PERIODICUM BIOLOGORUM
VOL. 110, No 3, 277–284, 2008

UDC 57:61
CODEN PDBIAD
ISSN 0031-5362

Original scientific paper

Combining abilities and gene effects on sunflower grain yield, oil content and oil yield

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Key words: sunflower, grain yield, oil content, oil yield, combining ability, correlations

Received April 5, 2006.

Abstract

Background and Purpose: *The purpose of this research was to estimate general (GCA) and specific combining ability (SCA) for grain yield, oil content and oil yield of sunflower inbred lines, to estimate the portion of genetic and additive component of variance, to determine relationships between inbred lines, two-line (SC) and three-line hybrids (TWC), and to determine perspective parental lines and hybrids.*

Materials and Methods: *Six inbred lines were used in the research, 15 experimental SC (male sterile) hybrids, 15 experimental TWC hybrids and 3 recognized hybrids. Obtained results were processed by analysis of variance, linear correlation analysis, Griffing's diallel analysis, and estimation of genetic and additive variance.*

Results: *OS-1 line had the largest GCA effect for grain yield, oil content and oil yield. OS-1 A x OS-6 B combination had the highest SCA effect for grain yield, as well as for oil content and oil yield. Genetic variance was larger than environmental variance, and additive variance was larger than dominant for all traits. High significant positive correlations were found for oil content among SC and their TWC hybrids. Line OS-1 transferred its positive effects for oil content and yield in TWC hybrids.*

Conclusions: *Line OS-1 has desirable agronomic traits and could be used in future breeding process aimed at genetic improvement of sunflower. Additive variance was greater for all investigation traits. Lines with the best GCA for oil content kept retained? these characteristics in SC and TWC hybrids. Lines with the best GCA did not give (produce?) hybrids of the best SCA and opposite. In the case of grain and oil yield a significant correlation between SC and their TWC hybrids did not exist, although it did for oil content . The best hybrid for commercial production was (OS-1A x OS-5B) x RF-28.*

INTRODUCTION

The sunflower breeding program at the Agriculture Institute Osijek has been aimed at developing hybrids that would have as many improved agronomic traits as possible *(1)*. It has been carried out in the direction of two-line (SC, single cross) and three-line (TWC, three way cross) hybrids by utilizing cytoplasmic male sterility and restorer lines. Bochkovoy *et al*. *(2)* reported that three-line hybrids had higher stability than two-line hybrids. The primary goal in developing new hybrids

TABLE 1

Grain yield, oil content and oil yield in SC hybrids, 2003.

Hybrids	Grain yield (kg/ha)		Oil content (%)		Oil yield (kg/ha)	
	Osijek	Đakovo	Osijek	Đakovo	Osijek	Đakovo
OS-1 A x OS-2 B	2983.3 **	2850.1 **	41.17 **	41.86 **	1231.2 **	1192.9 **
OS-1 A x OS-3 B	2842.9 *	2803.9 **	43.15 **	42.33 **	1230.0 **	1186.8 **
OS-1 A x OS-4 B	2682.2	2673.3 **	42.71 **	38.39	1142.1 **	1023.0 **
OS-1 A x OS-5 B	2828.6 *	2884.7 **	43.34 **	44.03 **	1221.5 **	1269.4 **
OS-1 A x OS-6 B	3171.5 **	2888.1 **	45.14 **	43.07 **	1427.8 **	1242.2 **
OS-2 A x OS-3 B	2321.5	2480.1 **	36.28	33.86	843.2	838.3
OS-2 A x OS-4 B	1975.1	1903.1	34.84	32.68	688.2	623.4
OS-2 A x OS-5 B	1846.5	1694.4	34.10	33.50	628.8	576.5
OS-2 A x OS-6 B	1525.0	1600.1	33.85	32.83	517.3	522.3
OS-3 A x OS-4 B	1964.4	1639.7	34.31	34.78	675.2	568.2
OS-3 A x OS-5 B	1853.6	2061.3	34.70	32.46	645.0	669.2
OS-3 A x OS-6 B	2321.5	2317.2	35.48	33.71	824.3	781.8
OS-4 A x OS-5 B	1802.6	1572.7	34.36	30.82	619.5	486.1
OS-4 A x OS-6 B	1807.2	1503.7	35.28	30.93	637.5	463.3
OS-5 A x OS-6 B	1492.2	1552.8	32.29	32.29	490.3	501.8
Mean	2228.0	2161.7	37.44	35.84	854.8	796.3
LSD 0.05	502.7	198.8	1.75	3.65	205.0	91.1
LSD 0.01	672.1	265.8	2.34	4.88	274.1	121.7

**, – significant at P≤0.01

*, – significant at P≤0.05

is increasing grain yield and oil content. Grain yield and grain oil content have a crucial role in oil yield *(3, 4)*.

Estimation of gene effects could be done by analyzing combining ability values based on F_1 mean values. GCA is indication of additive, and SCA of non-additive genetic variance *(5, 6)*. Jukić *(7)* reported that sunflower hybrids had the highest positive value of SCA for oil yield where one line had distinctly high GCA and another distinctly low GCA. Marinkovic *(8)* analyzed gene effects of inbred lines by diallel crosses, and reported that additive effect was more important for oil content inheritance than non-additive effect. Preliminary testing of combining ability by top-cross method has been in use since Johnes *(9)*. Based on this procedure, our objective was to estimate in our research the relationship between SC and TWC hybrids with the same fertility restorer pollinator line, where the aforementioned SC hybrids were mother's component.

The purpose of this research was to study sunflower inbred lines combining ability effects for grain yield, oil content and oil yield, to estimate the portion of genetic and additive component of variance, to determine perspective parental lines and hybrids, and to determine/reveal/establish relationships between inbred lines, two-line and three-line hybrids.

MATERIALS AND METHODS

Diallel cross 6x6 without reciprocals, with sunflower inbred lines was carried out in 2002. In 2003, fifteen two-line F_1žs (SC hybrids) were grown in an experiment, Randomized Complete Block Design with four replications, at two locations (Osijek and Đakovo). In Osijek, the trial was conducted on fertile soil (eutric cambisol) and in Đakovo on less fertile soil (hydromorphous black soil). The fertility restorer line RH-28 with recessively controlled branching, was grown around each trial. In 2004, 15 three-line hybrids from the 2003 F_1žs x RH-28 crosses and three (of?) the most grown commercial hybrids of the Agricultural Institute Osijek (Table 6), were grown in RCBD with four replications at the same two locations. There were four 22 plant rows per plot in each experiment. Forty plants per plot (two middle rows without border plants) were analyzed.

Grain yield was calculated on the basis of 9% moisture and 2% impurity, oil content was measured by NMR Newport 4000 analyzer, and oil yield was calculated from grain yield and oil content. The significance of difference between the mean values of hybrids was tested by LSD test in 2003 in comparison to the trial mean, and in 2004 in comparison to the registered hybrid Orion.

TABLE 2

GCA effects of inbred lines for grain yield, oil content and oil yield in SC hybrids.

Lines	Grain yield		Oil content		Oil yield	
	Osijek**	Đakovo**	Osijek**	Đakovo**	Osijek**	Đakovo**
OS-1	843.15 **	820.91 **	7.08 **	7.63 **	494.66 **	483.14 **
OS-2	–121.14	66.15˙	1.74˙˙	1.11	91.32˙˙	57.09˙˙
OS-3	40.49	121.48**	0.82˙˙	0.51	14.06	15.63
OS-4	–227.38˙˙	380.96˙˙	1.43˙˙	2.89˙˙	127.87˙˙	204.43˙˙
OS-5	329.16˙˙	256.65˙˙	1.95˙˙	1.52˙	167.22˙˙	119.70˙˙
OS-6	–205.26˙	238.63˙˙	1.13˙˙	1.59˙˙	94.19˙˙	117.56˙˙
Se [g (i)]	80.39	31.80	0.28	0.58	32.78	14.56
LSD 0.05	162.39	64.24	0.57	1.17	65.56	29.41
LSD 0.01	217.05	85.86	0.76	1.57	88.51	39.31

**, ˙˙ – significant at P ≤ 0.01

*, ˙ – significant at P ≤ 0.05

Analysis of combining abilities was done according to Griffing *(10),* method IV, model I. Differences between the combining abilities effects were tested on the basis of standard errors according to Singh and Chondhary *(11)*. Genetic variance (V_G) between two-line hybrids was estimated according to Singh *et al. (12)*. Calculation of additive (V_A) and dominative (V_D) variance was done on the basis of the general (GCA) and specific combining ability (SCA) results.

Statistical analysis was performed by SAS software *(13),* and software for analysis of diallel crosses *(14)*. Relationships between SC and TWC hybrids were evaluated by application of linear correlation coefficients, and effects of those lines in TWC hybrids, according to similar methodology used for GCA evaluation in SC hybrids.

RESULTS

Grain yield

Average grain yield in 2003 of two-line hybrids in Osijek was 2228.0 kg/ha, and in Đakovo 2161.7 kg/ha (Table 1). The highest grain yield in Osijek and Đakovo was determined for OS-1 A x OS-6 B (3171.5 and 2888.1 kg/ha). Apart from that hybrid, significantly higher (p=0.01) grain yield in comparison to the experimental mean, was determined in Osijek for hybrid OS-1 A x OS-2 B, and in Đakovo hybrids OS-1 A x OS-2 B, OS-1 A x OS-3 B, OS-1 A x OS-4 B, OS-1 A x OS-5 B and OS-2 A x OS-3 B.

Analysis of combining ability has shown very significant differences for GCA. The best general combiner for grain yield was OS-1 on the both locations (Table 2). This line is considered as a good general combiner for grain yield and therefore can be used in further breeding programs. For SCA, very significant differences were found only in Đakovo. From the total of 15 values, four were highly significant (p=0.01) positive (OS-3 A x OS-6 B, OS-2 A x OS-3 B, OS-2 A x OS-4 B, OS-1 A x OS-5 B) (Table 3).

In Đakovo, genetic variance was significantly larger than environmental variance for grain yield. Also, a part of additive genetical variance component was higher than dominance variance (Table 4). Analysis of additive and dominant effects was not carried out for Osijek, because significant differences in SCA effects were not found.

Analysis of grain yield in 2004 (Table 5) showed significant differences among genotypes at both locations. Average grain yield in Osijek was 4986.9 kg/ha, and 3753.4 kg/ha in Đakovo. By testing the significance of differences between average values of hybrids it was found that only H-4 hybrid [(OS-1 A x OS-5 B) x RF-28] showed significant values (p=0.05) in relation to the control hybrid in Osijek. Ten hybrids had exceptionally good (over 5 t/ha), but not significantly better, grain yield than the control , and among them seven were experimental hybrids. In Đakovo, four hybrids (Fakir, Olio, H-4 and H-5 [(OS-1 A x OS-6 B) x RF-28]) had higher grain yield than the control, and among them only Fakir had significantly higher grain yield.

For grain yield, the line OS-1 and line OS-5 showed a highly significant positive (p=0.01) effect in TWC hybrid combinations only in Đakovo (Table 6). The correlation between SC and TWC hybrids for this trait was low (from -0.18 to 0.45) and not significant (Table 7).

Oil content

In 2003 significant differences among two-line hybrids in oil content were found at both experimental locations. The average oil content in Osijek was 37.44%, and in Đakovo 35.84% (Table 1). OS-1 A x OS-6 B (45.14%) had the highest oil content in Osijek , and

TABLE 3

SCA effects of crosses for grain yield, oil content and oil yield in SC hybrids

Hybrids	Grain yield		Oil content		Oil yield	
	Osijek^{ns}	Đakovo**	Osijek**	Đakovo^{ns}	Osijek*	Đakovo**
OS-1 A x OS-2 B	38.93	-67.93	-1.60	-0.49	-26.95	-29.54
OS-1 A x OS-3 B	–262.12	–301.76	–0.55	–0.62	–105.43	–108.34
OS-1 A x OS-4 B	–61.96	70.03	–0.37	–2.17	–79.45	–52.00
OS-1 A x OS-5 B	86.26	157.14**	0.77	2.09	39.26	109.60**
OS-1 A x OS-6 B	305.88	142.55*	1.77**	1.19	172.55**	80.28**
OS-2 A x OS-3 B	173.75	261.53**	1.40**	–0.35	93.77	83.40**
OS-2 A x OS-4 B	95.18	186.96**	0.57	0.85	52.55	88.55**
OS-2 A x OS-5 B	68.40	–122.15	0.35	0.29	32.59	–43.07
OS-2 A x OS-6 B	–376.26	–258.40	–0.71	–0.30	–151.97	–99.34
OS-3 A x OS-4 B	–77.14	–264.07	–0.88	2.35	–37.63	–39.37
OS-3 A x OS-5 B	–86.08	33.20	0.03	–1.34	–28.52	–23.09
OS-3 A x OS-6 B	258.60	271.10**	0.01	–0.03	77.8	87.40**
OS-4 A x OS-5 B	131.78	47.06	0.29	–0.60	59.79	13.87
OS-4 A x OS-6 B	12.13	–39.97	0.39	–0.42	4.73	–11.05
OS-5 A x OS-6 B	–200.36	–115.25	–1.44	–0.44	–103.11	–57.30
Se [s (i,j)]		53.96	0.47		55.64	24.71
LSD 0.05		109.00	0.95		112.39	49.91
LSD 0.01		145.70	1.27		150.23	66.72

**, – significant at P≤0.01

*, – significant at P≤0.05

ns – not significant

TABLE 4

Components of variance for grain yield, oil content and oil yield in SC hybrids.

Components of variance	Grain yield	Oil content	Oil yield	
	Đakovo	Osijek	Đakovo	Osijek
V_P	247754.78	14.37	85733.62	70561.17
V_E	19412.72	1.50	20636.69	4070.97
V_G	228342.06	12.87	65096.93	66490.20
V_{GCA}	178523.68	11.83	58290.30	59329.30
V_{SCA}	49818.38	1.04	6806.63	7160.90
V_A	357047.36	23.65	116580.60	118658.60
V_D	49818.38	1.04	6806.63	7160.90

OS-1 A x OS-5 B hybrid (44.03%) in Đakovo. Significantly higher (p=0.01) oil content than the experimental mean at both locations was found for OS-1 A x OS-6 B, OS-1 A x OS-5 B, OS-1 A x OS-3 B and OS-1 A x OS-2 B hybrids, and OS-1 A x OS-4 B hybrid only in Osijek.

Analysis of combining abilities with the aim of detecting lines which would be good combiners for oil content, showed highly significant differences (p=0.01) among the lines in GCA at both locations, and in SCA at location Osijek. Line OS-1 had a highly significant positive

TABLE 5

Grain yield, oil content and oil yield in TWC hybrids.

Hybrids	Hybrid combinations	Grain yield (kg/ha)		Oil content (%)		Oil yield (kg/ha)	
		Osijek	Đakovo	Osijek	Đakovo	Osijek	Đakovo
H-1	(OS-1A x OS-2B) x RF-28	4053.6	3996.0	43.94	39.12	1781.4	1563.2
H-2	(OS-1A x OS-3B) x RF-28	5232.1	3883.5	45.48	37.80	2376.5	1467.1
H-3	(OS-1A x OS-4B) x RF-28	4614.3	3367.5	44.40	37.31	2048.5	1253.7
H-4	(OS-1A x OS-5B) x RF-28	5550.0 *	4539.3	44.56	39.02	2472.5 *	1771.1
H-5	(OS-1A x OS-6B) x RF-28	5264.3	4292.5	44.93	37.35	2367.6	1595.4
H-6	(OS-2A x OS-3B) x RF-28	5017.9	3532.7	42.55	34.39	2135.1	1215.7
H-7	(OS-2A x OS-4B) x RF-28	5207.2	3104.9	42.61	33.92	2216.3	1054.9
H-8	(OS-2A x OS-5B) x RF-28	4946.5	3846.1	42.68	37.12	2109.7	1426.9
H-9	(OS-2A x OS-6B) x RF-28	4917.9	2786.0	40.95	34.57	2022.0	958.9
H-10	(OS-3A x OS-4B) x RF-28	5017.9	3376.9	42.55	35.00	2152.0	1179.7
H-11	(OS-3A x OS-5B) x RF-28	4996.4	2954.8	43.75	35.76	2187.7	1054.9
H-12	(OS-3A x OS-6B) x RF-28	4478.6	2617.1	43.19	34.98	1935.2	917.0
H-13	(OS-4A x OS-5B) x RF-28	4992.9	4139.8	42.26	35.15	2111.7	1461.7
H-14	(OS-4A x OS-6B) x RF-28	5221.5	3733.4	41.20	36.46	2150.8	1362.7
H-15	(OS-5A x OS-6B) x RF-28	5335.7	3808.5	43.18	34.66	2303.7	1321.1
FAKIR		5042.9	4821.5*	40.53	36.23	2043.2	1752.4
ORION		4717.9	4183.7	44.15	38.29	2085.7	1602.1
OLIO		5157.2	4577.6	46.29	41.96**	2384.0	1922.1*
Mean		4986.9	3753.4	43.28	36.61	2160.2	1382.2
LSD 0.05		823.7	601.9	1.79	2.09	371.0	247.2
LSD 0.01		1097.9	802.3	2.38	2.79	494.5	329.5

**, – significant at P≤0.01
*, – significant at P≤0.05

effect of GCA at both locations (Table 2). Highly significant differences in SCA were found only in Osijek. Among the 15 hybrids, two (OS-1 A x OS-6 B, OS-2 A x OS-3 B) were significantly highly (p=0.01) positive (Table 3).

Because significant differences in SCA effects were not found in Đakovo, analysis of additive and dominant effects was not performed for this location. In Osijek, genetic variance was significantly larger than environmental variance for oil content. Also, a part of additive genetic variance component is higher than dominance variance (Table 4).

In 2004 significant differences in oil content were found among the TWC hybrids at both locations (Table 5). Average oil content in Osijek was 43.28%, and in Đakovo 36.61%. Only the commercial hybrid Olio had significantly higher oil content value than the control hybrid Orion at both locations.

Besides the SC hybrids, the line OS-1 also gave a high significant positive effect for oil content in TWC hybrid combinations on both locations (Table 6), which showed that a distinctly positive GCA value in SC hybrids transferred also in combinations of TWC hybrids. This proves (confirms?) distinctly positive correlations (o n average 0.81) of this trait between combinations of SC hybrids in 2003 and TWC hybrid combinations in 2004 year with the same fertility restorer pollinator line, where the mentioned SC hybrids were mother's component (Table 7).

Oil yield

Two-line hybrids tested in 2003 had oil yield in Osijek of 854.8 kg/ha, and in Đakovo 796.3 kg/ha (Table 1). Hybrid OS-1 A x OS-6 B (1427.8 kg/ha) had the highest oil yield in Osijek , and OS-1 A x OS-5 B (1269.4 kg/ha) in Đakovo. Besides them, significantly higher (p=0.01) oil yields in Osijek, in comparison to the experimental mean, were determined for hybrids OS-1 A x OS-2 B,

TABLE 6

Effects of inbred lines for grain yield, oil content and oil yield in TWC hybrids.

Lines	Grain yield		Oil content		Oil yield	
	Osijek	Đakovo	Osijek	Đakovo	Osijek	Đakovo
OS-1	–58.65	521.45**	1.81**	2.43**	64.11	278.98**
OS-2	–201.49	–181.83˙	–0.84˙˙	–0.44	–131.44	–78.76˙
OS-3	–51.50	–406.99˙˙	0.36	–0.74˙	–0.95	–175.06˙˙
OS-4	26.20	–67.61	–0.76˙	–0.76˙	–27.75	–55.50
OS-5	218.16	323.87**	0.09	0.21	98.75	125.24**
OS-6	67.26	–188.89˙	–0.66˙	–0.71˙	–2.72	–94.90˙˙
Se [g (i)]		81.62	0.30	0.35		32.17
LSD 0.05		165.69	0.61	0.71		64.98
LSD 0.01		220.37	0.81	0.95		86.86

**, ˙˙ – significant at P≤0.01

*, ˙ – significant at P≤0.05

TABLE 7

Correlations between SC and TWC hybrids for grain yield, oil content and oil yield.

Correlation	Grain yield	Oil content	Oil yield
OS_SC x OS_TWC	–0.184	0.813**	0.198
Đ_SC x Đ_TWC	0.334	0.809**	0.572*
Đ_SC x OS_TWC	–0.179	0.820**	0.217
OS_SC x Đ_TWC	0.452	0.780**	0.602*

** – significant at P≤0.01

* – significant at P≤0.05

OS-1 A x OS-3 B, OS-1 A x OS-4 B, OS-1 A x OS-5 B, and in Đakovo OS-1 A x OS-2 B, OS-1 A x OS-3 B, OS-1 A x OS-4 B and OS-1 A x OS-6 B. This indicates that diverse materials were chosen for research, which was a precondition for analysis of combining abilities.

In this research, inbred lines showed very significant differences in GCA for oil yield. The best line was OS-1, which had a highly significant (p=0.01) positive GCA effect at both locations (Table 2). In SCA, highly significant differences (p=0.01) among hybrids were found at both locations in 2003. In Osijek, hybrid OS-1 A x OS-6 B had a highly significant positive effect (Table 3). In Đakovo, five hybrids had highly significant positive SCA values (OS-1 A x OS-5 B, OS-2 A x OS-4 B, OS-3 A x OS-6 B, OS-2 A x OS-3 B, OS-1 A x OS-6 B).

Genetic variance was larger (greater) than environmental variance, and additive variance was larger (greater) than dominant for oil yield (Table 4).

Analysis of variance of the trial from 2004 (Table 5) showed that among the three-line hybrids differences in oil yield were significant at both locations. Average oil yield in Osijek was 2160.2 kg/ha, and in Đakovo 1382.2 kg/ha. Only H-4 hybrid had significantly higher oil yield in Osijek than the control hybrid. This was largely influenced by high grain yield of the H-4 hybrid. In Đakovo, only hybrid Olio had significantly higher and two hybrids (H-4 and Fakir) slightly higher oil yield than the control.

For oil yield, the line OS-1 showed a high significant positive effect in TWC hybrid combinations only in Đakovo (Table 6). The correlation between SC and TWC hybrids for oil yield is less significant in relation to oil content (Table 7).

DISCUSSION

One of the most important components in oil yield realization of sunflower hybrids is grain yield. In the breeding procedure it is very important to know the combining abilities of inbred lines that are used as parents in hybrids.

Joksimović *(15)* and Marinkovic *(8)* reported that lines with good GCA gave higher yielding hybrids than lines with low GCA. In our research, hybrid OS-3 A x OS-6 B

had the biggest (largest) positive value of SCA for grain yield , where line OS-3 had distinctly high GCA, and line OS-6 distinctly low GCA. Hybrid OS-1 A x OS-3 B created from the lines with distinctly good GCA had the lowest value of SCA. This is in accordance with the results reported by Jukic *(6)* that some parents with low GCA produced hybrids with high SCA.

In phenotype variance, genetic variance was significantly larger than environmental variance. Additive and dominant part of the variance had influence on inheritance of grain yield, although the influence of the additive part of variance was greater. This corroborates the research of Sindagi *et al*. *(16),* who found that GCA was more important than SCA in the case of sunflower grain yield and, that the additive component of genetic variance was greater than non-additive variance. Masud *et al*. *(17),* who found that SCA was more important than GCA, obtained different results.

Oil content of grain can vary from 20 to 55%, and depends on hull to kernel ratio. According to Đakov *(18)* high oil sunflower varieties have higher kernel ratio than the low oil content varieties. Oil content is a quantitative trait under the high influence of environmental factors *(4, 19)*. Vranceanu and Stoenescu *(20)* reported that oil content in the kernel was controlled by few genes with dominant (or heterotic) effect. Fick and Miller *(3)* emphasized the concern of some sunflower breeders regarding the achievement of (very small) very minor progress in increasing oil content in sunflower inbred lines and hybrids. They questioned the biological limit of this trait. Skoric and Marinkovic in *(3)* reported that further increasing the oil content through breeding is possible.

The hybrid OS-1 A x OS-6 B had the highest positive value of SCA for oil content, where one line had distinctly high and the other distinctly low GCA. The hybrid OS-1 A x OS-2 B had the largest negative value of SCA for oil content where one parental line had also distinctly high positive GCA. In Đakovo differences of SCA were not significant although the hybrid OS-3 A x OS-4 B had a distinctly positive value.

Since GCA is an indicator of additive, and SCA of non-additive genetic variance, by analyzing genetic variance valuable information on gene effects can be obtained. Our results show that inheritance of oil content depend on the additive and dominant part of variance, although the additive part was larger. This indicated that progeny might highly resemble parents. Sindagi *et al*. *(16)* obtained similar results. However, other authors *(21, 22)* reported that non-additive gene effects had considerably greater influence on inheritance of oil content.

Oil yield is a result of grain yield and oil content of grain. Lines with high oil content, which flower early and are resistant to lodging abiotic and biotic stresses and have good combining ability are (suitable?) for eastern Croatia *(23)*. A model of sunflower hybrid that would have oil yield over 1800 kg/ha was suggested by Krizmanić and Martinčić *(24)* for sunflower breeding program in Osijek.

Hybrid OS-1 A x OS-6 B in Osijek, and OS-1 A x OS-5 B in Đakovo had the highest positive value of SCA for oil yield. In each hybrid one line had distinctly high GCA, and another distinctly low GCA. Similar results were reported by Jukić *(7)*. The most negative SCA value in Osijek was realized with the hybrid OS-2 B x OS-6 B, where both lines had highly significant negative GCA, and in Đakovo with the hybrid OS-1 A x OS-3 B where only one line had good GCA.

Ratio between genetic and environmental variance showed the importance of genetic variance in inheritance of oil yield. Additive gene effects had a more important role than the dominant one in inheritance of oil yield. Jukić *(7)* found that oil yield was dependent equally on additive and dominant component of genetic variance, and Joksimović *(15)* reported the prevalence of the dominant part of variance in inheritance of this trait.

Correlations between SC and TWC hybrids (have depended?) regarding the analyzed traits. For grain yield, the correlation was low and not significant, and we cannot predict grain yield of TWC hybrids based on SC hybrids. In the case of oil content, where we had a high significant positive correlation, we can see that a distinctly positive GCA value of the OS-1 line in SC hybrids has transferred also in combinations of TWC hybrids. For oil yield, we had significant medium positive correlations only in combinations where we had positive values for grain yield.

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