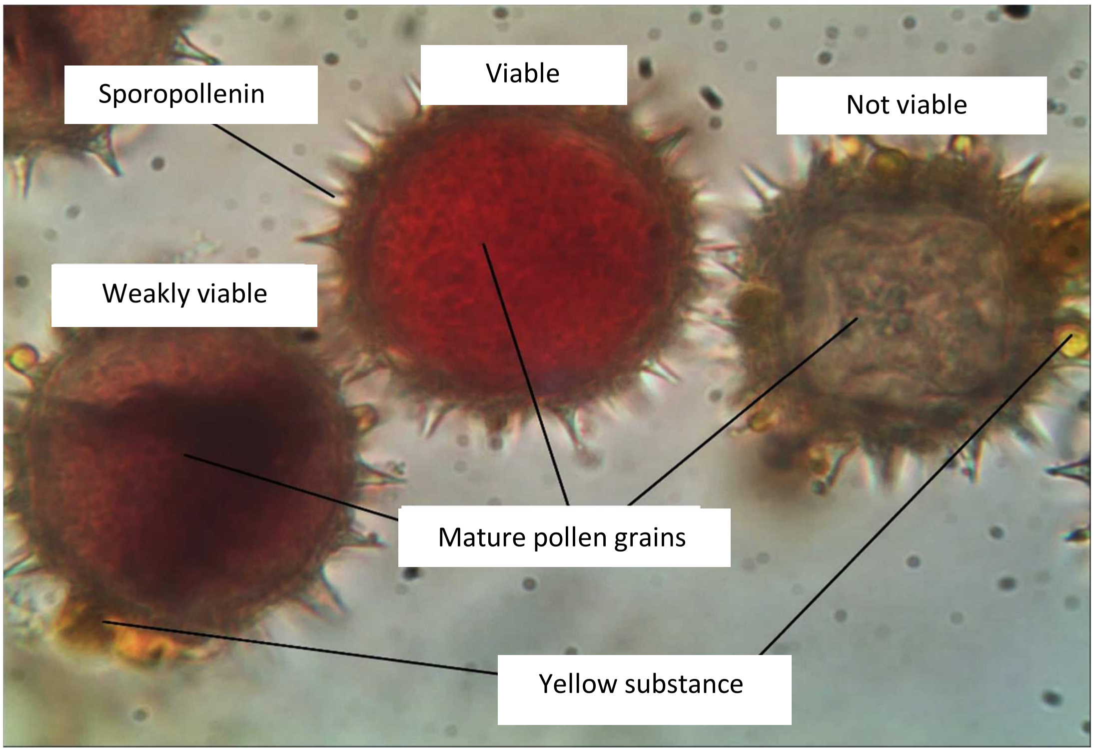

Fig. 1. Sunflower pollen grains stained with 1% tetrazole, 100 × magnification.

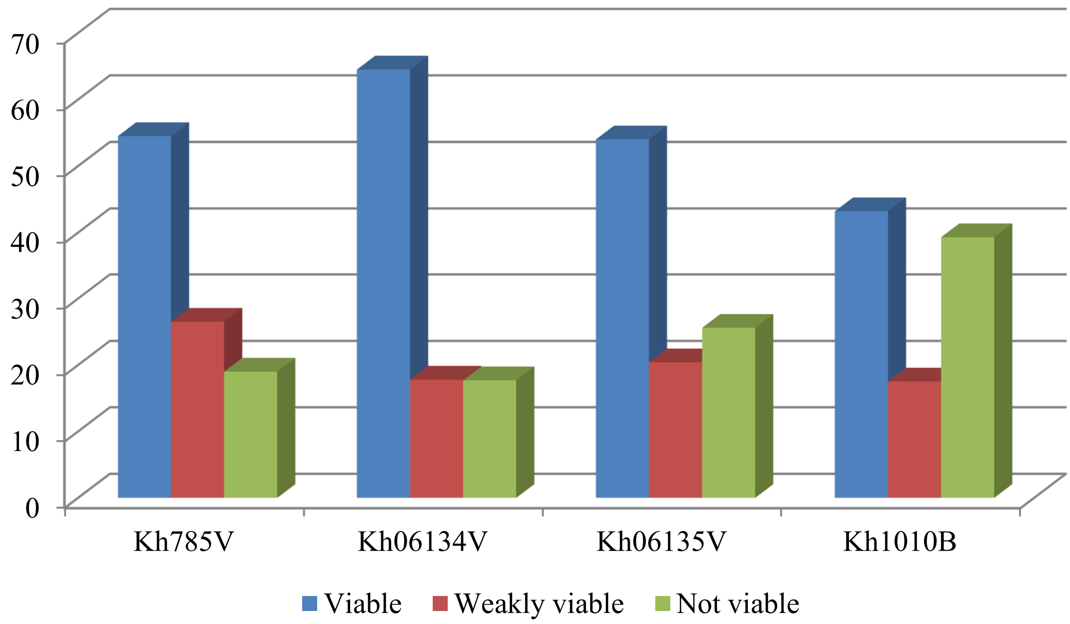

Fig. 2. Pollen viability in the fertile sunflower lines, average for 2018-2020.

Conclusions. The self-pollinating sunflower lines were evaluated in the field and laboratory for the main breeding and economically useful features in the Eastern Forest-Steppe of Ukraine. Of the sterile analogues of self-pollinated sunflower lines, Skh808A/Kh1002B and Skh808A were selected due to a yield of 3.0–3.3 t/ha, 1000-seed weight of up to 58.3 g and high oil content of 48.9–51.3 % under the test conditions. The best pollen fertility restorers were Kh785V and Kh06135V giving 1.7–2.2 t/ha, with a 1000-seed weight of 45.8–46.1 g and oil content of 39.0–43.2%.

It was found that the number of dry leaves per plant was not significantly correlated with the plant height, LSI and or with productivity (r = 0.05; -0.11; -0.13 respectively).

The new lines, KhNAU1133V, KhNAU63V, KhNAU488V and KhNAU505V, obtained via chemical and physical mutageneses, were assessed. Their low productivity of 0.5 t/ha and poor LSI of 1.3–2.5 m^2 were noted.

In the laboratory, the pollen viability in the sunflower lines Kh785V, Kh06134V, Kh06135V, and Kh1010B was assessed. The Kh06134V line had the highest percentage of viable pollen grains (64.5%) on average across the study years (2018–2020).

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ОЦІНКА ВИХІДНОГО МАТЕРІАЛУ СОНЯШНИКА ЗА СЕЛЕКЦІЙНО ЦІННИМИ ОЗНАКАМИ

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Мета дослідження. Визначення селекційних та основних корисних господарських ознак самозапилених ліній соняшника в умовах східної частини Лісостепу України.

Матеріали і методи. Вихідним матеріалом для дослідження були 14 самозапилених ліній соняшника різного генетичного походження. Польові і лабораторні дослідження проведено за загальноприйнятими методиками. Життєздатність пилку фертильних ліній соняшника визначали тетразольним методом.

Обговорення результатів. Серед досліджуваних генотипів соняшника було виділено п’ять генотипів: Сх808А/Х1002Б, Сх808А, Х785В та Х06135В, які в умовах східного

Лісостепу України мали найвищі показники продуктивності кошика в межах 30,0–57,8 г (1,7–3,3 т/га). Підтверджено результати інших науковців щодо відмирання листя та відсутності кореляції між ознаками висоти, ІЛП та продуктивності (r=0,05; -0,11; -0,13 відповідно). Відмічається, що ІЛП має важливе значення для формування олійності насіння та має з нею негативну кореляцію r=-0,57. За періодом розвитку сходи-цвітіння найменш тривалий період розвитку має лінія Сх808А – 60 діб, а найбільш тривалий ХНАУ1133В – 75 діб. Отримані лінії соняшника методом мутагенезу мають низькі показники врожайності (0,5 т/га). За показником життєздатності пилку виділено лінію Х06134В, яка продукує найбільшу кількість життєздатного пилку – 64,5 %

Висновки. Визначено особливості росту і розвитку ліній соняшника в умовах східної частини Лісостепу України. Проведено оцінку основних селекційних та корисних господарських ознак ліній соняшника. За результатами дослідження виділено генотипи Сх808А/Х1002Б, Сх808А, Х785В і Х06135В з найкращими показника продуктивності та якості. Виділено генотип Х06134В, що продукує найбільшу кількість життєздатного пилку.

Ключові слова: *соняшник, лінії, селекція, продуктивність, життєздатність пилку, індекс*

EVALUATION OF SUNFLOWER STARTING MATERIAL FOR BREEDING-VALUABLE TRAITS

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Purpose. To evaluate self-pollinated sunflower lines for major breeding-valuable and agronomically useful traits in the Eastern Forest-Steppe of Ukraine.

Materials and methods. Fourteen self-pollinated sunflower lines of different genetic origins were studied. The field and laboratory experiments were conducted in accordance with traditional methods. The pollen viability from the fertile sunflower lines was determined by the tetrazole method.

Results and discussion. Of the studied sunflower genotypes, five genotypes were distinguished: Skh808A/Kh1002B, Skh808A, Kh785V, and Kh06135V. They had the highest head productivity of 30.0–57.8 g (1.7–3.3 t/ha) in the Eastern Forest-Steppe of Ukraine. We confirmed other scientists' results on leaf death and absence of correlation between the plant height, LSI and productivity (r = 0.05; -0.11; -0.13, respectively). It was noted that LSI was important for oil content in seeds and negatively correlated with it (r = -0.57). As to the "shooting-anthesis" period, Skh808A has the shortest period of development (60 days) and KhNAU1133V – the longest one (75 days). The sunflower lines obtained via mutagenesis gave low yields (0.5 t/ha). Kh06134V was distinguished due to its pollen viability, as this line produced the largest amount of viable pollen grains (64.5%).

Conclusions. The main features of the growth and development of sunflower lines in the Eastern Forest-Steppe of Ukraine were determined. The main breeding and economically useful features of the sunflower lines were assessed. Owing to the study, the Skh808A/Kh1002B, Skh808A, Kh785V, and Kh06135V genotypes with the best productivity and quality were singled out. The Kh06134V line, which produced the largest amount of viable pollen grain, was identified.

Keywords: *sunflower, lines, breeding, productivity, pollen viability, leaf surface index*