

CORRELATION AND PATH COEFFICIENT ANALYSIS OF YIELD AND YIELD COMPONENTS IN CABBAGE (*Brassica oleracea* var. *capitata* L.)

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Abstract. This research was conducted to determine the interrelationships between yield and some yield components, and direct and indirect effects of such components on yield in cabbage (*Brassica oleracea* var. *capitata* L.). The experiment was carried out in a randomized complete block design with three replications using fourteen inbred lines of cabbage in Samsun, Turkey during 2011–2012. Correlation and path coefficient analysis were performed on 11 economic traits such as plant height, plant diameter, width of outer leaf, length of outer leaf, head weight, head diameter, head length, core length, diameter of interior stem, days to maturity and yield. A wide range of variation was observed among the cabbage genotypes for all the traits. It was found that all of the yield components except days to maturity and core length had highly significant and positive correlations with yield. The highest significant positive correlation was obtained between yield and head weight ($r = 0.927^{**}$). Path coefficient analysis indicated that head weight (0.7139, 56.81%) had the highest positive direct effect on yield followed by head length (0.2265, 23.82%) and plant diameter (0.1907, 16.59%). As a result, head weight, head length, plant diameter, plant height, width of outer leaf, length of outer leaf, head diameter and diameter of interior stem could be effectively used as selection criteria in the breeding programme of cabbage varieties with high yielding, because these traits were the most important yield components affecting yield in cabbage.

Key words: *Brassica oleracea* var. *capitata* L., correlation, path coefficient analysis, yield, selection

INTRODUCTION

Among the Cole crops, cabbage (*Brassica oleracea* var. *capitata* L.) is one of the most important vegetables being grown under temperate to tropical climate conditions for its head in more than ninety countries throughout the world and consumed widely

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around the globe [Singh et al. 2009]. Cabbage is consumed as raw, shredded in salads, cooked, boiled or braised in soups and different culinary dishes. It is also used to make sauerkraut and preserved as dehydrated or frozen. It is a rich source of protein comprising all essential amino acids, minerals (calcium, iron, magnesium, sodium, potassium and phosphorus), and antioxidants which is reported to have anti-carcinogenic properties [Singh et al. 2010a, b]. In addition, cabbage has high fiber content and vitamins A, C and K [Swarup 2006].

In Turkey, 498 073 t of cabbage was produced in an area of 14 941 ha with an average yield of 33.3 t·ha⁻¹ in 2011 and about 20% of the production was provided from Samsun province in the Black Sea Region situated in the north of Turkey [TUIK 2012]. It is intensely in demand by the consumers in Turkey, especially throughout the winter period, owing to its good taste, rich chemical composition, availability at local markets and low cost. For these reasons, cabbage breeding studies in our country have increased in the recent years to develop high-yielding hybrids/varieties of cabbage which are used intensively in the production.

Description of associations between economic traits of cabbage is very important in breeding programmes. The main purpose of breeders is to achieve an increase in cabbage yield. Yield is a complex character determined by several components having positive or negative effects upon this trait. Therefore, it is important to examine the contribution of each of the various components in order to give more attention to those having the greatest influence on yield [Marjanovic-Jeromela et al. 2007]. Correlation coefficient analysis measures the mutual relationship between various economic characters and determines the component character on which selection can be based for improvement in yield. Path coefficient analysis determines the direct and indirect contribution of independent variable on the dependent one and partitions the correlation coefficients into the components of direct and indirect effects [Sinha et al. 2001]. Hence, the knowledge of interrelationships among the various yield components and their direct and indirect effects on yield are of great importance in breeding of cabbage. Correlation and path coefficient analysis of important economic traits of cabbage help the cabbage breeders to find suitable selection criteria for improvement of yield in cabbage.

The interrelationships between yield and various yield components and effects of yield components on yield in cabbage have been studied previously using correlation and path analysis by many researchers [Zhang et al. 1997, Singh 2002, Yadav et al. 2003, Ji et al. 2005, Meena et al. 2009, 2010, Sharma 2010, Singh et al. 2010a]. Yield and yield-contributing traits are quantitative in nature and strongly influenced by the environmental and other factors. Therefore, the results obtained may vary according to environmental conditions, experimental materials and properties of experiments. Additionally, the information regarding the correlation and path coefficient analysis of cabbage in Turkey is inadequate and there is no study on this so far.

Therefore, the objectives of this study were to determine the interrelationships between yield and important yield components, and direct and indirect effects of such components on yield in cabbage using correlation and path coefficient analysis, so as to estimate the most effective selection criteria in cabbage breeding.

MATERIALS AND METHODS

This study was conducted at the experimental field of Black Sea Agricultural Research Institute, located in Samsun, the north of Turkey during 2011–2012 growing period. The experimental site is situated at 41°13' N latitude, 36°29' E longitude and at an altitude of 6 m above mean sea level. Samsun has a mild humid climate with an annual total precipitation of about 721.4 mm, annual relative humidity of 74%, and a mean annual air temperature of 14.4°C [TUMAS 2013]. The soil of the experimental area was clay-loam, pH value of 6.9, organic matter of 1.36% and lime ratio of 7.24%.

The experimental materials consisted of fourteen genetically diverse inbred lines developed at the Black Sea Agricultural Research Institute after inbreeding for 10 generations. The field experiment was performed in a randomized complete block design (RBD) with three replications. The seeds were sown in multi-pot plastic trays consist of 45 pots (4 × 4 × 4 cm), containing a mixture of peat and perlite (3:1, v/v). The seedlings were grown in plastic greenhouse by the usual procedures. The experimental plots consisted of two rows of 7 m length with spacing of 100 cm between the rows and 70 cm between the plants. In total, twenty plants of each cabbage genotype in each replication were transplanted to the field at 4–5 true leaf stage. Fertilization, irrigation and plant protection measures were followed regularly according to standard cultural practices recommended for cabbage cultivation in Turkey.

The plants were harvested for analysis at marketable stage of head. The data for 11 economic traits, including plant height (cm), plant diameter (cm), width of outer leaf (cm), length of outer leaf (cm), head weight (g), head diameter (cm), head length (cm), core length (cm), diameter of interior stem (cm), days to maturity and yield (t·ha⁻¹) were recorded on 10 randomly selected plants from each genotype in each of the three replication.

The interrelationships between investigated economic traits were examined by simple correlation coefficients. The direct and indirect effects of all investigated traits on yield were determined by path coefficient analysis. For path coefficient analysis yield was selected as the dependent variable and the other economic traits were selected as the independent variables. Statistical analyses were performed using SAS program [SAS Institute 1998].

RESULTS AND DISCUSSION

Range values, mean values with their standard errors, mean squares and coefficients of variation of investigated economic traits in cabbage genotypes are given in Table 1. Significant differences were observed among the genotypes for all the traits. These differences indicated the presence of variability and opportunity for improvement. Among cabbage genotypes, head weight ranged from 950–3800 g and yield ranged from 13.6–54.3 t·ha⁻¹. Days to maturity varied from 89 to 136 day. According to Table 1, the mean values of genotypes were recorded for plant height (46.86 cm), plant diameter (90.32 cm), width of outer leaf (37.14 cm), length of outer leaf (46.46 cm), head weight (2614.29 g), head diameter (23.13 cm), head length (17.94 cm), core length

(9.55 cm), diameter of interior stem (3.47 cm), days to maturity (108 day) and yield ($37.35 \text{ t}\cdot\text{ha}^{-1}$). A wide range of variation for head weight and the other yield components in cabbage under different environmental conditions had been reported by Balkaya et al. [2005], Kaygısız Ascıogul [2009], Meena et al. [2009], Sharma [2010], Cervenski et al. [2011] and Singh et al. [2011]. Coefficients of variation were the highest in head weight (29.50%) and yield (29.50%). However, the lowest coefficients of variation were obtained from the head length (10.65%) and head diameter (12.97%). Similar finding was reported by Antonova [2009] who stated more than 30% coefficient of variation for the weight of head in cabbage.

Table 1. Descriptive statistics of economic traits in cabbage genotypes

Traits	Range	Mean \pm SE	Mean square	Coefficient of variation (%)
Plant height (cm)	30–71	46.86 \pm 1.51	281.82**	20.83
Plant diameter (cm)	47–121	90.32 \pm 2.94	1125.65**	21.07
Width of outer leaf (cm)	24–54.5	37.14 \pm 1.12	154.43**	19.51
Length of outer leaf (cm)	30–66	46.46 \pm 1.57	310.44**	21.84
Head weight (g)	950–3800	2614.29 \pm 119.02	1.83**	29.50
Head diameter (cm)	17.5–29	23.13 \pm 0.46	24.79**	12.97
Head length (cm)	14.5–23	17.94 \pm 0.29	8.45**	10.65
Core length (cm)	7.5–13	9.55 \pm 0.21	4.40**	14.05
Diameter of interior stem (cm)	2–5	3.47 \pm 0.11	0.74*	19.60
Days to maturity (day)	89–136	108.00 \pm 2.61	877.85**	15.66
Yield ($\text{t}\cdot\text{ha}^{-1}$)	13.6–54.3	37.35 \pm 1.70	374.73**	29.50

* and ** – significant at the 0.05 and 0.01 probability level, respectively

Knowledge of relationships between yield and its components is essential as this may help in constructing suitable selection criteria for yield. In order to determine the relationships between yield and the other examined traits, correlation coefficients were calculated. Simple correlation coefficients calculated among the examined traits are shown in Table 2. Head weight had highest significant positive correlation coefficient with yield ($r = 0.927^{**}$). Highly significant and positive correlations were also found between yield and plant diameter ($r = 0.832^{**}$), head diameter ($r = 0.806^{**}$), plant height ($r = 0.798^{**}$), length of outer leaf ($r = 0.778^{**}$), head length ($r = 0.664^{**}$), width of outer leaf ($r = 0.642^{**}$) and diameter of interior stem ($r = 0.330^*$). The results suggested that any positive increase in these traits will accelerate the yield potential of cabbage. So, these traits should be paid attention in cabbage breeding programmes. The positive and significant correlations between yield and yield components in cabbage were also reported by Jamwal et al. [1996], Singh [2002], Rai [2003], Yadav et al. [2003], Rai and Asati [2005], Sharma et al. [2005], Meena et al. [2009, 2010], Sharma [2010] and Soni et al. [2013].

However, there was a non-significant negative correlation between yield and days to maturity ($r = -0.158$). Moreover, the relationship between yield and core length ($r = 0.161$) was found positive but non-significant. Owing to negligible effect of days to maturity and core length on yield, these two traits may not be taken into consideration in selection.

In the present study, plant height was positively and significantly associated with plant diameter, width of outer leaf, length of outer leaf, head weight, head diameter, head length and yield. Similarly, plant diameter had also significant positive association with plant height, width of outer leaf, length of outer leaf, head weight, head diameter, head length and yield. In this case, one should select the genotypes which have higher plant height and greater plant diameter as both traits showed significant positive correlations with yield. Zhang et al. [1997] also found a positive and significant correlation between plant width and head weight.

Width and length of outer leaf exhibited significant positive associations with plant height, plant diameter, head weight, head diameter, head length, diameter of interior stem and yield. On the other hand, these two traits were negatively and significantly correlated with days to maturity. It was reported in earlier studies that the yield had positive and significant correlation with leaf length and breadth [Rai 2003, Yadav et al. 2003].

As seen in Table 2, head weight had highly significant and positive correlations with all the examined traits except core length and days to maturity. Also, significant positive correlation was observed between head diameter and plant height, plant diameter, width of outer leaf, length of outer leaf, head weight, head length and yield. Likewise, head length displayed significant positive association with plant height, plant diameter, width of outer leaf, length of outer leaf, head weight, head diameter, core length and yield. Owing to the high positive correlation between yield, and head weight, head diameter and head length; the selection of genotypes with larger head size and heavier head weight would be effective to obtain high yielding varieties/genotypes. Some researchers also reported similar results [Prakash 2004, Ji et al. 2005, Posta and Berar 2006, Singh et al. 2010a]. Results are also in accordance with Surlan-Momirovic et al. [1997] and Antonova [2009] who informed that head diameter showed the significant positive influence on head weight. However, Zhang et al. [1997] found a negative correlation between head weight and head diameter.

Core length showed a significant and positive correlation only with head length. The correlation between this trait and yield was non-significant, so selection based on core length may not be effective for improvement of yield. These results are in consonance with the finding of Yadav et al. [2003]. On the other hand, non-significant positive correlation of interior stem length with head weight and yield is not in line with Rai [2003] and Ji et al. [2005]. Diameter of interior stem had also significant and positive correlations with width of outer leaf, length of outer leaf, head weight and yield.

Although days to maturity had a negative association with all the investigated traits, its association was only significant with width of outer leaf ($r = -0.322^*$) and length of outer leaf ($r = -0.330^*$). The negative association of yield with days to maturity suggested that the selection of early maturing cabbage genotypes to increase yield of cabbage. Results are in accordance with Meena et al. [2010] and Soni et al. [2013] who

confirmed negative correlation of days to maturity with yield. Nevertheless, Rai [2003] and Yadav et al. [2003] observed a positive and significant correlation between yield and days to maturity.

According to the results of the correlation analysis, all of the yield components except days to maturity and core length had highly significant and positive effects on yield. Furthermore, the yield components mostly exhibited positive and significant interrelationships among themselves, which indicated the need of their simultaneous selection for improvement of yield. Thus, yield can be increased through selection based on plant height, plant diameter, width of outer leaf, length of outer leaf, head weight, head diameter, head length and diameter of interior stem.

Correlation coefficients indicate only the general association between any two traits without possible causes of such association. Path coefficient analysis presents a better idea of cause and effect relationship among different characters and plays an important role in determining the degree of relationship between the yield and yield components. Therefore, the path coefficient analysis was performed to partition the correlation coefficient into direct and indirect effect of different characters on yield. The data pertaining to path coefficient analysis are presented in Table 3.

The path coefficient analysis based on yield as a dependent variable revealed that head weight (0.7139, 56.81%) had the highest positive direct effect on yield followed by head length (0.2265, 23.82%) and plant diameter (0.1907, 16.59%). As head weight had also maximum significant and positive correlation with yield ($r = 0.927^{**}$), direct selection for head weight should be done to improve yield of cabbage. Likewise, head length and plant diameter showed positive and significant correlation with yield. Due to significant positive correlation of head weight, head length and plant diameter with yield and also their high positive direct effect on yield, these yield components can be used in direct selection for yield improvement in cabbage breeding. These results are in consonance with Sharma [2010] and Soni et al. [2013] who reported that head weight had the highest positive direct effect on yield. Similar results were also obtained by Singh [2002], Rai and Asati [2005], Meena et al. [2010]. However, Rai [2003] and Yadav et al. [2003] reported that the leaf breadth had the highest direct effect on yield in cabbage.

It was observed that days to maturity, head diameter and length of outer leaf exhibited positive and relatively low direct effect on yield. Whereas, head diameter and length of outer leaf had highly significant positive correlation with yield. Although days to maturity had a negative correlation with yield ($r = -0.158$), the direct effect of this trait on yield was positive. Meena et al. [2010] found that days to maturity showed the direct negative effect on yield.

On the contrary, core length (-0.0876, 20.74%) showed the highest negative direct effect on yield and its correlation with yield is non-significant. These result indicated that selection of this trait may be ineffective in improving the yield. Although plant height, width of outer leaf and diameter of interior stem had positive and highly significant correlation with yield ($r = 0.798^{**}$, 0.642^{**} and 0.330^* , respectively), direct effects of these traits on yield were also negative (-0.1205, -0.0552 and -0.0024, respectively) which implied that these traits might probably contributed to yield through indirect effects.

Table 2. Correlation coefficients for economic traits in cabbage genotypes

Traits	Plant height	Plant diameter	Width of outer leaf	Length of outer leaf	Head weight	Head diameter	Head length	Length of interior stem	Diameter of interior stem	Days to maturity	Yield
Plant height	1.000	0.829**	0.671**	0.852**	0.855**	0.758**	0.600**	0.259	0.264	-0.098	0.798**
Plant diameter		1.000	0.701**	0.805**	0.857**	0.831**	0.471**	0.130	0.292	-0.281	0.832**
Width of outer leaf			1.000	0.751**	0.709**	0.522**	0.451**	0.111	0.442**	-0.322*	0.642**
Length of outer leaf				1.000	0.796**	0.739**	0.646**	0.166	0.399**	-0.330*	0.778**
Head weight					1.000	0.790**	0.601**	0.195	0.357*	-0.157	0.927**
Head diameter						1.000	0.620**	0.291	0.257	-0.149	0.806**
Head length							1.000	0.448**	0.229	-0.221	0.664**
Core length								1.000	-0.058	-0.200	0.161
Diameter of interior stem									1.000	-0.238	0.330*
Days to maturity										1.000	-0.158
Yield											1.000

* and ** – significant at the 0.05 and 0.01 probability level, respectively

Table 3. Path coefficients showing direct and indirect effects of some agronomical traits on yield in cabbage genotypes

Traits	Indirect effects											Correlation with yield
	Direct effects	plant height	plant diameter	width of outer leaf	length of outer leaf	head height	head diameter	head length	length of interior stem	diameter of interior stem	days to maturity	
Plant height	-0.1205 (10.34%) ¹	–	0.1581 (13.57%)	-0.0371 (3.18%)	0.0169 (1.45%)	0.6106 (52.40%)	0.0601 (5.15%)	0.1359 (11.66%)	-0.0227 (1.95%)	-0.0006 (0.05%)	-0.0028 (0.24%)	0.798**
Plant diameter	0.1907 (16.59%)	-0.0999 (8.69%)	–	-0.0387 (3.37%)	0.0160 (1.39%)	0.6115 (53.19%)	0.0659 (5.73%)	0.1067 (9.28%)	-0.0114 (0.99%)	-0.0007 (0.06%)	-0.0081 (0.71%)	0.832**
Width of outer leaf	-0.0552 (5.79%)	-0.0809 (8.48%)	0.1337 (14.01%)	–	0.0149 (1.56%)	0.5058 (53.02%)	0.0414 (4.34%)	0.1021 (10.71%)	-0.0097 (1.02%)	-0.0011 (0.11%)	-0.0093 (0.97%)	0.642**
Length of outer leaf	0.0199 (1.78%)	-0.1026 (9.20%)	0.1535 (13.76%)	-0.0415 (3.72%)	–	0.5685 (50.94%)	0.0585 (5.25%)	0.1464 (13.12%)	-0.0146 (1.30%)	-0.0010 (0.09%)	-0.0095 (0.85%)	0.778**
Head weight	0.7139 (56.81%)	-0.1030 (8.20%)	0.1634 (13.00%)	-0.0391 (3.11%)	0.0158 (1.26%)	–	0.0626 (4.98%)	0.1363 (10.84%)	-0.0171 (1.36%)	-0.0009 (0.07%)	-0.0045 (0.36%)	0.927**
Head diameter	0.0793 (7.16%)	-0.0913 (8.24%)	0.1585 (14.32%)	-0.0288 (2.60%)	0.0147 (1.33%)	0.5638 (50.92%)	–	0.1405 (12.69%)	-0.0255 (2.30%)	-0.0006 (0.06%)	-0.0043 (0.39%)	0.806**
Head length	0.2265 (23.82%)	-0.0723 (7.60%)	0.0898 (9.45%)	-0.0249 (2.62%)	0.0128 (1.35%)	0.4294 (45.14%)	0.0492 (5.17%)	–	-0.0393 (4.13%)	-0.0005 (0.06%)	-0.0064 (0.67%)	0.664**
Core length	-0.0876 (20.74%)	-0.0312 (7.38%)	0.0247 (5.85%)	-0.0061 (1.45%)	0.0033 (0.78%)	0.1392 (32.95%)	0.0230 (5.45%)	0.1015 (24.01%)	–	0.0001 (0.03%)	-0.0058 (1.36%)	0.161
Diameter of interior stem	-0.0024 (0.52%)	-0.0318 (6.90%)	0.0557 (12.08%)	-0.0244 (5.29%)	0.0079 (1.72%)	0.2550 (55.26%)	0.0204 (4.42%)	0.0518 (11.23%)	0.0051 (1.10%)	–	-0.0069 (1.49%)	0.330*
Days to maturity	0.0288 (9.28%)	0.0117 (3.78%)	-0.0537 (17.29%)	0.0178 (5.72%)	-0.0066 (2.11%)	-0.1120 (36.07%)	-0.0118 (3.79%)	-0.0501 (16.13%)	0.0175 (5.63%)	0.0006 (0.18%)	–	-0.158

* and ** – significant at the 0.05 and 0.01 probability level, respectively

¹ – % contribution of Path coefficients

Plant height, plant diameter, width of outer leaf, length of outer leaf, head diameter, head length, core length and diameter of interior stem showed high positive indirect effects on yield via head weight. While diameter of interior stem had the highest positive indirect effect on yield through head weight (0.2550, 55.26%), maximum negative indirect effect was observed in days to maturity (-0.1120, 36.07%) in relation to head weight. Although diameter of interior stem had a low negative direct effect (0.52%) on yield, its total positive indirect effect (85.81%) via other traits on yield was the highest. It had also significant positive association with yield. Therefore, indirect selection for diameter of interior stem may be effective to increase the yield. Days to maturity had a positive and moderate direct effect (9.28%) on yield, whereas this trait showed the highest total negative indirect effect (75.39%) on yield. So, selection for days to maturity may be ineffective to improve yield of cabbage.

Path coefficient analysis revealed that head weight, head length and plant diameter had high positive direct effects on yield and a higher indirect contribution was exhibited via these traits by most of the yield components. Accordingly, it can be said that head weight, head length and plant diameter are the most important properties affecting the yield of cabbage. Thus, importance must be given to these traits in the selection programme. In addition to, plant height, width of outer leaf, length of outer leaf, head diameter and diameter of interior stem contributed indirectly to yield. Therefore, considering of these traits as selection criteria will be advantageous for improvement of yield in cabbage.

CONCLUSIONS

The results of correlation and path coefficient analysis clearly indicate that head weight was the most important trait for increasing of yield in cabbage. Also, head length, plant diameter, plant height, width of outer leaf, length of outer leaf, head diameter and diameter of interior stem were important yield components in cabbage. Thus, the present study suggests that all these traits should be considered simultaneously in selection programme aimed at improving of cabbage varieties with high yielding.

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ANALIZA KORELACJI I WSPÓLCZYNNIKA ŚCIEŻKI DLA PŁONU ORAZ KOMPONENTÓW PŁONU KAPUSTY (*Brassica oleracea* var. *capitata* L.)

Streszczenie. Badanie przeprowadzono w celu ustalenia związków między pewnymi elementami plonu oraz bezpośredniego i pośredniego wpływu tych elementów na plon kapusty (*Brassica oleracea* var. *capitata* L.). Doświadczenie przeprowadzono w Turcji w latach 2011–2012 w układzie kompletnej randomizacji z trzema powtórzeniami przy użyciu czternastu linii wsobnych kapusty. Przeprowadzono analizę korelacji i współczynnika ścieżki na 11 cechach, takich jak wysokość rośliny, średnica, szerokość zewnętrznego liścia, długość zewnętrznego liścia, masa głowy, średnica głowy, długość głowy, długość głęba, średnica wewnętrznej łodygi, liczba dni do dojrzałości oraz plonu. Zaobserwowano duże zróżnicowanie między genotypami kapusty w odniesieniu do wszystkich cech. Stwierdzono, że wszystkie elementy plonu, z wyjątkiem liczby dni do dojrzałości oraz długości głęba, były istotne i wysoce skorelowane z plonem. Największą pozytywną korelację otrzymano między plonem a masą ($r = 0,927^{**}$). Współczynnik ścieżki wskazywał, że masa głowy (0,7139, 56,81%) miała największy pozytywny bezpośredni wpływ na plon, drugim ważnym czynnikiem była długość głowy (0,2265, 23,82%), a kolejnym – średnica rośliny (0,1907, 16,59%). W rezultacie masa głowy, długość głowy, średnica rośliny, wysokość rośliny, szerokość zewnętrznego liścia, długość zewnętrznego liścia, średnica głowy oraz średnica wewnętrznej łodygi mogą być skutecznie użyte jako kryteria selekcji w programie hodowlanym odmian kapusty o wysokim plonowaniu, ponieważ cechy te były najważniejszymi składnikami plonu wpływającymi na plon kapusty.

Słowa kluczowe: *Brassica oleracea* var. *capitata* L., korelacja, analiza współczynnika ścieżki, plon, selekcja

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