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MODE OF INHERITANCE OF HEAD HEIGHT AND HEAD WIDTH IN CABBAGE (*BRASSICA OLERACEA* VAR. *CAPITATA* L.)

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A diallel cross (including reciprocals), involving seven open-pollinated varieties having different head shape was made and 42 F_1 hybrids were produced under greenhouse conditions and in the experimental field of Scientific Institute of field and vegetable crops in Novi Sad. The objective of this paper was to determine mean value, components of variability and mode of inheritance of two morphological characters of head shape, head width and head height. In our study superdominance occurred the most with head height (as many as 23 times) and the least with head width (16 times). The negative heterosis was not occurred in any combination as like as partial dominance of the poorer parent. The results showed significant divergence of the traits under study, which will also constitute an important source of variability for future cycles of selection in our Institute.

Key words: cabbage, hybrid, head width, head height, inheritance, open-pollinated cultivar

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INTRODUCTION

Cabbage and kale (mostly cabbage) account for 15% of total vegetable consumption per household in Yugoslavia, averaging 15.6 kg a year. In order for this level of consumption to be maintained or even increased, it is necessary for cabbage heads to have an attractive appearance. One of the major considerations in cabbage breeding in addition to head mass is head shape, since the first thing we notice in a cabbage in the green market is the appearance of the head. Cabbage cultivars grown in Yugoslavia include those with elongated, round and flat heads. The annual production of 26,000 ha rests on cultivars and hybrids with round and oval heads.

The objective of this paper was to study the mode of inheritance of head shape components in cabbage, namely haed height and head width.

MATERIALS AND METHODS

Seven divergent open-pollinated cabbage genotypes with differing head shape components were chosen based on previous studies. These cultivars all have different origin, which represents a potential source of desirable gene combinations to be used in future breeding work. Used in the the study were the following cultivars: Futoški (a late domestic cultivar adapted to the conditions of the Vojvodina province, suitable for fresh use and pickling alike, with flat head type), SM-10 (a late cultivar, grown quite a lot in central Serbia, has a large head suitable for both fresh use and pickling, also with flat head type), Ditmar (domesticated foreign variety from German variety "Ditmarcher früher", one of the most widely grown cultivars for early production in Yugoslavia, with round elongated head), Kopenhaški (domesticated foreign variety from Danish variety "Kobenhavns Torve", for early and medium early production, suitable for fresh use, with round elongated head type), Prva Žetva (another, also domesticated foreign variety from Danish variety "Ditmarcher früher", intended for fresh use, with round elongated head type), Pourovo Červene (a late Czech cultivar of red cabbage, with elongated head type), Kboce (a medium late Bulgarian cultivar intended for fresh use, with flat round head type).

The experimental part of the study was carried out in the greenhouse and in the field at the Experiment Field of the Vegetables Department of the Institute of Field and Vegetable Crops in Novi Sad. In the greenhouse, the cultivars (each cultivar was represent with six plants) were crossed using the complete diallel cross method. After the fruit bearing and seed setting, a field trial was established. A randomized block design with five replications was used HADŽIVUKOVIĆ (1991). Each combination was represented by 30 samples and head height, head width, were measured. The results were statistically processed (mean value, standard deviation and coeficient of variability), HADŽIVUKOVIĆ (1991).

Differences between the parents' and hybrids' means were tested by the t-test in order to determine the mode of inheritance of the traits concerned, GRIFFING (1956).

The inheritance of quantitative traits in the diallel crosses was determined using regression analysis according to MATHER and JINKS (1982).

RESULTS

Mean value and variability components of head height - The highest parental head height variability was that of SM-10 and the lowest that of the cultivar Kboce. This variability is attributed to differences in head shape (Table 1).

The lowest value was obtained in the early cultivar Prva Žetva and the highest in the cultivar Pourovo Červene. The coefficient of variation for this trait ranged from the value found in Prva Žetva to that recorded in Ditmar, which was to be expected due to the variability of head shape in the parents (Table 1).

The mean values of F_1 hybrids were higher than in the parents and ranged from 14.5 cm in Ditmar x Pourovo Červene to 20.4 in Kboce x Futoški. The variability of the F_1s, expressed as standard deviation (S), varied from 0.07 in Pourovo Červene x Ditmar, SM-10 x Ditmar and Kopenhaški x Prva Žetva to 0.82 in Futoški x SM-10. The coefficient of variation (CV) ranged between 4.21 in the F_1 SM-10 x Ditmar and 10.4 SM-10 x Kopenhaški and was lower than in the parents (Table 1).

Table 1. Mean value (cm), and variability of head heigth in cabbage

VARIETIES AND HYBRIDS	Mean value $\bar{x} \pm S\bar{x}$	Standard deviation-(S)	Coeficient of variation CV	t-test ♀	t-test ♂
KBOCE	**13.5** ± 0.15	**0.08**	**6.08**		
K. x *FUTOŠKI*	20.4 ± 0.20	0.10	5.35	+	+ +
K. x *POUROVO ČERVENE*	17.1 ± 0.21	0.11	6.72	-	+
K. x *DITMAR*	17.9 ± 0.19	0.10	5.78	-	+
K. x *KOPENHAŠKI*	18.7 ± 0.23	0.12	6.83	-	+ +
K. x *PRVA ŽETVA*	15.8 ± 0.23	0.12	8.01	-	-
K. x *SM-10*	17.7 ± 0.28	0.15	8.53	-	+
FUTOŠKI	**15.7** ± 0.19	**0.10**	**6.87**		
F. x *KBOCE*	17.5 ± 0.17	0.09	5.41	+	-
F. x *POUROVO ČERVENE*	17.7 ± 0.16	0.09	5.17	-	-
F. x *DITMAR*	17.9 ± 0.17	0.09	5.36	+	-
F. x *KOPENHAŠKI*	17.7 ± 0.22	0.11	6.77	-	-
F. x *PRVA ŽETVA*	17.2 ± 0.22	0.12	7.11	-	-
F. *x SM – 10*	16.8 ± 0.15	0.82	4.90	-	-
POUROVO ČERVENE	**15.0** ± 0.29	**0.16**	**6.75**		
P.Č. x *KBOCE*	17.5 ± 0.18	0.10	5.71	+	-
P.Č. x *FUTOŠKI*	16.6 ± 0.26	0.14	8.52	-	-
P.Č. x *DITMAR*	17.5 ± 0.14	0.07	4.43	-	-
P.Č. x *KOPENHAŠKI*	16.7 ± 0.19	0.10	6.32	-	-
P.Č. x *PRVA ŽETVA*	15.2 ± 0.21	0.11	7.66	-	-
P.Č. x S*M-10*	16.5 ± 0.20	0.11	6.78	-	-

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DITMAR	**15.0** ± 0.11	**0.06**	**13.4**		
D. x *KbOSE*	17.8 ± 0.15	0.08	4.58	+ +	+
D. x *FUTOŠKI*	17.5 ± 0.17	0.09	5.31	-	-
D. x *POUROVO ČERVENE*	14.5 ± 0.15	0.08	5.64	-	-
D. x *KOPENHAŠKI*	15.2 ± 0.24	0.13	8.71	-	-
D. x *PRVA ŽETVA*	15.3 ± 0.22	0.11	7.78	-	-
D. x S*M-10*	16.5 ± 0.16	0.09	5.47	-	-
KOPENHAŠKI	**16.6** ± 0.20	**0.11**	**6.66**		
K. x *KBOCE*	18.4 ± 0.20	0.10	5.88	+ +	-
K. x *FUTOŠKI*	18.1 ± 0.23	0.12	6.90	-	-
K. x *POUROVO ČERVENE*	18.0 ± 0.17	0.09	5.08	-	-
K. x *DITMAR*	14.9 ± 0.17	0.09	6.32	-	-
K. x *PRVA ŽETVA*	15.3 ± 0.14	0.07	4.84	-	-
K. x S*M-10*	16.1 ± 0.25	0.13	8.45	-	-
PRVA ŽETVA	**14.3** ± 0.07	**0.05**	**3.72**		
P.Ž. x *KBOCE*	17.2 ± 0.20	0.10	6.32	+	-
P.Ž. x *FUTOŠKI*	16.7 ± 0.20	0.10	6.44	-	-
P.Ž. x *DITMAR*	16.3 ± 0.27	0.14	9.11	-	-
P.Ž. x *POUROVO ČERVENE*	14.8 ± 0.20	0.12	8.0	-	-
P.Ž. x *KOPENHAŠKI*	15.7 ± 0.18	0.09	6.18	-	-
P.Ž. x S*M-10*	17.0 ± 0.21	0.11	6.86	-	-
SM-10	**16.8** ± 0.19	**0.10**	**6.38**		
SM. x *KBOCE*	17.4 ± 0.18	0.09	5.55	+	-
SM. x *FUTOŠKI*	16.6 ± 0.20	0.09	5.40	-	-
SM. x *POUROVO ČERVENE*	16.8 ± 0.18	0.09	5.80	-	-
SM. x *DITMAR*	17.8 ± 0.14	0.07	4.21	+	-
SM. x *KOPENHAŠKI*	16.3 ± 0.31	0.17	10.4	-	-
SM. x *PRVA ŽETVA*	14.6 ± 0.19	0.10	6.07	-	-

LSD 0,05 = 0.58; 0.01 = 0.76

Mode of inheritance of head height - For this trait, the most frequent mode of inheritance was the superdominance of the better parent (23 instances). Positive heterosis occurred 16 times as well. Dominance occurred 16 times - 11 times as the dominance of the better parent and five times as dominance of the poorer parent.

Intermediacy occurred only three times, with Prva Žetva being once the mother and twice the father. Among the total 42 combinations for this trait, positive heterosis and the dominance of the better parent occurred 34 times in total (Figure 1).

Mean values and variability components of head width - The variability of head width in the parents ranged from the flat heads of the late cultivars Futoški and SM-10 to Pourovo Červene with its elongated head (Table 2).

The smallest standard deviation value was found in the early cultivar Prva Žetva and the highest in the late cultivar SM-10. The coefficient of variation for head diameter was the largest in Kopenhaški and the smallest in Prva Žetva (Table 2).

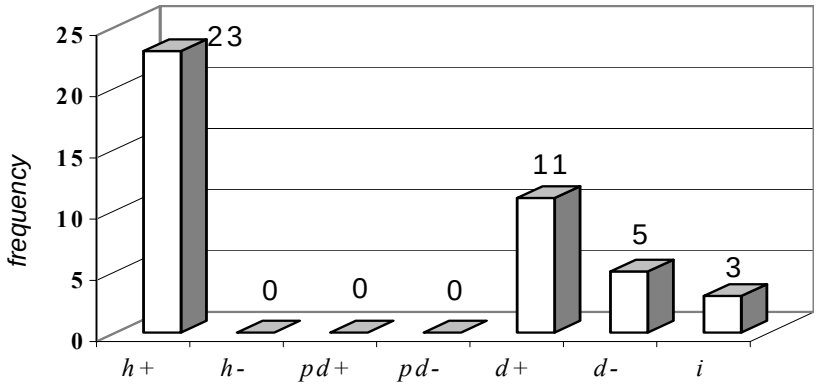

Fig. 1. Mode of inheritance of head height in all 42 diallel combinations. (h+ :positive heterosis; h- :negative heterosis; pd+ :partial dominance of the better parent; pd- :partial dominance of the poorer parent; d+ :dominance of the better parent; d- :dominance of the poorer parent; i :intermediacy)

With the parental head diameter means taken into account, the F_1 values ranged between 13.3 cm in Prva Žetva x Ditmar and 25 cm in Kboce x Futoški. The variability of head diameter in the F_1 hybrids, expressed as standard deviation (S), ranged from 0.06 in Pourovo Červene x Ditmar (elongated heads) to 0.16 in SM-10 x Kopenhaški (flat heads). The coefficient of variation (CV) ranged between 4.36% in the F_1 hybrid Ditmar x Pourovo Červene and 10.0% in Kopenhaški x Ditmar (Table 2).

Table 2. Mean values (cm), and variability of head width in cabbage

VARIETIES AND HYBRIDS	Mean value $\bar{x} \pm S\bar{x}$	Standard deviation-(S)	Coeficient of variation CV	t-test ♀	t-test ♂
KBOCE	**15.0** ± 0.17	**0.09**	**6.32**		
K. x *FUTOŠKI*	25.0 ± 0.27	0.14	5.83	+	++
K. x *POUROVO ČERVENE*	18.5 ± 0.20	0.10	5.90	+	-
K. x *DITMAR*	20.5 ± 0.21	0.11	5.68	++	++
K. x *KOPENHAŠKI*	20.6 ± 0.29	0.15	7.63	-	+
K. x *PRVA ŽETVA*	17.2 ± 0.21	0.11	6.81	-	-
K. x *SM-10*	20.8 ± 0.25	0.13	6.62	-	++
FUTOŠKI	**20.5** ± 0.18	**0.10**	**4.96**		
F. x *KBOCE*	21.9 ± 0.23	0.12	5.76	++	-
F. x *POUROVO ČERVENE*	19.5 ± 0.17	0.08	4.92	++	-
F. x *DITMAR*	19.5 ± 0.22	0.11	6.08	+	-
F. x *KOPENHAŠKI*	19.6 ± 0.25	0.13	7.03	-	-
F. x *PRVA ŽETVA*	19.1 ± 0.29	0.15	8.31	+	-
F. *x SM – 10*	21.5 ± 0.26	0.14	6.73	-	-

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POUROVO ČERVENE	**13.8** ± 0.30	**1.07**	**5.17**		
P.Č. x *KBOCE*	18.3 ± 0.21	0.12	6.13	-	+
P.Č. x *FUTOŠKI*	19.3 ± 0.25	0.13	7.01	-	+ +
P.Č. x *DITMAR*	17.0 ± 0.17	0.09	5.60	-	-
P.Č. x *KOPENHAŠKI*	16.8 ± 0.19	0.10	6.35	-	-
P.Č. x *PRVA ŽETVA*	16.4 ± 0.22	0.12	7.38	-	-
P.Č. x S*M-10*	19.1 ± 0.21	0.11	6.01	-	+ +
DITMAR	**15.0** ± 0.10	**0.05**	**3.69**		
D. x *KBOCE*	20.4 ± 0.23	0.12	6.12	+	+ +
D. x *FUTOŠKI*	19.6 ± 0.21	0.11	5.76	-	+
D. x *POUROVO ČERVENE*	14.6 ± 0.12	0.06	4.36	-	-
D. x *KOPENHAŠKI*	14.3 ± 0.17	0.09	3.69	-	-
D. x *PRVA ŽETVA*	16.0 ± 0.26	0.14	8.97	-	-
D. x S*M-10*	17.6 ± 0.16	0.08	5.01	-	-
KOPENHAŠKI	**16.5** ± 0.21	**0.11**	**7.20**		
K. x *KBOCE*	20.3 ± 0.22	0.11	5.81	+	-
K. x *FUTOŠKI*	19.8 ± 0.24	0.13	6.59	-	-
K. x *POUROVO ČERVENE*	17.5 ± 0.19	0.10	5.99	+	-
K. x *DITMAR*	15.0 ± 0.28	0.15	10.0	-	-
K. x *PRVA ŽETVA*	16.2 ± 0.19	0.10	6.30	-	-
K. x S*M-10*	19.6 ± 0.30	0.16	8.43	-	-
PRVA ŽETVA	**14.1** ± 0.80	**0.04**	**3.10**		
P.Ž. x *KBOCE*	19.6 ± 0.22	0.11	6.23	+	+ +
P.Ž. x *FUTOŠKI*	20.1 ± 0.26	0.14	7.02	-	+ +
P.Ž. x *DITMAR*	17.7 ± 0.25	0.13	7.62	-	-
P.Ž. x *POUROVO ČERVENE*	13.3 ± 0.20	0.11	8.0	-	-
P.Ž. x *KOPENHAŠKI*	16.2 ± 0.18	0.09	5.99	-	-
P.Ž. x S*M-10*	20.0 ± 0.25	0.13	6.96	-	+ +
SM-10	**20.5** ± 0.92	**1.10**	**5.12**		
SM. x *KBOCE*	20.7 ± 0.21	0.11	5.51	+ +	-
SM. x *FUTOŠKI*	20.1 ± 0.20	0.10	5.33	-	-
SM. x *POUROVO ČERVENE*	17.4 ± 0.15	0.08	4.71	+	-
SM. x *DITMAR*	19.6 ± 0.19	0.10	5.36	+	-
SM. x *KOPENHAŠKI*	17.8 ± 0.30	0.16	9.15	-	-
SM. x *PRVA ŽETVA*	17.1 ± 0.19	0.10	6.07	-	-

LSD 0,05 = 0.65; 0.01 = 0.86

Mode of inheritance of head width - The most common mode of inheritance of this trait was superdominance (16 instances). Positive heterosis occurred 16 times as well. Combinations involving Kboce as either the mother or the father exhibited positive heterosis in the vast majority of cases (10 times). Dominance was the second most common mode of inheritance with 12 occurrences. Nine times the positive dominance of the better parent had the higher mean value and three times the lower (Ditmar x Kopenhaški, Kopenhaški x Ditmar, Prva Žetva x Ditmar).

Partial dominance was recorded nine times. The mode of inheritance occurring in the smallest number of combinations was intermediacy (five instances).

This confirms that this trait is cultivar-specific, so crossing parents with different head diameter values will only increase its variability (Figure 2).

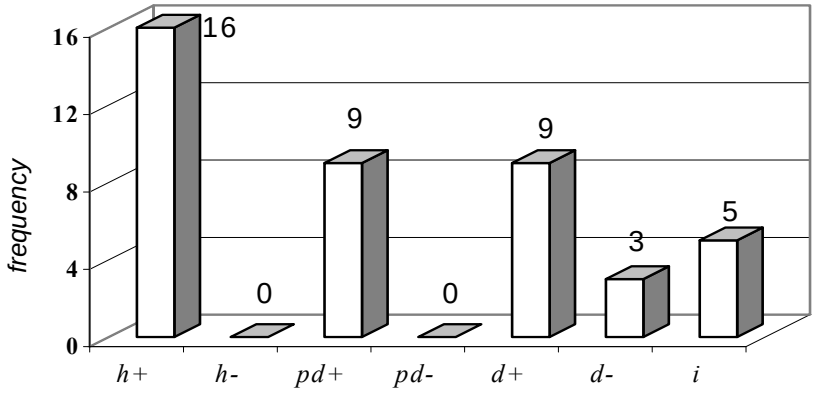

Fig. 2. Mode of inheritance of head width in all 42 diallel combinations. (h+ :positive heterosis; h- :negative heterosis; pd+ :partial dominance of the better parent; pd- :partial dominance of the poorer parent; d+ :dominance of the better parent; d- :dominance of the poorer parent; i :intermediacy)

DISCUSION

Head shape is a highly diverse and cultivar-specific characteristic ČERVENSKI *et al*. (1995). It is expressed based on the head height and head diameter values measured. DICKSON *et al*. (1986) report that the pointy head is dominant over the round one. MORE *et al*. (1988) have found superdominance to be the mode of inheritance of head height and diameter. They have also established that dominant alleles are more common in the parents and that these traits are controlled by multiple genes.

Our results have shown dominance and superdominance to have been the most frequent modes of inheritance. Dominance occurred 10 times with head diameter and 15 times with head height. Similar results are reported by KANDIĆ *et al*. (1992). That author reports a relatively high number of heterotic combinations for head height in the F_1 hybrids as well as dominance of the better parent and heterosis for head width. The predominant mode of inheritance of head height was superdominance, while for head width it was dominance of the parent with the larger head diameter. Our results support those of KANDIĆ *et al*. (1992). ČERVENSKI *et al*. (1995) compared head height and inner stem length and concluded that head height was more dependant on hereditary factors. The same author also found that head shape was more cultivar-specific and that round and

oval head shapes were typical for this region. MORE *et al*. (1988) found superdominance in the inheritance of head height and diameter and determined that the dominant alleles were more common in the parents and that these traits are controlled by more than one gene.

CONCLUSION

Used in this study were seven divergent cabbage cultivars, which were subjected to complete diallel crossing. The traits that were analyzed are significant for further breeding cycles, which was the principle they were selected on in the first place. We studied the variability of cabbage traits and the mode of their inheritance. The results showed significant divergence of the traits under study, which will also constitute an important source of variability for future cycles of selection. The following conclusions were made:

The parental genotypes differed phenotypically with respect to most traits under investigation.

Looking at the traits affecting the shape of the head, we can see variation in the parents as well as in the hybrids, primarily because of the different head shapes appearing in the study. The prevailing mode of inheritance of head height was superdominance, whereas in the case of head width it was dominance of the parent with a larger head diameter. In the inheritance of both these traits, non-additive gene action predominated.

In our study, superdominance occurred the most with head haight (as many as 23 times) and the least with head width (16 times). The negative heterosis was not occurred in any combination as like as partial dominance of the poorer parent. This leads us to conclude that higher heterosis values can be obtained if our crosses include a higher number of cultivars with high GCA values. This would produce combinations with the largest number of desirable genes. Our results have shown dominance and superdominance to have been the most frequent modes of inheritance. Dominance occurred 10 times with head diameter and 15 times with head height.

The higher number of combinations exhibiting heterosis for the traits from this study would enable the selection of cultivars with the best yield components and the correct choice of parents in developing F_1 hybrids with certain traits.

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NAČINI NASLEĐIVANJA VISINE I ŠIRINE GLAVICE KUPUSA (*BRASSICA OLERACEA* VAR. *CAPITATA* L.)

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Izvod

Napravljena su dialelna (uključujući recipročna) ukrštanja sedam slobodnooprašujućih varijeteta kupusa sa različitim oblicima glavice, kao i 42 F1 hibrida, u poljskim i veštačkim uslovima u Naučnom institutu za ratarstvo i povrtarstvo u Novom Sadu. Cilj rada je određivanje srednje vrednosti komponenti varijabilnosti i načina nasleđivanja dve morfološke karakteristike oblika glavice, visina i širina. U našem radu superdominantnost se javlja najviše kod visine glavice (u 23 slučaja) a najmanje kod njene širine (16 puta). Negativni heterozis se nije javio ni u jednoj kombinaciji kao ni delimična dominantnost lošijeg roditelja. Rezultati ukazuju značajne razlike izučavanih karakteristika, što predstavlja značajan izvor varijabilnosti za dalje cikluse selekcije u našem Institutu.

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