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Original scientific paper

LINE X TESTER ANALYSIS FOR YIELD COMPONENTS IN SUNFLOWER AND THEIR CORRELATIONS WITH SEED YIELD (*Helianthus annuus* L.)

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The creation of new sunflower hybrids with high genetic potential for seed yield on the basis of *interspecies* hybridization requires a possession of the information about the mode of inheritance and the combining abilities of the created inbreed lines for the total seed number per head and the mass of 100 seeds. Apart from this the research of interdependence between yield components and seed yield allows the defining of traits which have the biggest influence on the yield formation. Significant differences were found among the A lines, Rf testers and their F_1 hybrids in total seed number per head and the mass of 100 seeds. Analysis of variance of the combining abilities revealed highly significant

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differences for GCA and SCA. Highly significant positive value GCA was demonstrated by A-line NS-GS-5 for both traits. Hybrid NS-GS-5xRHA-R-PL-2/1 has the highest significant value SCA for both traits. The main role in inheritance of the total seed number per head and the mass of 100 seeds is played by non additive component of the genetic variance which is confirmed by the GCA/SCA relation in F_1 generation that is less than one (0.11, 0.24). Rf-testers had the highest average contribution in the expression of the total seed number per head (55.8%) while for the mass of 100 seeds a more significant contribution was given by A-line (70.6%). A strong positive interdependence has been determined between seed yield and total seed number per head (0.376*) and a very strong positive interdependence was determined between seed yield and the mass of 100 seeds (0.823**). These research can be significant for the creation of new high-yielding sunflower hybrids on the basis of *interspecies* hybridization.

Key words: combining abilities, correlation gene effect, sunflower, yield components

INTRODUCTION

One of the main directions of sunflower breeding both in Serbia and elsewhere is the development of hybrids with high genetic potential for seed yield and altered plant architecture capable of adapting to the conditions of the specific area in which they are being grown (HLADNI *et a*l., 2008). Sunflower is an extremely cross-pollinating plant species with bisexual flowers. The use of heterosis with sunflower is achieved in large part through two-line hybrids which are created by crossing self-pollinating mother lines that have cytoplasmic male sterility with self-pollinating father lines that posses the fertility restorer gene (HLADNI, 2010).

The occurrence of heterosis in sunflower hybrids is highly correlated with genetic distance between the parental lines. Heterosis does not appear in all hybrid combinations of the F_1 generation. Heterotic effects are different for different traits (HLADNI *et al*., 2007).

Breeding for a desirable plant architecture and yield components requires a study of the gene effects and the mode of inheritance of quantitative traits as well as the examination of general and specific combining abilities. The examination of the combining abilities of self pollinating inbreed lines is very important because with the crossing of genetically similar lines, meaning lines of similar origin, you cannot get heterosis. The genetic distance between parent lines is the precondition for the expression of good specific combining abilities, as it is stated by ŠKORIĆ *et al*. (2004). Breeding for high seed yield, components of seed yield and creating new sunflower ideotype demands an increase of genetic variability of sunflower (ŠKORIĆ *et al*., 2007).

Its genetic variability can be increased by the use of wild sunflower species and interspecies hybridization (HLADNI *et al*., 2009). The genus *Helianthus*, besides constituting the basic genetic stock from which cultivated sunflower originated, continues to contribute specific characteristics for cultivated sunflower improvement (SEILER, 2010). For development of new, high-yielding and stable sunflower hybrids by the method of interspecies hybridization, it is necessary to gain information on mode of inheritance and combining abilities of prospective inbred lines to be used as components (HLADNI *et al*., 2006). In sunflower breeding for productivity, it is important to find morphophysiological traits, which are easy to score and in the same time demonstrate a causal connection with the seed yield and therefore could be used as selection criteria (HLADNI *et al*., 2008).

Total seed number per head and the mass of 100 seeds are complex quantitative traits and important components of the sunflower seed yield. Breeding for the increase of the total seed number per head and the mass of 100 seeds significantly contributes to the increase of the sunflower seed yield. Total seed number per head is conditioned by the number of formed tubular flowers, attractiveness towards the pollinators, and the factors from the external environment at the time of the sunflower flowering and pollinization. In order to achieve high seed yield per surface unit it is necessary to increase the number of seeds per head up to more than 2000. Mode of inheritance of the number of seeds per head has been less studied with the sunflower plant.

The non-additive genetic effect in the inheritance of number of seeds per head was established by KUMAR *et al*. (1998), GOKSOY *et al*. (2004), BURLI *et al*. (2001)., The size i.e. the mass of 100 seeds affects the mode of sowing, sowing norm, the quality of the future hybrid seed and seed yield per area unit. Mass of 100 seeds is a very variable trait and can be found under both the influence of the genetic and the external environment factors. A bigger value of the non additive component of the genetic variance in the inheritance of the mass of 100 seeds in the F_1 generation has been determined by RATHER *et al*. (1998), KUMAR *et al*. (1998), while NAIK *et al*. (1999) state a bigger input of the additive component of the genetic variance in the inheritance of the 100 seeds.

In sunflower breeding for productivity, it is important to find morphophysiological traits, which are easy to score and in the same time demonstrate a causal connection with the seed yield and therefore could be used as selection criteria (HLADNI *et a*l., 2008b).

A significant positive interdependence of the total seed number per head and seed yield has been reported by PATIL *et al*., 1996, TAHIR *et al.,* 2002, DAGUSTU, 2002, RADIĆ, 2008. The number of seeds per head has a substantial direct effect on seed yield, as was determined by (TEKLEWOLD *et al*., 2000, DUŠANIĆ *et al*., 2004, BEHRADFAR, 2009). A high positive interdependence between the mass of 100 seeds and seed yield has been reported by GILL *et. al*., (1997), SINGH *et al*., (1998), ASHOK *et al*., (2000), TEKLEWOLD *et al*., (2001) in their papers.

The research goal in this paper is to examine the effect of the general combining abilities (GCA) of the new divergent inbreed lines made by interspecies hybridization, also examined were the specific combining abilities (SCA) of the F_1 hybrids, gene effect, components of the genetic variance, average contribution of lines (%), testers and their interaction in the expression of the total seed number per head and the mass of 100 seeds. Than to determine the interdependence between total seed number per head, mass of 100 seeds with seed yield per sunflower plant.

MATERIALS AND METHODS

For this research seven new divergent cms inbred lines (A) lines were used, three Rf restorers utilized as testers, and 21 F_1 hybrids. Female inbred lines developed from different populations produced by interspecies hybridization: NS-GS-1, NS-GS-2 (RES-834-1), NS-GS-3 (DEB-SIL-3672), NS-GS-4, NS-GS-5 (PRA-RUN-1321-1), NS-GS-6, NS-GS-7 (DES-1474-2) and restorer inbred lines with good combining characteristics (RHA-R-PL-2/1, RHA-N-49, RUS-RF-OL-168) were created at the Institute of Field and Vegetable Crops, Novi Sad.

Hybrids of the F_1 generation were created by crossing each tester with each, inbreed mother line. The experiment was set on the experimental field of the Institute of Field and Vegetable Crops at Rimski Šančevi in three repetitions in an experimental design as it is required by the method line x tester. The main sample for analysis of the examined trait was comprised from 30 plants (10 plants per repetition) taken from middle rows of each block. Total seed number per head was determined by the count of full seeds per head. Seed yield per plant was determined by counting of the full seeds after shelling of each head. Mass of 100 seeds was measured on the random sample of the absolutely clean and air dried seed. Total seed number per head was determined by the count of the full seeds per head. Seed yield per plant was determined by measuring of the total amount of seeds of the each plant acquired in free pollinization on a technical scale with the accuracy of 0.01 (g).

Determination of the middle values and correlation coefficient (r) as indicators of the interdependence between two variables was performed according to HADŽIVUKOVIĆ (1991). Analysis of the combining abilities was done by the method line x tester (SINGH and CHOUDHARY, 1976).

RESULTS AND DISCUSSION

The main task of sunflower breeding is to develop new hybrids with a high genetic potential for seed yield. In this paper two direct sunflower seed yield components have been studied total seed number per head and mass of 100 seeds.

Between the examined A-lines and Rf-tester lines and their F_1 hybrids significant differences have been determined in the total seed number per head and the mass of 100 seeds and the seed yield per plant (Tab.1).

The analysis of the combining abilities has shown that there significant differences between A-lines and Rf- tester lines when it comes to GCA for both traits. A highly significant positive value of GCA was demonstrated by A-line NS-GS-5, while the highly significant negative GCA value was demonstrated by inbreed line NS-GS-6 for both traits. With Rf tester lines a highly significant positive GCA for the total seed number per head is found with Rf-line RHA-N-49, while the mass of 100 seed was found with Rf-line RHA-R-PL-2/1. Rf-line RHA-R-PL-2/1 had a highly significant negative value for the total seed number per head, and for the mass of 100 seeds Rf-line RHA-N-49 (Tab.2).

Table 1. Mean values of total seed number per head, 100-seed mass and seed yield per plant in sunflower

No.	Parents and hybrids	TSN	100SM g	SY g
1	NS-GS-1	1033±8.2	5.0±0.08	35.6±1.46
2	NS-GS-2	1081±18.9	5.5±0.09	52.8±1.79
3	NS-GS-3	940±28.53	5.2±0.011	50.5±1.25
4	NS-GS-4	620±15.49	9.9±0.13	55.4±2.31
5	NS-GS-5	709±17.61	7.9±0.20	57.0±1.50
6	NS-GS-6	699±25.46	5.0±0.11	32.4±1.65
7	NS-GS-7	875±32.99	4.5±0.33	43.8±1.75
8	RHA-R-PL-2/1	614±21.00	4.9±0.07	30.1±1.19
9	RHA-N-49	806±29.51	2.8±0.05	23.7±1.08
10	RUS-RF-OL-168	969±23.68	3.0±0.05	25.5±0.86
11	1x8	1653±50.01	5.0±0.08	79.6±2.42
12	2x8	1596±38.18	5.2±0.09	82.2±2.65
13	3x8	1598±27.02	5.9±0.06	89.9±1.39
14	4x8	1559±64.03	7.9±0.11	111.1±2.67
15	5x8	2009±44.26	9.0±0.20	162.9±3.28
16	6x8	1390±61.82	5.2±0.12	79.0±3.18
17	7x8	1700±39.55	5.4±0.09	93.0±2.09
18	1x9	1996±61.98	4.7±0.09	91.8±3.48
19	2x9	209059.58	4.7±0.07	96.9±2.54
20	3x9	2121±50.89	5.2±0.12	106.2±2.65
21	4x9	1696±38.67	5.6±0.09	94.4±2.68
22	5x9	2026±72.78	6.4±0.11	117.0±3.71
23	6x9	2263±69.83	5.1±0.10	104.7±2.49
24	7x9	2071±69.06	5.3±0.09	100.4±2.23
25	1x10	1903±54.62	5.0±0.08	96.6±2.71
26	2x10	1738±47.23	4.8±0.011	81.7±2.49
27	3x10	1792±36.67	5.6±0.11	102.0±2.74
28	4x10	1521±37.50	6.6±0.13	103.3±1.81
29	5x10	1519±38.78	6.9±0.12	112.4±2.40
30	6x10	1716±54.71	5.5±0.10	87.4±2.45
31	7x10	1676±43.97	5.7±0.10	94.9±1.65
	LSD 0.05	99.72	0.15	3.16
	LSD 0.01	149.58	0.23	4.74

(*TSN*) *total seed number per head; (100SM) 100 seed mass; (SY) seed yield per plant*

Tab. 2. Values of GCA inbred lines and SCA hybrids for direct component of sunflower seed yield

	No.	Parents and hybrids	TSN	100SM
GCA	1	NS-GS-1	58.7**	-0,850
	2	NS-GS-2	15.9**	-0,847
	3	NS-GS-3	45.0**	-0,187
	4	NS-GS-4	-199.9	0.925**
	5	NS-GS-5	59.6**	1,683*
	6	NS-GS-6	-2.3	-0,470
	7	NS-GS-7	22.9**	-0,254
	8	RHA-R-PL-2/1	-148.4	0,471*
	9	RHA-N-49	245.5**	-0,446
	10	RUS-RF-OL-168	-97.1	-0,025
		LSD (1-7) 0.05	1.826	1.600
		LSD 0.01	2.739	2.000
		LSD (8-10) 0.05	1.196	0.330
		LSD 0.01	1.794	0.500
SCA	1	1x8	-49.4	-0.349
	2	2x8	-63.8	-0.216
	3	3x8	-90.6	-0.136
	4	4x8	115.6**	0.711**
	5	5x8	306.1**	1.065**
	6	6x8	-251.0	-0.517
	7	7x8	33.2**	-0.559
	8	1x9	-100.5	0.247
	9	2x9	36.4**	0.293**
	10	3x9	38.5**	0.086
	11	4x9	-142.0	-0.657
	12	5x9	-71.1	-0.540
	13	6x9	227.7**	0.278**
	14	7x9	10.9**	0.293**
	15	1x10	149.9**	0.102**
	16	2x10	27.3**	-0.076
	17	3x10	52.1**	0.050
	18	4x10	26.4**	-0.054
	19	5x10	-234.9	-0.526
	20	6x10	23.4**	0.239**
	21	7x10	-44.2	0.266
		LSD 0.05	3.16	0.15
		LSD 0.01	4.74	0.23
		GCA	3085.07	0.075
		SCA	27550.74	0.311
		GCA/SCA	0.11	0.24

Highly significant positive value SCA for total seed number per head is found with the following hybrid combinations NS-GS-5xRHA-R-PL-2/1, NS-GS-6xRHA-N-49, NS-GS-1xRUS-RF-OL-168,and for the trait mass of 100 seeds NS-GS-5xRHA-R-PL-2/1,NS-GS-4xRHA-R-PL-2/1,NS-GS-7xRHA-N-49

Hybrid combination NS-GS-5xRHA-R-PL-2/1 has manifested a highly significant positive value SCA for both traits (Tab. 2). The main role in the inheritance of total seed number per head and the mass of 100 seeds is played by the non-additive component of the genetic variance, which can be seen in the analysis of the combining abilities variance and the analysis of the components of the genetic variance. This confirms the relation GCA/SCA in the F_1 generation which is less than one (0.11; 0.24), (Tab. 2). This research is in coordination with, KUMAR *et a*l. (1998), BURLI *et al.* (2001), GOKSOY *et al*. (2004) for the total seed number per head and RATHER *et al*. (1998), KUMAR *et al*. (1998), for the mass of 100 seeds.

The largest average contribution in the expression total seed number per head was head by Rf-testers (55.8%) while for the mass of 100 seeds a more important contribution was given by A-line (70.6%), tab.3.

Table 3. Average contribution (%) of female lines and tester lines and their interactions to expression of total seed number per head and 100-seed mass

Average contribution	TSN	100SM
	%	%
Female line	12.9	70.6
Tester line	55.8	12.8
Line x tester	31.3	16.7

A strong positive correlation was determined between seed yield and number of seeds per head (0.376^{*}) and there was also a very strong positive interdependence between seed yield and the mass of 100 seeds (0.823^{**}), (Tab. 4). A large number of authors have established the existence of a strong and very strong positive interdependence between seed yield and total seed number per head (PATIL *et al*., 1996, TAHIR *et al*., 2002, DAGUSTU, 2002) and the mass of 100 seeds GILL *et a*l. (1997), ASHOK *et a*l. (2000), TEKLEWOLD *et al*. (2001), THITIPORN and CHIRAPORN (2008).

The determination of the mode of inheritance of the combining abilities and the interdependence of the yield components with the seed yield has allowed the creation of the new productive sunflower hybrids on the basis of interspecies hybridization. The data obtained in this research along with different data from the literature point out that the mass of 100 seeds and the total seed number per head are important components of the seed yield and an important selection criteria in sunflower breeding.

Table 4. Simple correlation coefficients of total seed number per head and 100-seed mass and seed yield per sunflower plant

Characteristic		SY
		Y
TSN	X_1	0.376*
100SM	X_2	0.823**

X - TSN (total seed number per head)
X_2 - 100SM (100-seed mass)
Y-SY (Seed yield per plant)

CONCLUSIONS

Significant differences were found among the A lines, Rf testers and their F_1 hybrids in total seed number per head and the mass of 100 seeds. Analysis of variance of the combining abilities revealed highly significant differences for GCA and SCA. Highly significant positive value GCA was demonstrated by A-line NS-GS-5 for both traits.

Hybrid NS-GS-5xRHA-R-PL-2/1 has the highest highly significant value SCA for both traits.

The main role in inheritance of the total seed number per head and the mass of 100 seeds is played by non additive component of the genetic variance which is confirmed by the GCA/SCA relation in F_1 generation that is less than one.

In sunflower breeding for a high genetic potential for seed yield, the emphasis should be on direct seed yield components which are strongly positively correlated with seed yield, namely total seed number per head and 100-seed weight.

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LINIJA X TESTER ANALIZA ZA KOMPONENTE PRINOSA SEMENA SUNCOKRETA I NJIHOVE KORELACIJE SA PRINOSOM SEMENA (*Helianthus annuus* L.)

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Izvod

Stvaranje novih hibrida suncokreta sa visokim genetskim potencijalom za prinos semena na osnovu interspecijes hibridizacije zahteva posedovanje informacija o načinu nasleđivanja i kombinacionim sposobnostima stvorenih inbred linija za ukupan broj semena po glavi i masu 100 semena. Pored ovoga, istraživanja međuzavisnosti komponenti prinosa i prinosa semena omogućavaju definisanjae svojstava koja imaju najveći uticaj na formiranje prinosa.

Pronađene su značajne razlike između A linija, Rf testera i njihovih F_1 hibrida u ukupnom broju semena po glavi i masi od 100 semena. Analizom varijanse kombinacionih sposobnosti uočene su visoko značajne razlike za OKS i PKS. Visoko značajnu pozitivnu vrednost OKS pokazala je A-linija NS-GS-5 za obe ispitivane osobine. Hibrid NS-GS-5xRHA-R-PL-2/1 ima visoko značajnu vrednost PKS za ukupan broj semena po glavi i masu 100 semena. Glavnu ulogu u nasleđivanju ukupnog broja semena po glavi i mase 100 semena igra neaditivna komponenta genetske varijanse, što je potvrđeno odnosom OKS/PKS u F_1 generaciji koji je manji od 1 (0.11, 0.24). Najveći prosečan doprinos u ekspresiji ukupnog broja semena po glavi (55.8%) imali su Rf testeri, dok je za masu od 100 semena mnogo važniji doprinos A-linija (70.6%). Jaka pozitivna međuzavisnost utvrđena je između prinosa semena i ukupnog broja semena po glavi (0.376^{*}) i vrlo jaka pozitivna međuzavisnost utvrđena je između prinosa semena i mase 100 semena (0.823^{**}). Ova istraživanja mogu biti značajna za stvaranje novih visoko prinosnih hibrida suncokreta na bazi interspecijes hibridizacije.

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