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EVALUATION OF SUNFLOWER HYBRIDS FOR YIELD VARIABILITY AT VERY HIGH AIR TEMPERATURES

[1]Makliak K.M., [1]Kyrychenko V.V., [2]Varenyk B.F., [3]Kutishcheva N.M., [4]Trotsenko V.I.
[1] – Plant Production Institute named after V.Ya. Yuriev of NAAS, Ukraine;
[2] – Plant Breeding and Genetic Institute - National Center of Seed and Cultivar Investigation, Ukraine;
[3] – Institute of Oil Crops of NAAS, Ukraine;
[4] – Institute of Agriculture of the North-East of NAAS, Ukraine

The results of evaluation of hybrids sunflower for yield variability at very high air temperatures in the moderately arid agroclimatic zone of Ukraine are presented. In 2007–2008 and 2014–2015, 99 simple and three-line hybrid combinations based on lines-parents bred in the Plant Production Institute named after V.Ya. Yuriev of NAAS, Institute of Oil Crops of NAAS and Plant Breeding and Genetic Institute - National Center of Seed and Cultivar Investigation were tested. The "heat resistance index" of the genotype was proposed; the best hybrid combinations, which maintain high performance at very high air temperatures, were selected.

Key words: *sunflower, trials, adaptability, general, specific, index, heat resistance*

Introduction. Major factors limiting the sunflower production in the moderately arid agro-climatic zone of Ukraine include very high (above 30°C) air temperatures called as "heat" [1]. The number of days in July-August, when the temperature is very high, in the southern and eastern regions is 20–40% of the total number of days per month [2]. Such extended action of very high temperatures (thermal stress) significantly reduces yields in comparison with the full genetic potential of the genotype [3]. Solving methodological issues of assessment of yield variability in the conditions of heat is of particular importance.

Analysis of literature, problem statement. Researchers from different countries reported about the significant influence of temperature regime during the growing season on the economic characteristics of sunflower (yield, oil content in seeds, oil output) and the genetically determined characteristics of the response of breeding material to air temperature [4, 5, 6]. Susceptible sunflower genotypes lose up to one third of their yields, when the maximum air temperature rises by 2°C above the optimum [7]. The main purpose of sunflower breeding for resistance to very high temperatures is to minimize yield losses, and high yields under such conditions are an indisputable criterion for selecting genotypes [8].

The development of techniques for distinguishing the effect of air temperature on yields in the field from the influence of other environmental factors involves creation of a maximum contrast stress load on the genotype, which can be provided by variety trials under various climatic conditions (environmental variety trials). Evaluation of sunflower genotypes in variety trials in different agro-soil zones of Ukraine allowed establishing the performance potential of hybrid combinations, levels of their general and specific adaptability, parameters of test environments as background for yield assessment [9, 10, 11].

HI Oka defined the general adaptive capacity of an agricultural crop as the ability to give a stable yield under various growing conditions and the specific adaptive capacity – as the ability to respond and to be stable under specific conditions (cold, heat, drought, disease, pests) [12]. In the latter case, specific factors of the environment that determine the crop yield variability and the peculiarities of their influence (ontogenetic phase, manifestation level of a factor ensuring the maximum differentiation of a population) must be known. For example, the sunflower yield is greatly affected by very high temperatures in July, during the sunflower anthesis and onset of seed filling. Temperatures above 31°C during anthesis reduce the pollen production and flower fertility, leading to pollen sterilization, "burnout" of stigmas and reduction in the amount of seeds, sometimes to zero [13, 14]. Temperatures above 27°C during the filling period (August) significantly reduces the ultimate weight of achenes [15]. Evaluation of genotypes on a provocative background, where the factor limiting yields in the region (in particular, very high temperatures) acts, will allow detecting resistant accessions [16].

Here, the methodical issue of choosing a statistical parameter for selection of accessions that can maintain stable yields under certain environmental conditions or reduce them less than other genotypes arises.

Purpose and objective. The purpose of the study was to develop methodological approaches to quantification of the yield variability of sunflower hybrids at very high air temperatures (heat).

Materials and methods. The field experiments were carried out in the scientific crop rotation fields of the Plant Production Institute named after V.Ya. Yuriev of NAAS (hereinafter referred to as PPI nd. a V.Ya. Yuriev), Kharkiv, Institute of Oil Crops of NAAS (hereinafter referred to as IOC), Zaporizhzhia and in the fields of the experimental base "Dacha" of the Plant Breeding and Genetic Institute - National Center of Seed and Cultivar Investigation (hereinafter referred to as PBGI-NCSCI), Odessa, in 2007-2008 and 2014-2015; in the scientific crop rotation fields of Luhansk Institute of Agricultural Production of UAAS (hereinafter referred to as LIAP), Luhansk, in 2014-2015; in the scientific crop rotation fields of the Institute of Agriculture of the North East of NAAS (hereinafter referred to as IANE), Sumy, in 2007–2008.

In the text, the following symbols are used: Khi - trials of genotypes were conducted in the PPI nd. a V.Ya. Yuriev in the i^{th} year; Zi – trials of genotypes were conducted in the IOC in the i^{th} year; Oi - trials of genotypes were conducted in the PBGI-NCSCI in the i^{th} year; Li – trials of genotypes were conducted in LIAP in the i^{th} year; Si - trials of genotypes were conducted in the IANE in the i^{th} year.

According to agroclimatic zoning, the lands used by the research institutions are located in the moderately arid zone and the insufficiently humidified zone [17]. The PPI’s land is located in the moderately arid agro-climatic zone; the agro-soil zone is the forest-steppe of the Left-Bank high southeast agro-soil province with typical black earths. The IOC's lands are located in the moderately arid zone; the agro-soil subzone is the northern steppe of the northern steppe Right-Bank agro-soil province with typical black earths. The lands of the experimental base "Dachna" of the PBGI-NCSCI are located in the moderately arid zone; the agro-soil subzone is the southern steppe of the southern-steppe Right-Bank agro-soil province with southern black earths. The LIAP’s lands are is located in the moderately arid zone; the agro-soil subzone is the northern steppe of Donetsk agro-soil province with common black earths. The IANE’s lands are located in the insufficiently humidified agro-climatic zone; the agro-soil zone is the forest-steppe of the north-eastern high agro-soil province with typical black earths.

The sum of active temperatures (above +10°C) varies from 3200–3400°C (PBGI-NCSCI) to 2400°C (IANE). The average annual precipitation varies from 350–390 mm (PBGI-NCSCI) to 590 mm (IANE).

The weather conditions during the sunflower growing season (May–August) significantly differed over the study years and sites.

In Kharkiv (data of the weather station "Airport", 49°55'N, 36°17'E), the average daily temperature in May–August was 21.1°C in 2007, 19.1°C in 2008, 20.5°C in 2014, and 20.1°C in 2015 (the norm of 1981–2010 = 19.1°C). The amount of precipitation during this period was 251.7 mm in 2007, 201.0 mm in 2008, 217.7 mm in 2014, and 253.7 mm in 2015 (the norm = 215.0 mm).

In Zaporizhzhia (data of the IOC weather station, 47°51'N, 35°9'E), the average daily temperature in May–August was 25.3°C in 2007, 23.2°C in 2008, 24.0°C in 2014, and 24.4°C in 2015 (the norm of 1961–1990 = 20.4°C). The precipitation amount was 105 mm in 2007, 149.8 mm in 2008, 156.5 mm in 2014, and 264.0 mm in 2015 (the norm = 184.0 mm).

In Odessa (data of the Hydrometeorological Center of the Black and Azov Seas, 46°26'N, 30°46'E), the average daily air temperature in May–August was 22.6°C in 2007, 20.7°C in 2008, 21.5°C in 2014, and 21.3°C in 2015 (the norm of 1961–1990 = 19.3°C). The precipitation amount was 93.8 mm in 2007, 161.5 mm in 2008, 166.4 mm in 2014, and 141.2 mm in 2015 (the norm = 164 mm).

In Luhansk (data of Luhansk Regional Hydrometeorological Center, 48°33'N, 39°19'E), the average daily air temperature in May–August was 22.3°C in 2007 and 20.0°C in 2008 (the norm of 1961–1990 = 20.0°C). The precipitation amount was 56.6 mm in 2007 and 163.8 mm in 2008 (the norm = 201 mm).

In Sumy (data of the IANE meteorological station, 50°88'N, 34°71'E), the average daily air temperature in May–August was 21.1°C in 2014 and 20.3°C in 2015 (the norm of 1961–1990 = 18.5°C). The precipitation amount was 245.8 mm in 2014 and 278.1 mm in 2015 (the norm = 254.0 mm).

Thus, the soil and weather-climatic conditions in the study years and sites significantly differed and allowed full covering the range of agroclimatic conditions of the potential dissemination acreage of sunflower hybrids.

The data on the average maximum temperature (t_{max}) in July and the first 10 days of August were used to determine differences between the temperature regimens of the study years and sites and to select the environment with the maximum stress load.

In environment Z_{07}, the t_{max} in July (34.3°C) was significantly (by 4.8°C) higher than the average t_{max} (29.5°C) (Table 1). The average yield of hybrids in Z_{07} was 2.51 t/ha and did not differ significantly from the average yield across the variants (2.49 t/ha).

Table 1

Average maximum temperature (t_{max}) in July and the yield of F_1 sunflower hybrids, 2007-2008

Parameter	Kh_{07}	Kh_{08}	$\mathbf{Z_{07}}$	Z_{08}	L_{07}	L_{08}	O_{07}	O_{08}	Average
t_{max} in July, °C	27.3	27.2	**34.3***	28.8	31.2	30.1	29.7	27.0	29.5
Yield, t/ha	3.81*	3.56*	**2.51**	2.20	2.02*	1.78*	1.37*	2.67*	2.49

Footnote 1. * – significantly different from the total average across the variants
Footnote 2. LSD_{05} of pair comparison between the yields: 0.40 t/ha

In environment Z_{14}, the t_{max} in August (34.6°C) significantly (by 3.4°C) exceeded the average t_{max} across the variants (31.2°C) (Table 2). The average yield of hybrids in Z_{14} amounted to 1.96 t/ha and was significantly lower (by 0.83 t/ha) than the average yield across the variants (2.79 t/ha).

Table 2

Average maximum temperature (t_{max}) for the first 10 days of August and the yield of F_1 sunflower hybrids, 2014–2015

Parameter	Kh_{14}	Kh_{15}	$\mathbf{Z_{14}}$	Z_{15}	O_{14}	O_{15}	S_{14}	S_{15}	Average
t_{max} for the first 10 days of August, °C	31,7	28,7	**34,6***	32,0	32,2	30,7	31,1	28,4	31,2
Yield, t/ha	3,76*	3,31*	**1,96***	3,22*	1,42*	3,11*	2,36	3,19*	2,79

Footnote 1. * – significantly different from the total average across the variants.
Footnote 2. LSD_{05} of pair comparison between the yields: 0.25 t/ha.

In 2007–2008, 65 simple hybrid combinations were tested; in 2014–2015, 34 three-line hybrid combinations were tested in plots with an area of 10.15 m^2 in three replications. The crop care is commonly used for the growing zone. Hybrid combinations were derived from crossing self-pollinated sunflower lines bred in the 3 institutions: sterile lines and lines – sterility fixers were bred in the PPI, PBGI-NCSCI and IOC; lines - pollen fertility restorers were bred in the PPI. In total, 12 sterile lines (indicated as Skh ... A (bred in the PPI) and as Od ... A (bred in the PBGI-NCSCI)), 12 lines – sterility – fixers (indicated as ZL ... B (bred in the IOC) and Od ... B (bred in the PBGI-NCSCI) and 7 lines - pollen fertility restorers (indicated as Kh ... V (bred in the PPI) were used in crossings.

The field investigation were planned and organized, and data were statistically analyzed in accordance with the field experimentation methodology [18, 19]. A licensed data analysis and statistics add-in for MS Excel and "Statistica 6.0" licensed software were used. The response of hybrids to the growing conditions was determined by A.V. Kilchevskiy and L.V. Khotylyova's method [16]. According to this method, the response of a hybrid to cultivation conditions is characterized by its general adaptability (V_i) and the specific adaptability (SA) effects (deviation from the general adaptability in a given environment). The integral index of the genotype breeding value (GBV_i) was compared with the mean GBV in the sample under investigation.

Results and discussion. In 2007–2008, tests of 69 hybrid combinations in four sites (Kharkiv, Zaporizhzhia, Odesa, Luhansk) allowed estimating the general adaptability V_i and eight values of SA_{ik} for each of the studied combinations. According to the data presented in Table 3, the high general adaptability of a hybrid combination does not affect the effects of specific adaptability. Thus, in environment Z_{08} hybrid combinations with high V_i had both weak (PerN A/Kh 785 V, SA_{ik} = -0.48*) and strong (Od 4301 A / Kh 785 V, SA_{ik} = 0.45*) SA effects. The SA_{ik} of hybrid combination Od 391 A/Kh 720 V with the maximum V_i (0.38*) varied from -1.33 * in environment O_{07} to 1.28* in environment Kh_{07}.

Table 3

SA_{ik} of the hybrid combinations that were the best in terms of V_i, in the 8 testing environments, 2007–2008.

Hybrid combination			*SA_{ik}*							
Female component	Male component	V_i	Kh_{07}	Kh_{08}	Z_{07}	Z_{08}	L_{07}	L_{08}	O_{07}	O_{08}
Od 4301 A	Kh 785 V	0.34*	1.60*	0.76*	0.17	0.45*	–0.42*	–1.01*	–1.61*	0.06
Od 973 A	Kh 720 V	0.35*	1.88*	0.89*	0.14	–0.23	–0.35*	–1.05*	–1.13*	–0.14
Od 4301 A	Kh 720 V	0.37*	1.75*	0.92*	0.12	0.11	–0.45*	–1.13*	–1.43*	0.11
PerN A	Kh 785 V	0.37*	1.27*	0.81*	0.47*	–0.48*	–0.59*	–0.72*	–1.23*	0.47*
Od 391 A	Kh 720 V	0.38*	1.28*	0.79*	0.41*	–0.11	–0.62*	–0.92*	–1.33*	0.51*

Footnote: * – significant effects with significance level of 5%

The SA_{ik} effects estimated for environment Z_{07}, in which the t_{max} in July significantly exceeded the average t_{max} across the variants (see Table 1), is proposed as the heat resistance index of the k^{th} genotype (I_h). In environment Z_{07}, 10 hybrid combinations (15% of the studied ones) with significantly stronger SA_{ik} effects (I_h), which varied from 0.30* to 0.61*, were selected (Table 4). The yields of these hybrid combinations ranged within 2.50 - 3.33* t/ha (the average yield = 2.49 t/ha in the experiment; the average yield = 2.51 t/ha across the environments), and, according to the general adaptability Vi, they belonged to the genotype group with a low (the average group value Vi = -0.30), or medium (the average group value Vi = 0.01) or a high (the average group value Vi = 0.29) general adaptability. Five hybrid combinations combined a high general adaptability with a high heat resistance index (from 0.32* to 0.50*). Hybrid combinations PerN A/Kh 785 V (3.33* t/ha) and Od 391 A/Kh 720 V (3.27* t/ha) gave the highest yields. As to GBV_i, hybrid combinations PerN A/Kh 720 V, Od 391 A/Kh 720 V, PerN A/Kh 785 V were the best in terms of yield and its stability (as compared to the average GBV of 1.25 in the experiment). However, among the genotypes selected by I_h, there were those that were inferior to other hybrids (ZL 52 A/Kh 843 V, GBV_i = 0.75) according to their breeding value.

Thus, hybrid combinations with a high heat resistance index at very high temperatures in July had low to high general adaptability, and 5 combinations (7.2% of the studied ones) combined a high general adaptability with a high heat resistance index.

Table 4

Adaptability of the yields of F_1 sunflower hybrids that were the best in terms of SA_{ik} in environment Z_{07}

Hybrid combination		SA_{ik} (I_h)	Yield, t/ha, Z_{07}	V_i	GBV_i
Female component	Male component				
ZL 42 A	Kh 785 V	0.30*	2.64	–0.15*	1,15
ZL 48 A	Kh 843 V	0.31*	2.50	–0.30*	0,97
PerN A	Kh 720 V	0.32*	3.03*	0.22*	1,32
ZL 42 A	Kh 720 V	0.36*	3.04*	0.19*	1,21
Od 391 A	Kh 720 V	0.41*	3.27*	0.38*	1,62
PerN A	Kh 843 V	0.45*	2.75	–0.19*	0,99
PerN A	Kh 785 V	0.47*	3.33*	0.37*	1,65
Od 395 A	Kh 720 V	0.50*	3.17*	0.13*	1,02
ZL 52 A	Kh 843 V	0.52*	2.82	–0.34*	0,75
Odol 1 A	Kh 843 V	0.61*	3.01*	–0.10	1,06
LSD_{05} for pair comparison		0.38	0.40	0.14	–

Footnote: * – significant differences with significance level of 5%

In 2014–2015, tests of 34 three-line hybrid combinations in four sites (Kharkiv, Zaporizhzhia, Odesa, Sumy) allowed estimating the general adaptability Vi and eight values of SA_{ik} for each combination under investigation. We propose the SA_{ik} computed for environment Z_{14}, in which the t_{max} of the first 10 days of August significantly exceeded the average t_{max} across the variants (see Table 2), as the heat resistance index of the k^{th} genotype (I_h). The best 10 genotypes were distinguished after ranking the hybrids by I_h (Table 5).

Table 5

Adaptability of the yields of three-line sunflower hybrids, that were the best in terms of SA_{ik} in environment Z_{14}

Hybrid combination		SA_{ik} (I_h)	Yield, t/ha, Z_{14}	V_i	GBV_i
Female component	Male component				
Skh 1002 A / Od 1050 B	Kh 06134 V	–0.68	2.12*	0.02	1,41
Od 1048 A / ZL 52 B		–0.68	2.05*	–0.07	1,59
Od 1050 A / ZL 40 B		–0.67	2.00*	–0.43*	1,53
Skh 51 A / Od 391 B		–0.65	2.24*	0.31*	1,57
Skh 1006 A / Od 973 B		–0.64	2.33*	–0.21*	1,71
Skh 51 A / ZL 50 B		–0.64	2.20*	0.41*	1,34
Skh 1002 A / ZL 50 B		–0.63	2.35*	–0.21*	1,75
Mkh 524 A / ZL 50 B		–0.62	2.01*	0.14	1,32
Od 529 A / ZL 42 B		–0.60	2.19*	–0.04	1,49
Od 973 A / ZL 10 B		–0.46	2.07*	0.03	1,37
LSD_{05} for pair comparison		0,34	0.17	0.12	–

Footnote: * – significant differences with significance level of 5%

The I_h of these combinations varied from -0.46 to -0.68, with the average of -0.83 in the environment. In terms of the general adaptability Vi, these hybrid combinations belonged to a group of genotypes with a low (the average group value Vi = -0.22), or medium (the average group value Vi = 0.00), or a high (the average group Vi = 0.21) general adaptability. Two hybrid combinations (5.9% of the investigated ones) coupled a high general adaptability with a high heat resistance index: Skh 51 A / Od 391 B // Kh 06134 V and Skh 51 A / ZL 50 B // Kh 06134 V. Their yields varied from 2.00* to 2.35* t/ha (the average = 2.79 t/ha in the experiment; the average = 1.96 t/ha in the environment); therefore, it was significantly lower compared to the average in the experiment, but exceeded the average in the environment. The highest yields were obtained from hybrid combinations Skh 1002 A / ZL 50 B // Kh 06134 V (2.35* t/ha) and Skh 1006 A / Od 973 B // Kh 06135 V (2.3* t/ha). The same hybrid combinations were the best in terms of yield and its stability (according to their GBV_i compared with the average GBV of 1.40 in the experiment). However, among the genotypes selected by I_h, there were those that were inferior to other hybrids by breeding value (GBV_i = 1.32 for combination Mkh 524 A / ZL 50 B // Kh 06134 V; GBV_i = 1.34 for combination Skh 51 A / ZL 50 B // Kh 06134 V).

Thus, at high temperatures of the first 10 days of August, two hybrid combinations (5.9% of the studied ones) coupled a high general adaptability with the highest heat resistance index of the studied combinations.

Line - pollen fertility restorer Kh 06134 V, which is resistant to downy mildew race 730, with a high combining ability for the seed yield and other useful features, was the male component of the best three-line hybrids [20].

Conclusions. Basing on dependence of the sunflower yield on the temperature regime during the growing season, we proposed the heat resistance index of a genotype in the field conditions, which is defined as the specific adaptability (SA_{ik}) effect calculated for each hybrid in an environment with a high temperature, i.e., the average maximum air temperature for a certain period.

In 2007 with the t_{max} of 34.3°C in July, in the IOC's experimental field, 5 hybrid combinations (7.2% of the studied ones) were selected. They combined a high general adaptability with a high heat resistance index (from 0.32* to 0.50*). In 2014 with the t_{max} of 34.6°C in the first 10 days of August, in the IOC's experimental field, 2 hybrid combinations (5.9% of the studied ones), which combined a high general adaptability with the highest heat resistance index of the combinations under investigation (from -0.64 to -0.65), were detected.

The heat resistance index is suitable for selection of accessions that, in a certain group of genotypes, at very high temperatures, are able to maintain stable yields, or reduce them less than other genotypes.

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ОЦІНКА ГІБРИДІВ СОНЯШНИКУ ЗА МІНЛИВІСТЮ ВРОЖАЙНОСТІ В УМОВАХ ДУЖЕ ВИСОКИХ ТЕМПЕРАТУР ПОВІТРЯ

[1]Макляк К.М., [1]Кириченко В.В., [2]Вареник Б.Ф., [3]Кутіщева Н.М., [4]Троценко В.І.
[1] – Інститут рослинництва ім. В.Я. Юр'єва НААН, Україна;
[2] – Селекційно-генетичний інститут–Національний центр насіннєзнавства і сортовивчення, Україна;
[3] – Інститут олійних культур НААН, Україна;
[4] – Інститут сільського господарства Північного Сходу НААН, Україна

Мета і задачі дослідження. Ціль дослідження – розробити методичні підходи до кількісної оцінки мінливості врожайності гібридів соняшнику в умовах дуже високої температури повітря (жари).

Матеріал і методика. Польові дослідження проведено в умовах помірно посушливої зони та зони недостатнього зволоження України, в п'яти географічних пунктах. Випробувано 99 простих і трилінійних гібридних комбінацій. Реакцію гібридів на умови вирощування оцінювали за показниками загальної та специфічної адаптивної здатності.

Обговорення результатів. Доведено можливість диференціації гібридів за ефектами специфічної комбінаційної здатності, значення яких у середовищах с дуже високими температурами впродовж чутливих етапів розвитку соняшнику прийнято за показник «індекс жаростійкості генотипу» ($I_{ж}$). В умовах дуже високих температур липня виділено гібридів комбінації з достовірно високими $I_{ж}$. П'ять гібридних комбінацій (7,2 % від досліджених) поєднували високу загальну адаптивну здатність з високим $I_{ж}$. В умовах дуже високих температур першої декади серпня виділено дві гібридні комбінації (5,9 % від досліджених)

З високою загальною адаптивною здатністю та високим $I_{ж}$.

Висновки. Показник «індекс жаростійкості» придатний для виділення зразків, які в певній групі генотипів в умовах дуже високих температур повітря здатні зберігати врожайність на стабільному рівні, або зменшувати її у меншому ступені, ніж інші генотипи.

Ключові слова: *соняшник, випробування, адаптивна здатність, загальна, специфічна, індекс, жаростійкість*

ОЦЕНКА ГИБРИДОВ ПОДСОЛНЕЧНИКА ПО ИЗМЕНЧИВОСТИ УРОЖАЙНОСТИ В УСЛОВИЯХ ОЧЕНЬ ВЫСОКИХ ТЕМПЕРАТУР ВОЗДУХА

[1]Макляк Е.Н., [1]Кириченко В.В. [2]Вареник Б.Ф., [3]Кутищева Н.Н., [4]Троценко В.И.
[1] – Институт растениеводства им. В.Я. Юрьева НААН, Украина
[2] – Селекционно-генетический институт–Национальный центр семеноведения и сортоизучения, Украина
[3] – Институт масличных культур НААН, Украина
[4] – Институт сельского хозяйства Северного Востока НААН, Украина

Цели и задачи исследования. Цель исследования – разработать методические подходы к количественной оценке изменчивости урожайности гибридов подсолнечника в условиях очень высокой температуры воздуха (жары).

Материал и методика. Полевые исследования проведены в условиях умеренно засушливой зоны и зоны недостаточного увлажнения Украины, в пяти географических пунктах. Испытаны 99 простых и трехлинейных гибридных комбинаций. Реакцию гибридов на условиях выращивания оценивали за показателями общей и специфической адаптивной способности.

Обсуждение результатов. Доказана возможность дифференциации гибридов по эффектам специфической комбинационной способности, значения которых в средах с очень высокими температурами на протяжении чувствительных этапов развития подсолнечника приняты за показатель «индекс жаростойкости генотипа» ($И_{ж}$). В условиях очень высоких температур июля выделены гибридные комбинации с достоверно высокими $И_{ж}$. Пять гибридных комбинаций (7,2 % от испытанных) объединяли высокую общую адаптивную способность с высоким $И_{ж}$. В условиях очень высоких температур первой декады августа выделены две гибридные комбинации (5,9 % от испытанных) с высокой общей адаптивной способностью и высокими $И_{ж}$.

Выводы. Показатель «индекс жаростойкости» пригодный для выделения образцов, которые в определенной группе генотипов в условиях очень высоких температур воздуха способны сохранять урожайность на стабильном уровне, или уменьшать ее в меньшей степени, чем другие генотипы.

Ключевые слова: *подсолнечник, испытание, адаптивная способность, общая, специфическая, индекс, жаростойкость*

EVALUATION OF SUNFLOWER HYBRIDS FOR YIELD VARIABILITY AT VERY HIGH AIR TEMPERATURES

[1]Makliak K.M., [1]Kyrychenko V.V., [2]Varenyk B.F., [3]Kutishcheva N.M., [4]Trotsenko V.I.
[1] – Plant Production Institute named after V.Ya. Yuriev of NAAS, Ukraine;
[2] – Plant Breeding and Genetic Institute - National Center of Seed and Cultivar Investigation, Ukraine;
[3] – Institute of Oil Crops of NAAS, Ukraine;
[4] – Institute of Agriculture of the North-East of NAAS, Ukraine

Purpose and objective. The purpose of the study was to develop methodological approaches to quantification of the yield variability of sunflower hybrids at very high air temperatures (heat).

Materials and methods. The field investigations were conducted in the moderately arid zone and the insufficiently humidified zone of Ukraine, in five geographical locations. Ninety nine simple and three-line hybrid combinations were tested. The response of the hybrids to the growing conditions was evaluated by general and specific adaptability measures.

Results and discussion. The possibility of differentiation of hybrids according to the specific combining ability effects was proved. The effect values in environments with very high tem-

peratures during the susceptible stages of sunflower development were taken as the heat resistance indices of genotypes (I_h). At very high temperatures in July, hybrid combinations with significantly high I_h were detected. Five hybrid combinations (7.2% of the studied ones) combined a high general adaptability with a high I_h. At very high temperatures during the first 10 days of August, two hybrid combinations (5.9% of the studied ones) with a high general adaptability and a high I_h were singled out.

Conclusions. The heat resistance index is suitable for detecting accessions that, in a certain group of genotypes, at very high air temperatures, are able to maintain stable yields, or reduce them less than other genotypes.

Key words: *sunflower, trials, adaptability, general, specific, index, heat resistance*

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ОСОБЛИВОСТІ ФОРМУВАННЯ БІОХІМІЧНОГО СКЛАДУ НАСІННЯ СУЧАСНИХ СОРТІВ СОЇ

Рябуха С.С., Чернишенко П.В., Сєрікова Л.Г., Святченко С.І.
Інститут рослинництва ім. В.Я. Юр'єва НААН, Україна

Установлено значну диференціацію сортів сої за показниками врожайності та якості насіння. Виділено сорти з максимальним проявом ознак: урожайності – сорт Красуня (1,6 т/га), вмісту білка в насінні – сорт Райдуга (38,1 %), вмісту олії та інтенсивності її утворення – сорт Спритна (18,2 % та 2,969 кг/га/добу відповідно), сумарного вмісту білка та олії, інтенсивності утворення білка, інтенсивності утворення білка та олії – сорт Перлина (55,6 %; 6,265 кг/га за добу; 9,176 кг/га за добу відповідно). Показано, що сорти ранньостиглої групи мають здатність до утворення білка та олії в насінні на рівні та вище, ніж сорти середньоранньої та середньостиглої груп.

Ключові слова: *соя, сорт, урожайність, насіння, вміст, білок, олія, інтенсивність утворення*

Вступ. Ріст народонаселення Землі і невідкладна необхідність забезпечення його продуктами харчування вимагає випереджаючого росту виробництва продовольчих ресурсів, зокрема білково-олійної сировини. Їх поповнення значною мірою забезпечується за рахунок сої, яка являє собою основу світової піраміди рослинного білка і олії, важливу складову продовольства [1, 2], забезпечуючи близько 20 % світових білкових ресурсів [3, 4].

Аналіз літературних джерел, постановка проблеми. Соя багата на повноцінний білок, поліненасичені ліпіди, харчові волокна, вітаміни, макро- та мікроелементи, що привертає увагу вчених і виробників для створення функціональних і лікувальних продуктів харчування [1, 2, 4].

Рослинний білок є найважливішою складовою частиною харчових і кормових ресурсів, використання яких суттєво впливає на стан здоров'я людей, тривалість і рівень життя. Наприкінці ХХ сторіччя у загальному балансі білка частка рослинного складала 70 %, а 30 % припадало на тваринний [5].

Завдяки здатності накопичувати в насінні понад 40 % високоякісного білка соя стала однією з головних культур світового землеробства [1, 2, 3, 4, 6]. Створюються спеціалізовані сорти сої харчового використання, спостерігається тенденція до збільшення вмісту білка в насінні нових сортів сої. В Кореї та КНР – країнах первинного центру походження

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