Polygenic Variations and Character Association in Early Maturing Indian Cauliflowers (*Brassica oleracea* var. *botrytis* L.)

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A B S T R A C T

Thirteen genotypes of early cauliflower were characterized for different quantitative parameters at the Vegetable Research Farm, at Bihar Agricultural University, Sabour during the Rabi season of 2010-2011 and 2011-2012. The experiment was laid out in a randomized complete block design with three replications. Pooled analysis of variance of the fifteen genotypes over two years indicated significant differences among the genotypes for all the characters under study. The range of variation was highest for marketable weight of curd followed by net weight of curd, days to 50% curd initiation, plant height, length of leaves and curd compactness. The traits such as net curd weight, curd compactness and marketable curd showed high PCV and GCV. High heritability along with moderate genetic advance were observed for marketable weight of curd, curd compactness, plant height and length of leaves which pointed towards the occurrence of additive gene action and hence phenotypic selection as such might be effective for improvement of these traits. Net weight of curd showed significant and positive genotypic and phenotypic correlation with plant height, length of leaves, width of leaves, diameter of curd, marketable weight of curd and curd compactness. Marketable weight of curd showed maximum direct positive contribution on net curd weight of curd at both genotypic and phenotypic level. The value for residual effect was found to be extremely low.

Introduction

Cauliflower (*Brassica oleracea* var. botrytis L.) is one of the important vegetable crops, grown throughout the year in different agro-climatic zones (Kaushal and Kaushal, 2013). It is mainly grown for its curds which are rich in vitamin-C (ascorbic acid) and also the minerals like phosphorus, potassium, calcium, sodium and iron. Also, cauliflower is low in fat, but high in dietary fiber. A high intake of cauliflower has been associated with reduced risk of aggressive prostate cancer (Kushwaha *et al.,* 2013).

During the course of cultivation in India, cauliflower has undergone significant changes in its morphological characteristics and

adaptability to warm and humid weather due to continuous selection and acclimatization. As a result, Indian cauliflowers today constitute a separate group both, morphologically and genetically from the temperate types (Swarup and Chatterjee, 1972). Agronomic traits such as curd yield and its components are major selection criteria for increasing its productivity (Yanglem and Tumbare, 2014). The morphological characters of a crop although subjected to variation through environmental influences, are undoubtedly the best indicators of yield and their correlation with yield. Therefore, they have received a great attention. The plant growth habit of the cultivars varies and exhibits a wide variation, which are unique and distinct. These morphological traits are useful in varietal identification and genetic purity testing. The data base of cauliflower genotypes generated by morphological characterization may be useful for the selection of suitable varieties developed in India as and when required.

Besides, crop improvement is based on available genetic variability and extent to which the desirable characters are heritable. Hence, studies on genetic variability with the help of suitable genetic parameters become indispensable for an effective breeding progamme. Yield is a very complex entity influenced by several yield components sensitive to the environmental fluctuations. Thus, the selection based on yield components will have better chance of success. It is therefore, necessary to know the types and nature of yield components and their inter relationship. The correlation coefficient analysis and path coefficient analysis provide information on the relative importance of various contributing characters. Measurement of existing variability in plant population has been the basic requirement of plant breeding.

Heritability and genetic advance have been proved useful in predicting the gain through selection. Therefore, the present investigation was carried out with the objectives of morphological characterization of cauliflower genotypes, estimates of genetic parameters of variation for different characters in cauliflower and inters relationship studies for yield and its contributing characters in cauliflower.

Materials and Methods

The experiment was conducted at Vegetable Research Farm, Department of Horticulture, at Bihar Agricultural College, Sabour, Bhagalur (Bihar) India during the Rabi season of 2010-2011 and 2011-2012. Experiment was laid out in a randomised complete block design with three replications. The sowing of all genotypes was done in nursery bed in the second fortnight of May and 23days old seedlings were transplanted at the spacing of 50 cm between rows and 40cm between plants within the rows. Fifty plants were maintained in each genotype per replication. The package of practices to raise a successful crop of cauliflower was followed.

Collection and characterization of the existing variability is the first step to any breeding programme. In the present study, fifteen diverse genotypes of early cauliflower were characterized for different quantitative parameters. Morphological characterization has been done based on characters like plant height (cm), number of leaves per plant, leaf length (cm), width of leaf (cm), days of curd initiation, days of curd maturity, average diameter of curd (cm), curd compactness and average weight of curd. Observations were recorded on 05 randomly selected plants from each plot. Mean data were subjected to statistical analysis to calculate range, standard deviation and coefficient of variability.

Results and Discussion

Pooled analysis of variance of the fifteen genotypes over two years indicated significant differences among the genotypes for all the characters under study. This points towards the existence of ample genetic variability worth exploiting in breeding program and was reflected in broad range value for different horticultural traits under study. The range of variation was highest for marketable weight of curd followed by net weight of curd, days to 50% curd initiation, plant height, length of leaves and curd compactness. Wide range of variability in cauliflower was also reported by Singh *et al.,* (2006) for curd weight and net curd weight, Kumar *et al.,* (2010) for days to 50%curd formation and net curd weight, Kumar *et al.,* (2011) for days to 50% curd formation, net curd weight and marketable curd yield, Chittora and Singh (2015) for total plant weight and net curd weight, Kumari *et al.,* (2016) for total plant weight and marketable curd yield. For the characters studied, phenotypic variance was higher than genotypic variance (Table.1). High level of genotypic and phenotypic variances was noted for the marketable weight of curd, net weight of curd, days to 50% curd initiation and days to 50% curd maturity, while low level of genotypic and phenotypic variances observed for curd maturity duration, diameter of curd, width of leaf, plant height and number of leaves.

The absolute values genotypic and phenotypic variance are however of little importance for direct selection as there is no clear cut ceiling to these values to classify their variances as high or low. The coefficient of variation is an index for amount of potential variability present in the individual economic traits. It was also observed that PCV was slightly higher than the corresponding GCV for all the traits. This clearly indicated the presence of environmental influence to some degree

affecting the expression of these characters. However the differences were narrow which implied their relative resistance to environmental variation (Roy Chowdhury and Tah, 2013). It also indicated that genetic factors were mainly accountable for expression of those traits and selection could be made effectively on the basis of phenotypic performance. Similar findings in cauliflower have been reported by Manaware *et al.,* (2017), Dipti and Singh (2013), Kumar *et al.,* (2011) and Singh *et al.,* (2006). The traits such as net curd weight, curd compactness and marketable curd showed high PCV and GCV (Table 1). This result is in line with the conclusion of Santhosha *et al.,* (2015) and in close harmony with findings of Manaware *et al.,* (2017). The advancement of such characters can be brought about by subjecting the progenies to vigorous environmental condition. Characters like days to 50% of curd maturity, diameter of curd, width of leaf, length of leaf, plant height and number of leaves per plant exhibited low phenotypic and genotypic variation which is in consonance with results reported by Akshay and Singh (2015) and Sahu (2017).

It is not possible to estimate heritable variation with the help of genetic coefficient of variation (GCV) alone. However, GCV together with heritability estimate gives a better picture of the amount of advances to be expected by selection. In the present study, heritability was recorded high for most of the vital characters like marketable weight of curd, net weight of curd, curd compactness, curd maturity duration plant height and length of leaves while diameter of curd, days to 50% curd maturity and width of leaves recorded low heritability percentage.

Heritability estimates in broad sense alone does not give clear indication for selection of traits since significant environment interaction is noted (Johnson *et al.,* 1955).

Hence, heritability values considered along with the predicted genetic gain increase the effectiveness of this parameter as a tool in selection program. Genetic advance though an independent entity, has an added advantage over heritability where the characters is to be improved through segregating generations. In the present study, high heritability was observed for marketable weight of curd, net weight of curd, days to fifty per cent curd initiation, curd compactness, plant height and length of leaves. However, high heritability coupled with high genetic advance and genetic advance as percent of mean were observed in marketable weight of curd, net weight of curd and days to fifty per cent curd initiation which suggested the prevalence of additive gene action in the expression of these characters. Therefore selection based on the phenotypic performance of these characters would be useful for achieving the desired results. The results were in close conformity with the findings of Sahu (2017) Santhosha *et al.,* (2015) and Singh *et al.,* (2011) in cauliflower.

High heritability along with moderate genetic advance were observed for marketable weight of curd, curd compactness, plant height and length of leaves which pointed towards the occurrence of additive gene action and hence phenotypic selection as such might be effective for improvement of these traits. These results were in close proximity with the findings of Chittora and Singh (2015) and Chatterjee *et al.,* (2018) in cauliflower. High heritability coupled with low genetic advance was observed curd maturity duration and number of leaves per plant. These findings were in agreement with the observations of Singh *et al.,* (2011) in cabbage. This revealed the predominance of non-additive gene action in the expression of these characters; hence direct selection would not be effective and so, heterosis breeding could be exploited.

Correlation coefficient analysis assesses the shared relationship between plant characters and determines the component characters on which selection can be made for genetic improvement of yield. Investigation regarding the presence of component and nature of association among themselves is important and indispensable requirement for improvement in yield. Unfavourable association among the yield attributes under selection may result in genetic slippage (Dickerson, 1955). In the present study, correlation coefficient was worked out at phenotypic, genotypic and environmental levels for all possible combination of eleven yield and its attributing characters (Table 2). It was observed that the magnitude of genotypic correlation was higher than the phenotypic correlation for all the traits which point towards inherent association between various characters. The findings were in agreement to Rai *et al.,* (2003), Rai and Asati (2004) and Meena *et al.,* (2012). Net weight of curd showed significant and positive genotypic and phenotypic correlation with plant height (cm), length of leaves (cm), width of leaves (cm), diameter of curd (cm), marketable weight of curd (g) and curd compactness. Similar observations were also reported by Kumar *et al.,* (2011), Santhosha *et al.,* (2015), and Kumar *et al.,* (2017) and Vanlalneihi1 *et al.,* (2017) in cauliflower. However, negative but non-significant correlation was observed for curd maturity duration. Some characters do not indicate significant correlation with net curd yield which might be due to severe negative effects.

Correlation analysis illustrates the association among the characters but it does not give account of direct effect on the magnitude and nature towards yield. Path coefficient analysis facilitates the partitioning of correlation coefficients into direct and indirect effects of various characters on yield.

Table.1 Estimates of genetic parameters of variations for different horticultural traits

Characters → / Variations Parameters ↓	Plant height (cm)	Number of leaves per plant	Length of leaves (cm)	Width of leaves (cm)	Average Diameter of Curd (cm)	Days to 50% Curd initiation	Days to 50% Curd maturity	Curd Maturity Duration	Marketable weight of curd (g)	Net weight of curd (g)	Curd compactness (g/cm3)
Var Genotypical	61.69	10.18	36.51	7.04	4.19	103.82	43.77	2.77	39483.98	35134.91	42.15
GCV	15.01	14.37	13.82	11.76	15.05	17.13	8.50	27.20	44.36	59.31	49.67
Var Phenotypical	75.93	16.16	45.54	12.56	8.23	126.66	85.37	3.62	40895.90	36733.03	51.62
PCV	16.65	18.11	15.43	15.70	21.09	18.93	11.87	31.08	45.14	60.65	54.97
h² (Broad Sense)	0.81	0.63	0.80	0.56	0.51	0.82	0.51	0.77	0.97	0.96	0.82
Genetic Advancement 5%	14.58	5.21	11.15	4.09	3.01	19.00	9.76	3.00	402.21	377.64	12.09
Gen.Adv as % of Mean 5%	27.87	23.49	25.49	18.13	22.14	31.95	12.54	49.05	89.78	119.49	92.46
General Mean	52.33	22.20	43.73	22.57	13.60	59.47	77.83	6.12	447.97	316.03	13.07
Exp Mean next Generation	66.92	27.42	54.87	26.66	16.61	78.47	87.59	9.13	850.17	693.67	25.16

Table.2 Estimates of genotypic and phenotypic correlation coefficients among Net Weight of Curd and its attributing traits

Characters		Plant height (cm)	Number of leaves per plant	Length of leaves (cm)	Width of leaves (cm)	Average Diameter of Curd (cm)	Days to 50% Curd initiation	Days to 50% Curd maturity	Curd Maturity Duration	Marketable weight of curd (g)	Curd compactness (g/cm3)
No. of Leaves per plant	G	0.0481									
	P	0.0605									
Length of Leaves (cm)	G	0.7860****	0.1703								
	P	0.6371***	0.1725								
Width of Leaves (cm)	G	0.6512****	-0.1513	0.8273***							
	P	0.6053***	-0.0906	0.6304***							
Diameter of Curd	G	0.4966****	0.3817***	0.5357***	0.2917**						
	P	0.2799**	0.1533	0.3546***	0.1553						
Days to 50% Curd Initiation	G	0.4624****	-0.4756***	0.5224***	0.3695***	0.3549***					
	P	0.3910***	-0.2021	0.4238***	0.2711**	0.2546*					
Days to 50% Curd Maturity	G	0.6069****	0.4756***	0.6826***	0.4781***	0.2180*	0.9596**				
	P	0.4731***	0.2092*	0.5272***	0.4024***	0.1707	0.7008***				
Curd Maturity Duration	G	-0.1185	0.2268*	-0.1222	-0.0621	-0.4713***	-0.8113	-0.4674***			
	P	-0.0869	0.0325	-0.1357	-0.0742	-0.1128	-0.6689***	-0.2811**			
Marketable Weight of Curd(g)	G	0.4890****	0.0216	0.3613***	0.3996***	0.5432***	0.146	0.0815	-0.1976		
	P	0.4357***	0.0035	0.3114***	0.2747**	0.3735***	0.1394	0.0511	-0.1593		
Curd compactness (g/cm^3)	G	-0.1625	-0.2434*	-0.3899***	-0.0961	0.5107 ***	-0.2611*	-0.3453***	0.0492	0.4837***	
	P	-0.1297	-0.1956	-0.3473***	0.0526	2701*	-0.2000	-0.2257*	0.1315	0.4415***	
Net Weight of Curd	G	0.4413****	0.0321	0.2801**	0.3254***	0.5047**	0.1062	0.0204	-0.1863	0.9987***	0.5356***
	P	0.3812***	0.0117	0.2450*	0.2215*	0.3472***	0.0956	0.0295	-0.1548	0.9764***	0.4917***

Table.3 Genotypic path coefficient showing direct and indirect effects of bulb yield and its contributing characters

Characters	Plant height (cm)	Number of leaves per plant	Length of leaves (cm)	Width of leaves (cm)	Average Diameter of Curd (cm)	Days to 50% Curd initiation	Days to 50% Curd maturity	Curd Maturity Duration	Marketable weight of curd (g)	Curd compactness (g/cm3)
Plant Height (cm)	**0.0434**	0.0021	0.0341	0.0282	0.0215	0.0201	0.0263	-0.0051	0.0212	-0.007
No. of Leaves per plant	-0.005	**-0.103**	-0.0175	0.0156	-0.0393	0.0429	0.049	-0.0234	-0.0022	0.0251
Length of Leaves (cm)	0.1575	0.0341	**0.2004**	0.1658	0.1074	0.1047	0.1368	-0.0245	0.0724	-0.0781
Width of Leaves (cm)	-0.1139	0.0265	-0.1447	**-0.1749**	-0.051	-0.0646	-0.0836	0.0109	-0.0699	0.0168
Diameter of Curd	0.0141	0.0108	0.0152	0.0083	**0.0283**	0.0101	0.0062	-0.0134	0.0154	-0.0145
Days to 50% Curd Initiation	-0.1105	0.0994	-0.1248	-0.0883	-0.0848	**-0.2389**	-0.2293	0.1938	-0.0349	0.0624
Days to 50% Curd Maturity	0.0026	-0.0021	0.003	0.0021	0.0009	0.0041	**0.0043**	-0.002	0.0004	-0.0015
Curd Maturity Duration	0.0172	-0.0329	0.0177	0.009	0.0683	0.1176	0.0677	**-0.1449**	0.0286	-0.0071
Marketable Weight of Curd(g)	0.451	0.0199	0.3332	0.3686	0.5011	0.1347	0.0752	-0.1822	**0.9225**	0.4462
Curd compactness (g/cm3)	-0.0152	-0.0228	-0.0364	-0.009	-0.0477	-0.0244	-0.0323	0.0046	0.0452	**0.0935**
Net Weight of Curd	**0.4413**	**0.0321**	**0.2801**	**0.3254**	**0.5047**	**0.1062**	**0.0204**	**-0.1863**	**0.9987**	**0.5356**
Partial R²	0.0191	-0.0033	0.0561	-0.0569	0.0143	-0.0254	0.0001	0.027	0.9212	0.0501
R SQUARE = 1.0024 RESIDUAL EFFECT =SQRT(1- 1.0024)										

Table.4 Phenotypic path coefficient showing direct and indirect effects of net weight of curd and its contributing characters

Characters	Plant height (cm)	Number of leaves per plant	Length of leaves (cm)	Width of leaves (cm)	Average Diameter of Curd (cm)	Days to 50% Curd initiation	Days to 50% Curd maturity	Curd Maturity Duration	Marketable weight of curd (g)	Curd compactness (g/cm3)
Plant Height (cm)	**0.0059**	0.0004	0.0038	0.0036	0.0017	0.0023	0.0028	-0.0005	0.0026	-0.0008
No.of Leaves er plant	0.001	**0.0157**	0.0027	-0.0014	0.0024	-0.0032	-0.0033	0.0005	0.0001	-0.0031
Length of Leaves (cm)	-0.01	-0.0027	**-0.0158**	-0.0099	-0.0056	-0.0067	-0.0083	0.0021	-0.0049	0.0055
Width of Leaves (cm)	-0.021	0.0031	-0.0218	**-0.0346**	-0.0054	-0.0094	-0.0139	0.0026	-0.0095	0.0018
Diameter of Curd	0.0099	0.0054	0.0126	0.0055	**0.0355**	0.009	0.0061	-0.004	0.0133	-0.0096
Days to 50% Curd Initiation	-0.042	0.0217	-0.0455	-0.0291	-0.0274	**-0.1075**	-0.0753	0.0719	-0.015	0.0215
Days to 50% Curd Maturity	0.0352	-0.0156	0.0392	0.0299	0.0127	0.0521	**0.0744**	-0.0209	0.0038	-0.0168
Curd Maturity Duration	0.006	-0.0022	0.0094	0.0051	0.0078	0.0462	0.0194	**-0.0691**	0.011	-0.0091
Marketable Weight of Curd(g)	0.4078	0.0033	0.2914	0.2571	0.3495	0.1304	0.0478	-0.1491	**0.9358**	0.4132
Curd compactness (g/cm3)	-0.0115	-0.0174	-0.0309	-0.0047	-0.0241	-0.0178	-0.0201	0.0117	0.0393	**0.089**
Net Weight of Curd	**0.3812**	**0.0117**	**0.245**	**0.2215**	**0.3472**	**0.0956**	**0.0295**	**-0.1548**	**0.9764**	**0.4917**
Partial R²	0.0023	0.0002	-0.0039	-0.0077	0.0123	-0.0103	0.0022	0.0107	0.9137	0.0438

In the present investigation path coefficient analysis study (Table.3 and Table.4) was done at phenotypic as well as genotypic level for characters under study using genotypic and phenotypic correlation coefficient and taking net weight of curd as dependable variable, so as to identify the direct and indirect effects of components affecting the net weight of curd. In the present study, almost similar trend was shown by both phenotypic and genotypic path coefficients. Genotypically, marketable weight of curd showed maximum direct positive contribution on net curd weight of curd and it was followed by length of leaves. At phenotypic level, marketable weight followed by curd compactness of curd had maximum direct positive contribution on net curd weight. This indicates that direct selection for marketable weight of curd and curd compactness would be very effective for net curd weight improvement. This is in conformity with the findings of Kumar *et al.,* (2011), Sheemar *et al.,* (2012), Nimkar (2013), Singh *et al.,* (2013) and Santhosha *et al.,* (2015). The negative direct effects were recorded for number of leaves per plant width of leaves, days to 50% curd initiation and curd maturity duration. More or less similar trends were observed at both genotypic and phenotypic level. Similar observations were recorded by Sahu (2017) for length of leaf and width of leaf and Singh *et al.,* (2006) and Sheemar *et al.,* (2012) for number of leaves per plant. At the genotypic level, diameter of curd followed by plant height, curd compactness, width of leaves and length of leaves exhibited major positive indirect effects on net curd weight. However, days to 50% curd maturity followed by curd maturity duration, showed maximum negative indirect effect on net curd weight. The value for residual effect was found to be extremely low which indicated the competency of the analysed characters in maximizing the curd yield and that there were very few other contributors which were responsible for net

yield but not taken into consideration in the present investigation. According to Sengupta and Kataria (1971), this residual effect towards yield might be due to other characters (which were not studied), environmental factors and sampling errors.

Thus the present findings highlighted the existence of adequate genetic variability in the germplasm and the need to evaluate them for economic traits improvement. The traits that showed positive correlation with yield and also exhibited direct or indirect effect on yield could be exploited to bring improvement in yield and yield components.

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