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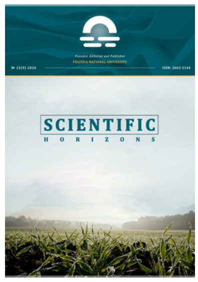

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Evaluation of sunflower breeding material for resistance to broomrape (*Orobanche cumana Wallr.*) and herbicides under artificial climate conditions to accelerate the breeding process

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Abstract. Sunflower is an important oilseed crop, so increasing its yield and resistance to diseases and pests can lead to significant economic improvements for agricultural businesses and the country as a whole. Climate change and the spread of new races of broomrape (*Orobanche cumana Wallr.*) pose serious threats to sunflower production, and research in this area is helping to develop varieties that can adapt to changing conditions. The purpose of the study is a comprehensive assessment of breeding

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material to identify the most resistant forms and hybrids of sunflower. To achieve the goal, an experiment was conducted in the period 2015-2023 in the LLP "Experimental Farm of Oilseed Crops", in which the assessment of sunflower breeding material for resistance to broomrape and herbicides was studied. As a result of the experiment, sunflower lines were successfully created that are resistant to broomrape and herbicides, which helps to increase productivity and reduce crop losses. The created sunflower lines were introduced into the breeding process in order to develop highly productive interline sunflower hybrids, which became an important step in improving the agriculture of Kazakhstan. These innovative hybrids, such as "Agribusiness 2050" and "Batyr", have shown high resistance to broomrape of races E-F, which significantly reduces crop losses and ensures reliable products. In addition, herbicide-resistant hybrids have been developed, such as Baiterek S and Baikonur, which can effectively control weeds and maintain crop cleanliness, which is important for increasing yields and reducing tillage costs. These hybrids have been recommended for use in agriculture in Kazakhstan and can help improve sunflower productivity. This study contributes to the expansion of scientific knowledge in the field of sunflower breeding and pest control, which is a relevant area for improving agricultural practices and ensuring food security

Keywords: variety; hybrid; agriculture; experimental conditions; genetic markers

INTRODUCTION

Agriculture plays an important role in ensuring food security and meeting the needs of the population for raw materials for industry. However, various factors stand in the way of increasing yields and quality of agricultural products, among which plant diseases and weeds occupy a special place. One of the major challenges for agriculture is the problem of sunflower blight (*Orobanche cumana Wallr.*). This parasitic organism can cause significant yield losses in sunflowers and can be a serious limiting factor for sunflower production.

Prevention and control of sunflower blight are of great importance for sustainable agricultural development (Tajibayev *et al.,* 2023). On the other hand, one of the most urgent problems of agriculture is weed infestation of cultivated crops. Yield losses caused by weeds can reach 30% or even more, especially in some crops. Herbicides are often used to combat this problem. However, previously used herbicides had environmental risks, a wide range of effects and could be toxic to mammals. In addition, they remained in the environment for a long time. Plant breeding for herbicide resistance is becoming an integral part of modern agriculture (Trotsenko *et al.,* 2020). A. Zatybekov *et al.* (2020) focused on genetic studies aimed at identifying specific genes and molecular mechanisms responsible for resistance to broomrape and herbicides. This helps to understand in more detail the mechanisms of resistance and the possibilities of editing them through genetic engineering. In turn, S. Liu *et al.* (2020) studied the ecological context of the interaction between sunflower, broomrape and herbicides. They studied which environmental factors facilitate or limit the spread of broomrape and how these factors can be used to control it without the use of herbicides.

In recent years, the demand among agricultural producers for sunflower hybrids resistant to sulfonylurea and imidazoline group herbicides has increased. These herbicides have a broader spectrum of action, covering perennial, single and dicotyledonous weeds as well as cereals. This is due to market needs, where high cultivation intensity of sunflower hybrids and reduced crop care costs play an important role in reducing the cost of final production (Pinar *et al.,* 2021). Researchers A. Babkenov *et al.* (2020) have also studied phytosanitary methods of controlling broomrape, such as biological control by using natural enemies of broomrape or the use of biological products that may be less harmful to the environment.

To accelerate the breeding process, it is necessary to conduct research under artificial climate conditions, which allow a more accurate and rapid assessment of the genetic characteristics of plants and their response to various stresses. With this in mind, researchers D. Kurylych and K. Makliak (2022) have begun work on creating herbicide-resistant linear breeding material. One such production system is the SUMO or Express Sun system, which is a combination of a herbicide-resistant sunflower hybrid and a herbicide with the active ingredient tribenuron-methyl. The introduction of the tribenuron-methyl resistance gene into the gene pool of cultivated sunflower has led to the establishment of two publicly available sources of this trait, known as SURES-1 and SURES-2. Other researchers, A. Ryzhenko *et al.* (2020), are exploring the possibility of using modern technologies, such as CRISPR-Cas9, to create genetically modified sunflower varieties that are resistant to broomrape and herbicides.

It should be noted that despite considerable research in plant breeding and pest management, many aspects remain completely unexplored. In particular, the genetic basis of resistance, as the mechanisms of plant resistance to Broomrape and herbicides are still not fully understood. A detailed study of the genetic basis of resistance and molecular mechanisms of plant response to stresses may lead to more effective breeding methods, hence the relevance of the study. The aim of the study is to comprehensively evaluate the breeding material that has been generated over the years in order to identify the most resistant forms and, using them as a starting point, to establish a new plant collection that will serve as a base for the development of resistant sunflower hybrids.

MATERIALS AND METHODS

To study the evaluation of sunflower breeding material for resistance to Broomrape (*Orobanche cumana Wallr.*) and herbicides in the period 2015-2023, an experiment was conducted in the limited liability partnership (LLP) "Experimental Farm of Oilseeds". The experiment was carried out under artificial climate conditions, using the following steps:

1. Collection and preparation of breeding material. Sunflower breeding material was collected, including different varieties and lines that had been grown for several years.

2. Evaluation of resistance to Broomrape. Two methods were used to evaluate the resistance of sunflower seeds to Broomrape. The first method involved visual assessment of the root system of sunflower plants and counting the number of Broomrape haustoria (nodules) on affected plants (Fig. 1). The second method was based on a more detailed evaluation of uninfected sunflower seedlings under a binocular lens. These seedlings were examined for the presence of brown necrotic spots at the sites of dead Broomrape haustoria, and the elongation of Broomrape seedlings was measured, as this contributed to the depletion of nutrient reserves in the seeds of the parasite and its subsequent die-off (Fig. 2). Race-differentiator samples were used as controls to assess the racial composition of the parasite: variety Kruglik (race A) and line LC-1093 (race F-Or_6). The degree of infestation was determined by multiplying the percentage of susceptible plants by the average number of nodules of the parasitic plant and dividing this value by 100.

Figure 1. *Visual assessment and counting of nodules of Broomrape*
Source: *composed by authors*

3. Development of resistant lines and hybrids. To create sunflower lines resistant to Broomrape, self-pollinated lines were used, which were isolated from interspecific varieties-populations, such as R-Y-60, as well as hybrids of foreign selection, such as 11 – Berk, 9 – Nika, and others. These lines provided donors of resistance to Broomrape, which were further used for crosses and creation of new resistant forms. When working on the development of lines resistant to herbicides of the sulfonylurea and imidazoline groups, donors (testers) with genetic resistance such as CB-c, CB-i, SUR 3, K 259 were also used. These testers served as a starting point for crosses and creation of new plants with resistance to these herbicides.

Figure 2. *Estimation of stable numbers under binoculars*
Source: *composed by authors*

4. Sowing and cultivation under artificial conditions. Every year, between November and April, sowing was carried out in a room with an artificially created climate. A mixture of soil and sand in the proportion of 2:1 was used as substrate. A certain amount of seeds of Broomrape was applied to the growing vessels, based on the calculation of 200 mg for each kilogram of soil mixture. A labelled sowing scheme was also created, and the tested samples were sown together with control samples, which were susceptible to Broomrape (Fig. 3).

Figure 3. *The growing box used to conduct the assessment of sunflower resistance to Broomrape*
Source: *composed by authors*

5. Herbicide treatment. Treatment was carried out on plants in the development phase with 2-3 pairs of true leaves. The recommended doses of herbicides were used: 30 g/ha for herbicide from sulfonylurea group (Express) and 1 litre/ha for herbicide from imidazolines group (Eurolightning) (Fig. 4).

Figure 4. *Sunflower plants before herbicide treatment*
Source: *composed by authors*

6. Selection of new parental forms. Based on the results of resistance assessment and herbicide treatment, the best plant samples were selected to create new parental forms with the desired resistance characteristics (Fig. 5).

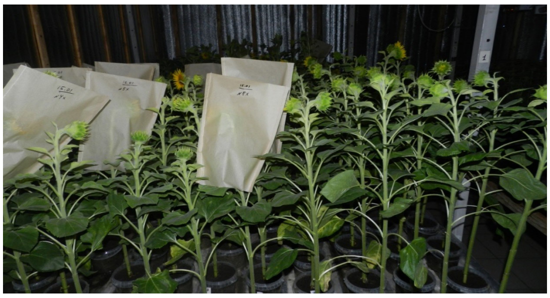

Figure 5. *Isolation of plants in cross-breeding and self-pollination operations*
Source: *composed by authors*

All these steps were improved and optimized in accordance with the sunflower breeding methodology, which allowed successfully achieving the objectives and obtaining stable sunflower hybrids and lines that contribute to improved agricultural productivity and sustainability. The authors followed the standards of the Convention on Biological Diversity (1992) and the Convention on Trade in Endangered Species of Wild Fauna and Flora (1979).

This research was carried out within the framework of programme-targeted financing of the Ministry of Agriculture of RK 2021-2023 (BR10765017 "Study and provision of storage, replenishment, reproduction and effective use of genetic resources of agricultural plants to ensure breeding process").

RESULTS

The material, including self-pollinated Broomrape lines and self-pollinated (F1) progeny, was studied with seeds from populations of the parasitic plant collected from different growing regions such as Ukraine and Kazakhstan. To improve the selection of forms of sunflower being resistant to Broomrape, a comparative evaluation of Broomrape populations represented by samples from the above-mentioned countries was carried out. The response of self-pollinated sunflower lines to infection by the parasitic plant strongly depended on the seed origin. For example, the sample of the variety 'Kruglik' (race A – Or1) was 100% affected by all types of Broomrape populations, while the line LC-1093, known to be resistant to Or6 (race F), showed the lowest degree of infestation when using seeds from the Krasnodar population – only 13.5% (Table 1).

Table 1. *Response of sunflower lines to infection by different populations of Broomrape*

Line, control	Kazakhstan (East Kazakhstan region)			Ukraine (Zaporizhzhia)		
	Tested plants, pcs.	Reproduced plants, %	Degree of infestation, %	Tested plants, pcs.	Reproduced plants, %	Degree of infestation, %
BKU101 A	14	29.3	2.3	15	62.3	4.9
BKU101 A	27	26.0	2.1	22	58.7	4.7
LC-1093	15	25.8	1.2	14	26.3	2.1
Kruglik	21	100	42.3	19	100	44.6

Source: *composed by authors*

All subsequent experiments on the resistance of breeding material to Broomrape were conducted on populations of Broomrape collected from commercial sunflower crops in Kharkiv, Zaporizhzhya and Donetsk regions of Ukraine, provided by Ukrainian specialists. Between November 2015 and April 2016, 427 sunflower breeding numbers including maternal lines and paternal forms (Rf) of different levels of backcrossing and incucht were analysed for resistance to Broomrape. As a result of screening, 20 accessions with 100% resistance were identified among the tested accessions (Table 2).

Table 2. *Results of analyses of sunflower breeding numbers (2015-2016)*

Number of lines, pcs.	Plants tested, pcs.	% of susceptible plants	% of resistant plants	Infestation degree, %
Control	1197	100	0	21.1
248	1806	61-78	28-42	23.2
112	896	39-45	11-19	14.3

Table 2, Continued

Number of lines, pcs.	Plants tested, pcs.	% of susceptible plants	% of resistant plants	Infestation degree, %
47	423	11-21	5-8	16.9
20	170	-	100	-
In total: 427	4492	-	-	-

Source: *composed by authors*

During the experiment, certain numbers of plants from backcross progenies BC_4-BC_6 and self-pollination $I_2 - I_3 - I_4$ that showed particular resistance were identified. These numbers include 3626 (BC_4), 3638 (BC_4), 3641 (BC_5), 4910, 4959, 4960, 4965, 4969 (I_2), 3323 (I^3), 4656, 4963 (I^2), 4614, 3889, 4043, 3473, 3504, 3936 (I^4), 6727 (BC^4), 8061 (BC_6) and 8652 (I_4). Resistant moulds that reached 100% resistance level were transplanted into special growing vessels for further cultivation and seed production (Fig. 6).

***Figure 6**. Sunflower plants after transplanting for resistance to Broomrape*

Source: *composed by authors*

During the flowering of fertile plants from backcross progenies, pollen was transferred to their sterile counterparts to produce new progeny. As for all plants of the fourth generation of Incucht (I_4), forced self-pollination was carried out on them. For 2016-2017, 331 self-pollinated sunflower lines that were grown in breeding nurseries in the experimental field under natural conditions in 2016 were also evaluated (Table 3). The aim of this evaluation was to confirm the presence of the trait of absolute resistance to the plant-parasite Broomrape (*Orobanche cumana Wallr.),* in the progenies obtained from backcrossing (BC) and self-pollination (I). Nineteen accessions were selected that showed complete resistance to Broomrape. Among them were 2 accessions from progeny of BC_6 (8757, 8794) and 17 accessions from progeny obtained from self-pollination $I_3 - I_4 - I_5$. These samples were selected based on evaluations conducted during the autumn-spring period of 2015-2016: I_3 – 8141, 8142, I_4 – 8019, 8033, 8051, 8065, 8089, 8097, I_5 – 6259, 6747, 8379, 8434, 8533, 8545, 8606, 8641. Then transplanting of plants resistant (100%) to Broomrape was carried out in order to further work on crossing and obtaining progeny under artificial climate conditions.

Table 3. *Results of analyses of sunflower breeding numbers (2016-2017)*

Number of lines, pcs.	Plants tested, pcs.	% of susceptible plants	% of resistant plants	Infestation degree, %
Control	960	100	0	11.4
214	1926	69-82	58-92	13.3
65	520	52-61	42-52	8.5
33	297	31-42	27-31	11.5
19	161	-	100	-
In total: 331	3864	-	-	-

Source: *composed by authors*

Evaluation of 208 sunflower accessions that were selected from self-pollinated progenies during summer 2017 was also carried out in 2017-2018 (Table 4). These accessions were evaluated under artificial climatic conditions and also included new promising numbers from breeding nurseries. From the whole set, 8 resistant accessions were identified and will be used for further breeding work.

***Table 4.** Results of analyses of sunflower breeding numbers (2017-2018)*

Number of lines, pcs.	Plants tested, pcs.	% of susceptible plants	% of resistant plants	Infestation degree, %
Control	280	100	0	9.9
114	832	64-73	39-42	9.6
63	475	59-61	16-20	16.1
23	184	32-46	9-12	11.3
8	59	-	100	-
In total: 208	1830	-	-	-

***Source:** composed by authors*

The studied sunflower accessions, totalling 187 numbers, were selected from different sources including backcross progeny nurseries, pollen fertility restorer lines, and initial breeding material (Table 5). These accessions were subjected to evaluation for resistance to Broomrape, and 6 resistant forms were selected based on the results. These selection samples, belonging to generations BC_6 and I_6, represent new maternal and paternal forms that will be used in the development of experimental sunflower hybrids.

***Table 5.** Results of analyses of sunflower breeding numbers (2018-2019)*

Number of lines, pcs.	Plants tested, pcs.	% of susceptible plants	% of resistant plants	Infestation degree, %
Control	77	100	0	8.3
96	653	60-71	30-59	4.9
61	488	51-55		11.3
24	201	34-41		16.8
6	59	-	100	-
In total: 187	1401	-	-	-

***Source:** composed by authors*

During the autumn-winter-spring period of 2019-2020, 352 breeding numbers were evaluated (Table 6). This work resulted in the isolation of 14 accessions that showed resistance to Broomrape. These accessions were transplanted to carry out crosses for subsequent backcrossing and self-pollination. The use of vegetative vessels over several years has improved the evaluation of the breeding material under study under practical conditions. This method eliminated the possibility of mixing sunflower root shoots with nodules of Broomrape, which increased the accuracy of the evaluations. As a result, 14 accessions were isolated that proved to be resistant to Broomrape and will be used in further breeding work.

***Table 6.** Results of analyses of sunflower breeding numbers (2019-2020)*

Number of lines, pcs.	Plants tested, pcs.	% of susceptible plants	% of resistant plants	Infestation degree, %
Control	125	100	0	16.4
211	1582	53-67	29-32	18.3
78	656	40-42	17-22	16.8
49	460	11-26	9-11	11.7
14	119	-	100	-
In total: 352	2942	-	-	-

***Source:** composed by authors*

In 2020-2021, 443 breeding numbers including 68 hybrid combinations were evaluated in the artificial climate room (Table 7). As a result of this evaluation, both maternal and paternal forms with 100% resistance to Broomrape were isolated. Based on the evaluation results, the following hybrid combinations were included in the breeding process: (R-Spase × CB 65), (R-Spase × CB 31 Rf), (R-Spase × CB 268), (CB 8 × R-Berk), (CB 55 × R-Nica), (R-Spase-90 × R-Berk), and the lines R-Berk, R-Nica, SRS-82, SiR-99, CB-R, CB 8 and CB 55.

***Table 7.** Results of analyses of sunflower breeding numbers (2020-2021)*

Number of lines, pcs.	Plants tested, pcs.	% of susceptible plants	% of resistant plants	Infestation degree, %
Control	470	100	0	14.2
249	2116	73-81	32-68	8.9

Table 7, Continued

Number of lines, pcs.	Plants tested, pcs.	% of susceptible plants	% of resistant plants	Infestation degree, %
103	814	52-61	14-41	11.3
78	647	40-46	16-21	10.8
13	86	-	100	-
In total: 443	4133	-	-	-

Source: *composed by authors*

During the autumn-winter-spring months of 2021-2022, 350 breeding numbers were evaluated. This set included 29 accessions that were pre-tested for seed production under artificial climates, 62 sterility fixing lines, 114 pollen fertility restoring lines and 145 new progenies obtained from breeding nurseries (Table 8).

Table 8. *Results of analyses of sunflower breeding numbers (2021-2022)*

Number of lines, pcs.	Plants tested, pcs.	% of susceptible plants	% of resistant plants	Infestation degree, %
Control	360	100	0	11.3
91	719	68-71	32-50	8.7
58	464	52-63	29-42	10.3
33	264	21-29	17-19	11.8
168	1310	-	100	-
In total: 350	3117	-	-	-

Source: *composed by authors*

To accelerate the breeding process in the creation of maternal lines and their fertile analogues of male sterility fixing lines, the method of sowing immature seeds was applied to obtain two generations under artificial climatic conditions and the third generation under field conditions. This approach made it possible to create new homozygous lines that proved to be resistant to Broomrape within 2-3 years. A total of 33 breeding numbers were obtained. In the winter of 2022-2023, 284 progenies of self-pollinated lines were tested (Table 9).

Table 9*. Results of analyses of sunflower breeding numbers (2022-2023)*

Number of lines, pcs.	Plants tested, pcs.	% of susceptible plants	% of resistant plants	Infestation degree, %
Control	336	100	0	11.2
64	512	63-69	32-41	8.3
41	324	49-51	29-34	6.7
29	242	28-33	23-28	14.8
150	1170	-	100	-
In total: 284	2584	-	-	-

Source: *composed by authors*

The main focus of the experiment was the evaluation and multiplication of promising breeding material. 150 selection numbers were identified, and two generations were obtained, each including 42 accessions. These accessions carry pollen fertility restoration (Rf) genes and 2 maternal forms (CMS) in combination with sterility fixers. To further study the Rf lines of the sixth and seventh generation of the insecta (I6-I7) under natural field conditions, 137 sunflower accessions were sown in the infected stationary experimental plot in 2023 (Table 10).

Table 10*. Evaluation of sunflower breeding material for herbicide resistance under artificial climate conditions*

Years of experiments	Resistant to Express			Resistant to Eurolightning		
	Estimated	Selected	Prospective numbers	Estimated	Selected	Prospective numbers
2016-2017	112	24	(93 × R 15) (92 × R 10) (45 × R 10) (123 × 1410) (123 × R 15) (19 × 10) and other	64	5	689/1, 723/1, 725/3, 725/4, 765/5
2017-2018	319	40	609/2, 612/2, 633/2, 650/1, SP 215, SP 222, SP 228 and other	58	4	685/10, 582/9, 683/2, 580/10
2018-2019	354	25	38/11, 33/9, 29/3, 34/5, 38/2, 34/13 and other	272	22	183/2, 183/3, 184/6, 185/5, 185/8, 192/3 CB215, CB219 and other

Table 10, Continued

Years of experiments	Resistant to Express			Resistant to Eurolightning		
	Estimated	Selected	Prospective numbers	Estimated	Selected	Prospective numbers
2019-2020	234	12	SP 329, SP 287, SP 341, SP 368, 6423/3, 6428/1, 6472/4 and other	136	4	CBK 629, CBK 712, CBK 763, CBK 766
2020-2021	184	115	SS 252, SS 262, SS 340, SS 268L, SS 269L, SS 332, SiS 45/4, SiS 43 (258 × Am 4), SiS 46/2 and other	92	6	CB 211/1, CB 214/3, CBK 811, CBK 842, CBK 798, CBK 781
2021-2022	347	224	6239/1, 6239/5, 6301/3, 6307/5, 6401/1, 6415/3, SP 347, SP 362, SP 388, SP 403 SP1459 and other	72	19	CBK 618, CBK 672, CBK 729, CBK 741, CBK 747, 6902/3, 6907/1, 6913/5 and other
2022-2023	400	208	249/3, 250/1, 256/3, 273/5, 286/3, 347/2, [BKU 140 × (258 × Am 4)-2], BKU 140 × Am1 SiS 44, SiS 45, SiS 44-1 and other	108	49	BKU 140 x (10 × Patra), BKU 140 x (10 × Patra)/2 5427, 5432, 5466, K 5, (80 × K5), K8 (80 × K 8), CBK 729 B, CBK 731 B, CBK 739 B and other

Source: *composed by authors*

Thus, as a result of experiments aimed at evaluating breeding material for resistance to herbicides of the sulfonylurea and imidazoline groups under artificial climate conditions, maternal and paternal forms were isolated. These forms became the basis for the creation of herbicide-resistant sunflower hybrids, such as Baiterek S and Baikonur, as well as interlinear sunflower hybrids Agrobusiness 2050 and Batyr, resistant to Broomrape of races E, F, which were entered in the Register of Breeding Achievements of the Republic of Kazakhstan in 2023.

DISCUSSION

Sunflower is a strategically important oilseed crop, and the area under sunflower cultivation continues to expand every year. However, this also provokes the emergence of new and more aggressive races of *Orobanche cumana Wallr.*, which is a parasite that is detrimental to the normal growth and development of sunflowers and can cause significant yield losses. The creation of sunflower hybrids (F1) involves crossing parental components that share several important characteristics, including herbicide and Broomrape resistance. Given that the creation of each of these components requires long and careful work in the breeding process, modern techniques and approaches are being used to accelerate the creation of new breeding material.

In vitro culture technology reduces the time required to develop herbicide resistant lines, for example. Pathogen resistance breeding usually involves testing on artificial infection media, both in the field and in the laboratory, to identify and isolate material with the desired resistant characteristics. This allows for more efficient selection and development of sunflower varieties and hybrids that will be resistant to both diseases and pests, as well as chemical defences (Kocira *et al.,* 2020). Thus, modern sunflower breeding aims to develop high-yielding varieties and hybrids that have not only high yields but also improved seed characteristics such as oil content, 1000-seed weight, huskiness. In addition, resistance to diseases and pests as well as adaptation to various abiotic factors are important criteria (Anastasi *et al.,* 2002).

In this regard, in order to establish the main components for hybrid combinations of sunflower D. Škorić *et al.* (2021) and E.O. Domaratskiy *et al.* (2018) paid attention not only to the quality of the source material, but also to its resistance to major diseases and pests. One of the main parasitic plants affecting sunflower is Broomrape (*Orobanche cumana Wallr.),* which is an obligate parasite and affects the root system of the host plant. Studies by scientists such as W. Adugna and M.T. Labushange (2002) and also D. Sisou *et al.* (2021) highlight the constant dynamics in the formation of new physiological races of the Broomrape, which represents a constant threat to sunflower. This evolution of the parasite emphasizes the need for continuous monitoring of Broomrape populations and ongoing research in this area, which also confirms the study carried out. At the same time, I. Sperdouli *et al.* (2022) notes that the specificity of resistance control to new, highly virulent races of Broomrape is determined by genetic factors. Genetic methods are becoming the best tools for Broomrape control. These methods allow identification and labelling of genes responsible for resistance, which contributes to more efficient breeding and development of varieties and hybrids resistant to the parasite, which is also confirmed by the study conducted.

A number of scientists, such as O. Kovalenko *et al.* (2021) and Z. Flagella *et al.* (2002) have identified and studied several key genes that are responsible for sunflower resistance to Broomrape. These genes were successfully labelled, representing a significant scientific breakthrough. This important step in breeding allows for more accurate detection of the presence of resistance in sunflower varieties and hybrids. Such markers allow breeders to more effectively select and develop varieties that are resistant to Broomrape. Thanks to the developed gene labelling methods, breeding for resistance to Broomrape has become more accurate and accelerated. This opens up new perspectives for improving existing breeding methods and creating new, more progressive approaches to the development of sunflower varieties that are highly resistant to this pest.

An equally significant aspect is the study of the relationship between resistance to new virulent races of the Broomrape and the valuable economic characteristics of F1 hybrids, allowing the development of hybrids that combine two important aspects: resistance to the parasite and high yield. Understanding which hybrids have not only resistance to the Broomrape, but also the ability to achieve high yields, is key to developing efficient sunflower varieties. These hybrids not only help to reduce yield losses caused by Broomrape, but also increase overall productivity, which is an important factor for the agricultural industry and food security. Research in this area helps in identifying the optimum combinations of genetic traits to develop resistant and high yielding sunflower varieties and hybrids (Casali *et al.,* 2022).

In addition, the study conducted by P. Deepika and D.M. Ali (2020) revealed that the application of biological defence methods such as the use of bacterial inoculants has the potential to reduce sunflower infestation by Broomrape and increase yield. This study emphasizes the importance of developing and implementing biological pest and pathogen control methods in agriculture. Bacterial inoculants can help improve plant health and reduce infection levels, which in turn can lead to higher sunflower yields and provide more sustainable agricultural outcomes. These results also emphasize the importance of integrating biological defence methods into agricultural practices to improve crop sustainability and productivity.

V. Giannini *et al.* (2022) state that with climate change, including increasing temperatures, it is clear that the intensity of sunflower infestation by Broomrape may increase. This encourages breeders to develop varieties that are not only resistant to the parasite, but also adapted to abiotic stresses caused by climatic changes. J. Louarn *et al.* (2016) note that the use of artificial climatic conditions allows for faster breeding cycles. This means that breeders can more quickly select and develop varieties that exhibit desired resistance and other characteristics. This process also allows evaluation of which herbicides are effective in controlling the Broomrape and which sunflower varieties are most responsive to certain chemical defences. This is important for the development of recommendations on the use of herbicides in agriculture, which is also reflected in the study.

The results of the study are echoed in the scientific works of S. Cvejić *et al.* (2020), who state that the development of varieties with herbicide resistance allows agricultural producers to manage weeds more effectively and reduce weed control costs. In addition, sunflower varieties that are resistant to Broomrape and herbicides can provide higher quality seeds and oil, which is important for the food and oil and fats industry. Similar results were also obtained in a study by T.A. Howell *et al.* (2015), in which the authors state that evaluation of sunflower breeding material for resistance to Broomrape and herbicides has high practical importance for agriculture. The results of the study confirm the importance of breeding in creating sunflower varieties that can effectively cope with these damage factors and provide a stable level of yield.

Thus, the results of this study confirm the importance of evaluating sunflower breeding material for resistance to Broomrape and herbicides under artificial climate conditions. This study has significant implications for agriculture and breeding as it contributes to the development of new sunflower hybrids that have high yields, resistance to diseases and pests, and can reduce weed control costs. This is an important contribution to food security and sustainable agricultural development.

CONCLUSIONS

Sunflower breeding is an important tool for the modern agricultural sector. It enables the development of varieties that meet the diverse needs of the agricultural industry, providing higher yields, resistance to diseases and pests, adaptation to changing climatic conditions and improved product quality. From 2015 to 2023, Oilseeds Experimental Farm LLP carried out successful work to develop resistant sunflower lines with resistance to the parasitic plant *Orobanche cumana Wallr*. and herbicides of the sulfonylurea and imidazoline groups. These lines represent valuable breeding material and have potential for further use in sunflower breeding. The created lines were integrated into the breeding process in order to develop high-yielding interlinear sunflower hybrids. This allowed the development of new hybrids such as Agrobiznes 2050 and Batyr, which are resistant to Broomrape races E and F, as well as herbicide-resistant sunflower hybrids such as Baiterek S and Baikonur. It is important to emphasize that these outstanding hybrids have been included in the State Register of Breeding Achievements and recommended for use in agriculture in the Republic of Kazakhstan. This is an important step in ensuring the sustainability and increasing the productivity of sunflower.

The results of the experiment show that the study of resistance of sunflower varieties to Broomrape and herbicides is an effective way to control pests and weeds. It can help to increase yields and reduce yield losses. The results of the experiment not only contribute to the development of agriculture, but also have the potential for export and exchange of agricultural resources with other countries, which contributes to the development of the agricultural sector and strengthening the position of the Republic of Kazakhstan in the world agri-food market. The practical significance of the study is the possibility of identifying genotypes and varieties of sunflower, which have increased resistance to harmful factors such as Broomrape and herbicides, which contributes to increased yields, and is of great importance for agricultural enterprises and food security. Molecular studies, identification of specific genes and genetic markers responsible for these traits may be a prospect for further research in sunflower breeding for resistance to Broomrape and herbicides, allowing more accurate and rapid selection.

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CONFLICT OF INTEREST

None.

REFERENCES

[1] Adugna, W., & Labuschagne, M.T. (2002). Genotype-environment interactions and phenotypic stability analyses of linseed in Ethiopia. *Plant Breeding*, 121(1), 66-71. doi: 10.1046/j.1439-0523.2002.00670.x.
[2] Anastasi, U., Cammarata, M., & Abbate, V. (2002). Yield potential and oil quality of sunflower (oleic and standard) grown between autumn and summer. *Italian Journal of Agronomy*, 4(1), 23-36.
[3] Babkenov, A., Babkenova, S., Abdullayev, K., & Kairzhanov, Y. (2020). Breeding spring soft wheat for productivity, grain quality, and resistance to adverse external factors in Northern Kazakhstan. *Journal of Ecological Engineering,* 21(6), 8-12. doi: 10.12911/22998993/123160.
[4] Casali, B., Brenna, E., Parmeggiani, F., Tentori, F., & Tessaro, D. (2022). Multi-step chemo-enzymatic synthesis of azelaic and pelargonic acids from the soapstock of high-oleic sunflower oil refinement. *Green Chemistry*, 24, 2082-2093. doi: 10.1039/D1GC03553C.
[5] Convention on Biological Diversity. (1992, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_030#Text.
[6] Convention on International Trade in Endangered Species of Wild Fauna and Flora. (1979, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_129#Text.
[7] Cvejić, S., Radanović, A., Dedić, B., Jocković, M., Jocić, S., & Miladinović, D. (2020). Genetic and genomic tools in sunflower breeding for broomrape resistance. *Genes (Basel)*, 11(2), article number 152. doi: 10.3390/genes11020152.
[8] Deepika, P., & Ali, D.M. (2020). Production and assessment of microalgal liquid fertilizer for the enhanced growth of four crop plants. *Biocatalysis and Agricultural Biotechnology*, 28, article number 101701. doi: 10.1016/j.bcab.2020.101701.
[9] Domaratskiy, E.O., Zhuykov, O.G., & Ivaniv, M.O. (2018). Influence of sowing periods and seeding rates on yield of grain sorghum hybrids under regional climatic transformations. *Indian Journal of Ecology*, 45(4), 785-789.
[10] Flagella, Z., Rotunno, T., Tarantino, E., Caterina, R.D., & de Caro, A. (2002). Changes in seed yield and oil fatty acid composition of high oleic sunflower (*Helianthus annuus* L.) hybrids in relation to the sowing date and the water regime. *European Journal of Agronomy*, 17(3), 221-230. doi: 10.1016/S1161-0301(02)00012-6.
[11] Giannini, V., Mula, L., Carta, M., Patteri, G., & Roggero, P.P. (2022). Interplay of irrigation strategies and sowing dates on sunflower yield in semi-arid Mediterranean areas. *Agricultural Water Management*, 260, article number 107287. doi: 10.1016/j.agwat.2021.107287.
[12] Howell, T.A., Evett, S.R., Tolk, J.A., Copeland, K.S., & Marek, T.H. (2015). Evapotranspiration, water productivity and crop coefficients for irrigated sunflower in the U.S. Southern High Plains. *Agricultural Water Management*, 162, 33-46. doi: 10.1016/j.agwat.2015.08.008.
[13] Kocira, S., Hara, P., Szparaga, A., Czerwińska, E., Beloev, H., Findura, P., & Bajus, P. (2020). Evaluation of the effectiveness of the use of biopreparations as seed dressings. *Agriculture*, 10(4), article number 90. doi: 10.3390/agriculture10040090.
[14] Kovalenko, O., Gamajunova, V., Neroda, R., Smirnova, I., & Khonenko, L. (2021). Advances in nutrition of sunflower on the southern steppe of Ukraine. In *Soils Under Stress* (pp. 215-223). Cham: Springer. doi: 10.1007/978-3-030-68394-8_21.
[15] Kurylych, D.V., & Makliak, K.M. (2022). Peculiarities of the sunflower breeding for resistance to broomrape (*Orobanche cumana wallr.*). *Breeding and Seed Production*, 122, 19-39. doi: 10.30835/2413-7510.2022.271748.
[16] Liu, S., Wang, P., Liu, Y., & Wang, P. (2020). Identification of candidate gene for resistance to broomrape (*Orobanche cumana*) in sunflower by BSA-seq. *Oil Crop Science*, 5(2), 47-51. doi: 10.1016/j.ocsci.2020.05.003.
[17] Louarn, J., Boniface, M-C., Pouilly, N., Velasco, L., Pérez-Vich, B., Vincourt, P., & Muños, S. (2016). Sunflower resistance to broomrape (*Orobanche cumana*) is controlled by specific QTLs for different parasitism stages. *Frontiers in Plant Science*, 7, article number 590. doi: 10.3389/fpls.2016.00590.

[18] Pinar, H., Yahya, H.N., Erċışlı, S., Coskun, O.F., Yaman, M., Turgunbaev, K., & Uzun, A. (2021). Molecular characterization of barberry genotypes from Turkey and Kyrgyzstan. *ERWERBS-OBSTBAU*, 63(4), 403-407. doi: 10.1007/s10341-021-00599-x.
[19] Ryzhenko, A.S., Kalenska, S.M., Prysiazhniuk, O.I., & Mokriienko, V.A. (2020). Yield plasticity of sunflower hybrids in the conditions of the Left-Bank Forest-Steppe of Ukraine. *Plant Varieties Studying and Protection*, 16(4), 402-406. doi: 10.21498/2518-1017.16.4.2020.224058.
[20] Sisou, D., Tadmor, Y., Plakhine, D., Ziadna, H., Hübner, S., & Eizenberg, H. (2021). Biological and transcriptomic characterization of pre-haustorial resistance to sunflower broomrape (*Orobanche cumana* W.) in sunflowers (*Helianthus annuus*). *Plants*, 10(9), article number 1810. doi: 10.3390/plants10091810.
[21] Škorić, D., Joiţa-Păcureanu, M., Gorbachenko, F., Gorbachenko, O., & Maširević, S. (2021). Dynamics of change in broomrape populations (*Orobanche cumana* Wallr.) in Romania and russia (Black Sea area). *Helia*, 44(74). doi: 10.1515/helia-2020-0025.
[22] Sperdouli, I., Adamakis, I.S., Dobrikova, A., Apostolova, E., Hanć, A., & Moustakas, M. (2022). Excess zinc supply reduces cadmium uptake and mitigates cadmium toxicity effects on chloroplast structure, oxidative stress, and photosystem ii photochemical efficiency in *salvia sclarea* plants. *Toxics*, 10(1), article number 36. doi: 10.3390/toxics10010036.
[23] Tajibayev, D., Mukin, K., Babkenov, A., Chudinov, V., Dababat, A.A., Jiyenbayeva, K., Kenenbayev, S., Savin, T., Shamanin, V., Tagayev, K., Rsymbetov, A., Yessimbekova, M., Yusov, V., Zhylkybaev, R., Morgounov, A., Altaf, M.T., Nadeem, M.A., & Baloch, F.S. (2023). Exploring the agronomic performance and molecular characterization of diverse spring durum wheat germplasm in Kazakhstan. *Agronomy*, 13(7), article number 1955. doi: 10.3390/agronomy13071955.
[24] Trotsenko, V., Kabanets, V., Yatsenko, V., & Kolosok I. (2020). Models of sunflower productivity formation and their efficiency in the conditions of the north-eastern Forest-Steppe of Ukraine. *Bulletin of Sumy National Agrarian University. The Series: Agronomy and Biology*, 40(2), 72-78. doi: 10.32782/agrobio.2020.2.9.
[25] Zatybekov, A., Anuarbek, S., Abugalieva, S., & Turuspekov, Y. (2020). Phenotypic and genetic variability of a tetraploid wheat collection grown in Kazakhstan. *Vavilovskii Zhurnal Genet Selektsii*, 24(6), 605-612. doi: 10.18699/VJ20.654.

Оцінка селекційного матеріалу соняшнику на стійкість до вовчка (*Orobanche cumana Wallr.*) та гербіцидів в умовах штучного клімату задля прискорення селекційного процесу

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Анотація. Соняшник є важливою олійною культурою, тому збільшення його врожайності та стійкості до хвороб і шкідників може призвести до значного економічного покращення для сільськогосподарських підприємств і країни в цілому. Зміни клімату та поширення нових рас вовчка (*Orobanche cumana Wallr.*) створюють серйозні загрози для виробництва соняшнику, а дослідження в цій галузі допомагають розробити сорти, здатні адаптуватися до мінливих умов. Мета дослідження – комплексна оцінка селекційного матеріалу для виявлення найбільш стійких форм і гібридів соняшнику. Для досягнення мети проведено експеримент у період 2015-2023 років у ТОВ «Дослідне господарство олійних культур», у якому вивчали оцінку селекційного матеріалу соняшнику на стійкість до вовчка та гербіцидів. У результаті експерименту успішно створено лінії соняшнику, які мають стійкість до вовчка та гербіцидів, що сприяє підвищенню продуктивності та зниженню втрат урожаю. Створені лінії соняшнику були впроваджені в селекційний процес з метою розробки високопродуктивних міжлінійних гібридів соняшнику, що стало важливим етапом у поліпшенні сільського господарства Казахстану. Ці інноваційні гібриди, такі як «Agribusiness 2050» і «Batyr», проявили високу стійкість до вовчка рас E-F, що істотно знижує втрати врожаю і забезпечує надійну продукцію. Крім того, розроблено гербіцидостійкі гібриди, як-от Baiterek S і Baikonur, які дають змогу ефективно боротися з бур'янами та зберігати чистоту посівів, що важливо для збільшення врожайності та зниження витрат на обробіток ґрунту. Ці гібриди були рекомендовані для використання в сільському господарстві Казахстану і можуть сприяти підвищенню рівня продуктивності соняшнику. Дане дослідження сприяє розширенню наукових знань у галузі селекції та боротьби зі шкідниками соняшнику, що є актуальним напрямком для поліпшення сільськогосподарської практики та забезпечення продовольчої безпеки

Ключові слова: сорт; сільське господарство; експериментальні умови; генетичні маркери