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Original article

Components Related to Higher Head Diameter, Heterosis and Type of Inheritance in Oil Seed Sunflower (*Helianthus Annuus* L.)

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Abstract

The head diameter in sunflower is of great importance, as it is directly related to the productive potential of the plants. A larger diameter usually provides a greater number of seeds, which leads to an increase in yield and oil yield. In addition, this morphological trait is an indicator of the efficiency of photosynthetic activity and nutrient uptake during the growing season. Head diameter is widely used as a selection criterion, as it is characterized by relatively high heritability and stability under different environmental conditions, which makes it a suitable indicator for the evaluation and selection of high-yielding genotypes. The aim of this investigation was to study the variation of the head diameter depending on the environmental changes, the type of inheritance and the heterosis effect in the hybrid combinations. The head diameter of the is a key breeding trait in sunflower, closely related to the yield and productive potential of the plants. The head diameter is determined by both genotypic characteristics and environmental conditions, and in the studied hybrid combinations it shows relative stability. This allowed the conclusion, that hybrid combinations 2008A x 100R, 2008A x 85R and 2008A x 84R possessed good to changeable environments according to this parameter. A significant correlation in the fertility restorer lines was obtained between head diameter and percent of protein and 1000 kernel weight. Similar direct effect was observed in the sterile lines as well according to number of leaves per plant. The inheritance of the parameter head diameter in the hybrid combinations varied from incomplete dominance to intermediary and over dominance and depended on the accumulation and recombination of genes inherited from the parental forms. Concerning heterosis, (best-parent and mid-parent), considerable dynamics was observed, which was conditioned by the high values of one or both parents involved in the hybrid combination.

Keywords: Sunflower, Head Diameter, Type of Inheritance, Heterosis

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INTRODUCTION

The head diameter and number of seeds per plant, kernel weight per plant and 1000 kernel weight are among the most important influencing directly the yield per plant and the yield per unit area. The formation of the head coincided with the months of vegetative growth, which were not favorable with regard to the climatic conditions and the plants were subjected to ecological stress.

Previous studies have indicated that this morphological trait is highly dependent on both genotype and environmental influences. The formation of large inflorescences with a large number of embryo florets was mostly determined by the favorable conditions for the development of the young plants from leaf formation stage to mass flowering stage. Branching is a genetic trait, but it is also induced by stress.

The duration of the period from the beginning of head formation to mass flowering depended on the cultivar, the hybrid and the climatic conditions. The head diameter was also significantly affected by the crop density. According to (Miller and Fick 1997), the head diameter and its size are strongly influenced by the genotype, the soil moisture and the soil fertility.

According to (Tavolzhanskiy 2000), the head diameter is influenced to the highest degree by the size and area of leaves. For the expression of the hybrid power (heterosis) in $F_{1,}$ it is necessary to find the proper combination of parents, which are ecologically and geographically distant, with valuable qualitative and quantitative parameters, since this phenomenon does not always occur (Hladni et al., 2007, Valkova D., 2013; Nenova et al., 2005). A peculiarity of the qualitative parameters is their constant variation due to two factors – the large number of genes determining it and the effect of the environment of them (Genchev et al, 1975).

MATERIALS AND METHODS

Material

The study included 5 sterile lines (217A, 813A, 1017A, 2003A, 2008A), 11 fertility restorer lines (84R, 85R, 87R, 88R, 89R, 97R, 138R, RW666) and 23 hybrid combinations (217A x 84R, 217A x 85R, 217A x 87R, 217A x 88R, 217A x 97R, 217A x 98R, 217A x 99R, 217A x 100R, 217A x RW666, 1017A x 84R, 1017A x 87R, 1017A x 98R, 1017A x 99R, 813A x 98R, 813A x 99R, 813A x 100R, 2003A x 84R, 2003A x 88R, 2003A x 98R, 2003A x 99R, 2003A x 100R, 2008A x 84R, 2008A x 85R, 2008A x 98R, 2008A x 99R, 2008A x 100R).The investigated lines were sown in three replications, the plot size being 10.25 m^2 The field experiment was carried out in the trial field of Dobrudzha Agricultural Institute – General Toshevo (DAI) during 2012 – 2014 according to a conventional technology for growing of sunflower (Georgiev et al., 1997).

METHODS

Two-way dispersion analysis (ANOVA – analysis of variances) was applied. Factors is Genotype, Year, Genotype x Year. The inheritance d/a was calculated for generation F_1 through the coefficient of (Mather and Jinks 1982); the occurrence of heterosis was estimated according to (Omarov 1975).

RESULTS AND DISCUSSION

The dispersion analysis carried out (Table 1) revealed different response of the fertility restorer lines during the period of investigation (2012 – 2014). The effect of the climatic conditions was significant at p=0.1 of the alternative hypothesis.

The difference in the genetic potential was significant at p=0.1. Based on the obtained mean values, the lowest values of this parameter were registered in fertility restorer lines 84R (9 cm), 88R (9 cm), 138R (9 cm). The highest values of parameter head diameter were found in the following fertility restorers: 99R (12.7 cm), 98R (12.2 cm) and in line 100R (11.3 cm). During the years of investigation, the parameter varied from 16 cm in 2012 to 10 cm in 2015. This difference in the head diameter was due to the unfavorable climatic conditions (rainfalls and temperature) during head formation. The maximum values of this parameter for all genotypes were registered in 2012 due to the fact that in that year the rainfalls during the growing of the head were the highest.

Table 1. Dispersion analysis of parameter head diameter in fertility restorer lines

Source of Variation	SS	df	MS	F	P-value	F crit
Genotype	439.49	10	43.94	23.2	7.47E-36	1.84
Year	1825.29	3	456.32	241.27	8.8E-115	2.38
Genotype x Year	510.90	40	12.77	6.75	2.41E-27	1.41
Error	936.2	495	1.89			
Total	3711.89	549				

(Skoric et al. 1989, 2002) found that plant height, the size and form of head, the position of the stem, the number of leaves and their size play an important role for the optimal plant architecture of the sunflower hybrid. When developing self-pollinated lines, selection is carried out according to the following parameters: combining ability, plant height, head diameter, vegetative growth, seed shedding, resistance to lodging, seed yield per plant, 1000 kernel weight, oil content in seed, protein content, resistance to diseases and *Orobanche* (P. Petrov et al., 1984).

The parameter head diameter varied according to the genotype and the environment, remaining stable in the obtained hybrid combinations. This allows the conclusion that hybrid combinations 2008A x 100R, 2008A x 85R and 2008A x 84R possess good ecological stability to the changeable environment according to this parameter. A significant correlation was found in the fertility restorers between head diameter and the percent of protein and 1000 kernel weight. Such a direct effect was also observed in the sterile lines according to the number of leaves per plant.

The inheritance of the head diameter in the hybrid combinations varied from incomplete dominance to intermediate and super dominance and depended on the accumulation and recombination of genes inherited from the parental forms. Concerning heterosis (best parent and mid parent), significant dynamics was observed, which was conditioned by the high values of one or both parents involved in the hybrid combination.

Table 2. Dispersion analysis of parameter head diameter in sterile lines

Source of Variation	SS	df	MS	F	P-value	F crit
Genotype	575.1	4	143.782	11.86977	1.4E-08	2.42184
Year	1818.9	3	606.300	50.05228	1.42E-23	2.65479
Genotype x Year	958.4	12	79.8625	6.59294	1.01E-09	1.80628
Error	2180.4	180	12.1133			
Total	5532.8	199				

The difference by this parameter in the genetic potential of the investigated sterile A-lines (Table 2) was statistically significant at p=0.1 of the alternative hypothesis. The interaction genotype x climatic conditions was with the same level of significance. The highest was the statistical significance (p=0.1, alternative hypothesis) of the effect of the climatic conditions. It was found during the study, that the parameter head diameter changed according to the climatic conditions of the year (temperatures and rainfalls), being from 28 cm in 2012 to 15 cm in 2014 in line 217A.

Similar variation of this parameter was found in line1017A – from 25 cm in 2012 to 16 cm in 2014. Line 813A was with lower variation among the investigated five sterile lines; this line was characterized by high adaptability to changeable environments. The highest value for head diameter was established in 2012 in lines 217A (28 cm), 2003A (26 cm) and 2008A (24 cm). In lines 2008A (11 cm), 2003A (14 cm) and 1017A (16 cm), the lowest values of this parameter were registered in 201.

Table 3. Dispersion analysis of the parameter head diameter in hybrid combinations

Source of Variation	SS	df	MS	F	P-value	F crit
Genotype	1468.28	77	19.0686	2.85846	8.28E-13	1.3027
Year	1357.88	3	452.627	67.8506	5.53E-38	2.6191
G x Y	5224.7	231	22.6177	3.39048	1.63E-33	1.1914
Error	4162.66	624	6.67094			
Total	12213.5	935				

The dispersion analysis presented in (Table 3) shows that the experiment was properly conducted and the results can be analyzed specifically. The parameter head diameter in all hybrid combinations was with the lowest values in 2015 due to the lower precipitation from emergence to flowering. Among the investigated hybrid combinations, high variation was not determined for the parameter head diameter over years in comparison to the parental lines, which was an important prerequisite for their adaptability to ecological stress. The results presented in (Figure 5) show that averaged for the four years of investigation in some hybrid combinations in the crossing of the same female sterile line to different male fertile lines (217A x 98R, 217Ax 99R, 2003A x 98R, 2003Ax 99R, 2008A x 100R и 2008A x 85R), the mean values of the head diameter were almost the same.

This indicated that the two fertility restorers were genetically close. The largest head diameter was obtained in the hybrid combinations involving lines 217A, 2003A and 2008A as female components. The average values showed that the hybrid combinations with the largest head diameter were 217A x 100R (21.4 cm), 2003A x 100R (21.2 cm), 813A x 99R (19.7 cm).The lowest values of this parameter were registered in crosses 813A x 84R (18.4 cm) and 1017A x 87R (18.6cm). The development of high-yielding hybrid sunflower varieties is a priority of modern sustainable agriculture. The contemporary hybrids combine high yield, low moisture at harvesting, resistance to stress factors such as drought, high temperatures, diseases and broomrape (Dozet, 1990; Hladni, 2010; Georgiev et al., 2014; Nenova, 2019).

The correlation analysis on 23 hybrid combinations (Table 4) revealed positive correlations of head diameter (0.467*) with plant height. A high correlation coefficient was found between weigh of seed per plant (0.645**), plant height and head diameter (0.501**). Seed yield per unit area was influenced positively by stem diameter (0.386*), weight of seed per plant (0.314*) and 1000 kernel weight (0.505**). The following authors also obtained similar results: (Ahmad et al., 1991; Marinkovic, 1992; Chikkadevaiah et al., 2002; Satjawattana, 2005; Hladni et al., 2006; Srimuenwai, 2006; Kaya et al., 2007). A positive correlation was found between number of leaves and plant height (0.842**), head diameter (0,482*) and 1000 kernel weight (0.339*). According to (Tavolzhanskiy 2000), the head diameter is most affected by the size and area of leaves. Low correlation values of head diameter were found with leaf area (0.197) and seed yield (0.157).

The low correlation coefficient at the genotype level proved that the inheritance of the studied parameters is controlled by different genes, and the climatic conditions in the individual years had significant effect for the larger head diameter. In most genotypes, there was no pleiotropy and gene linkage, and each trait was controlled by different genes, which acted independently.

Figure 1. 2008A x 100R

Figure 2. 2008A x 85R

Figure 3. 2003A x 100R

Figure 4. 2008A x 99R

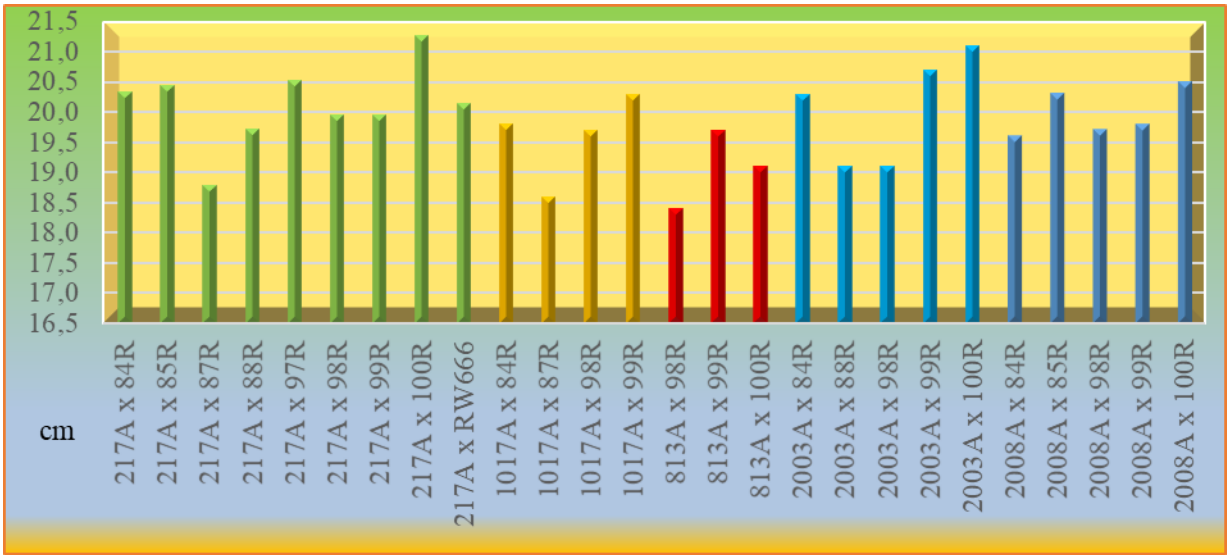

Figure 5. Mean values of parameter head diameter in hybrid combinations during 2012-2014

Figure 6 shows the type of inheritance of the parameter "head diameter" in eight hybrid combinations. In two of the hybrid combinations (2003A x 100R, 2008A x 100R), there was super dominance resulting from the accumulation and recombination of genes from the two parents in F_1 hybrids. The two parents, which participated in these crosses, were with high values of this parameter.

In two hybrid combinations (813A x 100R и 2008A x 98R), intermediary inheritance was determined tending towards dominant inheritance of this parameter. In these hybrid combinations, the values of one of the parents were higher than the values of the other parent. Similar results of super dominance and dominance of the parameter head diameter of the best parent, as well as non-additive way of inheritance of this parameter were also determined by Hladni et al. (2004) and Joksimovic et al. (2000).

Table 4. Phenotype correlations between 9 traits of 23 hybrid combinations

	PH	HD	DBS	NS/H	MS1P	M1000S	YIELD	LP	NLP
PH	1								
HD	0,467*	1							
DBS	0,261	-0,357	1						
NS/H	-0,692	-0,329	-0,311	1					
MS1P	0,645**	0,501**	0,209	-0,73	1				
M1000S	0,329*	-0,219	-0,315	-0,226	0,141	1			
YIELD	0,012	0,157	0,386*	-0,097	0,314*	0,505**	1		
LP	-0,408	0,197	-0,179	0,376*	0,047	-0,529	0,432*	1	
NLP	0,842***	0,482*	0,131	-0,886	0,78	0,339*	-0,02	-0,196	1

HD = head diameter,PH = plant height, NS/H = number of seeds per head, M1000S= 1000 seed weight, MS1P=seed weight per plant,Yield= per dka, LP= Leaf area, NLP=Number of leaves per plant

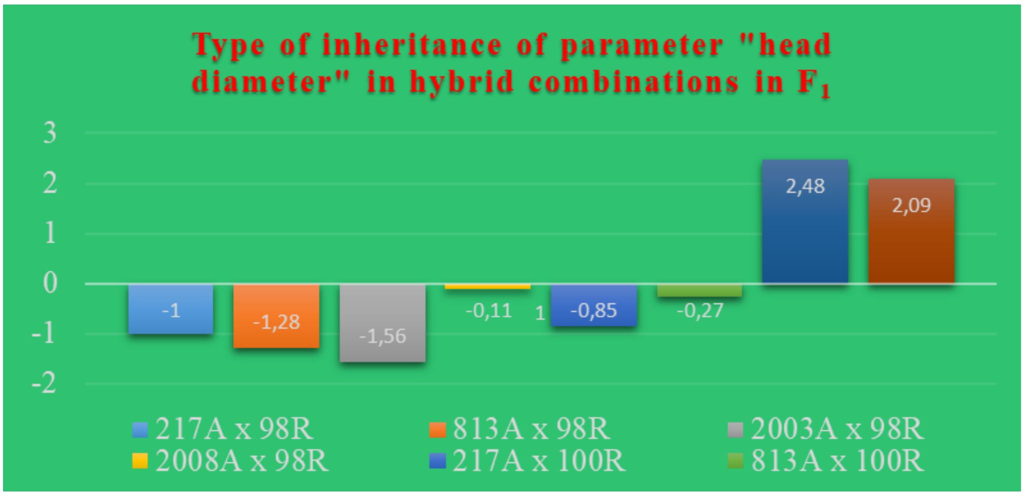

Figure 6. Type of inheritance of the parameter head diameter in hybrid combinations (F_1)

Incomplete dominance was found in hybrid combinations 217A x 98R, 813A x 98R and 2003A x 98R. One and the same fertility restorer line participated in this crosses as a component, crossed to different sterile lines.

In the parental lines, the parameter head diameter changed according to the genotype and the conditions of the environment, remaining stable in the obtained hybrid combinations. Therefore, the conclusion can be made, that the hybrids possess good ecological stability to changeable environments.

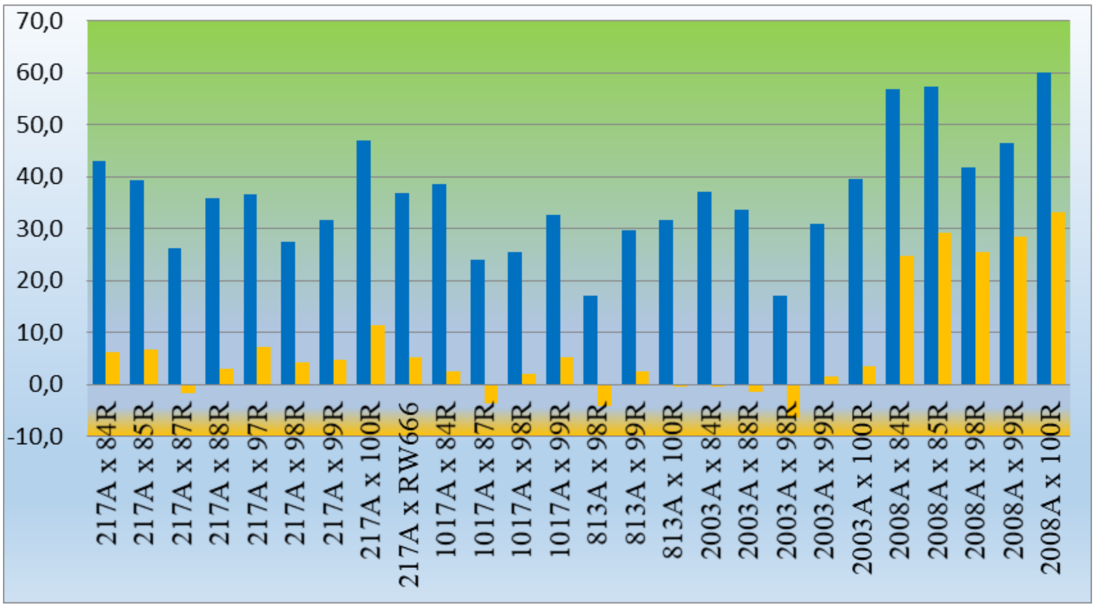

Figure 7. Mid-parent and best parent heterosis for parameter head diameter in F_1 hybrid combinations

In contrast to the parameter plant height, where close values of best parent and mid-parent heterosis were observed, great deviations were observed for head diameter due to heterosis (Figure 7). The highest values of mid-parent heterosis and best parent heterosis were obtained in the hybrid combinations involving mother line 2008A: 2008A x 100R (mid-parent heterosis 60.11%, best parent heterosis 30.57%), 2008A x 85R (mid-parent heterosis 57.36 %, best parent heterosis 29.29%), 2008A x 84R (mid-parent heterosis 56.8%, best parent heterosis 28.48%). These values were close only in these hybrid combinations, according to the two parents and the best parent.

Negative best parent heterosis (according to the best parent) was obtained in combinations 2008A x 84R (mid-parent heterosis 18.63%, best-parent heterosis 5.91 %), 813A x 98R (mid-parent heterosis 17.19%, best parent heterosis 4.16 %), 217A x 87R (mid-parent heterosis 26.17%, best parent heterosis 1.57%).

CONCLUSIONS

The parameter head diameter in the parental lines changed according to the genotype and the conditions of the environment, remaining constant in the obtained hybrid combinations. This allows the conclusion that hybrid combinations 2008A x 100R, 2008A x 85R and 2008A x 84R possess good ecological stability to changeable conditions of the environment according to the parameter.

Significant correlation in the fertility restorers was obtained between head diameter, percent of protein and 1000 kernel weight. Such direct effect was also obtained in the sterile lines according to the parameter number of leaves per plant.

Low and statistically insignificant correlations of this parameter with the others were determined in the investigated hybrid combinations. The inheritance of the parameter in the hybrid combinations varied from incomplete dominance to intermediary one and to super dominance depending on the accumulation and recombination of genes transferred from the parental forms. Concerning heterosis (best parent and mid-parent), considerable dynamics was observed conditioned by the high values of one or both parents included in the hybrid combination.

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