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VARIANCE COMPONENTS AND CORRELATIONS OF AGRONOMIC TRAITS AMONG CABBAGE (*Brassica oleracea* var. *capitata* L.) MATURITY GROUPS

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In this paper we studied the variability and correlation of cabbage traits in different maturity groups. The study included early spring cabbages (planted in early spring, harvested in early summer) and autumn cabbages (planted in mid-summer, harvested in late autumn). Using coefficients of variation and correlation coefficients, we analyzed 17 cabbage traits in 35 commercially grown cultivars, F1 hybrids, and experimental F1 hybrids. The traits were analyzed separately for each maturity group. In the early cabbages, the coefficients of variation ranged from 4.8 to 44.2%. The calculated correlation coefficients differed between the two maturity groups. The early cabbages had 26 significant positive correlations. The

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positive correlations calculated among different traits of early cabbages defined this group fully and made it distinct from the late-maturing genotypes. Plant height and rosette diameter in the early genotypes were highly positively correlated with rosette weight, whole plant weight, head weight, usable portion of head, head height, and head diameter. Plant height and rosette diameter participate in the formation of active photosynthetic area in early cabbages. Rosette width in these genotypes provides a greater influx of light and heat, which results in greater head weight. Also, in early cabbages that have greater plant height, the leaf rosette will not lie on the cold surface of the ground in the spring. The activity of the cabbage plant is thus more focused towards the formation of larger head weight. Head volume in the late genotypes was highly positively correlated with rosette diameter, whole plant weight, head weight, usable portion of head, inner stem length, and head height. In late cabbages plant activity is directed towards the formation of head volume due to the longer duration of the growth period, larger leaves, and differences in climatic conditions.

Key words: cabbages, correlations, head, maturity, variability.

INTRODUCTION

Most cabbage genotypes grown in the world today are hybrids. They are expected to form heads as early as possible and to produce as much yield as possible owing to the presence of heterosis, or hybrid vigor. The use of cabbage cultivars that form heads early in the season enables earlier harvesting in warmer and cooler environments alike. Such cultivars make it possible for growers to speed up their crop rotations and to cut costs on pesticides and fertilizers. All this makes early head formation a trait of significant interest in cabbage breeding (TANAKA *et al.,* 2006).

Parameters that are of primary importance when analyzing cabbage traits are their mean values, genetic variance, heritability, and correlations. The possibility that there may be significant genetic correlations among morphological traits is a precondition of indirect selection for head yield through yield components. Understanding their interrelationships may be an important criterion in cabbage breeding.

For intensive cabbage production it is necessary to have appropriate cultivars. Although the domestic cultivars available in Serbia are suitable for fresh consumption and sauerkraut making, local growers prefer to grow foreign cultivars (ČERVENSKI *et al.,* 2010).

Earliness in cabbage could be a desirable character when the need arises for varieties with a short growth cycle to meet early market demands. Conversely, early maturing varieties do not store well in the field because they are liable to bolt; yield loss could be higher if market demand falls (ADENIJI *et al.,* 2010).

According to ANTONOVA (2009), several independent studies of correlations in cabbage may produce different results. Most often, the reason for this is the presence of high genetic diversity in the cabbages as well as a clear differentiation among the materials used in different studies. The author concludes that if an analysis of correlations involves only genotypes from a certain maturity group (for instance, only late cabbages), then the results of the analysis should be interpreted as pertaining only to that particular maturity group when devising a breeding program.

When analyzing correlations among major cabbage traits, according to KLEINHENZ *et al.,* (2003), note should also be taken of the effects of the environment on a given genotype, i.e. of the genotype x environment interaction. With this approach, it is possible to more accurately assess the suitability of a given group of cultivars for a particular growing environment.

Correlations between the head and core traits were the subject of a study by WSZELAKI (2003). In that paper, among other things, the author indicates that by choosing a particular cultivar and planting date one can affect the formation of head weight, head diameter, head density, head volume, core length, core base width, core volume, and marketable yield. The same study has also confirmed that there is a strong link between head weight and head diameter. Genotypic and phenotypic correlations among cabbage traits have also been analyzed by CERVENSKI *et al.,* (1998).

Cabbage is among vegetable crops that can be found on the market throughout the year, starting with early genotypes, followed by summer ones, and ending with those from late maturity groups. Eventually, it is up to the growers to decide for themselves which maturity group will be best suited for the market at any given time. On the actual markets, however, all the different maturity groups are usually found all mixed together with one another, and the same goes for cabbage production in the fields as well.

Cabbage production can be accomplished almost all year along and landraces can be characterized by their ecological origin as well as their growing period (PADILLA *et al.,* 2007). Previous works suggested that both genotype and growing season influence the head development and yield (KLEINHENZ and WSZELAKI, 2003; WSZELAKI and KLEINHENZ, 2003), so it would be interesting to test the performance of cabbage maturity groups.

As can be seen from the literature discussed above, most authors have analyzed trait correlations within a particular maturity group. Because of this, we had decided to analyze the potential variability existing between different cabbage maturity groups in order to see if there are differences between them and also to compare trait correlations between the different maturity groups.

MATERIALS AND METHODS

The studied material consisted of 30 cabbage genotypes (11 commercial F1-hybrids grown in Europe, 7 varieties and 12 new experimental F1-hybrids) from two maturity groups (early and late). Among the varieties, there were two domestic ones, Futoski and Srpski melez, which are suitable for fresh use late in the season as well as for pickling and which have a history of being grown in the country for more than 30 years now. The other five varieties are from the list of cabbage varieties domesticated in Serbia (www.sorte.minpolj.gov.rs) and are well adapted to the climate and growing conditions under which the study was carried out. (Table 1).

Table 1 Varieties and F1-hybrids included, maturity type and origin.

No.	Genotypes		Type	Origin
1	H1	F1-hybrid	early	Experimental hybrid
2	H3	F1-hybrid	early	Experimental hybrid
3	H4	F1-hybrid	early	Experimental hybrid
4	H7	F1-hybrid	early	Experimental hybrid
5	H8	F1-hybrid	early	Experimental hybrid
6	H9	F1-hybrid	early	Experimental hybrid
7	H10	F1-hybrid	early	Experimental hybrid
8	H11	F1-hybrid	early	Experimental hybrid
9	H13	F1-hybrid	early	Experimental hybrid
10	H14	F1-hybrid	early	Experimental hybrid
11	H15	F1-hybrid	early	Experimental hybrid
12	H16	F1-hybrid	early	Experimental hybrid
13	Parel-F1	F1-hybrid	early	Bejo Zaden BV
15	Resistor-F1	F1-hybrid	early	Syngenta Seed
16	Balbro-F1	F1-hybrid	early	Nickerson Zwaan
17	Elisa-F1	F1-hybrid	early	Sakata Seed
18	Nosomi-F1	F1-hybrid	early	Sakata Seed
14	Copenhagen market	Variety	early	Domesticated
19	Ditmar	Variety	early	Domesticated
20	Prva zetva	Variety	early	Domesticated
24	Quisto-F1	F1-hybrid	late	Syngenta Seed
25	Castelo-F1	F1-hybrid	late	Nickerson Zwan
26	Rodeo-F1	F1-hybrid	late	Nickerson Zwan
27	Coronet-F1	F1-hybrid	late	Sakata Seed
28	Caid-F1	F1-hybrid	late	Clause S.A.
29	Robustor-F1	F1-hybrid	late	Syngenta Seed
21	Futoski	Variety	late	Local variety
22	Srpski melez-10	Variety	late	Local variety
23	Slava	Variety	late	Domesticated
30	Srpski melez-4	Variety	late	Local variety

The trial was carried out on chernozem at the Rimski Šančevi Experiment Field of the Institute of Field and Vegetable Crops in Novi Sad, Serbia (45°19'N, 19°50'W). The horizons in which most of the root system of cabbage developed were neutral in reaction and slightly calcareous. The soil had a medium supply of total nitrogen, an optimum supply of readily available phosphorus, and a high readily available potassium content (VASIN *et al.,* 2002).

The trial was carried out over a three-year period (2000, 2001, and 2002) using a randomized block design with three replications. The experimental units for the early cabbage genotypes were plots 6.0 m^2 in size. Each plot had three rows with 36 plants in total (60cm x 50cm; 33,300 plants per hectare). In the case of the late genotypes, the size of the experimental unit was 10.5m^2 with three rows per plot (70 x 50 cm; 28,500 plants per hectare) and 30 plants per plot in total. The varieties and hybrids were grown from transplants, which were started in the greenhouse on either March 20 (early genotypes), and May 20 (late genotypes).

The time and degree of head maturity were determined based on visual observation and head compactness. The seventeen basic plant characteristics were studied: plant height (cm), plant diameter (cm), number of developed leaves, weight of developed leaves, weight of total plant (kg), weight of head (kg), useful portion of head (kg), head stem length (cm), length of plant stem (cm), head length (cm), head width (cm), harvest index (weight of head/weight of total plant), head length/width ratio, head stem length/head length ratio, usable portion of head/ head weight ratio, head volume, head density.

Throughout the entire period of growing the transplants in the greenhouse, the plants were provided with optimal temperature and moisture conditions. The transplants were transferred into the open field on May 4 (early genotypes) or July 9 (late cabbages).

Before the planting, the plots were fertilized prior to primary tillage using NPK (8:16:24) at 600 kg per hectare. During the season, the crops were top-dressed on two occasions, and they were protected from diseases and pests as well. After the transplantation, irrigation was applied. The crops were also irrigated in the course of the growing season on several occasions depending on the soil moisture status and plant water requirements.

The time and degree of head maturity were determined based on visual observation and head compactness. Thirty plants were analyzed per replicate and genotype.

The experimental field has a temperate continental climate with some specific characteristics, such as a wide interval between the highest and lowest mean monthly temperature (21.4°C in July and -1.3°C in January, respectively). In the Vojvodina province (where the experimental field is located), the precipitation regime in general and the distribution of precipitation in particular are in part typical of those found in Central Europe/the Danube region, i.e. there are extremely rainy periods in early summer (June) and periods with little or no precipitation (October and March), (www.hidmet.gov.rs).

A brief description of the climatic conditions of each year is shown in Table 2.

Between the studied traits the calculations were done for indicators of variability and correlation coefficients. Testing of significance for these coefficients was conducted using the *t*-test. Statistical analyses were performed using the satistical program Statistica 9.1 (StatSoft, Inc., Tulsa, Oklahoma, USA).

Table 2. Average monthly temperatures (°C) and sum of precipitation (mm) in the years in which the genotypes were grown.

Months	Years					
	2000		2001		2002	
	°C	mm	°C	mm	°C	mm
January	-1.7	17.0	3.5	38	0.2	7.5
February	4.3	7.0	4.6	27	6.7	28.4
March	7.3	27.0	11.0	73	8.6	10.1
April	14.9	24	11.2	127	11.1	30.4
May	18.5	39	17.7	77	19.1	84.7
June	21.3	28	19.8	233	22.0	27.5
July	22.1	29	22.5	56	23.5	35.0
August	24.1	5	22.7	30	21.5	53.8
September	17.8	13	16.1	162	16.4	47.5
October	15.3	6	14.1	14.7	12.1	91.7
November	11.7	22	3.6	71.4	9.5	23.7
December	4.0	53	-3.4	27.6	0.5	41.6

RESULTS

The results of our correlation analysis are presented in separate tables and graphs for early and late cabbages. Differences in cultivar and hybrid means were observed not only between the two maturity groups but also within each group itself. The variability was especially high among the early cabbages. It was in this group that the largest difference between the highest and lowest coefficients of variation was observed. In the early-maturing cabbages, the values of the coefficients of variation ranged between 4.80% (proportion of the usable portion of head in head weight) and 44.2% (usable portion of head). The group of early cabbages included 19 cultivars and hybrids in total. In the group of late cabbages, which had a total of 11 cultivars and hybrids, the coefficients of variation were lowest for the proportion of the usable portion of head in head weight (5.60%) and highest for head volume (39.6%) (Table 3).

Table 3. Indicators of variability of cabbage traits studied.

		Early cabbage group					Late cabbage group				
		mean	standev	CV%	MIN	MAX	mean	standev	CV%	MIN	MAX
1	Plant height	23,00	3,12	13,60	15,00	29,10	28,80	7,28	25,30	20,30	46,30
2	Plant diameter	62,30	16,70	26,80	31,00	92,30	61,10	12,06	19,80	42,70	88,00
3	Number of developed leaves	13,20	1,32	10,00	11,00	17,30	16,20	3,82	23,60	12,00	26,00
4	Weight of developed leaves	0,70	0,22	31,50	0,20	1,20	0,90	0,37	39,40	0,40	1,90
5	Weight of total plant	2,70	1,04	38,30	0,80	5,10	2,80	0,80	29,10	1,00	4,20
6	Weight of head	2,00	0,85	42,40	0,40	4,10	1,80	0,58	31,40	0,60	2,60
7	Useful portion of head	1,70	0,74	44,20	0,40	3,50	1,60	0,52	33,00	0,50	2,30
8	Length of plant stem	8,40	1,46	17,40	5,90	12,70	15,40	5,77	37,50	7,70	24,20
9	Head stem length	6,80	1,18	17,30	4,10	9,20	7,70	1,48	19,10	5,00	10,80
10	Head length	16,50	2,61	15,80	10,10	21,20	16,00	1,59	9,90	11,60	18,40
11	Head width	17,10	3,39	19,80	9,30	22,10	16,60	3,50	21,10	9,20	22,90
12	Harvest index*	1,40	0,12	8,90	1,20	1,90	1,60	0,31	19,50	1,20	2,50
13	Head length/width ratio	1,00	0,09	9,00	0,80	1,20	1,00	0,16	16,40	0,70	1,30
14	Head stem length/head length	43,00	7,73	18,00	27,80	61,20	49,80	6,33	12,70	41,50	65,40
15	Usable portion of head/head weight	85,20	4,08	4,80	75,60	95,70	84,70	4,71	5,60	71,20	93,60
16	Head volume	2709,70	1189,12	43,90	476,00	5224,00	2412,90	955,05	39,60	587,00	4530,00
17	Head density	0,772	0,153	19,809	0,548	1,511	0,800	0,140	17,790	0,560	1,270

*(Weight of head/ Weight of total plant ratio)

The coefficients of correlation among 17 cabbage traits were calculated separately for each of the two maturity groups analyzed. The early cabbages had 50 significant correlations in total (significant at the 0.01 level), while the late-maturing (autumn) ones had 35 such correlations overall (Table 4).

Among the early genotypes, we recorded 32 significant positive correlations and 18 significant negative ones, whereas among the late cabbages there were 26 of the former and nine of the latter.

Among the 20 traits that were analyzed in both the early and late genotypes, some similar correlation values were observed. Highly significant positive correlations were recorded among 15 of the common traits investigated, while five of the correlations were highly significantly negative (Table 4).

Table 4. Correlation matrix among the variables studied

	Plant characteristic	maturity group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Plant height	early	1,00	**0,90**	0,19	**0,92**	**0,91**	**0,90**	**0,91**	0,24	0,19	**0,90**	**0,91**	**-0,68**	-0,50	-0,54	-0,06	0,54	-0,18
		late	1,00	0,18	0,70	0,67	0,51	0,03	-0,05	0,68	0,36	0,45	-0,05	0,59	0,34	0,53	-0,71	-0,05	0,09
2	Plant diameter	early		1,00	0,36	**0,86**	**0,94**	**0,92**	**0,93**	0,24	0,12	**0,84**	**0,96**	**-0,78**	**-0,64**	**-0,58**	-0,27	**0,63**	-0,19
		late		1,00	0,18	0,49	0,67	0,72	0,72	-0,34	0,57	0,62	**0,75**	-0,33	-0,55	0,40	-0,35	**0,75**	**-0,84**
3	Number of developed leaves	early			1,00	0,13	0,26	0,30	0,32	0,36	-0,10	0,17	0,30	-0,28	**-0,59**	-0,20	0,03	0,21	0,03
		late			1,00	**0,75**	0,34	-0,17	-0,2	0,73	0,17	0,17	-0,17	0,68	0,45	0,26	-0,42	-0,17	-0,06
4	Weight of developed leaves	early				1,00	**0,91**	**0,87**	**0,88**	0,10	0,19	**0,90**	**0,84**	**-0,63**	-0,42	-0,54	-0,22	0,44	-0,14
		late				1,00	**0,78**	0,42	0,38	0,62	0,62	0,65	0,40	0,19	-0,15	0,61	-0,55	0,40	-0,47
5	Weight of total plant	early					1,00	**0,99**	**0,98**	0,14	0,08	**0,93**	**0,97**	**-0,83**	-0,51	**-0,65**	-0,17	**0,58**	-0,09
		late					1,00	**0,79**	**0,76**	0,25	**0,86**	**0,95**	**0,75**	-0,26	-0,47	0,66	-0,60	**0,75**	-0,52
6	Weight of head	early						1,00	**0,99**	0,13	0,07	**0,91**	**0,96**	**-0,84**	-0,49	**-0,63**	-0,13	0,57	-0,00
		late						1,00	**1,00**	-0,27	**0,81**	**0,79**	**0,99**	**-0,74**	**-0,89**	0,48	-0,26	**0,99**	-0,65
7	Useful portion of head	early							1,00	0,18	0,07	**0,91**	**0,97**	**-0,84**	-0,54	**-0,65**	-0,12	0,55	-0,04
		late							1,00	-0,33	**0,79**	**0,76**	**0,99**	**-0,79**	**-0,90**	0,44	-0,20	**0,99**	-0,67
8	Length of plant stem	early								1,00	0,38	0,16	0,25	-0,36	**-0,63**	0,25	-0,20	-0,14	-0,35
		late								1,00	0,11	0,18	-0,34	0,64	0,50	0,23	-0,38	-0,34	0,30
9	Head stem length	early									1,00	0,27	0,12	-0,19	0,00	**0,63**	-0,27	0,20	**-0,66**
		late									1,00	**0,84**	**0,79**	-0,35	-0,52	**0,79**	-0,48	**0,79**	-0,41
10	Head length	early										1,00	**0,87**	**-0,80**	-0,36	-0,48	-0,13	0,56	-0,22
		late										1,00	**0,74**	-0,34	-0,49	0,60	-0,61	**0,74**	-0,50
11	Head width	early											1,00	**-0,85**	**-0,60**	**-0,61**	-0,13	**0,64**	-0,15
		late											1,00	**-0,76**	**-0,91**	0,46	-0,16	1,00	-0,70
12	Harvest indeks *	early												1,00	0,57	0,39	0,22	-0,53	0,07
		late												1,00	**0,89**	0,04	-0,25	**-0,76**	0,46
13	Head length/ width ratio	early													1,00	0,34	0,11	-0,18	0,16
		late													1,00	-0,23	-0,09	**-0,91**	0,64
14	Head stem length / Head length ratio	early														1,00	-0,14	-0,29	-0,31
		late														1,00	-0,67	0,46	-0,26
15	Usable portion of head/ head weight ratio	early															1,00	-0,11	0,04
		late															1,00	-0,16	0,11
16	Head volume	early																1,00	-0,16
		late																1,00	-0,70
17	Head density	early																	1,00
		late																	1,00

*(Weight of head/ Weight of total plant ratio)

In the early genotypes, plant height and rosette diameter were highly positively correlated with rosette weight, whole plant weight, head weight, usable portion of head, head height, and head diameter. Looking at the trait structure, we can see that plant height and rosette diameter were determinants of head weight and whole plant weight in the early cabbages. In essence, early cabbage genotypes have to make do with a short day, as their growth period coincides with the end of the winter and start of the spring. Because of this, they have to be provided with optimal living space in order that they can attain as high a level of photosynthesis as possible. Cabbage plants achieve this by developing a broad rosette of healthy leaves that are raised off the ground, i.e. through plant height. With early cabbages plant height is used as a way to avoid contact with the wet ground, which allows the leaf rosette to develop without any problems and enables the absorption of light and heat.

Correlations such as those found in the early cabbages were neither as pronounced nor significant in the late genotypes. In the late cabbages, unlike with the early ones, head volume was the trait that came to prominence. Head volume of the late genotypes was highly positively correlated with rosette diameter, whole plant weight, head weight, useful part of the head, inner stem length, and plant height. The importance of head volume in the late-maturing genotypes is explained by their greater head weight as compared to early-maturing ones. Late cabbages grow for a much longer period of time than early ones and produce more vegetative mass. The head leaves of late cabbages are also larger because of uses such as pickling or storage. In the present study, head volume was positively correlated with rosette diameter, whole plant weight, and head diameter.

In the late cabbages, positive correlations were also found between rosette weights on the one hand and whole plant weight, head weight, usable portion of head, head height, and head diameter on the other. In the late genotypes, rosette weight had a highly significant positive correlation only with whole plant weight.

Some negative correlations were also observed among the cabbage traits studied. In the early genotypes, the ratio of head weight to whole plant weight was highly negatively correlated with plant height, rosette diameter, rosette weight, whole plant weight, and head weight, usable portion of head, head height, and head diameter. In the late genotypes, this ratio was highly negatively correlated with only three traits, namely head weight, usable portion of head, and head diameter. As can be seen from the tables, significant negative correlation was also observed for head index and contribution of inner stem length to head height.

In both maturity groups, highly significant positive correlations were recorded between whole plant weight on the one hand and head weight, usable portion of head, head height, and head diameter. Further, there were also highly significant positive correlations observed between head weight on the one hand and usable portion of head, head height, and head diameter on the other. The usable part of the head was also highly significantly positively correlated with head height and head diameter. A highly significant positive correlation was found between head height and head diameter. The above traits have the greatest market value in the production of early and late cabbages, as they have a direct influence on head weight as the final product.

DISCUSSION

The characterization of a number of varietal groups indicated that the early maturing varietal groups generally belong to the so-called “leaf-weight“ type, whose head weight is influenced mainly not by the number of leaves but by the weight of leaves, (TANAKA *et al.,* 2003). In our paper we found high positive correlations between weight of rosette leaves and height weight. The value of this correlation was 0.87. Positive correlations were also found between the weight of rosette leaves and total plant weight (0.91) and weight of rosette leaves and usable portion of the head (0.88).

TANAKA *et al.,* (2008) examined the relationships between the earliness of head formation and developmental characteristics in the spring and compared them with the same relationships in the autumn. They reported that it is empirically known that the use of autumn early-head forming cultivars in the spring is not always successful. However, lighter or heavier heads can be equally valuable, depending on variations in the way the product is used and on consumer preferences in different parts of the world. Head weight variation of early maturing cabbage in our results was from 0.4 kg up to 4.1 kg. In the autumn season head weight values ranged between 0.6 and 2.6 kg.

CERVENSKI *et al.,* (1998) in their results have found correlations between head weight and head height, head height and head diameter, and head height and yield. These correlations, however, do not meet the strict selection criteria and are therefore significant only as a warning of the negative interdependence that may occur during the selection process. The results of our present analysis are in agreement with these.

A number of relationships between head traits were apparent, regardless of cultivar and planting date. For example, head weight and diameter displayed a clear polynomial relationship, indicating that as head diameter increased, head weight increased consistently as well. Moreover, the average ratio between head polar and equatorial diameters was nearly 1, demonstrating that heads were mostly round and suggesting that reliable estimates of head volume and density are possible. Head density generally exceeds 0.70 g cm^3. In our experiment these values in some cases were lower. However, other relationships among head and core traits challenged existing assumptions. Also, no apparent relationship was found between head density and diameter in the numerous mature (market-ready) heads. The most variable trait across cultivars was head volume, which was affected by planting date in all cultivars (WSZELAKI *et al.,* 2003).

RADOVICH *et al.,* (2004) found a strong curvilinear relationship (R2=0.96) between head mean diameter and head weight. Head weight, size, shape, density and core dimensions, as well as relationships among them, are also critical indicators of quality in the development, evaluation and selection of cabbage germplasm. Relationship between head size and weight is noteworthy because it suggests an ability to predict head weight (and, therefore, crop yield) across a wider range of head size and maturity. Economically important relationships between head size and weight, polar and equatorial diameter, and core and head volume were also affected by harvest date and strongly suggest that accurate assessments of developmental stage are required to establish harvest schedules intended to maximize head quality. These authors also reported that the head density, a primary indicator of horticultural maturity, appeared to be significantly influenced by plant spacing. Minimal head density values are cultivar and market specific, but generally exceed 0.70 gcm^3.

High head density may be commercially advantageous for farmers who prefer greater heads to achieve specified weight with less effort and for processors who want high yield of shredded cabbages. High density heads seem to be suitable for industrial shredded cabbage because of their high yield and no defects in quality (KOHYAMA *et al.,* 2009).

The most variable trait across cultivars was head volume, which was affected by planting date in all cultivars. Several clear relationships were found among selected head and core traits. Head weight and average head diameter were strongly related. Relationships between weight and average diameter for trimmed heads taken from May- and June-planted plots were described by quadratic equations having R^2 values of 0.93 and 0.91, respectively, (KLEINHENZ *et al.,* 2003).

A positive, linear relationship (r^2= 0.89) was found between head volume and head weight. (RADOVICH *et al.,* 2005). This correlation is in agreement with our results (with the caveat that such correlation in our paper was present only in the case of late-maturing genotypes).

For intensive cabbage production it is necessary to have appropriate cultivars. Although the available domestic cultivars are suitable for fresh consumption and sauerkraut making, local growers prefer to grow foreign cultivars, (CERVENSKI *et al.,* 2010).

Studies of genetic variability, heritability and correlation between properties can show the extent to which certain traits are genetically determined and which of them have the greatest importance in the selection and creation of new cultivars (MILATOVIC *et al.,* 2010).

Success in the breeding process mainly depends on selection of most superior genotypes from a population. However because the selection of elite genotypes is mostly based on phenotypic values, in many cases the effectiveness of the selection is very low, especially when the phenotypic differences are not under strong genetic control (MARJANOVIC-JEROMELA *et al*., 2011).

In their investigation, SORKHEH *et al.,* (2010) have concluded that the presence of significant correlations among traits and their assessment would facilitate an advanced procedure of indirect selection aimed at improving a character by selecting it over another. A close relationship between traits could facilitate or hinder the breeding process, since the selection for a given trait could favor the presence of another desirable or undesirable characteristic.

The results we obtained provide a more precise definition of the links among particular traits in early and late cabbages.

CONCLUSION

The positive correlations calculated among different traits of early cabbages define this group fully and make it distinct from the late-maturing genotypes. Plant height and rosette diameter participate in the formation of active photosynthetic area in early cabbages. The width of the rosette in these genotypes will provide a greater influx of light and heat, resulting in a greater head weight. Also, in early cabbages that have greater plant height, the leaf rosette will not lie on the cold surface of the ground in the spring. The activity of the cabbage plant is thus more focused towards the formation of larger head weight. In late cabbages plant activity is directed towards the formation of head volume due to the longer duration of the growth period, larger leaves, and differences in climatic conditions.

In both maturity groups, highly significant positive correlations were observed among whole plant weight, head weight, usable portion of head, head height, and head diameter. These traits achieve their full values at technological maturity and there is a direct positive connection among them. Any change in any of them will directly alter the values of the other traits from this group in both early and late cabbages.

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KOMPONENTE VARIJANSE I KORELACIJE AGRONOMSKIH SVOJSTAVA KUPUSA (*Brassica oleracea* var. *capitata* L.) RAZLIČITIH GRUPA ZRENJA

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I z v o d

U radu smo istraživali varijabilnost i korelacije svojstava kupusa iz različitih grupa zrenja. Ubuhvaćeni su rani-prolećni kupusi (posejani rano u proleće, posečeni u rano leto), i jesenji kupusi (posejani sredinom leta, posečeni kasno u jesen). Koeficijentima varijacije i korelacionim koeficijentima analizarano je 17 kupusnih svojtava, izmedju 35 komercijalno gajenih sorata, F1-hibrida i eksperimentalnih hibrida kupusa. Svojstva sorata i F1-hibrida kupusa smo analizirali posebno kod svake grupe zrenja. Koeficijent varijacije analiziranih svojstava se kretao od minimalnih 4,8% do maksimalnih 44,2%. Navedeni koeficijenti varijacije su pripadali kupusima iz rane grupe zrenja. Medjutim korelacioni koeficijenti su bili različiti izmedju analiziranih grupa zrenja kupusa. Kupusi iz rane grupe zrenja imali su 32 signifikantno pozitivne korelacije, a kasno jesenji kupusi su imali 26 signifikantno pozitivnih korelacija. Visina biljke i prečnik rozete kod ranih genotipova je u visokoj pozitivnoj korelaciji sa masom rozete, masom cele biljke, masom glavice, korisnim delom glavice, visinom glavice i prečnikom glavice. Kod ranih kupusa sa većom visinom glavice, lisna rozeta tokom proleća neće ležati na hladnoj površini zemljišta. Ovako je aktivnost biljke više usmerena na formiranje veće mase glavice. Zapremina glavice kod kasnih genotipova je u visoko pozitivnoj korelaciji sa prečnikom rozete, masom cele biljke, masom glavice, korisni delom glavice, dužinom unutašnjeg kočana i visinom glavice. Aktivnost biljaka kod kasnih kupusa na formiranju veće zapremine glavice je u funkciji dužeg vegetacionog perioda, većih listov rozete i drugačijih klimatskih uslova.

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