International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(5): 2731-2737

Received: 29-07-2019
Accepted: 30-08-2019

Shaina Sharma
Department of Vegetable Science and Floriculture, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh, India

Sanjay Chadha
Department of Vegetable Science and Floriculture, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh, India

Nitish Sharma
Department of Vegetable Science and Floriculture, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh, India

Paras Singh
Department of Vegetable Science and Floriculture, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh, India

Corresponding Author:
Shaina Sharma
Department of Vegetable Science and Floriculture, College of Agriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh, India

Correlation and path analysis among CMS lines and their maintainers for yield and quality attributes in cabbage (*Brassica oleracea* var. *capitata* L.)

Shaina Sharma, Sanjay Chadha, Nitish Sharma and Paras Singh

Abstract
The present investigation was undertaken at 'Vegetable Research Farm' of the Department of Vegetable Science and Floriculture, CSKHPKV Palampur. Twenty three genotypes [15 CMS lines + six maintainer lines + two checks namely KGMR-1 (public sector commercial hybrid) and Varun (private sector commercial hybrid)] were evaluated in Randomized Complete Block Design with three replications during *Rabi,* 2017-18. Estimates of correlation coefficient revealed significant positive association of marketable head yield per plot with net head weight, equatorial diameter, gross head weight, polar diameter, plant spread and ascorbic acid content. At phenotypic level, the main characters which showed the maximum direct positive effect on marketable head yield per plot were net head weight, marketable heads per plot, polar diameter, compactness of head and equatorial diameter and at genotypic level high positive direct effect on marketable head yield per plot was observed for equatorial diameter, head shape index, compactness of head, gross head weight, marketable heads per plot, polar diameter, days to harvest and TSS. Estimates of indirect effect showed that most of the traits contributed towards marketable head yield per plot via net head weight.

Keywords: Cabbage, *Brassica oleracea* var. *capitata,* correlation, path analysis

Introduction
Cabbage, *Brassica oleracea* var. *capitata* L. (2n=2x=18) member of family *Brassicaceae* is one of the most important cole-group vegetable crops. It is originated from *Brassica oleracea* var. *oleracea* L. (syn. *Brassica oleracea* var. *sylvestris* L.) commonly known as wild cabbage through mutation, human selection and adaptation. It is rich source of sulphur containing amino acids, minerals, carotenes, ascorbic acid and anti-carcinogenic properties (Singh *et al*., 2009) [10]. Cabbage is grown throughout the world and the leading countries are China, India, Russia, Korea, Japan, Indonesia, Poland, Romania and USA. It is next to cauliflower in India with acreage and production statistics of 399 thousand hectares and 9,037 thousand MT, respectively (Anonymous, 2018) [3]. In Himachal Pradesh, it is being cultivated extensively as an off-season vegetable with an area of 4852 ha and production of 161108 MT (Anonymous, 2017) [2]. In CSKHPKV, a number of low chill requiring genotypes of cabbage have been developed for the last over two decades and consequently, good seed crop is possible in about 8-9 months period in the mid hills of Himachal Pradesh. The work on incorporation of CMS in these low chill requiring genotypes started in CSKHPKV Palampur during the last one decade had resulted in development of a number of low chill requiring CMS lines quite comparable with their male fertile counterparts. The knowledge of inter relationships among the various components and their direct and indirect effect on yield are essential to bring genetic improvement in cabbage. Path coefficient will help plant breeders to decide suitable selection criteria to improve yield. The information regarding the correlation and path coefficient analysis in cabbage is inadequate. Therefore, present studies were carried out with objective to examine the association between important yield traits and their path analysis in cabbage, so as to make effective selection for the improvement of cabbage.

Materials and Methods
The present investigation was undertaken at the Vegetable Research Farm of the Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya,

Palampur, (H.P.), during *Rabi*, 2017-18. The experimental farm is situated at 32º 6' North latitude, 76º 3' East longitude at an elevation of 1290.8m above mean sea level. Sowing of cabbage seeds in nursery was done on 6th September, 2017 and transplanted in the main field on 4th October, 2017. The experimental materials consisted of 15 cytoplasmic male sterile (CMS) lines developed at CSKHPKV, Palampur from different male sterility sources (old ogura and new improved ogura system) using six well adapted low chill requiring open pollinated parents along with two checks of cabbage (commercial hybrids – KGMR-1 from public and Varun from private sector) (Table 1). All genotypes were transplanted in Randomized Complete Block Design (RCBD) with three replications in plot size of 2.7m × 1.35m. The genotypes were spaced at 45cm between row to row and 45cm between plant to plant. The standard cultural practices to raise the crop were followed as per the recommended package of practices for vegetable crops by CSKHPKV, Palampur. Observations were recorded on five randomly marked plants for characters namely plant spread (cm), number of non-wrapper leaves, polar and equatorial diameters of head (cm), days to harvest, head shape index, compactness of head (g/cm^3), total soluble solids i.e. TSS (^{0}Brix), ascorbic acid content (mg/100g), gross head weight (g), net head weight (g), marketable heads per plot and marketable head yield per plot (kg). The data were statistically analyzed as per the methods given by Panse and Sukhatme (1984) [8]. Phenotypic and genotypic coefficients of correlation were computed by following method given by Al-Jibouri *et al*., (1958) [1]. The path coefficient analysis of 13 components traits with marketable head yield per plot was carried out by following Dewey and Lu (1959) [5].

Statistical analysis

The statistical analysis was carried out for each observed character under study using MS-Excel and OPSTAT (developed by CCS Haryana Agricultural University, Hisar, India).

Results and Discussion

Correlation coefficient analysis

Knowledge of genetic association of yield and various component characters are of economic worth in formulating and executing the breeding programme. Knowledge of association between traits serves two main purposes for breeders, first for selection of characters which are not easily observed or genotypic values of which are modified by environment effects, and secondly to provide information about the nature and extent, and direction of selection pressure among different traits. A few of the component traits may be directly and positively associated with marketable head yield and often prove to be useful selection criteria for crop improvement. Genotypic correlation provides measures of genetic association between characters and is more reliable than phenotypic correlation and thus, helps to identify the characters to be utilized in breeding programme.

Phenotypic correlation coefficients

The phenotypic correlation coefficient among different traits showed that the most important trait i.e. marketable head yield per plot had positive and significant association with net head weight (0.865), equatorial diameter (0.787), gross head weight (0.774), polar diameter (0.591), plant spread (0.435), marketable heads per plot (0.396) and ascorbic acid content (0.250) and significant negative association with days to harvest (-0.613), head shape index (-0.490) and compactness of head (-0.237) (Table 2). Earlier reports of many research workers have also indicated positive and significant correlation of marketable head yield with net head weight (Atter 2004) [4], gross head weight (Meena *et al.*, 2009) [7], equatorial diameter (Soni *et al.*, 2013) [14], polar diameter (Kaur *et al.*, 2018) [6] and plant spread (Soni *et al.*, 2013) [14].

Among other traits, plant spread had positive significant correlation with equatorial diameter (0.572), net head weight (0.554), gross head weight (0.495), polar diameter (0.343) and TSS (0.240). Significant but negative correlation of plant spread was recorded with head shape index (-0.406), days to harvest (-0.389) and compactness of head (-0.253). Singh *et al.*, (2010) [13] had also reported positive correlation of plant spread with equatorial diameter, gross weight and net weight of head.

Polar diameter exhibited positive significant correlation with gross head weight (0.501) and equatorial diameter (0.491) and significant negative correlation with compactness of head (-0.541) and days to harvest (-0.268). Similar findings have also been reported for equatorial diameter (Rai *et al.*, 2003) [9].

Equatorial diameter was positively and significantly correlated with net head weight (0.854), gross head weight (0.707) and TSS (0.293). Its association was negative and significant with head shape index (-0.788), days to harvest (-0.570) and compactness of head (-0.526). Singh *et al.*, (2013) [12] also reported negative but non-significant correlation of equatorial diameter with days to maturity.

Days to harvest had significant positive correlation with head shape index (0.486) and compactness of head (0.290). Its association was significant negative with gross head weight (-0.484), net head weight (-0.469) and marketable heads per plot (-0.365).

Head shape index had no significant positive correlation, however, negative significant association with net head weight (-0.499), gross head weight (-0.461) and TSS (-0.300).

Compactness of head was significantly and negatively correlated with TSS (-0.255).

The estimates of correlation coefficient revealed that gross head weight had positive and significant correlation with net head weight (0.836). These results are in conformity with many earlier research workers (Singh *et al.*, 2010) [13].

Genotypic correlation coefficient

At genotypic level, marketable head yield had significant positive correlation with gross head weight (0.916), net head weight (0.903), equatorial diameter (0.872), ascorbic acid content (0.493), polar diameter (0.419), plant spread (0.339) and TSS (0.279) and significant negative association with days to harvest (-0.794), head shape index (-0.707) and number of non-wrapper leaves (-0.286). Earlier reports of many research workers have also indicated significant positive correlation of marketable head yield with net head weight (Soni *et al.*, 2013) [14], gross head weight (Meena *et al.*, 2009) [7], equatorial diameter (Soni *et al.*, 2013) [14] and polar diameter (Rai *et al.*, 2003) [9].

Among other traits, plant spread showed positive significant correlation with gross head weight (0.715), net head weight (0.661), equatorial diameter (0.624) and TSS (0.580) and significant negative correlation with marketable heads per plot (-0.770) and head shape index (-0.579). Singh *et al.*, (2010) [13] reported positive and significant correlation of plant spread with net weight of head, gross weight per plant and equatorial diameter. Number of non-wrapper leaves exhibited significant positive correlation with marketable heads per plot (0.642). Significant negative correlations of this trait were observed with polar diameter (-0.670), net head weight (-0.514), ascorbic acid content (-0.385) and gross head weight (-0.243). Atter (2004) [4] observed significant and negative association of number of non-wrapper leaves with marketable heads per plot.

Polar diameter was positively and significantly correlated with gross head weight (0.604), net head weight (0.534), ascorbic acid content (0.512), equatorial diameter (0.269) and TSS (0.259), whereas it had negative and significant correlation with marketable heads per plot (-0.251). Similar findings have also reported for polar diameter with equatorial diameter (Meena *et al.*, 2009) [7]. Equatorial diameter exhibited positive significant correlation with net head weight (0.908), gross head weight (0.843), TSS (0.470) and ascorbic acid content (0.237) and had significant negative correlation with head shape index (-0.897) and days to harvest (-0.611). Kaur *et al.*, (2018) [6] also reported positive significant correlation with TSS and ascorbic acid.

Days to harvest had significant positive correlation with head shape index (0.600) and compactness of head (0.401), whereas its association was significantly negative with marketable heads per plot (-0.809), gross head weight (-0.590), TSS (-0.433), net head weight (-0.432) and ascorbic acid content (-0.348). Kaur *et al.*, (2018) [6] observed significant positive correlation with head shape index and significant negative association with marketable heads per plot. In contrary, Singh *et al.*, (2013) [12] reported highly significant and positive correlation of days to harvest with net head weight. Head shape index had significant and negative correlation with net head weight (-0.663), gross head weight (-0.596) and TSS (-0.368). TSS had significant and positive correlation with ascorbic acid content (0.446), gross head weight (0.324) and net head weight (0.295). Ascorbic acid had significant positive correlation with gross head weight (0.488) and net head weight (0.444).

Gross head weight had significant positive correlation with net head weight (0.892) at genotypic level. Kaur *et al.*, (2018) [6] reported that gross head weight had significant positive correlation with net head weight. Net head weight exhibited significant negative correlation with marketable heads per plot (-0.313). In contrary, Kaur *et al.*, (2018) [6] observed significant positive correlation with marketable heads per plot.

Path coefficient analysis

The correlation coefficients provide information regarding the association of different characters among themselves, whereas better insight into the cause of the association is provided by the path coefficient analysis. It allows the partition of the correlation coefficients into direct and indirect effects of the traits contributing towards the dependent variable.

Estimates of direct effects at phenotypic and genotypic level

At phenotypic level, net head weight (0.680), marketable heads per plot (0.477), polar diameter (0.222), compactness of head (0.146) and equatorial diameter (0.112) are the five main characters which showed the maximum direct positive effect on marketable head yield per plot. Whereas, the maximum negative direct effects were observed mainly via head shape index (-0.097), plant spread (-0.031) and gross head weight (-0.017) (Table 3). Earlier researchers also reported positive direct effects of net head weight (Thakur and Vidyasagar 2016) [15] and marketable heads (Kaur *et al.*, 2018) [6] on marketable head yield. Kaur *et al.*, (2018) [6] also reported negative direct effects via head shape index on marketable head yield.

Estimates of direct effects at genotypic level showed that equatorial diameter (3.943) had the highest positive direct effect on marketable head yield per plot followed by head shape index (1.392), compactness of head (0.882), gross head weight (0.426), marketable heads per plot (0.415), polar diameter (0.194), days to harvest (0.168) and TSS (0.123), while net head weight (-2.091) and plant spread (-0.132) exhibited negative direct effects. Negative direct effects indicated the inappropriateness of selecting this character for improving the marketable head yield. Earlier researchers reported positive direct effect of gross head weight (Atter 2004) [4], polar diameter (Soni *et al.*, 2013) [14] and compactness of head (Sharma 2010) [11] on head yield.

Estimates of indirect effects at phenotypic and genotypic level

At phenotypic level, the maximum positive indirect effects of plant spread were observed mainly via net head weight (0.377), polar diameter (0.076), equatorial diameter (0.064) and head shape index (0.039) and the maximum negative indirect effect via marketable heads per plot (-0.055) and compactness of head (-0.037). At genotypic level, the maximum positive indirect effects of plant spread were observed mainly via equatorial diameter (2.461), gross head weight (0.304) and compactness of head (0.146), while it showed negative indirect effects through net head weight (-1.383), head shape index (-0.806) and marketable heads per plot (-0.319). Kaur *et al.*, (2018) [6] reported positive indirect effect via equatorial and polar diameter at phenotypic level. In contrary, Soni *et al.*, (2013) [14] reported negative indirect effect via equatorial diameter at genotypic level.

Number of non-wrapper leaves exerted positive indirect effects via net head weight (1.074) and marketable heads per plot (0.266) and negative indirect effects via equatorial diameter (-1.065), compactness of head (-0.156), polar diameter (-0.130) and gross head weight (-0.104) at genotypic level. Meena *et al.*, (2009) [7] observed that number of non-wrapper leaves had negative indirect effects via polar diameter at genotypic level.

Polar diameter exerted the maximum positive indirect effects to head yield via net head weight (0.450) and negative mainly via compactness of head (-0.079), marketable heads per plot (-0.026), head shape index (-0.013) and plant spread (-0.011) at phenotypic level. At genotypic level, positive indirect effects were noticed via equatorial diameter (1.060) and negative via net head weight (-1.117), compactness of head (-0.107) and marketable heads per plot (-0.104). In contrary, (Soni *et al.*, 2013) [14] reported negative indirect effect via equatorial diameter at genotypic level.

At phenotypic level, equatorial diameter imposed positive indirect effects mainly via net head weight (0.581) and polar diameter (0.109), and negative via compactness of head (-0.077). At genotypic level, this trait exerted positive indirect effect via gross head weight (0.359) and negative indirect effects via net head weight (-1.900) and head shape index (-1.248). Soni *et al.*, (2013) [14] reported that equatorial diameter exerted positive indirect effect via polar diameter.

Days to harvest showed positive indirect effects via compactness of head (0.042) and negative via net head weight (-0.318) and marketable heads per plot (-0.174) at phenotypic level. At genotypic level, the maximum positive indirect effects were noticed via net head weight (0.904), head shape index (0.835) and compactness of head (0.354) and negative indirect effect via equatorial diameter (-2.411), marketable heads per plot (-0.336) and gross head weight (-0.251). Kaur *et al.,* (2018) [6] reported negative indirect effect via marketable heads per plot at phenotypic level.

Head shape index showed positive indirect effects via compactness of head (0.033), polar diameter (0.031) and plant spread (0.012) and negative indirect effects via net head weight (-0.339), equatorial diameter (-0.088) and marketable heads per plot (-0.042) at phenotypic level. Head shape index exerted negative indirect effects at genotypic level via equatorial diameter (-3.536) and positive indirect effect via net head weight (1.387), compactness of head (0.145) and days to harvest (0.101). Sharma (2010) [11] reported head shape index had positive indirect effects via days to maturity.

At phenotypic level, compactness of head imposed positive indirect effects mainly via plant spread (0.008) and gross head weight (0.002) and negative indirect effect via net head weight (-0.138) and polar diameter (-0.120). Atter (2004) [4] reported positive indirect effect via gross head weight. In contrary, Kaur *et al.,* (2018) [6] observed negative indirect effect via gross head weight at phenotypic level. At genotypic level, TSS contributed positive indirect effects via equatorial diameter (1.853) and negative via net head weight (-0.616), compactness of head (-0.538) and head shape index (-0.511). At phenotypic level, ascorbic acid content contributed positive indirect effects towards marketable head yield per plot via net head weight (0.160), equatorial diameter (0.018) and marketable heads per plot (0.015) and negative indirect effect via plant spread (-0.006), gross head weight (-0.004) and number of non-wrapper leaves (-0.002). At genotypic level, this trait imposed positive indirect effects via equatorial diameter (0.935), gross head weight (0.208) and compactness of head (0.202) and negative via net head weight (-0.929) and days to harvest (-0.059). Soni *et al.,* (2013) [14] reported positive indirect effects via equatorial length at both phenotypic and genotypic level. In contrary, Kaur *et al.,* (2018) [6] observed negative indirect effect via equatorial diameter at genotypic level.

At phenotypic level, the maximum positive indirect effects of gross head weight were observed via net head weight (0.568) and polar diameter (0.111) and negative via compactness of head (-0.016). At genotypic level, the positive indirect effects were observed via equatorial diameter (3.322) and negative via net head weight (-1.865) and head shape index (-0.829). In contrary, Kaur *et al.,* (2018) [6] reported negative indirect effect via equatorial diameter at genotypic level.

At phenotypic level, net head weight recorded positive indirect effects mainly via polar diameter (0.147) and negative indirect effects via marketable heads per plot (-0.051), compactness of head (-0.030), plant spread (-0.017) and gross head weight (-0.014). At genotypic level, the maximum positive indirect effects were recorded via equatorial diameter (3.582) and gross head weight (0.380) and negative via head shape index (-0.923) and marketable heads per plot (-0.130). Kaur *et al.,* (2018) [6] also reported negative indirect effect via gross head weight at phenotypic level.

At phenotypic level, marketable heads per plot contributed positive indirect effect on marketable head yield via head shape index (0.008), plant spread (0.004), number of non-wrapper leaves and days to harvest (both with 0.003) and negative mainly via net head weight (-0.072), compactness of head (-0.016) and polar diameter (-0.012). In contrary, Sharma (2010) [11] observed that marketable heads percentage had negative indirect effects via head shape index.

Table 1: List of CMS and maintainer lines

CMS Lines	Maintainer lines	Source
I-MCMS, I-105CMS, I-SCMS, II-MCMS, II-105CMS, II-SCMS, III-MCMS, III-105CMS, GA(P)-MCMS, GA(P)-105CMS, GA(P)-SCMS, Glory I-MCMS, Glory I-SCMS, Glory-7-MCMS, Glory-7-SCMS	KGAT-1, KGAT-II, KGAT-III, GA(P), Glory-I, Glory-7	CSKHPKV, Palampur
Checks		
KGMR-1		IARI Regional Station, Katrain
Varun		Private sector

Table 2: Estimates of correlation at phenotypic (P) and genotypic (G) levels between different traits of cabbage

Traits		No. of non-wrapper leaves	Polar diameter (cm)	Equatorial diameter (cm)	Days to harvest	Head shape index	Compactness of head (g/cm^3)	TSS (^{0}Brix)	Ascorbic acid content (mg/100g)	Gross head weight (g)	Net head weight (g)	Marketable heads per plot	Marketable head yield (kg/plot)
Plant spread (cm)	P	0.088	0.343**	0.572**	-0.389**	-0.406**	-0.253*	0.240*	0.210	0.495**	0.554**	-0.116	0.435**
	G	0.191	0.122	0.624**	-0.092	-0.579**	0.165	0.580**	0.045	0.715**	0.661**	-0.770**	0.339**
No of non-wrapper leaves	P		-0.274*	-0.147	-0.003	-0.078	0.033	-0.055	-0.150	-0.082	-0.254*	0.185	-0.139
	G		-0.670**	-0.270*	-0.179	-0.052	-0.177	-0.084	-0.385**	-0.243*	-0.514**	0.642**	-0.286*
Polar diameter (cm)	P			0.491**	-0.268*	0.139	-0.541**	0.071	0.148	0.501**	0.662**	-0.055	0.591**
	G			0.269*	-0.210	0.175	-0.121	0.259*	0.512**	0.604**	0.534**	-0.251*	0.419**
Equatorial diameter (cm)	P				-0.570**	-0.788**	-0.526**	0.293*	0.158	0.707**	0.854**	0.016	0.787**
	G				-0.611**	-0.897**	-0.162	0.470**	0.237*	0.843**	0.908**	-0.161	0.872**
Days to harvest	P					0.486**	0.290*	-0.124	-0.169	-0.484**	-0.469**	-0.365**	-0.613**
	G					0.600**	0.401**	-0.433**	-0.348**	-0.590**	-0.432**	-0.809**	-0.794**
Head shape index	P						0.227	-0.300*	-0.065	-0.461**	-0.499**	-0.087	-0.490**
	G						0.164	-0.368**	0.005	-0.596**	-0.663**	-0.024	-0.707**
Compactness of head (g/cm^3)	P							-0.255*	0.054	-0.109	-0.203	-0.110	-0.237*
	G							-0.610**	0.229	-0.088	0.111	-0.143	0.090
TSS (^{0}Brix)	P								0.331**	0.202	0.172	0.030	0.173
	G								0.446**	0.324**	0.295*	-0.133	0.279*
Ascorbic acid content (mg/100g)	P									0.222	0.236	0.031	0.250*
	G									0.488**	0.444**	0.012	0.493**
Gross head weight (g)	P										0.836**	0.020	0.774**
	G										0.892**	-0.036	0.916**
Net head weight (g)	P											-0.106	0.865**
	G											-0.313**	0.903**
Marketable heads per plot	P												0.396**
	G												0.125

Table 3: Direct and indirect effects of component traits on marketable yield of cabbage at phenotypic (P) and genotypic (G) level

Traits		Plant spread (cm)	No. of non-wrapper leaves	Polar diameter (cm)	Equatorial diameter (cm)	Days to harvest	Head shape index	Compactness of head (g/cm^3)	TSS (^{0}Brix)	Ascorbic acid content (mg/100g)	Gross head weight (g)	Net head weight (g)	Marketable heads per plot)	Marketable head yield (kg/plot)
Plant spread (cm)	P	-0.031	0.001	0.076	0.064	0.003	0.039	-0.037	0.001	0.004	-0.008	0.377	-0.055	0.435^{**}
	G	-0.132	-0.010	0.024	2.461	-0.016	-0.806	0.146	0.071	-0.002	0.304	-1.383	-0.319	0.339^{**}
No of non-wrapper leaves	P	-0.003	0.015	-0.061	-0.016	0.000	0.008	0.005	0.000	-0.003	0.001	-0.173	0.088	-0.139
	G	-0.025	-0.051	-0.130	-1.065	-0.030	-0.072	-0.156	-0.010	0.016	-0.104	1.074	0.266	-0.286^{*}
Polar diameter (cm)	P	-0.011	-0.004	0.222	0.055	0.002	-0.013	-0.079	0.000	0.003	-0.008	0.450	-0.026	0.591^{**}
	G	-0.016	0.034	0.194	1.060	-0.035	0.244	-0.107	0.032	-0.022	0.257	-1.117	-0.104	0.419^{**}
Equatorial diameter (cm)	P	-0.018	-0.002	0.109	0.112	0.005	0.076	-0.077	0.002	0.003	-0.012	0.581	0.008	0.787^{**}
	G	-0.083	0.014	0.052	3.943	-0.103	-1.248	-0.143	0.058	-0.010	0.359	-1.900	-0.067	0.872^{**}
Days to harvest	P	0.012	0.000	-0.059	-0.064	-0.008	-0.047	0.042	-0.001	-0.003	0.008	-0.318	-0.174	-0.613^{**}
	G	0.012	0.009	-0.041	-2.411	0.168	0.835	0.354	-0.053	0.015	-0.251	0.904	-0.336	-0.794^{**}
Head shape index	P	0.012	-0.001	0.031	-0.088	-0.004	-0.097	0.033	-0.002	-0.001	0.008	-0.339	-0.042	-0.490^{**}
	G	0.077	0.003	0.034	-3.536	0.101	1.392	0.145	-0.045	0.000	-0.254	1.387	-0.010	-0.707^{**}
Compactness of head (g/cm^3)	P	0.008	0.001	-0.120	-0.059	-0.002	-0.022	0.146	-0.001	0.001	0.002	-0.138	-0.052	-0.237^{*}
	G	-0.022	0.009	-0.023	-0.639	0.067	0.229	0.882	-0.075	-0.010	-0.037	-0.232	-0.059	0.090
TSS (^{0}Brix)	P	-0.007	-0.001	0.016	0.033	0.001	0.029	-0.037	0.006	0.007	-0.003	0.117	0.014	0.173
	G	-0.077	0.004	0.050	1.853	-0.073	-0.511	-0.538	0.123	-0.019	0.138	-0.616	-0.055	0.279^{*}
Ascorbic acid content (mg/100g)	P	-0.006	-0.002	0.033	0.018	0.001	0.006	0.008	0.002	0.020	-0.004	0.160	0.015	0.250^{*}
	G	-0.006	0.020	0.099	0.935	-0.059	0.006	0.202	0.055	-0.043	0.208	-0.929	0.005	0.493^{**}
Gross head weight (g)	P	-0.015	-0.001	0.111	0.079	0.004	0.045	-0.016	0.001	0.004	-0.017	0.568	0.010	0.774^{**}
	G	-0.095	0.012	0.117	3.322	-0.099	-0.829	-0.078	0.040	-0.021	0.426	-1.865	-0.015	0.916^{**}
Net head weight (g)	P	-0.017	-0.004	0.147	0.096	0.004	0.048	-0.030	0.001	0.005	-0.014	0.680	-0.051	0.865^{**}
	G	-0.087	0.026	0.104	3.582	-0.073	-0.923	0.098	0.036	-0.019	0.380	-2.091	-0.130	0.903^{**}
Marketable heads per plot	P	0.004	0.003	-0.012	0.002	0.003	0.008	-0.016	0.000	0.001	0.000	-0.072	0.477	0.396^{**}
	G	0.102	-0.033	-0.049	-0.636	-0.136	-0.033	-0.126	-0.016	-0.001	-0.015	0.654	0.415	0.125

** Significant at P ≤ 0.01; *Significant at P ≤ 0.05 level; Residual effect (P): 0.00852; (G): -0.01936; The bold values indicate direct effect with marketable yield per plot

References

1. Al-Jibouri HA, Miller PA, Robinson HF. Genotypic and environmental variances and co-variances in an upland cotton cross of interspecific origin. Agronomy Journal. 1958; 50:633-636.
2. Anonymous. Area, production and productivity of cabbage in Himachal Pradesh. Department of Agriculture (H.P), Shimla-5, 2017.
3. Anonymous. Area, production and productivity of cabbage in India, 2018 http//.indiastat.com/
4. Atter RS. Study on genetic variability for head yield and component traits in cabbage (*Brassica oleracea* var. *capitata* L.). M.Sc. Thesis, 54p. Department of Vegetable Science, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P), India, 2004.
5. Dewey DR, Lu KH. A correlation and path coefficient analysis of components of crested wheat grass seed population. Agronomy Journal. 1959; 51:515-518.
6. Kaur M, Chadha S, Kumar N, Sehgal N, Kanwar S. Characters association and path analysis among CMS and SI based cabbage hybrids under mid hill conditions of Himachal Pradesh, India. International Journal of Current Microbiology and Applied Sciences. 2018; 7(1):424-430.
7. Meena ML, Ram RB, Rubee L. Genetic variability and correlation studies for some quantitative traits in cabbage (*Brassica oleracea* var. *capitata* L.) under Lucknow conditions. Progressive Horticulture. 2009; 41:89-93.
8. Panse VG, Sukhatme PV. Statistical Methods for Agricultural Workers. ICAR, New Delhi, 1984, 381.
9. Rai N, Singh AK, Yadav RK. Correlation and path coefficient analysis for the yield and its traits in cabbage. Indian Journal of Hill Farming. 2003; 16:61-65.
10. Singh BK, Sharma SR, Singh B. Heterosis for mineral elements in single cross-hybrids of cabbage (*Brassica oleracea* var. *capitata* L.). Scientia Horticulturae. 2009; 122:32-36.
11. Sharma KC. Genetic variability, characters association and path analysis in exotic lines of cabbage under mid hill, sub-humid conditions of Himachal Pradesh. Journal of Hill Agriculture. 2010; 1:146-150.
12. Singh B, Mishra AK, Sanwal SK, Singh PK, Rai M. Genetic variability and character association analysis in cabbage hybrids. Indian Journal of Horticulture. 2013; 70:296-299.
13. Singh BK, Sharma SR, Kalia P, Singh B. Character association and path analysis of morphological and economic traits in cabbage (*Brassica oleracea* var. *capitata* L.). Indian Journal of Agriculture Sciences. 2010; 80:116-118.
14. Soni S, Kumar S, Maji S. Correlation and path coefficient analysis studies for the yield and its traits in cabbage (*Brassica oleracea* var. *capitata* L.). Annals of Horticulture. 2013; 6:331-336.
15. Thakur H, Vidyasagar. Estimates of genetic variability, heritability and genetic advances for yield and horticultural traits in cabbage (*Brassica oleracea* var. *capitata* L.). Journal of Environment and Bio-Sciences. 2016; 30:155-157.