



Research Note

Association studies for yield and some yield contributing morpho-physiological components in cauliflower (*Brassica oleracea* L. var. *botrytis* L.)

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Abstract

Twenty five genotypes of cauliflower along with one check Madhuri were evaluated for yield and some yield contributing morpho physiological components in cauliflower. Further, the investigation was done to find out interrelationships among different characters and their direct and indirect contribution towards yield. Estimates of phenotypic and genotypic correlation coefficient revealed that marketable yield per plant was significantly and positively correlated with curd size index, gross weight per plant, curd solidity, curd compactness, curd diameter, stalk length, number of leaves per plant and harvest index. The high positive direct effect on marketable yield per plant was exhibited by curd size index, gross weight per plant, days to marketable curd maturity from date of transplanting, curd solidity, stalk length and per cent marketable curds. Therefore, these traits should be considered as the selection criterion to improve the marketable yield per plant.

Key words

Cauliflower, Correlation, path analysis, marketable yield per plant

Cauliflower (*Brassica oleracea* L. var. *botrytis*; $2n=2x=18$) is an important cruciferae vegetable belonging to *Brassicaceae* family and grown throughout world. It is good source of proteins, carbohydrates, minerals and vitamins. Being a member of Cole group, cauliflower can contribute immensely in improving the human health and have been classified as 'Super Food' as it possess robust oxidative defence systems *i.e.* antioxidants and polyphenols (Miean and Mohamed, 2001). It is low in fat but high in dietary fiber, foliate and water, possessing a high nutritional density. It contains several phytochemicals, common in the cabbage family that may be beneficial to human health. A high intake of cauliflower has been associated with reduced risk of aggressive prostate cancer (Kushwaha *et al.*, 2013).

In Himachal Pradesh, snowball group (late maturing) is the major cauliflower group both in terms of off-season as well as seed crop and provides ideal genotypes both to farmers and consumers. Owing to the different agroclimatic conditions, cauliflower is grown throughout the year in one or other part of the state. In cauliflower, growing of commercial hybrids in contrast to other *Brassica* vegetables picked up late and it is only since about 1985 they attained commercial reality. The reasons may be thermosensitivity of the crop and unavailability of good performing hybrids. But now almost all the cauliflower grown in the developed countries are F_1 hybrids, mainly because of economical interest and not for agronomical reasons. In India, the share of cauliflower hybrid cultivars is still less than 11 per cent (Muthukumar and Selvakumar, 2014) and the picture of many other developing countries is no way better than this. Further research on F_1 hybrid cultivars would also increase

the use of hybrid seeds. In Himachal Pradesh, to increase the production and productivity of cauliflower and elevate the income of farmers, it would be advisable to grow hybrids. For this reason, it is necessary to identify the environment specific best performing hybrids.

Yield is a complex character determined by several component characters. So selection for yield should take into account related characters as well (Selvi *et al.*, 2016). Keeping this in view, the present study was conducted to study correlation and path analysis of economically important characters in cauliflower genotypes. Singh *et al.* (2006) and Sheemar *et al.* (2012), in their studies reported that marketable yield per plant had significant positive correlation with curd size index, gross weight per plant, number of leaves per plant, stalk length, curd solidity, curd compactness, curd diameter and harvest index. Knowledge about association between horticultural traits viz., gross weight per plant, marketable yield per plant, plant height etc., is of great value in planning a breeding programme. Coefficients of correlation between different important traits and their path analysis help cauliflower breeders to decide suitable selection criteria to improve yield and other component traits.

The present investigation was carried out at the Research Farm of the Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, (H.P.), during *rabi*, 2014-2015 to study the performance of various cauliflower hybrids and to identify the promising ones. Twenty five genotypes along with one check Madhuri were evaluated in Randomized Complete Block Design with three replications. Details and source of genotypes are presented in

table 1. The standard cultural practices to raise the crop were followed. The observations were recorded on randomly taken ten competitive plants in each entry and replication for traits *viz.*, days to curd initiation from transplanting, days to marketable curd maturity from date of transplanting, gross weight per plant (g), marketable yield per plant (g), curd depth (cm), curd diameter (cm), curd size index (cm²), per cent marketable curds, curd compactness (degrees), curd solidity (g/cm), stalk length (cm), number of leaves per plant, plant height (cm), dry matter content (%), ascorbic acid content (mg/100g), total soluble solids (⁰Brix) and harvest index (%). The phenotypic and genotypic coefficients of correlation were calculated as suggested by Al-Jibouri *et al.*, (1958). Path coefficient analysis of different traits with marketable yield per plant was obtained by following the method suggested by Dewey and Lu (1959).

Significant differences were observed among all the genotypes for all the traits under study (Table 2). Knowledge of correlation and path analysis help plant breeder to ascertain the real components of yield and provide an effective basis of phenotypic selection (Gudmewad *et al.*, 2016). Correlation among different traits is of vital importance to know their association, as yield is an important outcome of many correlated characters.

An understanding of inter-character correlation is essential to successful selection of useful genotypes from the whole population but intensive selection for any characteristic might result in losses in others. The magnitude of the genotypic and phenotypic correlations and their utilization in the selection had been stated by a number of researchers (Ali *et al.*, 2008). Correlation coefficients have been worked out at genotypic and phenotypic levels. The data pertaining to correlation coefficient are presented in table 3.

Marketable yield per plant had significant positive correlation at both phenotypic and genotypic levels with curd size index, gross weight per plant, number of leaves per plant, stalk length, curd solidity, curd compactness, curd diameter and harvest index. This reflects that selection on the basis of these traits might lead to higher marketable yield per plant. However, it showed significant and negative association with days to initiation of curd from transplanting and plant height at both phenotypic and genotypic levels. The results corroborate with the findings of Sheemar *et al.*, (2012). All other characters have also recorded highly significant inter association among themselves *i.e.* an increase in any of these characters, led to a corresponding increase in the marketable yield.

The end product, yield has often been described as the product of its components under the influence of the environment and is known to show inter-dependence. The component traits have indirect effect towards yield apart from their direct contribution towards yield. It is quite likely that the contribution of a component showing significant association with yield may get diluted due to interaction with other components. The path coefficient analysis allows partitioning of correlation coefficients into direct and indirect effects of various traits towards dependent variable and thus, helps in assessing the cause-effect relationship as well as effective selection (Dewey and Lu, 1959). It plays an important role in determining the degree of relationship between yield and its component effects and also permits critical examination of specific factors that provide a given correlation. As depicted by table 4, curd size index (0.663), gross weight per plant (0.301), days to marketable curd maturity from date of transplanting (0.298), curd solidity (0.266), stalk length (0.225), curd diameter (0.216), per cent marketable curds (0.178), and harvest index (0.105) had high positive direct effects on marketable yield per plant at phenotypic level and traits such as days to marketable curd maturity from date of transplanting (1.392), curd diameter (0.956), curd size index (0.820), dry matter content (0.668), per cent marketable curds (0.631) and number of leaves per plant (0.590) also had appreciable positive direct contribution to the total association with marketable yield per plant at genotypic level. The direct effects of remaining traits were low.

Earlier researchers have also reported direct and positive effects of gross weight per plant (Singh *et al.*, 2006), harvest index and curd depth (Sheemar *et al.*, 2012), on the total association with marketable yield per plant.

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Table 1. List of genotypes and their sources

Hybrids	Sources	Hybrids	Sources
H 1	Rasi Seeds	H 13	US Agri Seeds
H 2	Rasi Seeds	H 14	Tokita Seeds
H 3	Noble Seeds	H 15	Seminis
H 4	Sungro	H 16	Indo-American Hybrid Seeds
H 5	Taki Seeds	H 17	US Agri Seeds
H 6	Rasi Seeds	H 18	Team Seeds
H 7	Noble Seeds	H 19	Pahuja Seeds
H 8	Rasi Seeds	H 20	Vigro Seeds
H 9	Rasi Seeds	H 21	US Agri Seeds
H 10	Seminis Seeds	H 22	Sakata Seeds
H 11	Team seeds	H 23	Noble Seeds
H 12	Suttind Seeds	H 24	Seminis
Standard Check Madhuri	Claus Seeds		

Table 2. Analysis of variance for different traits in cauliflower hybrids

Sources of variation	Mean squares		
	Replications	Genotypes	Error
df	2	24	48
Days to initiation of curd from transplanting	19.36	100.86**	0.40
Days to marketable curd maturity from date of transplanting	32.21	97.83**	1.66
Gross weight per plant (g)	11799.84	45477.00**	972.34
Marketable yield per plant (g)	1258.56	33255.67**	565.14
Curd depth (cm)	0.11	1.40**	0.02
Curd diameter (cm)	0.07	2.40**	0.10
Curd size index (cm ²)	1.37	455.70**	2.58
Curd compactness (⁰)	7.91	21.22**	17.82
Curd solidity (g/cm)	72.07	1223.75**	206.56
% Marketable curds	1.49	60.80**	1.71
Stalk length (cm)	0.01	0.71**	0.02
Number of leaves per plant	3.36	2.00**	0.82
Plant height (cm)	9.82	17.00**	1.12
Dry matter content (%)	1.72	3.11**	1.00
Ascorbic acid content (mg/100g)	18.66	207.01**	0.76
Total soluble solids (⁰ Brix)	0.81	0.77**	0.05
Harvest index (%)	1.50	169.91**	1.60

** Significant at 1% level



Table 3. Estimates of phenotypic (P) and genotypic (G) correlation coefficients among different horticultural traits in cauliflower hybrids

		Days to marketable curd maturity from d.o.t.	Gross weight per plant (g)	Curd size index (cm ²)	Curd depth (cm)	Curd diameter (cm)	Curd compactness (degrees)	Curd solidity (g/cm)	Per cent marketable curds	Stalk Length (cm)	Number of leaves per plant	Plant height (cm)	Dry matter Content (%)	Ascorbic acid content (mg/100g)	Total soluble solids ("Brix)	Harvest Index (%)	Correlation with marketable yield per plant (r)
Days to initiation of curd from transplanting	P	0.865**	-0.473**	-0.503**	-0.013	-0.545**	-0.197	-0.092	0.133	-0.067	-0.183	0.218	0.128	-0.156	0.171	0.099	-0.379**
	G	0.888**	-0.500**	-0.512**	-0.016	-0.590**	-0.875**	-0.134	0.141	-0.076	-0.332**	0.224	0.194	-0.157	0.176	0.099	-0.393**
Days to marketable curd maturity from d.o.t.	P		-0.282*	-0.376**	0.112	-0.268*	-0.133	-0.051	0.249*	-0.007	-0.074	-0.059	0.172	-0.144	0.203	0.250*	-0.169
	G		-0.293*	-0.386**	0.116	-0.303**	-0.614**	-0.086	0.278*	-0.012	-0.104	-0.058	0.253*	-0.161	0.228	0.259*	-0.177
Grossweight per plant	P			0.459**	0.005	0.422**	0.089	0.145	0.057	0.114	0.230*	-0.053	-0.294*	0.044	0.052	-0.288*	0.509**
	G			0.482**	-0.004	0.443**	0.575**	0.201	0.067	0.122	0.404**	-0.090	-0.407**	0.051	0.063	-0.302**	0.538**
Curd size Index	P				0.086	0.339**	0.280	0.462**	0.194	0.323**	0.408**	-0.170	0.266*	-0.111	-0.219	0.154	0.817**
	G				0.088	0.378 **	0.083	0.582**	0.200	0.338**	0.701**	-0.185	0.428**	-0.112	-0.243*	0.151	0.841**
Curd Depth	P					0.051	0.007	0.016	0.196	0.135	-0.009	-0.268*	0.179	-0.083	-0.151	0.263*	0.041
	G					0.048	0.050	0.020	0.200	0.135	-0.034	-0.300**	0.299**	-0.090	-0.169	0.278*	0.044
Curd Diameter	P						0.090	0.060	-0.250*	0.108	0.282*	-0.243*	0.138	0.036	-0.293	-0.086	0.282*
	G						0.639**	0.141	-0.254*	0.114	0.618**	-0.295*	0.220	0.036	-0.333*	-0.090	0.326**
Curd Compactness	P							0.638**	0.058	0.206	0.143	-0.281*	0.074	-0.066	0.058	0.267*	0.267*
	G							0.877**	0.190	0.941**	0.877**	-0.789**	0.175	-0.377**	0.049	0.675**	0.437**
Curd Solidity	P								0.225*	0.279*	0.278*	-0.234*	0.002	-0.285*	-0.017	0.412**	0.388**
	G								0.289*	0.329**	0.626**	-0.317**	0.001	-0.380**	-0.074	0.539**	0.501**
Per cent marketable Curds	P									-0.034	-0.140	-0.109	0.301**	0.177	0.253*	0.141	0.158
	G									-0.038	-0.246*	-0.136	0.548**	0.188	0.289*	0.150	0.165
Stalk Length	P										0.212	0.085	-0.083	0.090	0.029	0.226	0.411**
	G										0.458**	0.085	-0.150	0.097	0.056	0.233*	0.440**
Number of leaves per plant	P											-0.222*	-0.078	-0.207	-0.080	0.227*	0.439**
	G											-0.374**	-0.239*	-0.384**	-0.095	0.365**	0.724**
Plant Height	P												-0.194	0.242*	-0.036	-0.482**	-0.352**
	G												-0.391**	0.276*	-0.045	-0.541**	-0.405**
Dry matter Content	P													0.099	0.066	0.305**	-0.169
	G													0.152	0.149	0.476**	0.195
Ascorbic acid content	P														0.058	0.012	-0.219
	G														0.057	0.013	-0.225
Total soluble solids	P															0.161	-0.070
	G															0.175	-0.094
Harvest Index	P																0.237*
	G																0.244*

** Significant at $P \leq 0.01$; *Significant at $P \leq 0.05$



Table 4. Estimates of direct and indirect effects of different traits on marketable yield per plant at phenotypic (P) and genotypic (G) levels of cauliflower hybrids

Traits		Days to initiation of curd from transplanting	Days to marketable curd maturity from d.o.t.	Gross weight per plant (g)	Curd size Index (cm ²)	Curd depth (cm)	Curd diameter (cm)	Curd compactness (degrees)	Curd solidity (g/cm)	Per cent marketable curds	Stalk length (cm)	Number of leaves per plant	Plant height (cm)	Dry matter Content (%)	Ascorbic acid content (mg/100g)	Total soluble solids (°Brix)	Harvest index (%)	Correlation With marketable yield per plant (r)
Days to initiation of curd from transplanting	P	-0.241	0.258	-0.143	-0.334	0.003	0.118	-0.020	0.024	-0.024	-0.015	-0.008	-0.037	0.009	0.026	-0.002	0.010	-0.379**
	G	-1.533	1.236	-0.080	-0.420	0.006	0.564	0.023	0.053	-0.089	-0.017	-0.196	-0.017	0.130	0.006	-0.020	-0.037	-0.393**
Days to marketable curd maturity from d. o.t.	P	-0.208	0.298	-0.084	-0.249	-0.003	0.057	-0.014	0.014	-0.044	-0.002	-0.003	0.010	0.012	0.024	-0.003	0.026	-0.169
	G	-1.360	1.392	-0.046	-0.316	-0.005	0.289	0.018	0.034	-0.175	-0.003	-0.062	0.004	0.169	0.006	-0.027	-0.096	-0.177
Gross weight per plant	P	0.114	-0.084	0.301	0.304	-0.001	-0.091	0.009	-0.038	0.010	0.026	0.009	0.009	-0.021	-0.007	-0.001	-0.030	0.509**
	G	0.766	-0.407	0.159	0.395	0.002	-0.424	-0.017	-0.080	0.042	0.028	0.238	0.006	-0.272	-0.002	-0.007	0.112	0.538**
Curd	P	0.121	-0.112	0.138	0.663	0.002	-0.073	0.029	-0.123	0.034	0.073	0.017	0.029	-0.019	0.018	0.003	0.016	0.817**
Size index	G	0.784	-0.537	0.077	0.820	0.004	-0.361	-0.032	-0.232	0.126	0.077	0.414	0.013	-0.286	0.004	0.028	-0.056	0.841**
Curd depth	P	0.003	0.033	0.002	-0.057	0.023	-0.011	0.007	-0.004	-0.030	0.030	-0.004	0.046	0.013	0.014	0.002	0.028	0.041
	G	0.024	0.162	-0.007	-0.072	0.040	-0.045	-0.002	-0.007	-0.126	0.031	-0.020	0.021	0.200	0.004	0.020	-0.103	0.044
Curd diameter	P	0.131	-0.080	0.127	0.225	-0.001	0.216	0.009	-0.015	0.045	0.024	.0120	0.042	-0.010	-0.006	0.004	-0.009	0.282*
	G	0.904	-0.421	0.070	0.309	-0.002	0.956	-0.019	-0.056	0.160	0.026	0.364	0.021	-0.147	-0.001	0.039	0.033	0.326**
Curd compactness	P	0.047	-0.039	0.026	0.185	-0.002	-0.020	0.030	-0.169	-0.010	0.046	0.006	0.048	0.005	0.011	-0.001	0.028	0.267*
	G	1.341	-0.855	0.091	0.888	-0.002	-0.611	0.103	-0.406	-0.120	0.213	0.890	0.077	0.117	0.015	-0.006	-0.467	0.437**
Curd solidity	P	0.022	-0.015	0.043	0.306	-0.004	-0.013	0.066	0.266	0.040	0.063	0.012	0.040	0.002	0.047	0.002	0.043	0.388**
	G	0.204	-0.119	0.032	0.477	-0.008	-0.134	-0.030	0.399	0.182	0.074	0.369	0.022	0.010	0.015	0.009	-0.201	0.501**
Per cent marketable curds	P	-0.032	0.074	-0.017	-0.128	-0.005	0.054	0.006	0.059	0.178	-0.008	-0.006	0.019	0.021	-0.029	-0.003	0.015	-0.158
	G	-0.216	0.386	-0.011	-0.164	-0.008	0.243	-0.006	0.115	0.631	-0.009	-0.145	0.010	0.366	-0.007	-0.034	-0.056	-0.165
Stalk length	P	0.016	-0.002	0.034	0.214	-0.003	-0.023	0.021	-0.074	0.006	0.225	0.009	-0.015	-0.006	-0.015	-0.004	0.024	0.411**
	G	0.117	-0.017	0.020	0.277	-0.005	-0.109	-0.028	-0.131	0.024	0.226	0.270	-0.006	-0.101	-0.004	-0.006	-0.089	0.440**
Number of leaves per plant	P	0.044	-0.022	0.060	0.270	0.002	-0.061	0.015	-0.074	0.025	0.048	0.042	0.038	-0.006	0.039	0.001	0.024	0.439**
	G	0.508	-0.145	0.065	0.575	0.001	-0.590	-0.045	-0.250	0.155	0.104	0.590	0.027	-0.160	0.015	0.011	-0.136	0.724**
Plant height	P	-0.052	-0.017	-0.015	-0.112	0.006	0.052	-0.029	0.062	0.019	0.019	-0.009	-0.171	-0.014	-0.040	0.001	-0.051	-0.352**
	G	-0.358	-0.081	-0.014	-0.152	0.012	0.282	0.032	0.127	0.085	0.019	-0.221	-0.071	-0.261	-0.011	0.005	0.201	-0.405**
Dry matter content	P	-0.030	0.051	-0.088	-0.176	-0.004	0.030	0.008	-0.008	-0.053	-0.019	-0.003	0.033	0.071	-0.016	-0.001	0.032	-0.169
	G	-0.297	0.352	-0.065	-0.351	-0.012	0.210	-0.005	-0.006	-0.346	-0.034	-0.141	0.028	0.668	-0.006	-0.017	-0.177	-0.195
Ascorbic acid content	P	0.037	-0.043	0.013	-0.073	0.002	-0.008	-0.007	0.075	-0.031	0.020	-0.009	-0.041	0.007	-0.164	-0.001	0.001	-0.219
	G	0.240	-0.223	0.008	-0.092	0.004	-0.034	0.011	0.152	-0.118	0.022	-0.226	-0.020	0.101	-0.039	-0.007	-0.005	-0.225
Total soluble solids	P	-0.041	0.060	0.016	-0.145	0.004	0.063	0.006	0.005	-0.045	0.007	-0.003	0.006	0.005	-0.010	-0.013	0.017	-0.070
	G	-0.270	0.318	0.010	-0.199	0.007	0.318	-0.002	0.030	-0.182	0.013	-0.056	0.003	0.099	-0.002	-0.116	-0.065	-0.094
Harvest index	P	-0.023	0.074	-0.087	0.102	-0.006	0.019	0.027	-0.109	-0.025	0.051	0.010	0.082	0.022	-0.002	-0.002	0.105	0.237*
	G	-0.151	0.360	-0.048	0.124	-0.011	0.086	-0.037	-0.216	-0.094	0.053	0.216	0.038	0.318	-0.001	-0.020	0.372	0.244*

** Significant at P ≤ 0.01; *Significant at P ≤ 0.05 level; Residual effect (P): 0.152; (G): -0.044; The bold values indicate direct effect with marketable yield per plant