INHERITANCE OF SEED SIZE IN SUNFLOWER

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SUMMARY

There are several ways to increase yield per unit area. One of the most commonly used ways is to increase seed size and seed number per head while maintaining or raising the number of plants per unit area. Breeding for seed size may prove to be of great importance in increasing sunflower yields.

In order to study the mode of inheritance, components of genetic variance and combining ability for seed length, width and thickness (seed size), half diallel crosses of six divergent sunflowers inbred lines were made. The results have shown that there existed significant differences between the parent lines and their progenies regarding the mean values of the three traits.

In the inheritance of seed length, width and thickness, the additive gene effect proved to be of great importance since the value of the additive component (D) was considerably higher than that of the dominant component (H_1, H_2). The average degree of dominance indicates the presence of partial dominance in the inheritance of the three investigated traits in the progenies. The inbred line cms-13 had the highest positive values of general combining ability for all examined characters. The best specific combinations for all three investigated traits were R-15 x cms-19 and cms-77 x R-18.

INTRODUCTION

Sunflower seed yield is the product of three basic components: number of heads per unit area, number of seeds per unit area and the mass of single seed (*Merrien, 1992*). The commonly used method of yield increase involves the increases in seed number and size per head while simultaneously maintaining or increasing the number of plants per unit area. The ratio kernel vs. husk too plays an important role in increasing oil yield per unit area (*Škorić, 1996*). *Evans* (1981) points out that the key for increased genetic yield potential is an increased ability of the sink to compete with other organs for assimilates. The competitive ability depends on the relative size of organs, their relative distance from the source of assimilates and the relative orientation and volume of their vascular bonds. An increased sink should be put in balance with stem height and leaf architecture. The increase in the sink, i.e., the increase in the number and mass of grains per spike, ear, head, etc., is a way for further improvement (*Borojević, 1992*). The botanical name for the sink in the sunflower is 'achene', while the commonly used term is 'seed'. It is comprised of pericarp, meristem and the germ with cotyledons. For the purposes of oil industry, the seed is divided into husk and kernel with germ.

Đakov (1969) maintained that the best way to increase oil yield per unit area is to increase kernel yield per unit area, i.e., to increase the number of kernel's cells capable of oil accumulation. High oil and low oil varieties differ more in kernel yield than in oil-accumulating capacity of the kernel. According to *Škorić* (1974) seed yield and oil content in seed determine oil yield forming, while *Pathak* (1974) found a significant positive correlation between seed yield per plant and the mass of 1,000 seeds (kernels). Conversely, *Putt* (1943) reported negative correlations between kernel content and seed size, which occurred in nine out of eleven cases. It led him to believe that the selection for lines with small seeds may produce breeding material with high kernel content. However, according to *Pustovoit* (1966), the pioneer breeder of high oil sunflower varieties, seed quality, i.e., seed size is an important resource for increased yield. The selection for seed size, i.e., for increased mass of 1,000 seeds, may be an important asset in sunflower yield increase. Studies have shown that the increase in the mass of 1,000 seed by a single gram increases the yield by 40 kg/ha (*Morozov*, 1970). *Sun Lianging* (1996) believes that the selection for elongated seed and the mass of 1,000 seeds over 70 g leads to yield increase.

When breeding for seed size, it is well advised to keep in mind the findings of *Đakov* (1982) on high negative correlation between seed size and the number of seeds per plant - if an increased number of seeds are formed, each seed has a smaller portion of available resources. The regression between seed number and seed size has the form of a hyperbola, while the correlation between the two traits is negative. The additive component of genetic variance governed the inheritance of seed length and width, the non-additive component governed the inheritance of seed thickness (*Marinković and Škorić,* 1987). *Stojanova and Porisova* (1982) found a direct positive effect of seed length and thickness on seed yield level, and a direct negative effect of seed width on seed yield level. Seed length was negatively correlated while seed thickness was positively correlated with oil content in seed (*Marinković and Škorić*, 1988). Absence of negative correlation between oil content and seed size was reported by *Zali and Samadi*, (1978).

The objectives of this study were to establish the components of genetic variability for seed size (length, width and thickness) in sunflower and to examine the effects of general and specific combining abilities for these traits employing the diallel cross method.

MATERIALS AND METHODS

Six sunflower inbred lines (restorer lines R-15, R-17, R-18, and maintainer lines cms-13, cms-19 and cms-77) were selected for analysis of components of genetic variance, general and specific combining abilities for seed length, width and thickness. The lines were divergent regarding the investigated traits.

In the first year of the experiment (1997), the lines were diallelly crossed for n(n-1)/2 combinations, excluded reciprocals. The plants used as the female component were emasculated by hand, in early morning, before anthers open up. In 1998, the parents and the F_1 generation were sown in a comparative trial established after the system of random blocks in three replicates. The comparative trial was sown in the optimum period, on a well-prepared chernozem soil, at the Rimski Šančevi experiment field of the Institute of Field and Vegetable Crops. Intensive cultivation practices were applied in the trial. The harvesting was done by hand.

Thirty plants (ten plants per replicate) were taken from the comparative trial for analyses. The sampled plants were taken from inner rows. Seed length, width and thickness were measured with a micrometer caliper. Data were processed by MSTATC (Michigan State University, version 1986), Program for Quantitative Genetic Analysis IDC-AGRO/CuSof (Institute of Field and Vegetable Crops) and SYSTAT, Version 5.02, 1991, Systat Inc. The analysis of combining ability was done after *Griffing* (1956), method 2, model I, the analysis of components of genetic variance after the method of *Jinks* (1954), *Hayman* (1954) and *Mather and Jinks* (1971).

RESULTS AND DISCUSSION

The studied sunflower inbred lines differed significantly regarding seed length, width and thickness. Among the parent lines, the line R-15 had the smallest seed length, the line cms-13 the largest, 8.57 mm and 15.08 mm, respectively (Table 1). In the F_1 generation, the largest average seed length was found in the combination cms-77 x cms-13, the smallest in R-15 x R-18, 14.22 mm and 8.98 mm, respectively. The parents' mean values for seed width varied from 3.51 mm in the inbred line R-18 to 8.71 mm in cms-13. The largest average seed width in the F_1 generation was found in the hybrid combination cms-13 x R-17, the lowest in R-15 x R-18, 8.02 mm and 3.86 mm, respectively. The inbred line cms-13 had the highest mean value for seed thickness, the line R-18 the lowest, 4.71 mm and 2.41 mm, respectively. In the F_1 generation, the highest and the lowest mean values were found in the combinations cms-13 x R-17 and R-15 x R-18, respectively. Seed length, width and thickness were largest in the combinations of lines with highest mean values for these traits and vice versa.

The analysis of variance showed highly significant differences in GCA and SCA for all three traits (Table 2). Since GCA is considered as an indicator of additive genetic variance, and SCA an indicator of non-additive variance, i.e., of dominance and epistatis, it may be concluded that seed length, width and thickness are controlled by both additive and non-additive gene action. However, the additive effects are much higher, as indicated by the high values of the ratios GCA/SCA for all traits. The analysis of general combining ability showed that the parents with highest mean values were at the same time best general combiners for the studied traits. This is also an indication of the additive mode of inheritance of these traits. The inbred cms-13 had the highest positive values of general combining ability, which were highly significant for all three traits (Table 3). Also, the lines cms-77 and cms-19 were good general combiners for seed length, while the lines cms-19 and R-17 were good general combiners for seed width and thickness. The combinations R-15 x cms-19 and cms-77 x R-18 had highly significant values of specific combining ability for the studied traits (Table 3). These combinatiosn confirm once again that high SCA values are frequently obtained by crossing parents with high GCA (in our case cms-19 and cms-77) to parents with poor GCA R-15, R-18).

Table 4 shows the values of and ratios among the components of genetic variance for seed length, width and thickness. The values of the additive component (D) being much higher than the values of the dominant component (H_1, H_2), it may be concluded that, when all combinations are taken into account, the additive gene effect is more important than the non-additive effect in the inheritance of the studied traits. These results are not in full agreement with the results of *Marinković and Škorić*(1987) who found the additive gene action to control the inheritance of seed length and width and the non-additive gene action to control the inheritance of seed thickness. The F value was positive in all cases, indicating the predominance of dominant over the recessive genes. This was further confirmed by the frequencies of dominant (u) and recessive alleles (v), the former being higher for all three traits. The dominant and recessive alleles were not evenly distributed among the parents since the values of $H_2/4H_1$ were not equal to 0.25. The ratio Kd/Kr was larger than unity in all parents and for all traits, indicating the prevalence of dominant over the recessive alleles. As the average degree of dominance $[(H_1/D)^{1/2}]$ was invariably lower than unity, it may be concluded that, when all combinations are taken into account, seed length, width and thickness are inherited partially dominantly.

CONCLUSION

The obtained results indicate that the studied lines differed significantly in the investigated traits. Significant differences in mean values were also found among parent lines and hybrids. Both additive and non-additive component of genetic variance were important for the inheritance of seed length, width and thickness. However, the ratio between the components indicates that the additive gene action prevails over the non-additive one. This is in full agreement with the results of the analysis of components of genetic variance, which indicated the preponderance of the additive component over the dominant component. The line cms-13 was the best general combiner for the investigated traits; the combinations R-15 x cms-19 and cms-77 x R-18 were the best specific combiners. When all combinations are taken into account, seed length, width and thickness are inherited partially dominantly.

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Table 1 - Mean seed length (SL), seed width (SW) and seed thickness (ST) of parents (diagonal) and F_1 generation (upper right) for a 6 x 6 diallel cross in sunflower (values are totaled over three replications)

Parent	Character	Parent					
		R-15	cms-77	cms-19	cms-13	R-17	R-18
R-15	SL	8.57	10.96	10.82	11.86	10.09	8.98
	SW	3.58	5.70	6.35	5.79	5.23	3.86
	ST	2.52	3.79	3.92	3.90	3.43	2.53
cms-77	SL		12.42	12.29	14.22	12.11	11.51
	SW		5.18	5.69	7.19	6.65	5.57
	ST		2.92	3.48	3.58	4.23	3.42
cms-19	SL			11.42	13.80	11.62	10.48
	SW			5.68	7.51	6.52	5.97
	ST			3.45	3.96	3.87	3.44
cms-13	SL				15.08	13.20	12.12
	SW				8.71	8.02	6.12
	ST				4.71	4.42	3.58
R-17	SL					10.24	9.54
	SW					5.81	4.48
	ST					3.62	2.28
R-18	SL						9.19
	SW						3.51
	ST						2.14

Table 2 - Analysis of variance of combining ability for seed length (SL), seed width (SW) and seed thickness (ST)

Source of variance	Character	Degrees of freedom	Mean of squares	Fe	F 0.05	F 0.01
GCA	SL	5	11.52	589.11	3.51	2.45
SCA		15	0.13	6.61	2.55	1.94
E		40	0.02			
GCA/SCA			88.61			
GCA	SW	5	6.04	503.05	3.51	2.45
SCA		15	0.41	34.03	2.55	1.94
E		40	0.01			
GCA/SCA			14.73			
GCA	ST	5	1.19	165.71	3.51	2.45
SCA		15	0.15	21.27	2.55	1.94
E		40	0.01			

Table 3 - Combining ability for seed length (SL), seed width (SW) and seed thickness (ST)

Parent and hybrid	SL	Rank	SW	Rank	ST	Rank
GCA values						
R-15	-1.303	6	-0.866	5	-0.259	5
cms-77	0.697	2	0.013	4	-0.011	4
Cms-19	0.240	3	0.296	2	0.111	3
Cms-13	1.885	1	1.376	1	0.556	1
R-17	-0.404	4	0.185	3	0.173	2
R-18	-1.115	5	-1.004	6	-0.570	6
SE (gi)	0.045		0.035		0.027	
LSD 5%	0.141		0.111		0.086	
1%	0.180		0.148		0.115	
SCA values						
R-15 x cms-77	0.096	10	0.694	4	0.536	3
R-15 x cms-19	0.413	2	1.060	1	0.538	2
R-15 x cms-13	–0.185	14	–0.583	15	0.076	7
R-15 x R-17	0.331	4	0.049	8	–0.005	10
R-15 x R-18	–0.068	11	–0.133	12	–0.168	12
cms-77 x cms-19	–0.120	13	–0.478	13	–0.144	11
cms-77 x cms-13	0.172	9	–0.058	10	–0.219	13
cms-77 x R-17	0.348	3	0.590	6	0.540	1
cms-77 x R-18	0.452	1	0.695	3	0.473	4
cms-19 x cms-13	0.205	8	–0.028	9	–0.234	14
cms-19 x R-17	0.318	5	0.180	7	0.065	9
cms-19 x R-18	0.238	7	0.811	2	0.368	5
cms-13 x R-17	0.257	6	0.593	5	0.160	6
cms-13 x R-18	–0.119	12	–0.115	11	0.067	8
R-17 x R-18	–0.410	15	–0.567	14	–0.251	15
SE (ij)	0.102		0.080		0.062	
LSD 5%	0.346		0.271		0.210	
LSD 1%	0.463		0.363		0.281	

Table 4 - Components of genetic variability in sunflower

Component	Character		
	Seed length	Seed width	Seed thickness
D	7.59	3.61	0.83
H_1	0.51	1.50	0.55
H_2	0.40	1.33	0.46
F	0.65	0.92	0.38
E	0.01	0.01	0.01
$H_2/4H_1$	0.23	0.22	0.70
U	0.65	0.67	0.30
V	0.35	0.33	0.21
$(H_1/D)^{1/2}$	0.26	0.64	0.82
Kd/Kr	1.39	1.49	1.79