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Influence of Some Mutant Genes on Certain Agronomically Important Traits in Sunflower

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Abstract: During two growing seasons there were studied 11 sunflower breeding lines and their 30 analogues obtained via backcrossing, chemical mutagenesis and selected as natural mutants. The variability of such agronomic traits as crop yield, seed oil content, 1,000 seed weight, plant height, leaf and petiole size, number of leaves and branches, and head diameter was investigated. The traits of crop yield, leaf size, number of branches were the most variable, whereas the most stable were 1,000 seed weight, seed oil content, plant height, and the number of leaves. The influence of mutant genes which control ray flower color and shape, leaf color and shape, dwarfness, number of leaves and ray flowers, and shape of bracts on the manifestation of important agronomic traits was estimated. No negative impact of the genes of ray flower color and shape and leaf color was noticed. The gene of fringed leaf margin reduced plant height while the gene of erect petiole increased development of that trait. The genes of dwarfness can negatively influence seed oil content and 1,000 seed weight.

Keywords: gene, line, mutant, sunflower, trait, variability

Introduction

Genetics of sunflower has been studied for a long time already. Among the published reports on sunflower genetics one can note the book by V. Gavrilova and I. Anisimova “Sunflower”, published in 2003 (Gavrilova and Anisimova, 2003). This review describes about 130 genes which cover all the linkage groups. At that time, however, the research on gene mapping has just started. One of the most recent review on sunflower is the book by world’s leading scientists on sunflower, co-published and edited by D. Škorić in 2012 (Škorić *et al.*, 2012). Zhao

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Liu and Chao-Chien Jan in the chapter on genetics presented broad molecular studies conducted around the world on mapping the genome of sunflower and its individual genes. Unfortunately, there is presently little research on the effect of individual morphological marker genes on the genotype as a whole – we refer here to the traits of quantitative nature that are highly required for breeding. It should be noted that there is a number of works where inheritance of quantitative traits was studied and for several of them a genetic component has been identified. For example Škorić (1985) and Hladni et al. (2004) have marked significant genetic component for leaf surface area and petiole length, and Borisenko and Chebanova (2015) proved existence of genetic component for plant height (h^2=80.0%), head diameter (66.0%), and number of leaves (62.0%). All those research, however, were conducted with the groups of lines of unrelated origin and without studying influence of morphological marker traits.

The last known study where lines of related origin were investigated was the examination on a number of sunflower analogue lines of sunflower, made by V. Pimahin (Pimahin, 2000). In that paper the author studied a series of 36 lines made after backcrossing on the basis of YuV28B line. Those analogues differed from the source line by ray floret color (6 types), leaf color (7 types), short height (8 types) and some other traits.

The goal of our research was to study the influence of mutant genes on the manifestation of the agronomic traits and their variability.

Materials and methods

The collection of sunflower (*Helianthus annuus* L.) lines from the Institute of Oilseed Crops served as the material. The following accessions were used as donors for morphological marker traits: No. UE0100416 – for *er1* gene, No. UE0100439 – *Fr* gene, No. UE0100546 – *Dw* gene, No. UE0100486 – *sp* gene, No. UE0100499 – *lb* gene, and No. UE0100421 – for *hba* gene. The work was carried out with 11 breeding lines used in commercial hybrids, namely ZL9B, ZL102B, ZL169B, ZL22B, ZL678V, ZL809B, ZL95B, KLV80/1V, L06B, L14B, and LVO7V. On the basis of those breeding lines there were developed 30 analogue lines, which differed for a single trait from the source lines. The lines with proved monogenic inheritance of the modified morphological traits were used as donors for those traits. To make most of analog lines (M790, M791, ZL678/1992, ZL678/327, ZL678/794, LVO7/1020, ZL169/332, ZL169/431, L14/313, L06/1005, L06/726, ZL22/319, ZL22/320, ZL22/434, ZL102/314, ZL102/316) a multiple backcrossing with the initial breeding line (6–7 backcrosses) was conducted. Other part of the accessions (M10, M17, M17/1, M19, and M23) was obtained at

the breeding plots as spontaneous mutants. And the last nine lines (SLM2, SLM3, SLM5, SLM7, SLM8, MV1, MV3, MV4, MV5) were derived by chemical mutagenesis – treating immature seeds and embryos with ethyl methanesulfonate (Lyakh *et al.*, 2005; Soroka and Lyakh, 2009). The study on identification of genes and their inheritance was performed after production of lines and their reproduction. Gene symbols are used according to Gavrilova and Anisimova (2003) and Soroka and Lyakh (2015). The study of genetics peculiarities was conducted according to M. Tihomirova techniques (Tihomirova, 1990). Statistical analysis of the results was performed by the method of Lakin (1980), calculating the mean, standard error and standard deviation (SD), least significance difference (LSD), and coefficient of variation (CV). Hybridization was made as described by Plotnikov (1940) using manual castration. Experiment design included sowing of accessions at plots of 25 square meters in 4 replications.

Sunflower crops were seeded after barley as a predecessor. Sowing cultivation was carried out at a depth of 6–8 cm with simultaneous application of the "Herb" herbicide at a dose of 2.5 l/ha. Sowing was carried out to a depth of 7–8 cm at the density of 40000 plants per hectare.

During the growing season phenological observations of the phases of plant development as well as biometric measurements (plant height, head diameter, number of leaves, leaf and petiole size, number of branches) were carried out. To study morphological traits 5 plants were used for each accession. Yield was determined by direct weighting of seeds from 20–40 plants in three or four replicates. After harvesting laboratory tests were conducted to establish seed oil content, using the Nuclear Magnetic Resonance instrument, and 1,000 seed weight.

The collection of sunflower analogue lines was studied for two growing seasons – years 2013 and 2014. In order to analyze the level of variability of traits for each of the studied parameter the average coefficient of variation and standard error were calculated. In all the tables the data which have coefficient of variation above 10% are marked with letter "**a**", and those with coefficient of variation above 20% – with letter "**b**". The means are presented with their standard error (mean ± standard error). The h^2 coefficients for the power of influence of a trait were calculated according to G. Lakin (1980) after two-way analysis of variance for non-orthogonal complexes.

Results and discussion

The results for calculation of average coefficients of variation for various traits in analogue, mutant and source lines of sunflower are presented in Table 1.

Table 1: Average coefficients of variation for various traits in analogue, mutant and source lines of sunflower (2013–2014).

Trait	Mean	SD	CV, %
Crop yield, t/ha	1.1	2.1	36.7 ± 3.4
1000 seed weight, g	41.8	6.3	7.6 ± 0.6
Seed oil content, %	38.7	6.0	8.0 ± 0.7
Plant height, cm	102.0	2.6	5.0 ± 0.4
Number of leaves	24.5	11.1	9.5 ± 0.8
Head diameter, cm	15.5	14.3	13.4 ± 1.1
Length of the leaf blade, cm	11.1	23.2	11.8 ± 0.9
Width of the leaf blade, cm	17.1	17.0	14.4 ± 1.2
Length of the petiole, cm	9.3	12.2	16.6 ± 1.3
Number of branches	4.4	35.6	18.4 ± 2.3

The data obtained demonstrate constantly high coefficients of variation for crop yield, as well as number of branches, leaf size and head diameter. Because of strong variability the descriptiveness of those traits for characterization of a particular accession is very limited. Moreover, it was shown that environmental conditions influenced significantly plant height and the power of influence was high (h^2 ranges from 3.75% up to 83.97%). However, the influence of mutant gene is still present – i.e. the difference between genotypes is visible. Such trait as number of branches also strongly depended on growing conditions – the power of influence h^2 reached 71.0% for some groups of accessions. Leaf size and head diameter in most cases are influenced by year conditions as well (h^2 varies between 5.21 to 76.39% for leaf size, and between 7.82 to 57.06% for head diameter). At the same time both environmental conditions and the mutant gene had no pronounced effect upon the crop yield (h^2 coefficient was not significant in most cases).

Table 2 shows the average values of the studied traits in the original paternal line KLV 80/1 and its analogue lines obtained by different methods. Among the figures presented those which have coefficient of variation above 10% are marked with letter “a”, and those with coefficient of variation above 20% – with letter “b”. For most samples the highest level of variability (coefficient of variation exceeded 20%) was noted for the trait of petiole length. In addition it should be noted that such parameters as leaf size and head diameter had a sufficiently high coefficient of variation, which however depended on the year of study. Namely, growing conditions in 2013 resulted in a higher variability.

From the parameters presented the most stable and reliable were: 1,000 seed weight, seed oil content, plant height and number of leaves. Nevertheless, each of the studied lines and their analogs had some peculiarities with regard

Table 2: Average data for some quantitative characteristics of KLV 80/1 paternal line analogues (2013–2014).

Line	Gene	Trait	1000 seed weight, g	Seed oil content, %	Plant height, cm	Number of leaves	Head diameter, cm	Leaf length, cm	Leaf width, cm	Petiole length, cm
KLV80/1V		**Source line**	26.5 ± 0.35	38.6 ± 1.1	120.4 ± 2.3	24.9 ± 1.7[a]	12.1 ± 0.7[a]	8.9 ± 1.2[a]	16.3 ± 1.3[a]	10.1 ± 1.4[b]
M10	*o*	Orange ray flowers	37.7 ± 1.8	35.6 ± 1.5	105.8 ± 3.3	24.6 ± 1.3	11.9 ± 0.8[a]	10.7 ± 0.9[a]	16.3 ± 1.0[a]	11.3 ± 0.7[a]
M17	*shc*	Stripe-shaped ray flowers	29.5 ± 1.6	42.2 ± 1.2	119.3 ± 2.2	25.7 ± 1.1	11.5 ± 0.8[a]	10.2 ± 1.3[a]	15.5 ± 1.1[a]	12.6 ± 1.1[b]
M17/1	*tu2*	Long tubular ray flowers	24.4 ± 1.6	40.7 ± 1.1	114.0 ± 2.9	22.9 ± 1.1[a]	10.9 ± 0.8[a]	9.3 ± 0.8[a]	13.1 ± 1.0[a]	8.3 ± 0.8[b]
M19	*l*	Lemon ray flowers	27.4 ± 1.6	38.7 ± 1.2	123.2 ± 1.8	25.8 ± 0.9[a]	11.9 ± 0.8[a]	9.1 ± 0.9[a]	14.0 ± 1.2[a]	7.1 ± 0.7[b]
M23	*ly*	Light yellow ray flowers	26.5 ± 1.6[a]	39.7 ± 1.4	113.4 ± 2.0	25.4 ± 1.2[a]	11.6 ± 0.6[a]	10.1 ± 1.1[a]	14.1 ± 0.9[a]	8.1 ± 0.8[b]
M790	*lb, Dw*	Light brown leaf color; Dwarfness	18.6 ± 1.2	38.7 ± 1.6	110.2 ± 2.9	21.7 ± 1.1[a]	11.7 ± 0.8[a]	13.5 ± 1.1[a]	17.2 ± 1.2[a]	9.7 ± 0.9[b]
M791	*lb*	Light brown leaf color	23.7 ± 1.7	40.9 ± 1.0	121.4 ± 2.4	27.4 ± 1.0[a]	13.4 ± 0.8[a]	3.5 ± 1.4[a]	18.0 ± 2.1[a]	11.0 ± 0.9[b]
LSD			7.26	1.75	8.23	7.52	1.36	5.40	5.13	2.02
P			8.11	1.55	2.61	8.32	4.2	8.22	9.78	8.77

Note: [a]indices with coefficient of variation above 10%, [b]those with coefficient of variation above 20%.

to stability characteristics. Thus, fertility restorer lines KLV80/1 and ZL678B (Tables 2 and 3) during two years of studies were characterized by stable performance regarding seed oil content and plant height, and KLV80/1B line – by 1,000 seed weight as well. Among the analogues of the line KLV80/1 (Table 2) a spontaneous mutant M10 (gene of orange ray flowers) was reliably distinguishable, it had larger seeds and lower seed oil content, as well as reduced plant height. Analogue line M790 (genes of brown leaf color and dwarfness) had smaller seeds as compared to the source line. Apparently that was an influence of *Dw* gene as M791 analogue (*lb* gene only) did not differ in 1,000 seed weight from the source line. Other genes of ray flower color and shape had no visual impact on the studied agronomic characteristics.

The "number of leaves" trait was not as stable as reported in other research (Marinkovic, 1982). Thus the number of leaves for the lines M17/1, M19, and M23 varied significantly from year to year while their average indices indicated the absence of significant changes in comparison with the reference line.

Table 3 shows the analogue lines which are largely indistinguishable from the source lines. In ZL678/327 analogue with the gene of short tubular ray flowers a decrease in the mass of 1,000 seeds was found.

Analogue line LVO7/1020 with the gene controlling the fringed leaf margin (*Fr*) showed an increase in the 1,000 seed weight and reduction in the plant height.

Tables 4 and 5 show analogs of parental breeding lines divided into two groups – early and middle-early ripening lines. The differences between them are observed only for the trait of number of leaves per plant, which demonstrates large coefficients of variation in earlier ripening lines.

Describing the action of genes, the mutant MV1 with the gene of yellow terminal bud (*y*) and ZL169/431 analogue with the gene of light brown leaf color (*lb*) had larger 1,000 seed weight. ZL169/332 analogue with the gene controlling erect petioles (*er1*) has a greater height than the original line.

The SLM3 mutant with the gene of brown-red color of seed coat as well as the mutant with fan-shaped leaf venation did not differ the source line for all the traits studied. The SLM2 mutant with a small number of ray flowers displayed increase in the 1,000 seed weight as compared to the reference line ZL809, and the SLM2 and SLM7 mutants with the small number of ray flowers and increased number of leaves, respectively – decrease in seed oil content.

Line L14/313–analogue of L14 line, in addition to the introduced gene controlling erect petiole showed an increase in plant height as compared to the source line. This change in height at the presence of the erect petiole gene has been observed in ZL169/332 analogue as well.

Table 3: Average data for some quantitative characteristics for some analogue lines of the paternal lines ZL678V and LVO7V (2013–2014).

Line	Gene	Trait	1,000 seed weight, g	Seed oil content, %	Plant height, cm	Number of leaves	Head diameter, cm	Leaf length, cm	Leaf width, cm	Petiole length, cm
ZL678V		**Source line**	17.2 ± 1.5[a]	37.9 ± 1.7[a]	94.5 ± 3.9	25.6 ± 1.3[a]	9.7 ± 0.6[a]	7.9 ± 0.8[a]	11.1 ± 0.9[b]	7.1 ± 0.6[b]
ZL678/1992	*Fr*	Fringed leaf margin	22.3 ± 1.4[a]	36.4 ± 1.3	94.8 ± 2.7	24.1 ± 1.2	9.9 ± 0.9[a]	10.9 ± 0.9[a]	9.3 ± 0.9[b]	5.9 ± 0.8[b]
ZL678/327	*hba*	Short tubular ray flowers	12.9 ± 1.5[a]	39.1 ± 1.2	95.2 ± 2.9	25.3 ± 1.3	9.4 ± 0.9[a]	10.4 ± 0.9[a]	8.4 ± 0.8[b]	5.6 ± 0.7[b]
ZL678/794	*sp*	Spoon-like leaf blade	21.7 ± 2.2[a]	38.4 ± 1.5	89.1 ± 2.7	20.1 ± 1.2[a]	9.5 ± 0.8[a]	8.9 ± 0.9[a]	7.7 ± 0.8[a]	5.2 ± 0.7[a]
LSD			5.28	1.77	12.9	2.55	1.53	2.65	3.78	1.95
P			7.80	1.56	4.8	3.7	5.59	7.5	12.9	10.9
LVO7V		**Source line**	45.3 ± 4.6[a]	43.0 ± 1.2	112.1 ± 2.5	27.1 ± 0.9[a]	15.9 ± 0.7[a]	9.8 ± 0.9[a]	16.1 ± 1.1[a]	9.4 ± 1.1
LVO7/1020	*Fr*	Fringed leaf margin	56.6 ± 3.2	34.6 ± 3.5[a]	93.4 ± 2.5	27.5 ± 1.5	14.3 ± 1.1*	10.9 ± 1.0[a]	13.1 ± 0.9[a]	7.6 ± 0.8[b]
LSD			10.52	4.47	11.74	2.93	1.63	2.01	3.44	1.52
P			8.20	3.08	4.34	3.59	4.07	4.35	8.15	5.7

Note: [a]indices with coefficient of variation above 10%, [b]those with coefficient of variation above 20%.

Table 4: Average data for some quantitative characteristics of maternal early-maturity lines analogues (2013–2014).

Line	Gene	Trait	1,000 seed weight, g	Seed oil content, %	Plant height, cm	Number of leaves	Head diameter, cm	Leaf length, cm	Leaf width, cm	Petiole length, cm
ZL169B		**Source line**	37.7 ± 1.7	44.9 ± 2.6	100.8 ± 2.6	22.2 ± 1.7	17.7 ± 1.5	8.9 ± 1.2	15.6 ± 1.9[b]	9.0 ± 1.0
MV1	*y*	Yellow terminal bud	56.0 ± 2.0	41.6 ± 6.7[a]	96.0 ± 4.8	22.0 ± 1.3[a]	17.2 ± 2.0[b]	8.9 ± 1.5	23.2 ± 2.8[b]	11.8 ± 0.5[a]
MV3	*dw*	Dwarfness	36.0 ± 1.2	36.3 ± 1.3	63.0 ± 0.9	24.2 ± 1.8[a]	22.6 ± 1.6[a]	8.7 ± 0.7	24.8 ± 0.5	7.8 ± 0.7[a]
ZL169/332	*er1*	Erect petiole	45.0 ± 2.0	45.6 ± 6.8[a]	130.0 ± 1.6	25.6 ± 0.6	23.6 ± 1.4*	8.2 ± 1.1	24.0 ± 1.3	8.8 ± 0.8
ZL169/431	*lb*	Light brown leaf color	49.1 ± 1.8	40.9 ± 2.8	104.2 ± 2.9	24.3 ± 0.9[a]	18.6 ± 1.2[a]	10.3 ± 1.1[a]	19.0 ± 1.2[a]	9.5 ± 0.8[a]
LSD			10.1	4.50	6.8	3.2	3.2	2.50	4.50	1.57
P			7.2	3.25	2.5	4.6	5.3	4.00	7.00	5.40
ZL95B		**Source line**	51.0 ± 2.1	40.2 ± 1.2[a]	112.4 ± 5.8[a]	22.1 ± 1.5[a]	23.5 ± 1.6[a]	21.9 ± 1.6[a]	28.5 ± 1.3[a]	13.8 ± 1.2[a]
SLM3	*bs*	Brown-red color of seed coat	45.5 ± 1.7	35.7 ± 3.3[a]	103.0 ± 0.9	23.2 ± 1.1	24.8 ± 1.3	21.6 ± 1.0	30.8 ± 0.7	14.8 ± 1.1
LSD			13.80	5.99	16.44	3.24	2.6	4.47	5.69	3.04
P			4.50	4.04	4.78	5.32	5.65	4.95	6.36	6.66
ZL9B		**Source line**	51.0 ± 1.8	38.2 ± 2.8[a]	117.2 ± 1.5	26.2 ± 1.6[a]	25.4 ± 1.8[a]	22.3 ± 0.9	22.2 ± 1.0	15.6 ± 1.6
SLM8	*vf1*	Fan-shaped leaf venation	45.0 ± 1.9	40.3 ± 3.1[a]	116.6 ± 2.5	22.8 ± 1.6[a]	17.8 ± 0.9	23.9 ± 1.1	17.2 ± 0.7	13.4 ± 0.9[a]
LSD			4.50	3.87	3.57	6.94	6.42	3.33	2.32	4.67
P			5.25	3.01	0.79	7.22	7.57	3.96	3.00	8.21
ZL809B		**Source line**	53.0 ± 2.1	40.8 ± 1.2[a]	96.0 ± 1.9	19.3 ± 1.5[a]	14.5 ± 1.5[a]	13.3 ± 1.4[a]	17.0 ± 1.03[a]	10.5 ± 1.0[a]

SLM2	*ff*	Small number of ray flowers	78.5 ± 2.7	32.6 ± 6.1[a]	83.4 ± 3.1	19.2 ± 2.1[b]	16.2 ± 1.1[a]	10.8 ± 0.9[a]	18.4 ± 1.3[a]	12.7 ± 1.0[b]
SLM5	*lg*	Light green leaf color (*viridis*)	54.0 ± 2.3	39.9 ± 1.3[a]	90.5 ± 3.1	21.7 ± 1.1[a]	15.3 ± 1.5[b]	11.8 ± 1.2[a]	15.6 ± 1.3[a]	9.9 ± 1.1[a]
SLM7	*ll*	Increased number of leaves	53.0 ± 2.1	30.2 ± 4.2[a]	89.4 ± 2.3	23.9 ± 1.3[a]	17.4 ± 0.9[a]	10.2 ± 0.9[a]	17.2 ± 1.0[a]	11.5 ± 0.9[a]
LSD			5.66	2.33	14.54	3.24	2.6	2.90	3.57	2.09
P			3.10	1.34	5.58	5.32	5.65	5.80	7.22	6.58
L14B		**Source line**	56.4 ± 2.9	35.9 ± 3.7[a]	91.7 ± 3.2	18.7 ± 0.9[a]	16.0 ± 1.2[a]	9.3 ± 1.9[a]	21.10 ± 2.2[b]	9.6 ± 0.9[b]
L14/313	*er1*	Erect petiole	55.8 ± 2.2	32.7 ± 1.2	102.4 ± 2.2	22.0 ± 0.9[a]	16.8 ± 1.0[a]	9.9 ± 1.1[a]	21.7 ± 1.3	11.1 ± 0.9[a]
LSD			7.10	2.87	6.18	1.90	3.17	4.10	5.39	1.88
P			3.40	2.01	1.99	2.93	6.05	5.88	7.88	5.69

Note: [a]indices with coefficient of variation above 10%, [b]those with coefficient of variation above 20%

Table 5: Average data for some quantitative characteristics of maternal middle-maturity lines analogues (2013–2014).

Line	Gene	Trait	1,000 seed weight, g	Seed oil content, %	Plant height, cm	Number of leaves	Head diameter, cm	Leaf length, cm	Leaf width, cm	Petiole length, cm
L06B		**Source line**	31.0 ± 0.1	42.0 ± 6.5[a]	114.6 ± 2.0	21.2 ± 1.3[a]	18.4 ± 1.1[a]	18.1 ± 1.3[a]	23.2 ± 1.3[a]	13.2 ± 1.1[b]
L06/1005	*Fr*	Fringed leaf margin	43.2 ± 3.2[a]	42.7 ± 4.4[a]	104.7 ± 2.3	27.4 ± 1.1	16.7 ± 1.1[a]	10.3 ± 1.4[a]	21.0 ± 1.4[a]	6,9 ± 0.6[a]
L06/726	*er1*	Erect petiole	88.6 ± 3.2	38.9 ± 1.5[a]	112.9 ± 2.2	27.3 ± 1.1[a]	16.5 ± 1.1[a]	9.7 ± 1.3[a]	19.8 ± 1.2[a]	5.5 ± 0.8[a]
LSD			11.1	2.51	14.5	2.2	1.92	2.66	2.5	1.56
P			10.0	1.93	4.16	3.92	3.98	4.08	3.32	9.18
ZL22B		**Source line**	51.4 ± 2.1	42.5 ± 1.4	95.3 ± 3.1	24.5 ± 1.0[a]	21.3 ± 1.8[a]	16.8 ± 1.0	25.4 ± 1.4[a]	9.3 ± 0.9[a]
ZL22/319	*lb*	Light-brown leaf color	50.3 ± 2.5	42.7 ± 2.8	102.9 ± 2.9	26.3 ± 1.4[a]	17.3 ± 1.2[a]	16.3 ± 1.4[a]	16.2 ± 1.3[a]	10.5 ± 1.2[b]
ZL22/320	*Fr*	Fringed leaf margin	59.3 ± 2.9[a]	40.2 ± 2.7[a]	88.1 ± 3.1[a]	27.8 ± 1.4	17.8 ± 1.3[a]	20.5 ± 1.4[a]	20.6 ± 1.4[a]	8.5 ± 0.9[b]
ZL22/434	*Dw*	Dwarfness	37.6 ± 1.9	33.1 ± 2.6[a]	72.9 ± 2.3	30.4 ± 1.3[a]	22.6 ± 1.6 [a]	10.9 ± 1.5 [a]	21.3 ± 1.7 [a]	9.9 ± 0.9[a]
LSD			13.5	3.80	12.7	3.1	3.3	3.0	3.6	2.6
P			8.3	3.10	4.9	3.9	5.9	4.8	5.9	9.1
ZL102B		**Source line**	43.4 ± 1.5	39.3 ± 4.2[a]	131.7 ± 3.4	25.5 ± 1.3	20.2 ± 1.3	10.7 ± 0.9	20.3 ± 1.1	11.3 ± 0.7

MV4	*ly*	Light-yellow ray flowers	43.5 ± 2.6	42.8 ± 6.6[a]	133.2 ± 2.0	24.2 ± 2.4[a]	20.2 ± 1.2[a]	12.7 ± 0.8[a]	28.0 ± 1.5[a]	13.4 ± 1.1[a]
MV5	*l*	Lemon ray flowers	49.7 ± 2.4	44.0 ± 1.3	147.4 ± 2.0	26.8 ± 0.7	27.2 ± 1.4	12.4 ± 0.9	28.8 ± 1.0	16.0 ± 1.4
ZL102/314	*Bu*	Bulbous bracts	50.4 ± 2.6	40.1 ± 4.3[a]	133.7 ± 3.4	26.7 ± 1.4	22.1 ± 1.3[a]	13.5 ± 1.8[a]	20.8 ± 1.8[a]	10.8 ± 0.9[a]
ZL102/316	*Fr*	Fringed leaf margin	44.3 ± 2.3	39.1 ± 4.1[a]	129.1 ± 2.8	26.5 ± 1.3	21.1 ± 1.6[a]	11.4 ± 1.3	18.9 ± 1.4[a]	12.3 ± 1.1
LSD			8.40	6.70	8.0	3.7	4.1	3.40	4.00	2.50
P			5.20	4.50	2.0	4.8	6.3	4.30	5.30	6.00

Note: [a]indices with coefficient of variation above 10%, [b]those with coefficient of variation above 20%.

Table 5 presents the analogues for the parent breeding lines L06B, ZL22B, and ZL102B. Most of them, like the source lines, have a coefficient of variation for seed oil content at the 10% level. The most indicative traits were 1,000 seed weight and plant height. Speaking of the genes, increase in the 1,000 seed weight, as compared to the source line, was observed for L06/726 analogue having the gene of erect petiole (*er1*), and for L06/1005 analogue with the gene of fringed leaf margin (*Fr*). Those genes (*er1* and *Fr*) also influenced leaf length in a negative way.

A tendency to reduction in plant height compared to the source line was observed in L06/1005 and ZL22/320 analogues carrying the gene of fringed leaf margin. ZL22/434 line with introduced gene of dwarfness (*Dw*) has showed reduction in seed oil content. The MV5 mutant with lemon ray flowers (*l*) demonstrated the biggest differences from the source line: increased plant height and head diameter, and a tendency to the increased seed oil content.

Generalizing the data obtained it can be said that the gene of fringed leaf margin in some cases significantly reduced plant height, and the gene of erect petiole increased the trait. Moreover, the gene of fringed leaf margin can increase 1,000 seed weight as well as the gene of erect petiole. Those facts should be taken into account while creating analogue lines as the genes mentioned above have a big impact on the valuable agricultural characteristics. The research we conducted had made it possible to create a collection of breeding lines and their analogues for individual genes controlling important morphological characteristics.

Conclusions

Of the studied traits the most variable were crop yield, leaf size, number of branches whereas the most stable were 1,000 seed weight, seed oil content, plant height, and the number of leaves.

The genes of fringed leaf margin (*Fr*) and erect petiole (*er1*) influence plant height in different directions – the gene of fringed leaf margin significantly reduces plant height, while the gene of erect petiole increases plant height. Both of these genes can also positively influence 1,000 seed weight.

The genes of ray flower color and shape do not negatively influence important agronomic traits, with the exception of gene which controls orange ray flowers (*o*). Moreover, the gene of lemon ray flowers (*l*) can positively influence the traits studied.

The genes of leaf color *lb* (light brown), *lg* (light green), *y* (yellow terminal bud) had no negative impact on such traits as 1,000 seed weight, seed oil content, head diameter, number of leaves, and plant height.

The recessive and dominant genes of dwarfness (*dw*, *Dw*) can lower seed oil content, and the latter reduces 1,000 seed weight.

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Résumé

Pendant deux saisons de croissance y ont été étudiés 11 lignes de tournesol de reproduction et leurs 30 analogues obtenus par croisement en retour, la mutagenèse chimique et sélectionné comme mutants naturels. La variabilité de

ces caractères agronomiques comme le rendement des cultures, la teneur en huile des graines, le poids de 1000 graines, hauteur de la plante, la feuille et la taille pétiole, le nombre de feuilles et de branches, et le diamètre de la tête a été étudiée. Les traits de rendement des cultures, la taille des feuilles, numéro des branches étaient le plus variable, alors que les plus stables ont été le poids de 1000 graines, teneur en huile de la graine, hauteur de la plante, et le nombre de feuilles. L'influence des gènes mutants qui contrôlent rayons couleur de la fleur et la forme, la couleur et la forme des feuilles, nanisme, le nombre de feuilles et de fleurs de rayons, et la forme de bractées sur la manifestation de traits agronomiques importants a été estimé. Aucun impact négatif des gènes de rayons couleur de la fleur et la forme et la couleur des feuilles a été remarqué. Le gène de la feuille franges marge réduite hauteur de la plante tandis que le gène de l'érection pétiole augmenté développement de ce trait. Les gènes de nanisme peuvent influencer négativement la teneur en huile des graines et le poids de 1000 graines.

Resumen

Durante dos temporadas de cultivo se estudiaron 11 líneas de mejoramiento de girasol y sus 30 análogos obtenidos mediante retrocruzamiento, mutagénesis química y seleccionado como mutantes naturales. La variabilidad de tales características agronómicas como el rendimiento del cultivo, contenido de aceite de la semilla, peso de 1000 semillas, altura de planta, tamaño de la hoja y del pecíolo, número de hojas y ramas, y el diámetro de la cabeza fue investigado. Los rasgos de rendimiento de los cultivos, tamaño de la hoja, el número de ramas eran las más variables, mientras que los más estables eran 1.000 peso de la semilla, el contenido de aceite de semilla, altura de la planta, y el número de hojas. La influencia de los genes mutantes que controlan rayos color de la flor y de la forma, el color y la forma de la hoja, enanismo, número de hojas y flores de rayos, y la forma de brácteas en la manifestación de importantes características agronómicas se estimó. Sin impacto negativo de los genes de rayos color de la flor y la forma y color de las hojas se notó. El gen de la hoja con flecos margen reducido altura de la planta, mientras que el gen del pecíolo erecto aumentó desarrollo de ese rasgo. Los genes de enanismo pueden influir negativamente en el contenido de aceite de la semilla y peso de 1000 semillas.