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RESEARCH ARTICLE

Genetic Variability and Association Studies in Mid-late and Late Group of Cauliflower (*Brassica oleracea* L. var. *botrytis*)

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Abstract

Sufficient genetic variability was recorded in 26 genotypes based on various genetic variability parameters, indicating the scope for selection. High heritability and genetic advance for days to curd initiation, curd solidity, gross plant weight, net curd weight and marketable curd weight indicate the importance of additive gene action. Correlation and path analysis directed to focus selection on the basis of gross plant weight, harvest index, curd size index, curd solidity, curd depth and net curd weight to evolve high-yielding cauliflower genotypes. DPCaf US, DPCa CMS 1, DPCaf W3, DPCaf 30, DPCaf W3 and DPCaf US showed promise for curd yield, mainly attributed to the traits identified based on parameters of genetic variability.

Keywords: Cauliflower, Correlation coefficient, Heritability, Path coefficient.

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Introduction

Cauliflower, botanically known as *Brassica oleracea* L. var. *botrytis* with chromosome number $2n = 2x = 18$ and belongs to family Brassicaceae. Vegetable brassicas are rich in different bioactive compounds and phytochemicals. It is, therefore, important to identify promising genotypes with high productivity and increasing nutritional value (Ram *et al.,* 2017).

Knowledge about levels and patterns of genetic variability plays an important role in detecting diverse parents to generate segregating progenies with diverse backgrounds and introgression of desirable genes from variable germplasm into the existing genetic base. This implies that the extent of genetic variability in the germplasm is relatively proportional to the improvement potential of a crop and provides an opportunity to enhance the yield and quality through a planned breeding programme. Heritable characters, genetic parameters and association among traits are of prime importance in breeding (Sekhon and Sharma, 2019). The heritability estimates predict the consistency of phenotypic values in the expression of trait (Unche et al., 2008).

Curd yield is a complex trait as many genes control it and hence are highly influenced by environmental conditions. It is crucial to understand the nature and magnitude of association between different yield components to improve the plant as a whole rather than the individual trait. The effective yield improvement would be achieved through the characters with significant and positive/desirable correlations. Some of the component traits may be positively and directly associated with the marketable curd weight, thus can be used as a criterion of selection in the crop improvement programme. The association among the traits can be used for the selection of such traits whose genotypic values are modified by environmental effects and thus cannot be easily observed. It also gives information about the nature and extent of the direction and selection pressure among different characters (Sharma *et al*., 2016). Genotypic and phenotypic correlations reveal the degree of association with different characters and helps to base the selection procedure when two opposite desirable characters affecting the principal character are to be selected. It also helps to improve different characters simultaneously. Thus, it would be imperative to examine the magnitude and direction of correlation of different attributes with marketable curd weight and to identify the traits of interest to obtain high yield. Correlation analysis indicates the association pattern of component traits with yield, thus showing inter-dependence. It simply represents the overall influence of a particular trait on yield rather than providing cause and effect relationship. The correlation *per se* does not provide the absolute picture of interrelationships when more than two variables are involved. The relative contribution of the component traits to the yield also provides the appropriate weightage for selection purpose. Therefore, path coefficient analysis is used to assess the cause-effect relationship and effective selection. It also helps in determining the degree of relationship of yield with its component effects and allows the critical examination of specific factors for a given correlation It allows partitioning of correlation coefficients into direct and indirect effects of various traits towards dependent variable and plays an important role in determining the degree of relationship between yield and its component effects.A clear picture of each character's contribution toward the final expression of complex trait like marketable curd weight would emerge through the study of correlations coefficient and path coefficient analysis revealing different ways in which component attributes influence the complex characters.

Keeping this in mind, the present investigation was undertaken to develop a variety with high in marketable curd yield and quality through correlation and path analysis studies.

Materials and Methods

An experiment was conducted with 26 genotypes, including standard checks (Table 1) of cauliflower during 2018 and 2019 at the experimental farm of the Department of Vegetable science and floriculture, CSK HPKV, Palampur. The experimental material comprised of 26 genotypes of cauliflower, including standard checks (Table 1). The trail was laid out in randomized complete block design (RBD) with three replications having 2.7 m row length at a spacing of 45 cm each within and between rows. The standard package of practices was followed to raise the healthy crop. The observations were recorded on randomly taken five competitive plants in each entry over replications during both the years for days to curd initiation, days to marketable curd maturity, stalk length (cm), leaves/plant, leaf length (cm), leaf width (cm), plant height (cm), plant frame (cm), curd depth (cm), curd diameter (cm), curd angle (^{0}), curd size index (cm^2), curd solidity (g/cm), gross plant weight (g), net curd weight (g), marketable curd weight (g), marketable curds (%), total soluble solids (^{0} Brix) using hand refractometer and harvest index (%).

Table 1: List of genotypes

Genotype	*Source*
DPCa CMS 1, DPCa CMS 2, DPCa CMS 3, DPCaf 8, DPCaf 10, DPCaf 1, DPCaf 2, DPCaf W3, DPCaf US, DPCaf S5-1, DPCaY 1, DPCaY 7, DPCaf 9, DPCaf 12, DPCaf 13, DPCaf 18, DPCaf 24, DPCaf 29, DPCaf 30, DPCaf 35, Palam Uphar (Check)	Department of Vegetable Science &Floriculture, COA, CSKHPKV, Palampur
Pusa Paushja	ICAR-IARI, New Delhi
Pusa Himjyoti, Pusa Snowball KT-25, Pusa Snowball-1, Pusa Snowball K-1 (Check)	ICAR-IARI, Regional Station, Katrain, Kullu, HP

Statistical analysis of pooled data was subjected to analysis of genotypic coefficient variation (GCV), phenotypic coefficient of variation (PCV) and heritability (h^2) in broad sense were computed according to Burton and Devane, 1953. Genetic advance (GA) was estimated following Johnson *et al.,* 1955. The phenotypic and genotypic coefficients of correlation were worked out by the procedure of Al- Jibouri *et al.,* 1958; Dewey and Lu, 1959. The direct and indirect effects of component characters on marketable curd weight were computed using appropriate correlation coefficients of different component characters as suggested by Wright, 1921 and elaborated by Dewey and Lu, 1959.

Results and Discussion

The knowledge of phenotypic and genotypic coefficients of variation envisages the magnitude of variations present in the existing genetic material based on which the desirable breeding programme can be formulated for the genetic improvement of the target crop. Phenotypic coefficients of variation were greater than the genotypic coefficient variation values for all the characters studied (Table 2). Therefore, caution has to be exercised in making selection for these characters on the basis of phenotype alone since environment had also its role in influencing the trait of interest. Moderate PCV and GCV was recorded for days to curd initiation (17.42, 17.69), days to marketable curd maturity (13.41, 14.84), plant frame (11.52, 13.55) and curd size index (11.55, 13.46), curd solidity (24.4, 55.99), gross plant weight

Table 2: Genetic parameters of variability for different agro-morphological traits of cauliflower

Traits	GCV (%)	PCV (%)	GCV (%)	PCV (%)	GCV (%)	PCV (%)	h^2_{bs}			GA (%)		
	2018-19		2019-20		pooled		2018-19	2019-20	pooled	2018-19	2019-20	pooled
Days to curd initiation	13.56	13.89	11.78	12.20	17.42	17.69	95.42	93.16	96.94	27.29	23.42	34.98
Days to marketable curd maturity	10.13	12.96	8.75	9.77	13.41	14.84	61.09	80.21	81.83	16.31	16.14	24.76
Stalk length (cm)	5.43	8.45	10.87	13.89	7.92	10.85	41.31	61.24	53.33	7.19	17.52	11.76
Leaves/ plant	8.66	11.28	5.62	8.04	9.14	11.22	59.05	48.82	66.46	13.72	8.09	15.20
Leaf length (cm)	5.69	8.85	7.40	9.92	8.52	10.84	41.33	55.58	61.86	7.54	11.36	13.63
Leaf width (cm)	6.61	10.80	7.28	11.22	9.27	12.62	37.46	42.06	53.97	8.34	9.73	13.80
Plant height (cm)	6.72	9.21	8.20	11.91	9.95	12.56	53.29	47.48	62.80	10.11	11.65	16.03
Plant frame (cm)	7.54	10.53	10.49	12.57	11.52	13.55	51.29	69.61	72.30	11.13	18.02	20.09
Curd depth (cm)	4.80	6.58	4.92	6.08	6.30	7.45	53.24	65.42	71.42	7.21	8.19	10.80
Curd diameter (cm)	4.07	5.28	5.81	7.21	5.93	7.07	59.51	65.01	70.37	6.47	9.65	10.14
Curd angle (^{0})	2.70	4.78	3.28	4.05	3.71	4.92	31.75	65.55	57.00	3.13	5.47	5.79
Curd size index (cm^2)	7.46	10.35	10.02	12.04	11.55	13.46	51.96	69.27	73.61	11.08	17.18	20.23
Curd solidity (g/ cm)	23.06	24.57	15.20	16.42	24.94	25.99	88.10	85.75	92.08	44.59	29.00	49.25
Gross plant weight (g)	16.24	16.71	16.00	17.10	21.76	22.37	94.50	87.55	94.60	32.52	30.84	43.31
Net curd weight (g)	25.01	26.52	17.59	18.62	28.26	29.21	88.93	89.24	93.58	48.58	34.22	55.99
Marketable curd weight (g)	18.12	18.81	16.52	17.86	22.81	23.61	92.78	85.60	93.36	35.96	31.49	45.23
Marketable curds (%)	4.92	10.25	6.18	9.92	9.17	12.42	23.03	38.77	54.43	4.86	7.93	13.82
Total soluble solids (^{0} Brix)	5.59	6.46	5.32	6.74	7.12	8.03	74.92	62.29	78.57	9.97	8.65	12.88
Harvest index (%)	5.02	6.44	4.39	6.65	5.81	7.38	60.83	43.59	62.03	8.07	5.97	9.42

(21.76, 22.37), net curd weight (28.26, 29.21) and marketable curd weight (22.81, 23.61) on pooled basis, respectively suggesting their improvement by exploiting heterosis or following hybridization programme. Earlier workers have also found moderate PCV and GCV for stalk length and curd size index (Dubey *et al.,* 2003), net curd weight (Kumar *et al.,* 2011), marketable curd weight and gross plant weight (Chittora and Singh, 2015).

Heritability is a component which computes expected progress but it becomes more meaningful when

Table 3: Estimates of phenotypic (P) and genotypic (G) correlation coefficients for different traits in cauliflower (pooled over years)

Traits		Days to curd initiation	Days to marketable curd maturity	Stalk Length (cm)	Leaves/ plant	Leaf length (cm)	Leaf width (cm)	Plant height (cm)	Plant Frame (cm)	Curd depth (cm)	Curd diameter (cm)	Curd Angle (0)	Marketable curds (%)	Total soluble solids (0 Brix)	Harvest index (%)	Curd solidity (g/cm)	Curd Size index (cm2)	Gross plant weight (g)	Net curd Weight (g)
Days to marketable curd maturity	P	0.844*																	
	G	0.928*																	
Stalk length (cm)	P	-0.315*	-0.368*																
	G	-0.436*	-0.408*																
Leaves/plant	P	-0.357*	-0.341*	-0.013															
	G	-0.463*	-0.470*	0.017															
Leaf length (cm)	P	0.161	0.054	0.147	-0.012														
	G	0.225*	0.252*	0.090	-0.243*														
Leaf width (cm)	P	0.089	0.090	0.201	-0.247*	0.501*													
	G	0.102	0.217	0.289*	-0.667*	0.436*													
Plant height (cm)	P	0.191	0.134	0.181	-0.261*	0.750*	0.440*												
	G	0.259*	0.247*	0.201	-0.506*	0.852*	0.476*												
Plant frame (cm)	P	-0.261*	-0.345*	0.291*	-0.165	0.490*	0.499*	0.562*											
	G	-0.328*	-0.407*	0.448*	-0.383*	0.585*	0.585*	0.654*											
Curd depth (cm)	P	0.370*	0.199	-0.077	0.251*	0.351*	0.096	0.309*	0.053										
	G	0.449*	0.318*	-0.114	0.166	0.397*	-0.028	0.346*	-0.042										
Curd diameter (cm)	P	0.064	-0.113	-0.072	0.196	0.329*	0.131	0.340*	0.293*	0.655*									
	G	0.093	-0.072	-0.173	0.151	0.285*	-0.100	0.306*	0.185	0.716*									
Curd angle (0)	P	0.458*	0.316*	-0.069	-0.019	0.082	0.061	0.029	-0.103	0.518*	0.375*								
	G	0.626*	0.588*	-0.024	-0.108	-0.082	-0.013	0.047	-0.200	0.547*	0.543*								
Marketable curds %)	P	-0.484*	-0.471*	0.054	0.247*	-0.007	-0.025	-0.116	0.119	0.058	0.389*	0.017							
	G	-0.652*	-0.697*	-0.033	0.546*	-0.158	-0.172	-0.352*	0.300*	0.031	0.553*	-0.019							
Total soluble solids (0 Brix)	P	-0.377*	-0.412*	0.150	-0.048	-0.126	0.146	-0.057	0.327*	-0.039	0.234*	-0.147	0.389*						
	G	-0.442*	-0.522*	0.196	-0.108	-0.211	0.219	-0.136	0.443*	-0.013	0.267*	-0.185	0.586*						
Harvest index (%)	P	-0.034	-0.143	0.089	0.170	-0.223*	-0.265*	-0.200	-0.019	0.233*	0.258*	0.260*	0.329*	0.036					
	G	-0.019	-0.199	-0.023	0.270*	-0.402*	-0.418*	-0.301*	-0.015	0.299*	0.283*	0.405*	0.367*	-0.005					
Curd solidity (g/cm)	P	0.199	0.208	0.047	-0.054	0.036	0.041	0.090	0.163	0.301*	0.418*	0.584*	0.173	0.067	0.306*				
	G	0.222	0.244*	0.054	-0.078	0.064	0.072	0.137	0.203	0.421*	0.539*	0.852*	0.261*	0.109	0.412*				
Curd size index (cm2)	P	0.241*	0.050	-0.081	0.241*	0.367*	0.130	0.355*	0.191	0.913*	0.904*	0.496*	0.241*	0.110	0.268*	0.397*			
	G	0.295*	0.133	-0.147	0.164	0.365*	-0.052	0.353*	0.081	0.930*	0.921*	0.595*	0.314*	0.144	0.312*	0.517*			
Gross plant weight (g)	P	0.205	0.238*	0.060	0.116	0.324*	0.263*	0.313*	0.214	0.604*	0.541*	0.570*	0.137	0.105	0.000	0.724*	0.637*		
	G	0.219	0.286*	0.140	0.087	0.351*	0.261*	0.325*	0.181	0.710*	0.601*	0.759*	0.198	0.122	0.059	0.754*	0.715*		
Net curd weight (g)	P	0.274*	0.232*	0.020	0.014	0.122	0.063	0.168	0.164	0.534*	0.555*	0.653*	0.174	0.061	0.334*	0.966*	0.602*	0.804*	
	G	0.299*	0.280*	0.017	-0.035	0.146	0.062	0.207	0.174	0.607*	0.650*	0.883*	0.247*	0.107	0.430*	0.976*	0.679*	0.830*	
Marketable curd weight (g)	P	0.186	0.181	0.075	0.163	0.220	0.157	0.221	0.194	0.642*	0.590*	0.623*	0.233*	0.121	0.320*	0.796*	0.683*	0.946*	0.878*
	G	0.207	0.224*	0.113	0.143	0.205	0.124	0.214	0.163	0.741*	0.638*	0.827*	0.284*	0.126	0.320*	0.837*	0.750*	0.964*	0.909*

*Significant at $P \leq 0.05$

accompanied by genetic advance. Prediction on the basis of heritability and genetic advance estimates could be more useful in selection (Sharma *et al.,* 2016). High heritability along with high genetic advance was reported for days to curd initiation (96.94, 34.98), curd solidity (92.08, 49.25), gross plant weight (94.60, 43.31), net curd weight (93.58, 55.99) and marketable curd weight (93.36, 45.23) in pooled over years, respectively that indicated the importance of additive gene action for the inheritance of these traits and improvement can be possible through phenotypic selection for these traits in the early generation (Sharma *et al.,* 2006; Kumar *et al.,* 2018).

The correlation coefficient estimates degree of association between two traits worked out at the same time. The correlation studies between various curd yield attributes and curd yield provide a basis for further breeding programmes in cauliflower. The results of the experiment revealed that the genotypic and phenotypic correlation coefficient was similar in directions, while in magnitude, genotypic correlations were mostly higher than corresponding phenotypic correlations. The low phenotypic correlation could result from the masking and modifying effect of environment factors on the association of traits at the genotypic level. At phenotypic and genotypic levels, the marketable curd weight had a positive and significant correlation with curd depth (0.642, 0.740), curd diameter (0.590, 0.638), curd angle (0.623, 0.827), marketable curds (%) (0.233, 0.284), harvest index (0.320, 0.32), curd solidity (0.796, 0.837), curd size index (0.683, 0.750), gross plant weight (0.946, 0.964) and net curd weight (0.878, 0.909), respectively on pooling data over the years. Besides, days to marketable curd maturity shows a positive and significant correlation with marketable curd weight at the genotypic level only (Table 3 and Figure 1). Earlier researchers have also reported significant and positive association of marketable curd weight with different curd attributes in their respective studies in different environments (Sharma *et al.,* 2006; Singh *et al.,* 2014; Shruthy and Celine, 2016; Vanlalneihi *et al.,* 2017).

The intercorrelation between marketable curt weight contributing characters may affect the selection for component characters either in favourable or unfavorable direction. A significant and positive association of leaf length, leaf width, plant height and plant frame were recorded among themselves at both phenotypic and genotypic levels. Further, critical insight into the correlation coefficients showed that curd depth, curd diameter, curd angle, harvest index, curd solidity, curd size index, gross plant weight and net curd weight showed a significant and positive association with one another at both phenotypic and genotypic.

On the basis of correlation studies and their coefficients of determination, it can be concluded that leaf length, leaf width, plant height, curd depth, curd diameter, curd angle, harvest index, curd solidity, curd size index, gross plant weight and net curd weight should be taken into consideration while isolating plants with high marketable curd weight. In addition, days to curd initiation and marketable curd maturity would be given due consideration for selecting early/late maturing genotypes within the maturity group. The majority of these traits showed a correlation in the same direction over the years, emphasizing their importance for the improvement of cauliflower.

In order to understand the cause of the correlations among the traits studied, the estimates of a direct and indirect contribution of different traits towards marketable curd weight, the path coefficient analysis was done (Table 4). The direct effects at a genotypic level were different than that at a phenotypic level. These differences might be due to varying degree of influence of environment on various traits studied, which were also observed from the results of component variance analysis and correlation studies. In few cases, the direct effects were observed to be of opposite sign (positive to negative and vice-versa) at corresponding phenotypic and genotypic levels like in days to curd initiation, leaves/plant, leaf length, leaf width, plant height, plant frame, curd depth, curd diameter, curd angle, curd size index, curd solidity, net curd weight and total soluble solids. Such a change in direction and magnitude of direct and indirect effects might be due to environmental factors influencing various traits. Therefore, path analysis at the phenotypic level may not provide a true picture of direct and indirect causes. It would be advisable to understand the contribution of different traits towards the marketable curd weight at the genotypic level. Gross plant weight had maximum positive and direct effect on marketable curd weight (0.923/ 1.042) followed by harvest index (0.308/0.152) at phenotypic and genotypic levels, respectively. Net curd weight also contributed significantly to the total association directly at a phenotypic level in pooled years. Besides, leaf length and curd solidity in pooled years also showed a good magnitude of direct effects at genotypic level only. Earlier workers have also reported positive and direct effects of different traits with marketable curd weight (Liu *et al.,* 2004; Sharma *et al.,* 2006; Sheemar *et al.,* 2012; Vanlalneihi *et al.,* 2017).

The significant and positive association of marketable curd weight with days to marketable curd maturity, curd depth, curd diameter, curd angle, curd size index, curd solidity, gross plant weight, net curd weight, marketable curds (%) and harvest index was due to indirect effect via gross plant weight followed by harvest index both at phenotypic and genotypic levels, curd size index at genotypic level only in pooled over years along with curd solidity at genotypic level. On the contrary, net curd weight reduced the magnitude of total association of marketable curd weight with most traits due to its negative indirect

Table 4: Estimates of direct and indirect effects of different traits on marketable curd weight at phenotypic (P) and genotypic (G) levels in cauliflower (pooled over years)

Traits		Days to Curd initiation	Days to Marketable curd maturity	Stalk length (cm)	Leaves/ plant	Leaf length (cm)	Leaf width (cm)	Plant Height (cm)	Plant Frame (cm)	Curd depth (cm)	Curd diameter (cm)	Curd angle (⁰)	Curd size index (cm²)	Curd solidity (g/cm)	Gross plant weight (g)	Net curd weight (g)	Marketable curds (%)	Total soluble solids (⁰ Brix)	Harvest index (%)	r
Days to curd initiation	P	**0.012**	-0.012	0.004	-0.003	-0.002	0.000	0.000	0.000	0.018	0.005	-0.003	-0.046	-0.041	0.190	0.077	0.002	-0.005	-0.011	0.186
	G	**-0.371**	-0.140	0.055	0.276	0.067	-0.051	-0.073	0.014	-2.375	-0.634	0.012	3.777	1.299	0.228	-1.966	0.037	0.055	-0.003	0.207
Days to marketable curd maturity	P	0.011	**-0.014**	0.004	-0.003	-0.001	0.000	0.000	0.000	0.010	-0.009	-0.002	-0.009	-0.043	0.220	0.065	0.002	-0.006	-0.044	0.181
	G	-0.344	**-0.151**	0.051	0.280	0.075	-0.108	-0.070	0.018	-1.68	0.491	0.011	1.699	1.427	0.297	-1.846	0.039	0.065	-0.030	0.224*
Stalk length (cm)	P	-0.004	0.005	**-0.012**	0.000	-0.001	0.001	0.00	0.000	-0.004	-0.006	0.000	0.015	-0.010	0.055	0.006	0.000	0.002	0.027	0.075
	G	0.162	0.062	**-0.125**	-0.010	0.027	-0.144	-0.057	-0.019	0.604	1.175	0.000	-1.882	0.317	0.145	-0.115	0.002	-0.024	-0.004	0.113
Leaves/plant	P	-0.004	0.005	0.000	**0.009**	0.000	-0.001	0.000	0.000	0.012	0.016	0.000	-0.046	0.011	0.107	0.004	-0.001	-0.001	0.052	0.163
	G	0.172	0.071	-0.002	**-0.596**	-0.072	0.331	0.142	0.016	-0.876	-1.028	-0.002	2.098	-0.457	0.091	0.231	-0.031	0.013	0.041	0.143
Leaf length (cm)	P	0.002	-0.001	-0.002	0.000	**-0.01**	0.002	0.001	0.000	0.017	0.027	-0.001	-0.070	-0.007	0.299	0.034	0.000	-0.002	-0.069	0.22
	G	-0.083	-0.038	-0.011	0.145	**0.297**	-0.217	-0.240	-0.025	-2.100	-1.933	-0.002	4.660	0.375	0.366	-0.963	0.009	0.026	-0.061	0.205
Leaf width (cm)	P	0.001	-0.001	-0.002	-0.002	-0.005	**0.004**	0.000	0.000	0.005	0.011	0.000	-0.025	-0.008	0.243	0.018	0.000	0.002	-0.082	0.157
	G	-0.038	-0.033	-0.036	0.398	0.129	**-0.497**	-0.134	-0.025	0.145	0.679	0.000	-0.668	0.423	0.272	-0.410	0.01	-0.027	-0.064	0.124
Plant height (cm)	P	0.002	-0.002	-0.002	-0.002	-0.008	0.002	**0.001**	0.000	0.015	0.027	0.000	-0.068	-0.019	0.289	0.047	0.000	-0.001	-0.062	0.221
	G	-0.096	-0.037	-0.025	0.302	0.253	-0.236	**-0.282**	-0.028	-1.829	-2.079	0.001	4.507	0.802	0.338	-1.366	0.020	0.017	-0.046	0.214
Plant frame (cm)	P	-0.003	0.005	-0.004	-0.001	-0.005	0.002	0.001	**0.001**	0.003	0.024	0.001	-0.037	-0.033	0.198	0.046	0.000	0.005	-0.006	0.194
	G	0.122	0.062	-0.056	0.228	0.174	-0.291	-0.184	**-0.043**	0.224	-1.258	-0.004	1.036	1.185	0.189	-1.145	-0.017	-0.055	-0.002	0.163
Curd depth (cm)	P	0.005	-0.003	0.001	0.002	-0.004	0.000	0.000	0.000	**0.048**	0.053	-0.003	-0.175	-0.062	0.558	0.150	0.000	-0.001	0.072	0.642*
	G	-0.167	-0.048	0.014	-0.099	0.118	0.014	-0.097	0.002	**-5.287**	-4.86	0.010	11.889	2.464	0.740	-3.997	-0.002	0.002	0.045	0.741*
Curd diameter (cm)	P	0.001	0.002	0.001	0.002	-0.003	0.000	0.000	0.000	0.031	**0.081**	-0.002	-0.173	-0.086	0.499	0.156	-0.001	0.003	0.080	0.590*
	G	-0.035	0.011	0.022	-0.090	0.085	0.050	-0.086	-0.008	-3.785	**-6.789**	0.010	11.778	3.150	0.627	-4.28	-0.031	-0.033	0.043	0.638*
Curd angle (⁰)	P	0.006	-0.004	0.001	0.000	-0.001	0.000	0.000	0.000	0.025	0.030	-0.006	-0.095	-0.120	0.526	0.184	0.000	-0.002	0.080	0.623*
	G	-0.232	-0.089	0.003	0.064	-0.024	0.007	-0.013	0.009	-2.892	-3.683	0.019	7.610	4.983	0.791	-5.811	0.001	0.023	0.062	0.827*
Curd size index (cm²)	P	0.003	-0.001	0.001	0.002	-0.004	0.000	0.000	0.000	0.044	0.073	-0.003	**-0.191**	-0.082	0.587	0.170	-0.001	0.002	0.082	0.683*
	G	-0.110	-0.020	0.018	-0.098	0.108	0.026	-0.099	-0.003	-4.917	-6.256	0.011	**12.782**	3.022	0.744	-4.470	-0.018	-0.018	0.047	0.750*
Curd solidity (g/cm)	P	0.002	-0.003	-0.001	0.000	0.000	0.000	0.000	0.000	0.014	0.034	-0.004	-0.076	**-0.206**	0.668	0.272	-0.001	0.001	0.094	0.796*
	G	-0.082	-0.037	-0.007	0.047	0.019	-0.036	-0.039	-0.009	-2.228	-3.658	0.016	6.608	**5.846**	0.786	-6.423	-0.015	-0.014	0.063	0.837*
Gross plant weight (g)	P	0.003	-0.003	-0.001	0.001	-0.003	0.001	0.000	0.000	0.029	0.044	-0.004	-0.122	-0.149	**0.923**	0.226	-0.001	0.001	0.000	0.946*
	G	-0.081	-0.043	-0.017	-0.052	0.104	-0.130	-0.091	-0.008	-3.755	-4.083	0.014	9.133	4.410	**1.042**	-5.461	-0.011	-0.015	0.009	0.964*
Net curd weight (g)	P	0.003	-0.003	0.000	0.000	-0.001	0.000	0.000	0.000	0.026	0.045	-0.004	-0.115	-0.199	0.742	**0.282**	-0.001	0.001	0.103	0.878*
	G	-0.111	-0.042	-0.002	0.021	0.043	-0.031	-0.058	-0.007	-3.210	-4.414	0.017	8.680	5.704	0.864	**-6.583**	-0.014	-0.013	0.065	0.909*
Marketable curds (%)	P	-0.006	0.006	-0.001	0.002	0.000	0.000	0.000	0.000	0.003	0.031	0.000	-0.046	-0.035	0.127	0.049	**-0.004**	0.005	0.101	0.233*
	G	0.242	0.105	0.004	-0.326	-0.047	0.085	0.099	-0.013	-0.165	-3.752	0.000	4.017	1.525	0.206	-1.624	**-0.056**	-0.073	0.056	0.284*
Total soluble solids (⁰ Brix)	P	-0.005	0.006	-0.002	0.000	0.001	0.001	0.000	0.000	-0.002	0.019	0.001	-0.021	-0.014	0.096	0.017	-0.001	**0.014**	0.011	0.121
	G	0.164	0.079	-0.025	0.064	-0.063	-0.109	0.038	-0.019	0.069	-1.810	-0.004	1.841	0.636	0.127	-0.705	-0.033	**-0.125**	-0.001	0.126
Harvest index (%)	P	0.000	0.002	-0.001	0.001	0.002	-0.001	0.000	0.000	0.011	0.021	-0.002	-0.051	-0.063	0.000	0.094	-0.001	0.001	**0.308**	0.320*
	G	0.007	0.030	0.003	-0.161	-0.119	0.208	0.085	0.001	-1.581	-1.923	0.008	3.990	2.409	0.062	-2.830	-0.021	0.001	**0.152**	0.320*

Residual effect at phenotypic level (p) = 0.00168 and genotypic level (G) = -0.00767
*Significant at P ≤ 0.05; bold values indicate direct effects; r: correlation coefficient with marketable curd weight

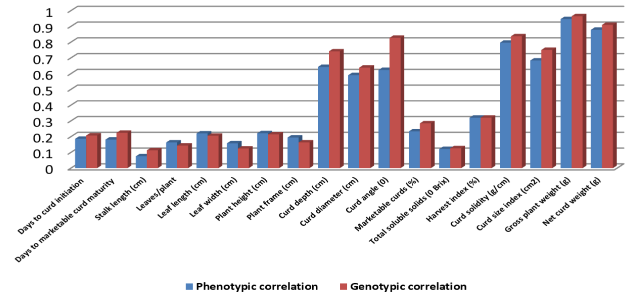

Figure 1: Genotypic and phenotypic correlation of marketable curd weight with 18 characters in cauliflower (pooled over years)

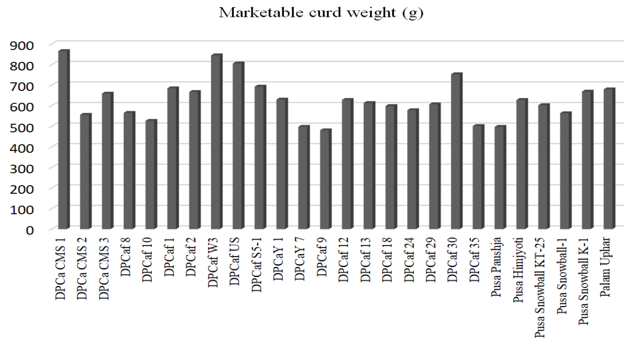

Figure 2: Performance of genotypes for marketable curd weight (pooled over years)

contribution. The magnitude of unexplained variation for marketable curd weight was very low at phenotypic (0.00168) and genotypic (-0.00767) levels suggesting that the traits included in the present investigation accounted for the substantial part of the variation present in the dependable variation i.e. marketable curd weight. In view of the direct and indirect contribution of component traits, selection on the basis of gross plant weight along with harvest index, curd size index, curd solidity, curd depth and net curd weight would be a rewarding proposition for evolving high-yielding cauliflower genotypes.

Genotypes namely, DPCaf US, DPCa CMS 1, DPCaf W3 and DPCaf 30 showed good marketable curd yield (Figure 2) that was mainly the result of better curd depth, curd diameter, leaf length, leaf width, leaves/plant, optimum plant frame, curd compactness, curd solidity, gross plant weight and net curd weight. Besides, DPCaf W3 and DPCaf US had better harvest index than DPCa CMS 1 and DPCaf 30 which may be attributed to moderate plant frame, leaf length, leaf width, and height along with short stalk length. Therefore, it is quite apparent from the results that inference drawn on the basis of heritability, genetic advance and correlation studies that focus on these traits have direct bearing on the marketable curd yield and to create genetic variability in the existing germplasm pool.

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