Genetic Divergence in Snowball Cauliflower (*Brassica oleracea* var. *botrytis* L.)

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The genetic divergence analysis using Mahalanobis D^2 statistics was carried out in 52 snowball cauliflower germplasm including 3 superior CMS (Ogura) lines based on 12 quantitative characters. These 52 germplasm lines were grouped in 10 clusters, of which cluster IX accommodates 13 genotypes, while cluster VII was solitary. Morphological characterization for curd colour and compactness, leaf colour and plant types was also performed for all the lines. The snowball cauliflower lines under present investigation showed little deviation from original snowball group for plant type and their adaptability. High inter-cluster distance indicated considerable amount of diversity in the present population. Cluster I, II and VIII were important because they had high yield potential. First two clusters also accommodate 3 CMS lines (Ogu1A, Ogu 2A and Ogu 3A). These CMS lines would be immensely useful in heterosis breeding after crossing with divergent genotypes based on cluster distance.

Key Words: CMS lines, D^2 analysis, Genetic diversity, Heterosis, Snowball cauliflower

Introduction

Snowball cauliflower represents the late group of Indian cauliflower cultivated during *rabi* season throughout the Indian sub-continent. In the hilly temperate regions of India, they are cultivated almost year round. Cauliflower contributes around 5% of total vegetable production (NHB Database, 2008) in India and major chunk of it is represented by the snowball types. Snowball cauliflowers are also known as 'Erfurt' or 'Alpha' in Europe. Snowball cauliflower is characterized by dwarf plant with short stem, erect glaucous green leaves, solid and well protected curd. The genetic base of the snowball cauliflower is very narrow. Low genetic diversity is because of high degree of self-compatibility and consequent selfing to a considerable percentage (Watts, 1963; Nieuwhof, 1963). Moreover, most of the snowball cauliflower lines in India were derived from European materials. Genetic base of Indian snowball cauliflower is low as the base population have low genetic diversity. Astrini *et al*. (2006) also reported narrow genetic base in cauliflower. However, there is wide variability among different groups of cauliflower (Quamruzzaman *et al*., 2007). Early types are very distinct from late snowball types. However, group III of Indian cauliflower (~ December maturity group) shares few similarities with snowball group because of possible gene flow between these two groups because of simultaneous flowering at high altitudes. However, the present snowball lines in India are not exactly similar to European summer cauliflower. Snowball cauliflowers in India are adapted to comparatively higher temperature and rainfall in contrast to European summer cauliflowers. Semi-erect and spreading plant types have also evolved in the Indian snowball cauliflowers.

Information on nature and magnitude of variability present in a population is an important pre-requisite for starting any systematic breeding programme. Identification of superior genotypes among the existing germplasm becomes imperative for promoting production/unit area of this crop. Three superior CMS (Ogura) lines were also included to identify divergent genotypes from these lines for their use in heterosis breeding. Considering these points, studies on genetic variability in snowball group of cauliflowers were undertaken.

Materials and Methods

The present investigation was carried out at the Research Farm of Indian Agricultural Research Institute, Regional Station, Katrain, Kullu Valley, Himachal Pradesh, during *rabi* season of 2009-10. The experimental materials comprised of 52 genotypes of snowball cauliflower including 4 commercially released varieties from our station and 3 promising CMS (Ogura) lines. All the lines were characterized for morphological traits, like curd colour and compactness, and leaf colour and plant type. Lines were divided into four groups (loose, medium compact, compact and very compact) based on curd compactness. Curd compactness was determined physically by the pressure applied to the curd with the help of fingers and thumb. Similarly, all the lines were classified into two groups for curd colour (cream and white), four groups for leaf colour (light green, green, dark green and blue green) and three groups for plant type (erect, semi erect and semi

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spreading). The experiment was laid out in random block design (RBD) with 3 replications in 3 rows with 6 plants/ row with spacing of 45 cm × 45 cm. Standard cultural practices as suggested by Singh *et al*. (1959) were followed to raise a successful crop. Observations were recorded for 12 quantitative characters *viz.*, (i) Days to 50% curd initiation, (ii) Days to 50% curd maturity, (iii) Plant height (cm), (iv) Number of leaves, (v) Leaf length (cm), (vi) Leaf width (cm), (vii) Gross plant weight (kg), (viii) Curd length (cm), (ix) Curd width (cm), (x) curd depth (cm), (xi) Net curd yield (t/ha), and (xii) Harvest index (%). Five plants were selected randomly for recording observation. The D^2 statistics was used for assessing the genetic divergence among the populations as suggested by Mahalanobis (1936). Based on the D^2 values thus obtained, the entire germplasm was classified into distinct clusters, grouping together the less divergent genotypes (Rao, 1952).

Results and Discussion

Evaluation of Curd Quality, Leaf Colour and Plant Type

All the genotypes were characterized for curd quality (colour and compactness), leaf colour and plant type (Table 1). Leaf colour and curd compactness varied widely. Most of the lines possessed white but few had cream curd. Very compact curd was produced by Kt-33, Kt-16 and Kt-20 and loose curd was found in the lines, Kt-18 and RSK-119. Majority of the lines had compact curd and few lines showed medium compactness of curd. Most of the lines had semi-erect plant stature except Kt-16, Jonavon, EC-162587, Composite and King Kong with erect plant type where as CIF No. 1 had semi-spreading plant type. Morphological characterization depicts that changes might have occurred in the snowball lines in India from the original population. Majority of the lines had semi-erect plant type in contrast to the erect in original snowball population. The Indian lines are more tolerant to high temperature and rainfall and less prone to the riceyness. Astrini *et al*. (2006) also reported significant deviation in the Indonesian cauliflower lines from European snowball types. The available lines in India would be highly useful in the development of cultivars with wider adaptability.

Grouping of Genotypes into Various Clusters

Based on D^2 analysis the 52 lines were classified into 10 clusters (Table 2). The cluster IX had maximum lines (13) and cluster VII had only one line. The cluster III and cluster II had 9 and 8 lines, respectively. Three identified cultivars for commercial cultivation (Pusa Snowball-1, Pusa Snowball K-1 and Pusa Snowball K-25) were grouped together in cluster II along with Kt-22, Kt-9, Kt-16 and two CMS lines, Ogu1A and Ogu 2A. However, the remaining CMS line, Ogu 3A was placed with Helna, Kt-2, White Gold and Kt-8 in cluster I. The clustering pattern depicts the close ancestry of almost all the identified lines for commercial cultivation. In snowball cauliflower there are no identified F_1 hybrids in India. This was mainly attributed to the non-availability of suitable pollination control mechanism. Self-incompatibility is very weak and promising CMS lines with good setting are not available in this group (Sharma *et al*., 2004). However, three CMS (Ogura) lines developed in this station were free from any floral deformities and had good seed setting (data not shown). These lines will be useful in the development of F_1 hybrids in snowball cauliflower after identification of suitable parent combinations.

Intra- and Inter-cluster Distances

There was considerable amount of genetic divergence in the present collection as evident from inter- and intra-cluster distances among ten clusters (Table 3). Intra-cluster distance was highest in cluster V with four lines and lowest in cluster VII as represented by only one line (Pyramis). Highest inter-cluster distance, however, was between cluster VI *vs* VII (12654.1) followed by VI *vs* IX (9767.2), VI *vs* II (9418.5) and VII *vs* IV (8185.5). The lowest inter cluster distance was between cluster I *vs* VIII (554.3) followed by II *vs* VIII (600.1), II *vs* IX (616.1) and III *vs* IX (742.4). Cluster II which contain two CMS lines, Ogu1A and Ogu 2A was highly divergent from the cluster VI, IV and X. According to Arunachalam *et al*. (1984), the optimum level of genetic divergence between the parents gives the best heterosis and better segregants. However, Shwe *et al*. (1972) and Sichkar *et al*. (1988) suggested that hybridization between highly divergent parents generate promising breeding material. Thus, there is possibility in developing heterotic CMS based F_1 hybrids through selection of parents from highly divergent clusters with similar flowering time. Divergent genotypes can also be used in different breeding schemes for developing snowball cauliflower lines with better adaptability and high yield potential.

Cluster Mean Analysis

The study of cluster mean value of 10 clusters indicated considerable differences for the character studied (Table 4). After leaving out the solitary cluster, range of variation for curd length, curd width, curd depth and number of

Table 1. Characterization of 52 snowball cauliflower genotypes for important morphological traits

Genotype	Curd colour and compactness	Leaf colour and plant type	Genotype	Curd colour and compactness	Leaf colour and plant type
Helna	White, compact	Blue green, semi-erect	Kibogiant	Cream, medium compact	Green, semi-erect
Kt-2	White, compact	Green, semi-erect	Jonavon	White, compact	Green, erect
DB-187-1	Cream, compact	Green, semi-erect	Doc Elgon	Cream, medium compact	Dark green, semi-erect
Pushpa	Cream, medium compact	Light green, semi-erect	Helna-1	White, compact	Blue green, semi-erect
HL	Cream, medium compact	Green, semi-erect	Grodan	Cream, compact	Dark green, semi-erect
Kt-33	White, very compact	Blue green, semi-erect	Autumn Giant	Cream, compact	Green, semi-erect
White Gold	Cream, compact	Green, semi-erect	White Satin	White, compact	Blue green, semi-erect
Kt-9	White, very compact	Green, semi-erect	Early Snowball	Cream, compact	Green, semi-erect
Kt-15	White, medium compact	Light green, semi-erect	RSK-1385	White, compact	Blue green, semi-erect
RSK-1301	Cream, compact	Light green, semi-erect	Kn-81	White, compact	Dark green, semi-erect
Kt-22	White, compact	Light green, semi-erect	EC-162587	White, compact	Green, erect
Kt-18	White, loose	Light green, semi-erect	ACC-329	White, medium compact	Green, semi-erect
RSK-119	White, loose	Blue green, semi-erect	ACC-330	White, compact	Blue green, semi-erect
Agrotech	Cream, compact	Dark green, semi-erect	NCFH-23	White, meium compact	Dark green, semi-erect
White Fox	Cream, compact	Dark green, semi-erect	Igloo	Cream, compact	Green, semi-erect
SR-05	Cream, medium compact	Green, semi-erect	Composite	Cream, medium compact	Green, erect
Hermia	White, medium compact	Light green, semi-erect	Dominate	White, medium compact	Light green, semi-erect
PSBK-25	White, compact	Dark green, semi-erect	King Kong	White, medium compact	Blue green, erect
PSB-1	White, compact	Blue green, semi-erect	Himlata-2	White, compact	Blue green, semi-erect
PSBK-1	White, compact	Blue green, semi-erect	CIF No. 1	White, compact	Light green, semi-spreading
Kt-8	White, compact	Blue green, semi-erect	Pyramis	Cream, compact	Blue green, semi-erect
Kt-16	White, very compact	Green, erect	Kt-17	White, compact	Blue green, semi-erect
Kt-20	White, very compact	Dark green, semi-erect	Kt-44	White, compact	Dark green, semi-erect
Kt-6	White, compact	Light green, semi-erect	Ogu1A	White, compact	Blue green, semi-erect
Kt-19	White, compact	Blue green, semi-erect	Ogu2A	White, compact	Dark green, semi-erect
Alpha	Cream, compact	Blue green, semi-erect	Ogu3A	White, compact	Blue green, semi-erect
Alpha	Cream, compact	Blue green, semi-erect	Ogu3A	White, compact	Blue green, semi-erect

Table 2. Cluster classification of 52 genotypes of snowball cauliflower based on D^2 analysis

Cluster No	Genotypes
I	Helna, Kt-2, White Gold, Kt-8, Ogu3A
II	Kt-9, Kt-22, Pusa Snowball K-25, Pusa Snowball-1, Pusa Snowball K-1, Kt-16, Ogu1A, Ogu2A
III	DB-187-1, White Fox, Kt-6, Kibogiant, RSK-1385, EC-162587, ACC-330, Dominate, Kt-17
IV	Pushpa, Agrotech
V	Kt-33, Kt-18, RSK-119, Kt-19
VI	Igloo, Himlata-2, CIF No.1
VII	Pyramis
VIII	Kt-15, SR-05, Jonavon, Kn-81
IX	HL, Hermia, Kt-20, Alpha, Doc Elgon, Helna-1, Grodan, Autumn Giant, White Sation, Early Snowball, NCFH-23, Composite, Kt-44
X	RSK-1301, ACC-330, King Kong

Table 3. Inter- and Intra-cluster distances among 10 clusters based on D^2 analysis

Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X
I	337.8	586.6	1069.2	3321.2	1371.2	6889.1	2233.1	554.3	1131.8	1767.8
II		323.8	1091.9	5061.2	2373.3	9418.5	1992.7	600.1	616.1	2467.8
III			342.4	2971.6	1156.6	6703.9	3560.7	898.9	742.4	1159.1
IV				589.3	899.0	1327.5	8185.5	3857.6	5198.9	2244.7
V					899.0	3087.6	4924.4	1688.8	2451.4	1166.3
VI						843.9	12654.1	7944.6	9767.2	5783.9
VII							0.0	3063.8	2465.2	5419.3
VIII								388.1	918.4	1474.8
IX									417.1	2241.4
X										581.1

leaves were low among the multi-member cluster. The characters *viz*., leaf length, leaf width, gross plant weight, plant height, net curd yield and harvest index exhibited moderate variation. The high range of variation was observed for days to 50% curd initiation and days to 50% curd maturity among the different clusters.

Table 4. Cluster means of 52 genotypes for 12 characters based on D^2 analysis

Cluster	Days to 50% curd initiation	Days to 50% curd maturity	Plant height (cm)	Number of leaves	Leaf length (cm)	Leaf width (cm)	Gross plant weight (kg)	Curd length (cm)	Curd width (cm)	Curd depth (cm)	Net curd yield (t/ha)	Harvest index (%)
I	114.02	123.94	46.66	18.61	47.41	25.42	1.80	10.92	12.99	5.86	41.85	43.53
II	124.58	135.36	44.20	19.32	46.65	23.45	1.90	11.14	13.24	6.45	38.97	36.59
III	116.51	123.64	39.12	18.89	34.34	16.75	0.90	9.80	11.20	5.18	20.39	40.98
IV	79.48	89.00	39.14	21.78	34.73	17.73	0.94	9.77	10.93	4.53	24.69	49.48
V	94.80	106.50	42.57	18.01	36.69	19.96	1.06	10.95	12.52	5.75	26.25	45.54
VI	56.68	72.28	42.79	19.40	36.79	21.86	0.99	10.78	11.55	6.08	22.58	42.31
VII	131.00	139.60	73.63	20.33	70.27	36.11	1.26	9.96	11.14	6.76	28.16	45.71
VIII	119.96	127.55	44.69	18.53	35.00	18.11	1.68	10.39	11.99	6.22	43.48	43.14
IX	127.56	137.26	42.27	18.03	39.86	20.27	1.24	10.33	12.38	5.82	24.64	36.96
X	107.86	116.37	37.67	17.97	26.47	11.91	0.78	9.49	11.14	5.41	27.62	64.33
Overall mean	107.245	117.15	45.274	19.08	40.82	21.15	1.25	10.35	11.91	5.81	29.86	44.86

The variation observed in cluster means also point out the degree of variability. In the present investigation, cluster IV, V and VI contain genotypes with early maturity, whereas, cluster II, VII and IX were represented by genotypes with late maturity. Thus, considerably good amount of diversity was recorded for days to maturity. For vegetative traits, like plant height, numbers of leaves, leaf length and width significant amount of variability was also observed. Dwarf plants (< 40 cm) was observed in the clusters III, IV and X. All the clusters had plant height in the range of 40–50 cm except the solitary cluster VII which had plant height of 73.63 cm. The numbers of leaves/plant was 17–22 among the clusters. Smallest leaf size (26.47 × 11.91 cm^2) was recorded in the cluster X. The solitary cluster VII had very large leaf size with length and width of 70.27 cm and 36.11 cm, respectively. All the remaining clusters had medium leaf size. Gross plant weight was highest (1.90 kg) in cluster II while it was lowest (0.78 kg) in cluster X. The genotypes included in cluster I, II, V, VI and VIII had more curd length than population mean and similarly genotypes in the cluster I, II, V, VIII and IX had greater curd width whereas clusters I, II, VI, VII, VIII and IX had greater curd depth. Cluster III with 9 genotypes had lowest curd yield (20.39 t/ha) while it was highest (43.48) in cluster VIII with four genotypes. The population mean for yield was 29.86 t/ha and the clusters with better yield than population were I (5 genotypes), II (8 genotypes) and VIII (4 genotypes). Cluster I, II and VIII had all the desirable yield related traits. Moreover, three CMS lines were also included in the cluster I and II. Desirable horticultural traits of parents are important for their utilization in heterosis breeding (Sharma *et al.*, 2004). Therefore, these CMS lines could be utilized in the heterosis breeding programme after testing their combining ability.

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