57

PERFORMANCE OF CAULIFLOWER (*Brassica oleracea var. botrytis L.*) GENETIC STOCKS FOR HORTICULTURAL AND YIELD CHARACTERS

THESIS

by

SANJEEV KUMAR

Submitted in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE

in

HORTICULTURE

(VEGETABLE CROPS)

1985

COLLEGE OF HORTICULTURE
Dr. YASHWANT SINGH PARMAR
UNIVERSITY OF HORTICULTURE AND FORESTRY
NAUNI SOLAN 173 230 (H.P.) INDIA
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1998

To
my
parents
&
sister

Dr. B.N. Korla
Professor (Vegetable Crops)

Department of Vegetable Crops
College of Horticulture
Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) - 173 230

CERTIFICATE-I

This is to certify that the thesis entitled **"Performance of cauliflower (*Brassica oleracea* var. *botrytis* L.) genetic stocks for horticultural and yield characters"**, submitted in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE** in **HORTICULTURE (Vegetable Crops)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.) is a bonafide research work carried out by **Mr. Sanjeev Kumar (H-96-48-M)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received by him during the course of investigations have been fully acknowledged.

Place : Nauni, Solan
Dated : 21 December, 1998

Dr. B.N. Korla
Chairman
Advisory Committee

CERTIFICATE-II

This is to certify that the thesis entitled **"Performance of Cauliflower (*Brassica oleracea* var. *botrytis* L.) genetic stocks for horticultural and yield characters"** submitted by **Mr. Sanjeev Kumar (H-96-48-M)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (HP), in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE** in **HORCITULTURE (Vegetable Crops)** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the external examiner.

5/1/99

Chairman
Advisory Committee

5.1.99

External Examiner

6.1.99

Professor and Head
Department of Vegetable Crops

Dean
College of Horticulture

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At last I thank DPT Computers, Nauni and staff for typing this manuscript well in time.

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To err is human.

Nauni, Solan
Dated :21/12/1998

Sanjeev Kumar
(Sanjeev Kumar)

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INTRODUCTION

INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis* L.) a member of Cruciferae, is the major and popular vegetable among cole crops due to its delicious taste, flavour and nutritive value. This crop is native of Southern Europe. It is grown for its white tender curd which is commonly used as vegetable besides, it is used in curry, soup and pickle making. Cauliflower is good source of proteins, carbohydrates, minerals and vitamins (Chaudhary, 1996).

At global level, cauliflower is grown in an area of 704,000 ha with a production of 1,34,45,000 MT, while in India it occupies an area of 2,80,000 ha with annual production of 5000 MT (Anonymous, 1997). The leading cauliflower growing states in the country are West Bengal, Bihar, Uttar Pradesh, Punjab, Rajasthan and Karnataka.

In Himachal Pradesh, cauliflower is grown in an area of 690 ha with annual production of 13,800 MT (Anonymous, 1995) of which Snowball group is the major contributor both in terms of off-season as well as seed crop. In mid and high hills of the state, it is grown as an off-season crop during summer months which sells at a premium in plains and bring lucrative returns to the farmers. The seed production of late cauliflower is also highly remunerative and is being done on commercial scale in mid hills of Himachal Pradesh.

Cauliflower was introduced in India from England by Britishers in 1822 (Chatterjee, 1986) and in such a short period of its introduction, it has gained lot of importance among the breeders, farmers and consumers. Consequently a large number of cultivars are available for cultivation in early and mid season group. This probably is due to the presence of variability in both the groups.

However, there are very limited number of cultivars in Snowball group as much variability is not available in this type. Though the snowball group provides an ideal genotype both to the farmer and consumers, yet these cultivars are very sensitive to the fluctuating environmental conditions resulting sometimes in the development of undesirable characters which makes the curds undesirable for marketing. The characters like yellowness, leafyness and riceyness generally observed in the population are controlled largely by environmental factors especially temperature, however, the reports of their being controlled genetically are also available (Dickson and Lee, 1980; Chatterjee *et al.*, 1991). Thus, an attempt have been made to study the performance of these characters along with other horticultural and yield characters in the progenies developed by selecting the desirable plants. The objectives of the study were as under:

i) To study the performance and variability of genetic stocks/progenies for horticultural, yield and quality characters.

ii) To study the heritability and genetic advance in different characters.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Not much work has been done on "Snow Ball" or "late group" of cauliflower in India and abroad. Hence, the literature available on the cauliflower as a whole is reviewed and reported under following heads:

2.1 Mean and variability

2.2 Heritability and genetic advance

2.3 Correlation studies

2.4 Quality characters

2.4.1 Riceyness

2.4.2 Leafyness

2.4.3 Curd compactness/solidity

2.4.4 Curd colour

2.1 MEAN AND VARIABILITY

A wide range of variability in any crop provides the better chance of selecting desirable types. The variation exhibited by the quantitative characters include both heritable and non-heritable components (Fisher, 1918).

Nieuwhof and Garretsen (1961) worked out the inheritance of the solidity of the curd in Snowball group and concluded that it is polygenically inherited. It was visually observed through a score of curd from 1-7. Visual scoring for curd compactness has also been reported by Singh *et al.* (1978). However, Watts (1966) measured by curd angle and showed wide range of variability for this

character in parents, and similar results have also been reported by Vashistha *et al.* (1984) in mid-season group.

Pal and Swarup (1966) had reported variability for total leaf number, marketable curds and net yield per plot. In a study on nine intervarietal crosses, the variation ranged from 34.14 - 155.55 per cent.

Chatterjee and Swarup (1972) observed that the mean curd weight of D-96 and Improved Japanese were 650 g and 536 g, respectively.

Singh *et al.* (1975) while involving eight inbred lines in diallel cross recorded the mean value of 151.60, 30.00 and 501.67 g for days to curd maturity, number of leaves and curd weight, respectively. The average performance of the F_1 hybrids exceeded the mean value of the parents.

Lal *et al.* (1976) found that cross 301 x 108 and 30 x 108 gave the highest mean value for curd weight (545.00) and curd maturity (106.9 days), respectively when five inbred lines of maturity group III were crossed with same number of lines of maturity group I.

Sandhu *et al.* (1977) while studying crosses and their parents of mid group reported variation for days taken to 50 per cent maturity and curd weight. The phenotypic coefficient of variability in segregating generations were much higher than those for non-segregating generations. In F_2's transgressive segregation was observed in both the directions (Sandhu and Singh, 1977).

Crisp and Kesavan (1978) observed the highest mean curd weight in Autumn Glory (328 g) while studying genotypic x environmental effects. Thamburaj *et al.* (1980) also found significant differences for curd weight and yield in early and mid season varieties of cauliflower. The cultivars viz. Mid

Season Marvel, Patna Mid Season and Second Early were found as the highest yielders.

Wurr *et al.* (1981) reported that the mean curd diameter of Janavon and St. Keverne was 9.8 cm and 7.5 cm, respectively. The cultivar St. Keverne took over 200 days to reach 50 per cent curd initiation and more than 11 months to mature.

Sharma *et al.* (1988) in a study involving three summer and three winter types found that Pyramis (winter season), gave the highest mean value for gross weight (1.390 kg), curd weight (1.096 kg), days to 50 per cent curd formation (188.6), curd size index (222.03 cm^2) and leaf size index (1071.26 cm^2).

Aditya *et al.* (1989) observed genetic variability in eight cultivars for nine yield related characters. Highly significant differences were observed among cultivars for all the characters. Kartika being the earliest and Snowball Y was latest in curd maturity. Early Snowball produced the highest curd weight (895 g) and yield (35.8 t/ha).

Aalbersberg (1990a, b) observed that early maturing varieties like Planca and Siria took 118 and 123 days from sowing to maturity, respectively while Sernio, Linex, Jura and Orco matured late (140-150 days). Siria, Arfak, Plana, Fortune, Profil and Lindon were recommended for early autumn cultivation. Acciarri *et al.* (1990) found a new selection, "Speedy cauliflower", having white corymbs besides possessing a range of desirable morphological and agronomical characters.

Lal *et al.* (1990) reported that for curd diameter, depth and angle, phenotypic variability in F_3 families was higher than those of BIP's in all the

crosses of Indian cauliflowers, including Pusa Synthetic except for curd angle in a cross (452 x 294) where the magnitude of variability was higher in the BIP's.

Pandey and Naik (1991) observed significant differences for days to curd initiation, and maturity; total plant weight and curd weight while studying the genetics and characters association in biparental, F_2 and F_3 progenies of cauliflower.

Thakur (1998) while studying 21 genotypes in cauliflower observed significant differences for different characters. The mean performance of the characters indicated wide variation for gross weight of the plant, marketable yield of curd and leaf size index while it was moderate to narrow for number of leaves per plant, stalk length, curd depth and days to marketable maturity.

2.2 HERITABILITY AND GENETIC ADVANCE

Fisher (1918) was the first worker, who partitioned the continuous variation into heritable and non-heritable components. Wright (1921, 1934) gave detailed division of genotypic variances into additive and non-additive (dominance and epistatic effects). From these findings he suggested that additive components of genetic variance contributes towards the genetic improvement in selection.

Lush (1940) defined heritability in two ways, that is broad and narrow sense. In broad sense it refers to the ratio of genetic variance to the total variance and in narrow sense to the ratio of additive genetic variance to the total variance.

Buiatti *et al.* (1974) reported high heritability estimates for days to flowering in cauliflower. Sandhu and Singh (1977) reported high heritabiity

(broad sense) and expected genetic advance for maturity period and curd weight in crosses. Whereas, Crisp (1977) found low heritability for maturity period.

Dhiman (1979) reported heritability (broad sense) estimates of medium order for marketable yield, curd size index, number of leaves per plant and gross weight per plant. Sabita and Vashistha (1986) revealed that the heritability in broad sense ranged from 26.3 - 67 per cent in five crosses of cauliflower for curd weight.

Lal *et al.* (1990) found low heritability estimates (narrow sense) for curd weight, curd diameter, curd depth curd angle, and maturity while studying the comparison of BIP's with Indian cauliflower (III group).

Dutta (1991) reported that estimates of heritability were high in the progenies of Pusa Snowball K1 x Janavon for days to curd initiation, number of leaves per plant, stalk length and gross weight. However, low heritability was observed for days to marketable maturity from curd initiation. The genetic advance as percentage of mean was comparatively high for gross weight, number of leaves per plant, net curd weight and days to curd initiation and low for days to marketable maturity from curd initiation and curd diameter.

Radhakrishna and Korla(1994)found that heritability and genetic advance as a percentage of mean were high for gross plant weight, net curd weight, harvest index and stalk length.

2.3 CORRELATION STUDIES

The efficiency of selection can be improved by the study of correlation between different characters. Some characters like yield are complexly inherited and involves several closely related factors. The extent of observed relationship

between two characters is indicated by phenotypic correlation which include both heriditary and environmental influences, while the real association between the two characters is indicated by genotypic correlation coefficient which may be useful for selection (Johnson *et al*., 1955a).

Jensma (1957) found a positive correlation between earliness and leaf number in cauliflower. An association between early curding and low leaf number and late curding with high leaf number may be of value in breeding for earliness (Watts, 1965).

Lal (1973) worked out the correlation coefficients among different characters in the F_2 and concluded that curd weight was significantly associated with curd size index, leaf size and plant spread. The environmental correlation between curd weight and curd size index were significant and positive.

Baroncelli *et al*. (1974) studied correlation among days to flowering, leaf length, leaf width and curd diameter. They observed negative correlation between days to flowering and curd diameter and positive between curd diameter and leaf width.

Thamburaj *et al*. (1982) recorded that plant height and weight were related to curd yield. During two years study, Sharma *et al*. (1982) reported the correlation coefficients of curd yield with curd diameter, dry matter production, leaf number and leaf area index were highly significant.

Dhiman *et al*. (1983) reported that marketable yield per plant was positively correlated with the number of leaves, curd size index and gross weight per plant.

Jamwal (1984) worked out correlation coefficient between various economic characters in F_1 and F_2 and concluded that gross weight per plant was positive and highly significant with marketable yield at phenotypic level. Both of these characters also had almost similar association with leaf size, curd index, stalk thickness, curd compactness and days to curd maturity.

Singh (1984) reported that the leaf number per plant, curd diameter, plant height and leaf weight per plant were positively and significantly correlated with yield. The cultivar Early Kunwari (early maturing) showed the strongest correlation for curd diameter and Snowball (late) for the leaf weight. Pandey and Naik (1985) reported that yield was affected by characters like days taken to curd initiation, curd weight, weight of leaves and plant height.

Dadlani *et al.* (1986) while comparing biparental progenies with F_3 selfs in Indian cauliflowers, found that the curd weight was significantly correlated with curd depth, diameter and angle in both types of progenies. Pandey and Naik (1986) reported that number of leaves were directly correlated with net curd weight.

Aditya *et al.* (1989) studied correlation for yield related characters and reported that curd weight was positively correlated with all the other characters studied. Booij (1990) reported non-significant association between curd weight and number of days from curd initiation to maturity.

Dutta and Korla (1991) studied correlation and regression in advanced generations of late group cauliflower and reported that net curd weight was positively and significantly correlated with days to marketable maturity from curd initiation, curd depth, curd diameter, gross weight of the plant and harvest index.

Pandey and Naik (1991) found that days to curd maturity were significantly and positively correlated with total plant weight, curd weight and weight of leaves per plant. The total plant weight was positively and significantly correlated with curd weight, number and weight of leaves per plant. The net curd weight had positive and significant correlation with number and weight of leaves per plant, whereas number of leaves per plant had significant positive association with weight of leaves per plant.

Dutta *et al.* (1992) while studying path coefficient analysis of 24 progenies of six families (two F_4's, three BC_3's and one S_3) found that gross weight was positively and significantly correlated with stalk length, leaves per plant, curd diameter and curd depth whereas net curd weight with curd diameter, curd depth and harvest index. Days to curd initiation showed negative association with net curd weight and harvest index and positive with stalk length, curd depth. Leaves per plant with gross weight and gross weight and harvest index with net curd weight showed positive direct effects.

Radhakrishna and Korla (1995) reported that net marketable curd weight was positively and significantly correlated with gross plant weight, curd diameter and curd depth while curd diameter was positively correlated with curd depth and negatively with days to marketable maturity.

Zhang *et al.* (1995) reported a close correlation between curd weight and weight of other organs in studies involving leaf removal, cutting roots and use of different fertilizers and water regimes. The closest positive correlation was found between curd weight and leaf weight and stem diameter (r=0.7703 and 0.8023, respectively).

2.4 QUALITY CHARACTERS

2.4.1 Riceyness

This is also sometimes known as "wooliness" and is due to the appearance of out growth of about 1 mm diameter from the curd surface which are clearly visible under the microscope as immature floral buds.

Weibe (1973) observed that higher temperature, especially with pre-transplanting vernalization reduced the deviation in curd size compared to cold raised plants. This treatment also caused reduction in curd size and riceyness. Later Weibe (1975) reported that a pre-matured initiation of floral buds is characterised by riceyness in cauliflower and is considered to be of poor quality for marketing. It appears to be induced by cold temperature on the curd surface as it matures and the cold threshold probably varies between varieties. Major genetic factors determining the cold requirement for curd induction are probably close to some of these causing riceyness.

Dickson and Lee (1980) observed that inheritance of white curd was controlled by 2 or 3 genes and had a narrow sense heritability of 33-38 per cent. They found that PI 183214 was free from riceyness, leafyness and bracting.

Zweep *et al.* (1984) observed that early cultivars (Celesta and RS1848) and late cultivars (Andes and Delna) were moderately resistant to riceyness.

Chatterjee *et al.* (1991) produced Pusa Deepali by inbreeding from the stock collected from Punjab and maintained by mix pollination. The cultivar was having medium sized curds weighing 500-700 g with a low tendency towards riceyness.

Spehia (1996) observed riceyness in different genotypes of late cauliflower when transplanted on 20th October or 5th November, while it was absent when transplanting was done on 5th October.

Thakur (1998) while studying 21 genotypes of cauliflower reported that three genotypes viz. KJ38, KJ47 and Kathmandu Local exhibited riceyness of varying level while it was absent in others.

2.4.2 Leafyness

Curds become leafy due to growing of small green leaves between the curd segments. This tends to reduce the market value of curd considerably.

Crisp *et al.* (1975) advocated that double selection, first in field and then in culture, would increase the likelihood of breeding bract-free cauliflowers. Pusa Deepali, a variety resistant to leafyness was developed by Chatterjee *et al.* (1991) in cauliflower.

Greesan *et al.* (1994) observed that the occurrence of bracting was positively correlated with the average temperature during ten days after curd initiation, however, it varies with cultivars. Spehia (1996) reported no leafyness at the time of curd maturity in any of the genotypes when transplanted on 9th October, 20th October and 5th November.

2.4.3 Compactness/solidity

It is the character which means how much the curd is solid. A solid or compact curd is more liked. Singh *et al.* (1978) reported that curd compactness is governed by two dominant major genes designated as C0-1 and CO-2 while studying the F_1's, F_2's, BC's of four Indian cauliflower varieties.

Jamwal (1984) observed correlation coefficient between various economic characters for F_1 and F_2 sets and concluded that gross weight per plant and marketable maturity had positive and significant association with curd compactness in F_2.

Vashistha *et al.* (1984) reported that recurrent selection may be effective in improving compactness in two interacting crosses (P-35 x Sel-1 and Improved Japanese x 74 -6C).

Butt *et al.* (1988) reported that curd compactness was significantly affected both by cultivar and planting dates.

Dutta (1991) observed that all the progenies in the population, in general, gave compact curds except 2-66 of family 4 where the curds were semi-compact. Some loose curds in the experiment were also observed.

Radhakrishna (1992) reported that most of the progenies including checks in general, produced compact curds ranging from 70-100 per cent, while three progenies exhibited 12-17 per cent semi-compact curds. The progeny which showed maximum semi-compact curds also had the maximum loose curds.

Spehia (1996) showed that maximum solid curds were obtained in PSBK1, KJKBC_3F_2-2-65 and KTF_4-4-11 out of 15 advanced generations when transplanted on 5th October in comparison to the 20th October.

2.4.4 Curd colour

Crisp *et al.* (1975) reported single gene with partial dominance for large white curds, and double recessive for dwarf, orange curds. Singh *et al.* (1978)

reported two major genes (B_{11} and B_{12}) governing the leaf cover of the curd, and hence its discolouration by sunlight.

Dickson and Lee (1980) reported a line PI183214 from Egypt with two or three incompletely dominant genes which controlled the persistence of whiteness in curds when exposed to sunlight. This persistent white curd character has resulted in the cauliflower production simple and relatively inexpensive. Dickson (1985) developed a male sterile line NY7642A, which was early in maturing and produced persistent white curds.

Dutta (1991) showed that in general, the progenies of the crosses involving PSB-I, PSBK-I with Janavon were snow white in colour. However, sporadic cream white curds in the population were also noticed.

Radhakrishna (1992) observed different F_4 progenies of a cross PSB-1 and Janavon of which, three produced maximum snow white curds, 11 progenies had dull white curds and none except one showed pale curds.

Spehia (1996) reported that the colour of curds was significantly affected by the transplanting dates. The genotypes transplanted on 5th October and 20th October gave maximum number of snow white to white curds, while when transplanted on 5th November, they developed dull white colour.

Thakur (1998) reported that out of 21 genotypes Monopreco, Janavon and Janavon S-3 gave yellowish white curds while snow white to white in the remaining lines/genotypes.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present investigations were carried out at the experimental field of the Department of Vegetable Crops, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) 173 230 during 1996-98.

3.1 LOCATION AND ENVIRONMENTAL CONDITION

The geographical location of the site is as follows:

Altitude : 1200 m amsl
Latitude : 30-50°N
Longitude : 77.8°E

The university campus comes under semi-temperate zone of Himachal Pradesh. The data pertaining to temperature, relative humidity, rainfall and number of days during the period of experiment are given in the table below.

Month	Temperature (°C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
1997				
September	27.3	18.1	75.5	43.2
October	22.5	10.3	70.5	45.6
November	20.5	6.6	75.0	59.2
December	18.7	2.0	51.0	4.5
1998				
January	17.6	1.8	52.0	84.8
February	19.1	7.6	62.0	70.1
March	23.4	10.1	59.0	62.8

3.2 EXPERIMENTAL MATERIAL

The materials comprised of 13 different genotypes of cauliflower of which nine were late and four of mid season group. These were obtained from the department of Vegetable Crops, UHF, Nauni-Solan for undertaking the study. In these genotypes, different plants were selected on the basis of good curd size, less leaves per plant, curd depth, net curd weight along with absence of leafyness and riceyness and were bud pollinated/mix pollinated in 1996-97, the seed of all these plants were collected separately for next year planting (1997-1998).

Genotype	Source	Maturity group
KJ-38	Vegetable Deptt. UHF, Nauni	Late
KJ-47	-do-	-do-
EC162587	-do-	-do-
Pyramis	-do-	-do-
KM1	-do-	-do-
KT9	-do-	-do-
PSBK1	-do-	-do-
Monopreco	-do-	-do-
PSB1	-do-	-do-
Janavon	-do-	Mid
KK104	-do-	-do-
Pusa Himjyoti	-do-	-do-
Pusa Synthetic	-do-	-do-

The experimental materials, thus, comprising 40 progenies of 13 genotypes including check PSBI were transplanted in the field during 9th October, 1997 in a Randomized Block Design keeping three replications. Three rows of five plants of each progeny were planted at a spacing of 45x30 cm. All other recommended package of practices of the crop were followed to raise a healthy crop.

3.3 OBSERVATIONS RECORDED

Observations on the following characters were recorded on all the plants of each genotype including checks in each plot.

3.3.1 Stalk length (cm)

Length of stalk was measured in centimetres from the first secondary root level to the position of first leaf.

3.3.2 Number of leaves per plant

Total number of leaves at the time of maturity were counted.

3.3.3 Plant frame (cm)

The girth of the plant was measured in centimetres and was taken as plant frame.

3.3.4 Leaf size index (cm^2)

The leaf size index is obtained by multiplying the leaf length (from the base of the leaf to the tip) and its width in the centre and is expressed in cm^2.

3.3.5 Curd depth (cm)

The length from surface to the first flower segment of vertically cut curd was measured in centimetres.

3.3.6 Gross curd weight (g)

Gross weight including, curd, leaves and stalk was recorded in grams.

3.3.7 Net curd weight (g)

Net curd weight excluding all the leaves and stalk was weighed to record the net curd weight in grams.

3.3.8 Days taken to marketable maturity

The number of days from the day of transplanting to the day when curds attained marketable maturity were worked out.

3.3.9 Harvest index (%)

Harvest index was calculated as a ratio of net curd weight to the gross curd weight and expressed in percentage.

3.3.10 Curd solidity

Curd solidity was judged visually by putting thumb pressure and categorized into three groups :

i) compact,
ii) semi-compact and
iii) loose curds.

3.3.11 Leafyness

The leafyness was visually recorded in each plant at the time of harvesting and the progenies were classified as:

i) leafy and
ii) non-leafy.

3.3.12 Riceyness

The incidence of riceyness were also recorded visually at the time of harvesting and the progenies classified as:

i) ricey and
ii) non-ricey.

3.3.13 Curd colour

Colour of the curd was observed visually and grouped into three classes namely:

i) snow-white,
ii) white and,
iii) dull-white.

3.4 STATISTICAL ANALYSIS

The averaged values of all the 15 plants for various traits were subjected to statistical analysis at the Computer and Instrumentation Centre, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan and were analyzed as per Gomez and Gomez (1976). The analysis of variance was as under:

Source of variation	df	Mean sum of square	Variance ratio (VR)
Replications	r-1	Mr	Mr/Me
Treatments	t-1	Mt	Mt/Me
Error	(r-1) (t-1)	Me=Ve	

where,

r = Number of replications
t = Number of treatments
Ve = Error variance

The observed 'F' value was compared with tabulated value for judging the significance. All those characters which differed significantly, were further utilized for the estimation of following genetic parameters:

i) Coefficient of variability (phenotypic and genotypic)
ii) Heritability
iii) Genetic gain
iv) Correlation coefficients
v) Path coefficients

3.4.1 Coefficient of variability

The genotypic and phenotypic coefficient of variability were calculated as per the method suggested by Burton and DeVane (1953).

Genotypic coefficient of variability

$$GCV = (Vg/\bar{x}) \times 100$$

Phenotypic coefficient of variability

$$PCV = (Vp/\bar{x}) \times 100$$

where,

Vg = Genotypic variance (Mt-Me)/r
Vp = Phenotypic variance (Vg+Ve)
$\bar{X}$ = Population mean.

3.4.2 Heritability

Heritability in broad sense was calculated as per formulae given by Allard (1960).

$$H = (Vg / Vp) \times 100$$

where,

H = Heritability (%)

Vg = Genotypic variance (Mt-Me)/r

Vp = Phenotypic variance (Vg+Ve)

3.4.3 Genetic advance

The expected genetic advance (GA) resulting from selection of five per cent superior individuals was calculated as per Allard (1960).

$$GA = H \times \sigma p \times K$$

where,

σp = Phenotypic standard deviation

K = 2.06 (Selection differential at 5 per cent selection intensity)

H = Heritability

3.4.4 Genetic gain

Genetic advance expressed as per cent of population mean was calculated by the formula suggested by Johnson *et al* (1955b).

$$GG = (GA/\bar{x}) \times 100$$

where,

GG = Genetic gain (%)

$\bar{X}$ = Population mean

3.4.5 Correlation

The genotypic and phenotypic correlation coefficients were calculated as per Al-Jibouri *et al.* (1958) by using analysis of variance-covariance table as given below:

Analysis of variance and covariance

Source of variation	df	MSS x	MSS y	Mean sum of products
Replications	(r-1)			
Genotypes/entries	(t-1)	Mgx	Mgy	Mgxy
Error	(r-1) (t-1)	Mex	Mey	Mexy

where,

Genotypic Covariance (CoVgxy) = (Mgxy - Mexy)/r

Phenotypic Covariance (CoVpxy) = Covgxy + Covexy

Phenotypic coefficient of correlation

$$rp = CoVpxy / \sqrt{Vpx \times Vpy}$$

where,

CoVpxy = Phenotypic covariance between characters x & y

Vpx = Phenotypic variance of character x

Vpy = Phenotypic variance of character y

Genotypic coefficients of correlation

$$rg = CoVgxy / \sqrt{Vgx \times Vgy}$$

where,

CoVgxy = Genotypic covariance between characters x & y

Vgx = Genotypic variance of character x

Vgy = Genotypic variance of character y

Calculated correlation coefficients (r) were compared with tabulated 'r' values (Fisher and Yates, 1963) at (n-2) degree of freedom at 5% or 1% level of significance. If the calculated 'r' value at 5% were greater than tabulated value of 'r' the correlation was said to be significant.

3.4.6 Path coefficient analysis

The characters showing significant genotypic correlation with net curd weight were utilized to compute direct and indirect contribution.

The direct and indirect paths were obtained following Dewey and Lu (1959). The path coefficients were obtained by the simultaneous selection of the following equations, which expresses the basic relationship between genotypic correlation (r) and path coefficients (p)

$$r_{14} = p_{14}+p_{24}r_{12}+p_{34}r_{13}$$

$$r_{24} = p_{14}r_{21}+p_{24}+p_{34}r_{23}$$

$$r_{34} = p_{14}r_{31}+p_{24}r_{32}+p_{34}$$

where,

r_{14}, r_{24} and r_{34} are the genotypic correlation of component characters with yield (dependant variable) and r_{12}, r_{13} and r_{23} are the genotypic correlations among the component characters (independent variables).

The direct effects were calculated by the following set of equations :

$$p_{14} = C_{11}r_{14}+C_{12}r_{24}+C_{13}r_{34}$$

$$p_{24} = C_{21}r_{14}+C_{22}r_{24}+C_{23}r_{34}$$

$$p_{34} = C_{31}r_{14}+C_{32}r_{24}+C_{33}r_{34}$$

where,

C_{11}, C_{12}, C_{22}, C_{23} and C_{33} are constants derived by using abbreviated Doolittles technique as explained by Goulden (1959).

$r_{12}p_{24}$, $r_{13}p_{34}$, $r_{21}p_{14}$, $r_{23}p_{34}$, $r_{31}p_{14}$ and $r_{32}p_{24}$ are indirect effects.

3.4.7 Residual effects

$$1 = p^2x_4+p_{14}^2+p_{24}^2+p_{34}^2+2p_{14}r_{12}p_{24}+2p_{14}r_{13}p_{34}+2p_{24}r_{23}p_{34}$$

EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS

The present study was undertaken to evaluate various genotypes/progenies of cauliflower (*Brassica oleracea* var. *botrytis* L.) for horticultural and yield characters. The results obtained are explained under following subheads:

4.1 Evaluation of genotypes/progenies
4.2 Parameters of variability
4.3 Correlation
4.4 Path coefficient analysis

4.1 EVALUATION OF GENOTYPES/PROGENIES

The analysis of variance for nine characters is given in the Table 1. The 'F' values revealed that differences among genotypes/progenies were significant for all the characters namely stalk length, number of leaves per plant, plant frame, leaf size index, curd depth, gross curd weight, net curd weight, days taken to marketable curd maturity and harvest index. The mean values obtained for various characters are presented in Table 2a.

4.1.1 Stalk length

The data obtained on average stalk length revealed significant differences (Table 1). It ranged from 1.05 cm in KJ38-7 and KJ47-6 to 3.69 cm in Pusa Himjyoti-4 (Table 2a).

None of the genotypes gave stalk length less than the general mean as well as check (PSB-1). Four progenies viz. Pusa Himjyoti-4 (3.69 cm); PSBK1-2MP (3.33 cm); KJ47-2MP (2.54 cm) and KJ38-6MP (1.97 cm) gave stalk length

Table 1. Analysis of variance for randomized block design

Source of variation	Replications (2)	Treatments (39)	Error (78)
1. Stalk length	0.085	0.914*	0.082
2. Leaves per plant	2.615	10.662*	0.691
3. Plant frame	6.584	132.261*	13.135
4. Leaf size index	19570.801	94458.289*	10597.655
5. Curd depth	0.318	0.493*	0.081
6. Gross curd weight	36841.602	157162.940*	32378.695
7. Net curd weight	4642.800	41830.461*	8781.005
8. Days for marketable maturity	7.087	56.146*	9.647
9. Harvest index	19.109	54.104*	17.504

** Significant at 5% level of significance*

significantly more than the general mean, while it was more than the check in seven besides above four. All other progenies gave stalk length at par with PSB-1. In most of the cases the mix pollinated progenies gave stalk length more than bud pollinated.

4.1.2 Number of leaves per plant

The observations recorded for number of leaves per plant depicted significant differences among the various genotypes studied (Table 1). The number of leaves per plant varied from 15.13 in Pusa Himjyoti-4 to 23.60 in KJ47-6 (Table 2a), PSB-1 (check) gave 17.07 leaves per plant.

The number of leaves were significantly less than the mean (19.86) in seven progenies viz. KJ38-4 (18.00); KJ38-6MP (17.73); Monopreco-2 (17.40); Janavon-1 (17.27); PSB-1 (17.07); PSBK1-2MP (15.67) and Pusa Himjyoti-4 (15.13), while 10 genotypes gave more number of leaves per plant than the mean. None of the progeny gave leaves per plant less than the check PSB-1 except for PSBK1-2MP (15.67) and Pusa Himjyoti-4 (15.13) whereas majority of the progenies gave significantly more than the check of which major share was contributed by KJ38 and KJ47 progenies.

In general, the progenies developed through mix pollination gave less number of leaves over bud pollinated ones.

4.1.3 Plant frame

The genotypes differed significantly for plant frame. It was found minimum in KM1-4MP (33.63 cm) and maximum (59.68 cm) in Monopreco-1MP (Table 2a).

Table 2a. Mean performance of different characters.

Genotypes/ progenies	Stalk length (cm)	Leaves per plant	Plant frame (cm)	Leaf size index (cm^2)	Curd depth (cm)	Gross curd weight (g)	Net curd weight (g)	Days for marketable maturity	Harvest index (%)
KJ38-1	1.17	22.00	53.57	740.24	2.73	1000.00	446.67	121.00	45.65
KJ38-3	1.27	20.93	44.10	557.43	3.07	980.00	466.67	121.00	44.07
KJ38-3 (MP)	1.50	22.40	44.87	584.71	3.31	1073.33	450.00	122.33	45.76
KJ38-4	1.59	18.00	47.85	690.39	2.93	1153.33	443.33	128.00	45.54
KJ38-4 (MP)	1.27	20.73	50.97	522.46	3.73	1016.00	510.00	115.33	43.69
KJ38-5	1.07	21.00	45.31	558.85	3.37	936.67	453.33	118.00	47.06
KJ38-6 (MP)	1.97	17.73	51.14	803.74	3.53	1030.00	576.67	130.00	55.60
KJ38-7	1.05	20.67	42.41	462.24	3.91	1076.00	620.00	127.33	57.99
KJ47-2	1.27	19.73	49.67	724.24	2.99	1113.33	516.67	117.67	46.57
KJ47-2(MP)	2.54	19.27	40.52	570.94	2.62	803.33	386.67	118.00	48.48
KJ47-3	1.41	20.27	42.63	490.92	3.27	926.67	490.00	125.33	42.16
KJ47-3 (MP)	1.31	21.67	47.25	1213.35	3.23	1180.00	703.33	124.67	52.62
KJ47-4	1.79	20.00	54.67	1047.72	3.57	1433.33	633.33	124.00	44.65
KJ47-5	1.30	22.13	43.83	716.39	3.17	916.67	390.00	119.33	42.87
KJ47-5 (MP)	1.39	19.40	45.19	558.78	3.00	843.33	430.00	112.67	51.53
KJ47-6	1.05	23.60	57.39	798.86	3.90	1566.67	746.67	126.00	47.80
KJ47-6 (MP)	1.19	19.33	49.43	644.80	2.79	973.33	520.00	121.67	50.32
KJ47-7	1.16	23.40	40.58	582.69	3.60	1150.00	600.00	123.33	53.11
KJ47-7 (MP)	1.83	21.27	59.11	785.41	3.07	1245.00	550.00	120.00	45.48
Janavon-1	1.63	17.27	44.92	529.89	3.57	750.00	403.33	122.00	55.43
Janavon-2	1.58	19.80	59.13	896.71	3.20	1136.67	513.33	118.00	45.26
Janavon-2 (MP)	1.35	19.57	44.98	668.72	3.47	1063.33	526.67	115.67	50.29

contd...

Genotypes/ progenies	Stalk length (cm)	Leaves per plant	Plant frame (cm)	Leaf size index (cm^2)	Curd depth (cm)	Gross curd weight (g)	Net curd weight (g)	Days for marketable maturity	Harvest index (%)
EC162587-1	1.16	23.40	40.58	582.69	3.60	590.00	270.00	120.67	46.14
KK104-1	1.14	21.20	43.72	578.30	3.13	560.00	260.00	125.00	46.71
KK104-1 (MP)	1.25	21.60	50.69	873.03	2.17	946.67	450.00	121.67	47.49
Pusa Himjyoti-4	3.69	15.13	44.67	499.77	3.20	726.67	403.33	118.67	55.21
Pyramis-2	1.61	20.20	55.56	780.19	2.82	1016.67	493.33	118.67	49.05
KM1-1	1.46	18.80	53.08	561.23	3.21	903.00	470.00	118.67	52.13
KM1-4 (MP)	1.17	21.93	33.63	504.64	3.45	1050.00	500.00	118.33	47.66
KM1-5	1.28	18.67	58.20	889.79	3.23	1243.33	696.67	118.00	55.04
KT9-2	1.13	20.77	45.09	364.42	3.60	600.00	330.00	127.00	55.19
PSBK1-1	1.08	20.53	50.94	648.04	2.99	886.67	450.00	121.00	51.02
PSBK1-2	1.25	18.73	55.31	1019.21	3.63	1330.00	703.33	124.67	52.62
PSBK1-2 (MP)	3.33	15.67	35.60	604.78	3.23	783.33	420.00	113.33	48.30
Monopreco-1	1.33	19.33	45.53	797.52	2.30	946.00	450.00	130.00	47.29
Monopreco-1 (MP)	1.62	18.60	59.68	840.12	3.30	1590.00	850.00	126.00	54.43
Monopreco-2	1.28	17.40	41.66	765.64	2.50	940.00	450.00	125.00	47.40
Monopreco-2 (MP)	1.40	19.20	54.99	781.34	3.07	910.00	403.33	129.00	43.97
Pusa Synthetic 1	1.40	19.45	46.31	633.20	3.27	1053.33	490.00	122.00	46.91
PSB1 (check)	1.08	17.07	40.10	604.13	2.60	940.00	440.00	122.00	46.44
Mean	1.49	19.86	48.29	694.99	3.18	1009.63	492.75	121.72	48.97
SE±	0.23	0.68	2.96	84.05	0.23	146.92	76.51	2.54	3.41
CD(5%)	0.46	1.35	5.90	167.60	0.46	292.96	152.56	5.06	6.79
CV(%)	19.20	4.18	7.50	14.81	8.93	17.82	19.02	2.55	8.54

The mean performance of the progenies indicated that it was significantly less in Monopreco-2 (41.66 cm); KJ47-7 (40.58 cm); EC162587-1 (40.58 cm); KJ47-2MP (40.52 cm); PSB-1 (40.10 cm); PSBK1-2MP (35.60 cm) and KM1-4MP (33.63 cm) while more in nine progenies than the grand mean. None of the progenies except KM1-4MP gave plant frame less than the check (PSB-1) while it was significantly more in 20 progenies. Half of the mix pollinated progenies gave plant frame statistically equal to the check while the remaining half gave more.

4.1.4 Leaf size index

Significant variation for leaf size index was observed among the genotypes studied. The minimum leaf size index was recorded in KT9-2 (364.42 cm^2) and maximum was recorded in KJ47-3MP (1213.35 cm^2).

Observations showed that leaf size index for KT9-2 (364.42 cm^2) was significantly low than that of PSB-1 (604.13 cm^2) a check in the present study. On the other hand 13 genotypes showed significantly higher leaf size index than that of PSB-1. Six genotypes viz., KJ38-4MP (522.46 cm^2); KM1-4MP (504.64 cm^2); Pusa Himjyoti-4 (499.77 cm^2); KJ47-3 (490.92 cm^2); KJ38-7 (462.24 cm^2) and KT9-2 (364.42 cm^2) gave leaf size index significantly less than the general mean (694.99 cm^2) while it was more in six genotypes viz., KJ47-3MP, KJ47-4, PSBK1-2, Janavon-2, KM1-5 and KK104-1MP.

4.1.5 Curd depth

Curd depth ranged from 2.17 cm in KK104-1MP to 3.91 cm in KJ38-7. PSB1 (check) gave curd depth of 2.60 cm. None of the progenies gave significantly less curd depth than PSB1. However, it was significantly more in 28 and at par in the remaining progenies. Eight out of 14 mix pollinated progenies gave curd depth significantly more than the check (Table 2a).

The curd depth more than the general mean (3.18 cm) was observed in KJ38-7 (3.91 cm); KJ47-6 (3.90 cm) and KJ38-4MP (3.73 cm) while less in KJ47-2MP (2.62 cm), PSB1 (2.60 cm); Monopreco-2 (2.50 cm); Monopreco-1 (2.30 cm) and KK104-1MP (2.17 cm).

4.1.6 Cross curd weight

A wide range of variability was observed for gross curd weight among the various genotypes studied. The gross curd weight was maximum (1590.00 g) in Monopreco-1MP and minimum (560.00 g) in KK104-1 (Table 2a).

Data depicted that gross curd weight observed in Monopreco-1MP (1590.00 g); KJ47-6 (1566.67 g); KJ47-4 (1433.33 g); PSBK1-2 (1330.00 g), KJ47-7MP (1245.00 g) and KM1-5 (1243.33 g) was significantly higher than PSB1 (940.00 g) used as check, of which first four progenies also showed significantly high gross weight over the over all mean weight. The gross weight of the mix pollinated progenies ranged from 783.33 g to 1590.00 g while of bud pollinated from 560.00 g to 1566.67 g.

4.1.7 Net curd weight

Analysis of variance showed significant differences among the progenies for net curd weight. The maximum net curd weight (850.00 g) was obtained in Monopreco-1MP and minimum (260.00 g) in KK104-1. Only five progenies viz., Monopreco-1MP (850.00 g); KJ47-6 (746.67 g); KJ47-3MP (703.33 g); PSBK1-2 (703.33 g) and KM1-5 (696.67 g) gave net curd weight significantly more than over all mean weight while it was significantly more than PSB1 (440.00 g) in KJ38-7 (620.00 g) and KJ47-4 (633.33 g) besides above mentioned progenies. The net curd weight of the mix pollinated progenies ranged from 386.67 g to

850.00 g and of bud pollinated from 260.00 g to 746.67 g. The over all mean of both type of progenies did not exhibit much differences.

4.1.8 Days for marketable curd maturity

Significant variation among genotypes were observed for days for marketable maturity. KJ38-6MP and Monopreco-1 took the maximum days for maturity (130.00), while KJ47-5MP took minimum days (112.67).

Five progenies viz., Monopreco-1 and KJ38-6MP (130.00); Monopreco-2MP (129.00); KJ38-4 (128.00) and KJ38-7 (127.33) took more number of days than PSB-1 (122.00), while KT9-2 (127.00) in addition those over the general mean (121.72). The bud pollinated progenies were comparatively late than the mix pollinated as observed from the over all mean of both the types. It ranged from 112.67 days to 130.00 days in mix pollinated and 117.67 days to 130.00 days in bud pollinated progenies.

4.1.9 Harvest index

Significant variation was observed for harvest index in various genotypes studied. Maximum harvest index was found in KJ38-7 (57.99%) and minimum in KJ47-3 (42.16%). PSB-1 (check) gave 46.44 % harvest index.

Data depicted that only one progeny viz., KJ38-7 gave harvest index (57.99%) significantly more than the over all mean (48.97%) while it was found to be significantly low in KJ47-3 (42.16%). Rest of the genotypes/progenies were at par with the general mean. Harvest index was significantly more than the check in KJ38-7 (57.99%); KJ38-6MP (55.60%); Janavon-1 (55.43%); Pusa Himjyoti-4 (55.21%); KT9-2 (55.19%); KM1-5 (55.04%) and Monopreco-1MP (54.43%). The over all mean of the mix and bud pollinated progenies showed

very little differences though the harvest index varied from 43.69% to 55.60% in the former and 42.16% to 57.99% in latter.

4.1.10 Quality characters

4.1.10.a Curd solidity

Number of solid/compact curds observed visually in each progeny were expressed in percentage. Maximum compact curds were observed in the progenies. Only one progeny KK104-1 gave some loose curds. Janavon-1 gave semi-compact curd. The percentage of compact curds was comparatively more in the mix pollinated progenies. The progenies like KJ38-3; KJ38-5; KJ38-6MP; KJ38-7; KJ47-3; KJ47-3MP; KJ47-4, Janavon-2, Janavon-2MP; KK104-1MP; KM1-5; PSBK1-2; Monopreco-1MP and Monopreco-2 gave completely compact curds.

4.1.10.b Riceyness

Wide range of variation was found among the various genotypes/progenies studied for riceyness (Table 2b). Most of the genotypes/progenies exhibited riceyness and was complete in KJ38-4; KJ38-7; KJ47-4; KJ47-6; KJ47-7MP and Pusa Synthetic-1. The progenies like Janavon-2MP; EC162587-1; KM1-5; PSBK1-2 and Monopreco-1MP gave completely non-ricey curds.

4.1.10.c Leafyness

No leafyness was observed in the experimental materials.

Table 2b. Performance of the progenies for quality characters

Genotypes/ Progenies	Curd solidity (%)			Curd colour			Riceyness (%)	
	Compact	Semi compact	Loose	Snow white	White	Dull white	Present	Absent
KJ38-1	46.67	53.33	-	13.33	86.67	-	60.00	40.00
KJ38-3	100.00	0.00	-	73.33	26.67	-	73.33	26.67
KJ38-3 (MP)	40.00	0.00	-	6.67	93.33	-	60.00	40.00
KJ38-4	73.33	26.67	-	6.67	93.33	-	100.00	-
KJ38-4 (MP)	73.33	26.67	-	26.67	73.33	-	33.33	66.67
KJ38-5	100.00	-	-	26.67	73.33	-	66.67	33.33
KJ38-6 (MP)	100.00	-	-	-	100.00	-	6.67	93.33
KJ38-7	100.00	-	-	-	100.00	-	100.00	-
KJ47-2	66.67	33.33	-	46.67	53.33	-	33.33	66.67
KJ47-2(MP)	93.33	6.67	-	66.67	33.33	-	53.33	46.67
KJ47-3	100.00	-	-	66.67	33.33	-	46.67	53.33
KJ47-3 (MP)	100.00	-	-	-	53.33	46.67	86.67	13.33
KJ47-4	100.00	-	-	-	66.67	33.33	100.00	-
KJ47-5	46.67	53.33	-	53.33	46.67	-	73.33	26.67
KJ47-5 (MP)	26.67	66.67	-	13.33	66.67	20.00	66.67	33.33
KJ47-6	60.00	40.00	-	-	53.33	46.67	100.00	-
KJ47-6 (MP)	93.33	6.67	-	80.00	13.33	6.67	20.00	80.00
KJ47-7	86.67	13.33	-	33.33	66.67	-	40.00	60.00
KJ47-7 (MP)	60.00	40.00	-	-	100.00	-	400.00	-
Janavon-1	-	100.00	-	6.67	60.00	33.33	40.00	60.00
Janavon-2	100.00	-	-	-	100.00	-	53.33	46.67
Janavon-2 (MP)	100.00	-	-	26.67	73.33	-	-	100.00

Contd. .....

Table 2b continue .....

Genotypes/ Progenies	Curd solidity (%)			Curd colour			Riceyness (%)	
	Compact	Semi compact	Loose	Snow white	White	Dull white	Present	Absent
EC162587-1	73.33	26.67	-	66.67	33.33	6.67	-	100.00
KK104-1	-	93.33	6.67	-	93.33	-	13.33	86.67
KK104-1 (MP)	100.00	-	-	40.00	60.00	66.67	13.33	86.67
Pusa Himjyoti-4	80.00	20.00	-	-	33.33	60.00	20.00	80.00
Pyramis-2	93.33	6.67	-	-	40.00	-	33.33	66.67
KM1-1	80.00	20.00	-	-	100.00	-	20.00	80.00
KM1-4 (MP)	86.67	13.33	-	6.67	93.33	-	33.33	66.67
KM1-5	100.00	-	-	-	100.00	-	-	100.00
KT-9-2	73.33	26.67	-	46.67	53.33	-	20.00	80.00
PSBK1-1	93.33	6.67	-	40.00	60.00	-	6.67	93.33
PSBK1-2	100.00	-	-	100.00	-	-	-	100.00
PSBK1-2 (MP)	46.67	53.33	-	-	26.67	73.33	73.33	26.67
Monopreco-1	60.00	40.50	-	6.67	93.33	-	80.00	20.00
Monopreco-1 (MP)	100.00	-	-	53.33	46.67	-	-	100.00
Monopreco-2	100.00	-	-	-	100.00	-	13.33	86.67
Monopreco-2 (MP)	80.00	20.00	-	60.00	40.00	-	60.00	40.00
Pusa Synthetic 1	93.33	6.67	-	-	100.00	-	100.00	-
PSB1 (check)	93.33	6.67	-	100.00	-	-	6.67	93.33

Characters	Mean±SE(d)	Range	Variance	
			Genotypic	Phenotypic
1. Stalk length (cm)	1.49±0.23	1.05-3.69	0.28	0.36
2. Leaves per plant	19.86±0.68	15.13-23.60	3.32	4.01
3. Plant frame (cm)	48.29±2.96	33.63-59.68	39.71	52.84
4. Leaf size index (cm^2)	694.99±84.05	364.42-1213.35	27953.54	38551.20
5. Curd depth (cm)	3.18±0.23	2.17-3.91	0.14	0.22
6. Gross curd weight (g)	1009.63±146.92	560.0-1590.0	41594.75	73973.44
7. Net curd weight (g)	492.75±76.51	260.0-850.0	11016.48	19797.50
8. Days for marketable maturity	121.72±2.54	112.67-130.0	15.50	25.15
9. Harvest index (%)	48.97±3.41	42.16-57.99	12.20	29.70

4.1.10.d Curd colour

Colour of the curd was also studied visually at the time of harvesting. The majority of the plants irrespective of bud or mix pollinated gave either snow-white or white curds though percentage of lateral were more (Table 2b). The progenies like PSBK1-2MP; KK104-1MP; Pusa Himjyoti-4; KJ47-3MP and KJ47-6 gave comparatively more number of dull white curds. The curd in PSBK1-2 and Pusa Snowball-1 were completely snow white, while were white in KJ38-6MP, KJ38-7, KJ47-7MP; Janavon-2; KM1-1; KM1-5; Monopreco-2 and Pusa Synthetic-1.

4.2 PARAMETERS OF VARIABILITY

The estimates of coefficients of variability (phenotypic and genotypic), heritability (broad sense), genetic advance and genetic advance as percentage of mean were worked out to facilitate selection for various characters. The results are given in Table 4.

4.2.1 Coefficients of variability

The data depicted that phenotypic coefficients of variability were higher in magnitude than genotypic ones for all the characters under study (Table 4). The phenotypic and genotypic coefficients of variability were comparatively high for stalk length (40.20% and 35.33%); moderate for net curd weight (28.55% and 21.30%) and gross curd weight (26.94% and 20.20%) and low for the remaining characters viz., plant frame (15.05% and 13.05%); harvest index (11.13% and 7.13%); leaves per plant (10.09% and 9.18%) and marketable maturity (4.12% and 3.23%).

Table 4. Estimates of coefficients of variability, heritability, genetic advance and genetic gain for different characters.

Character	Coefficient of variability (%)		Heritability (%)	Genetic advance	Genetic advance as %age of mean
	Genotypic	Phenotypic			
1. Stalk length	35.33	40.20	77.22	0.95	63.96
2. Leaves per plant	9.18	10.09	82.79	3.42	17.21
3. Plant frame	13.05	15.05	75.14	11.25	23.30
4. Leaf size index	24.06	28.25	72.51	29.33	42.20
5. Curd depth	11.64	14.67	62.91	0.60	19.01
6. Gross curd weight	20.20	26.94	56.23	315.04	31.20
7. Net curd weight	21.30	28.55	55.65	161.29	32.73
8. Days for marketable maturity	3.23	4.12	61.64	6.37	5.23
9. Harvest index	7.13	11.13	41.07	4.61	9.42

4.2.2 Heritability

The heritability in broad sense varied from 41.07% to 82.79% (Table 4). It was high for leaves per plant (82.79%) followed by stalk length (77.22%); plant frame (75.14%); leaf size index (72.51%); curd depth (62.91%); day for marketable maturity (61.64%); gross curd weight (56.23%) and net curd weight (55.65%). It was moderate for harvest index (41.07%).

4.2.3 Genetic advance

Genetic advance as percentage of mean is given in Table 4. It was maximum in stalk length (63.96%) followed by leaf size index (42.20%). It was found to be moderate for net curd weight (32.73%); gross curd weight (31.20%) and plant frame (23.30%) while low for remaining characters viz., curd depth (19.01%); leaves per plant (17.21%); harvest index (9.42%) and days for marketable maturity (5.23%).

4.3. CORRELATIONS

The correlation coefficients among different characters were worked out at phenotypic and genotypic levels and are presented in Table 5. The results showed that the genotypic correlation were higher in magnitude than phenotypic ones.

4.3.1 Phenotypic correlation

The phenotypic correlation among different characters showed that leaves per plant had negative association with stalk length (-0.557) and harvest index (-0.326), while plant frame showed positive and significant correlation with gross curd weight (0.570); leaf size index (0.556) and net curd weight (0.551).

Table 5. Phenotypic (P) and genotypic (G) correlation coefficients among different characters.

		V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9
V_1 Stalk length	P	-0.557**	-0.106	-0.011	0.018	-0.033	0.030	-0.257	0.137
	G	-0.647	-0.172	-0.117	-0.088	-0.258	-0.178	-0.339	0.173
V_2 Leaves per plant	P		0.089	0.041	0.155	0.116	-0.049	0.133	-0.326*
	G		0.115	0.074	0.213	0.133	-0.054	0.177	-0.439
V_3 Plant frame	P			0.556**	0.121	0.570**	0.551**	0.134	0.032
	G			0.630	0.087	0.666	0.627	0.272	0.056
V_4 Leaf size index	P				-0.066	0.618**	0.510**	0.140	-0.226
	G				-0.132	0.647	0.501	0.232	-0.357
V_5 Curd depth	P					0.287	0.354*	0.102	0.257
	G					0.179	0.267	0.237	0.383
V_6 Gross curd weight	P						0.906**	0.061	-0.116
	G						0.937	0.223	-0.023
V_7 Net curd weight	P							0.070	0.276
	G							0.242	0.323
V_8 Days for marketable maturity	P								0.089
	G								0.135
V_9 Harvest index	P								1.000
	G								1.000

* *Significant at 5% level of significance*

** *Significant at 1% level of significance*

Net curd weight was positively and significantly associated with gross curd weight (0.906); plant frame (0.551); leaf size index (0.510) and curd depth (0.354), whereas gross curd weight showed positive association with leaf size index (0.618) and plant frame (0.570).

4.3.2 Genotypic correlation

The correlation coefficient at genotypic levels followed the same trend as was observed at phenotypic levels. Besides these, harvest index with curd depth (0.383) and net curd weight (0.323) showed positive correlation while its association with leaf size index was negative (-0.357).

4.4. PATH COEFFICIENT ANALYSIS

All those characters which showed significant correlation with net curd weight at genotypic levels were used for path coefficient analysis and the results obtained as direct and indirect effects are presented in Table 6.

Gross curd weight gave highest positive direct effect (0.962) followed by harvest index (0.383). The direct effects of leaf size index (0.050), plant frame (-0.063) and curd depth (-0.040) irrespective of their positive or negative contribution, were poor in magnitude. The maximum indirect contribution towards net curd weight was through gross weight of the curd in all the cases. The positive indirect contributions through harvest index (0.147) in curd depth and negative in leaf size index (-0.136) was of sufficient magnitude. Plant frame, leaf size index and curd depth gave negligible indirect effects. The contribution made by the characters not taken into consideration in the study was nil as shown by residual effects.

Table 6. **Estimates of direct and indirect effects and genotypic correlation coefficients between various characters and net curd weight**

Characters	Plant frame	Leaf size index	Curd depth	Gross curd weight	Harvest index	Genotypic correlation with net curd weight
1. Plant frame	-0.063	0.031	-0.004	0.641	0.021	0.627
2. Leaf size index	-0.040	0.050	0.005	0.622	-0.136	0.501
3. Curd depth	-0.005	-0.007	-0.040	0.172	0.147	0.267
4. Gross curd weight	-0.042	0.032	-0.007	0.962	-0.009	0.937
5. Harvest index	-0.003	-0.018	-0.015	-0.023	0.383	0.323

Residual effects = 0.0001

Underlined figures indicate direct effects

DISCUSSION

DISCUSSION

The present investigations were carried out in late group of cauliflower (*Brassica oleracea* var. *botrytis* L.) for obtaining information in order to select suitable genotype(s)/progenies for their use as a variety or for further breeding programmes. Cauliflower is an important off-season vegetable crop of hilly areas and the growers are interested in cultivar(s) having good horticultural characters along with compact, snow white curds of uniform maturity. Thus, a breeder has to make lot of efforts to select/identify such ideal genotype(s). In the present investigations an attempt has been made by selecting desirable plants in the population of different type of lines/cultivars. These plants were either bud or mix-pollinated and the progenies obtained were evaluated for different traits like stalk length, number of leaves per plant, plant frame, leaf size index, curd depth, gross curd weight, net curd weight, days for marketable maturity and harvest index along with quality characters like curd compactness, curd colour, leafyness and riceyness, to elicit information on the nature and magnitude of variability, association among various traits and causal factors for the observed association between net curd weight and component traits.

The information derived on these aspects in different characters shall be utilized for the development of desirable lines either through inbreeding as done by Chatterjee and Mukherjee (1964) or utilization in the development of inbred lines for their use in the development hybrid or synthetic cultivars. The results obtained on the progenies developed through bud pollination/mix pollination for different horticultural and quality characters are discussed as under:

5.1 MEAN AND VARIABILITY

Present investigations depicted considerable scope for improvement in cauliflower as characters like stalk length, leaf size index, net curd weight and gross curd weight showed wide range of variability. Earlier Pal and Swarup (1966), Howe and Waters (1984), Sharma *et al.* (1988), Aditya *et al.* (1989), Jamwal *et al.* (1992) and Thakur (1998) have also reported wide range of variability for various traits in cauliflower. Based on the mean performances of progenies with respect to various horticultural and yield characters. Monopreco-1MP, KH47-3MP, KH47-6, PSBK1-2, KM1-5 and KJ38-7 gave curd weight significantly higher over PSB-1 (check) as well as overall mean of the progenies. These progenies also gave good performance for stalk length, number of leaves per plant, curd depth and harvest index. Among the high yielding progenies Monopreco-1MP was late while KM1-5 was early in maturity, with good number of desirable characters, required exploitation for further use. KJ38-7 was the best progeny as it gave minimum stalk length, maximum curd depth, harvest index and number of days to marketable maturity besides comparatively lesser leaves and plant frame whereas moderate for net weight, with compact and white but ricey curds. The difference in the over all mean performance of the progenies raised by bud and mix pollination did not exhibit pronounced effects indicating that both inbreeding as well as selfing and massing approaches can be adopted.

Since phenotypic and genotypic variances do not have clear cut ceilings and their categorisation as high or low is not feasible, therefore unsuitable for the comparison. Whereas, phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) are free from units of measurement and thus, helps in comparison among different characters. In the present study phenotypic coefficient of variability (PCV) were higher with smaller magnitude than genotypic coefficient of variability (GCV), indicating little influence of environmental factors.

The estimates of these were low (<15%) for days to marketable maturity, plant frame, leaves per plant, harvest index, curd depth while moderate to high for stalk length, leaf size index, gross curd weight and net curd weight (>20%). The results obtained are in agreement with the findings of Dadlani *et al.* (1986), Jamwal *et al.* (1992), who have also reported difference in magnitude in the values of genotypic and phenotypic coefficients of variability.

The ratio of genetic variance to the total variance called heritability, is an useful measure in predicting the progress to be achieved through selection. In the present studies all the characters except harvest index gave moderate to high heritability which indicated that large proportion in the expression of the phenotypic variance was attributable to the genotypic variance and the differences for these traits among the genotypes were real. Hence, selection made for these characters on the basis of phenotypic expression could be relied upon. These findings are in agreement with the results of Jamwal *et al.* (1992), Radhakrishna and Korla (1994).

5.2 HERITABILITY AND GENETIC ADVANCE

Heritability and genetic advance are two complimentary parameters, the former may be used to estimate expected genetic advance through selection. The success of any selection programme depend upon the extent of heritability as well as genetic advance which usually changes from population to population and environment to environment. Burton (1952) was of the opinion that the genetic coefficient of variation along with heritability give the best picture of the genetic advance to be expected from selection whereas Johnson *et al.* (1955b) advocated that heritability together with genetic advance is more useful than the heritability alone in predicting the resultant effects in selecting best individuals. The expected genetic advance expressed as percentage of mean varied from 5.23 to 63.96 per cent for days to market and stalk length, respectively. It was

comparatively high for stalk length, plant frame, leaf size index, gross curd weight and net curd weight. High degree of genetic advance for net curd weight and gross curd weight were reported by Jamwal *et al.* (1992). The characters which exhibited high genetic advance were also having high heritability and genotypic coefficient of variability, indicating thereby that selection based on phenotypic performance could be effective for the improvement of these characters as these are controlled by additive gene action (Panse, 1957). While, leaves per plant, curd depth, harvest index and days to marketable maturity were controlled by non-additive genes and the selection would not be effective as in these cases the estimates either of genotypic coefficient of variability, heritability or genetic advance were low or didn't corroborate with the conclusions of Burton (1952) or Johnson *et al.* (1955b).

5.3 CORRELATION STUDIES

In any improvement programme, selection is oftenly effective if concentrated towards one or at the most a few characters. Though a breeder is always interested in the improvement of several characters which inturn results in the selection of uneconomic characters when selection pressure is applied for the improvement of desirable/economic characters. It is, therefore, beneficial to know the inter-relationships amongst the various economically important characters. This consideration becomes still important when one visualized that yield being a complex character is product of the interaction of several component traits. In fact Adam and Grafius (1971) have mentioned that yield should be considered as an end-product of a number of characters and breeder should not ignore the principle of balance among these components. In the present investigations, genotypic correlation coefficients, in general, were higher than their corresponding phenotypic ones, signalling the inherrent association among the various traits/characters studied. It is evident from the correlation studies that the maximum net curd weight can be obtained by increasing plant

frame, leaf size index, curd depth and gross curd weight of the curd. Lal (1973), Dhiman *et al.* (1983), Jamwal (1984), Aditya *et al.* (1989), Dutta *et al.* (1992) and RadhaKrishna and Korla (1995) have also reported positive and significant correlation of curd yield with gross weight, leaf size index, plant frame and curd depth. The negative relationship between number of leaves per plant with stalk length and harvest index is as per expectation.

For the above discussion, it can be interpreted that selection for more gross weight, bigger plant frame and larger leaf area will affect the curd weight though larger plant frame and leaf area will result in accommodation of less number of plants per unit area. The present results are in agreement with the findings of Jamwal (1984).

5.4 PATH COEFFICIENT STUDIES

Correlation coefficients are quite helpful in determining the components of net curd weight even then an exact picture of the relative importance of direct and indirect influence of each component character is not provided by these. Path coefficients help in partitioning the correlation coefficients and thus provide an important information in predicting the direct and indirect causes of association.

The present studies revealed that gross weight of curd as well as harvest index has contributed maximum directly or indirectly in all the cases which has ultimately resulted in the positive association with net curd weight. The contributions of other characters viz. plant frame, leaf size index and curd depth (direct and indirect) was almost negligible. The very low value of residual factors also indicated that the characters not taken into consideration in present study have also not contributed much. Our findings are in agreement with those of Sharma *et al.* (1982), Jamwal (1984), Singh (1984) and Aditya *et al.* (1989).

From the above studies, it can be concluded that the characters like plant frame, leaf size index, curd depth and gross weight needs attention while identifying the desirable genotype in late cauliflower as these will affect the net curd weight and harvest index. Inbreeding and massing will be effective in some of the progenies irrespective of the fact whether these are maintained by bud or mix pollination.

SUMMARY

SUMMARY

The present study entitled, "Performance of cauliflower (*Brassica oleracea* var. *botrytis* L.) genetic stocks for horticultural and yield characters" was carried out at the Vegetable Research Farm, Nauni of the Department of Vegetable Crops, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan during 1996-98.

The materials consisted of 40 progenies including check PSB1 developed either by bud or mix pollination of the selected plants of 13 late and mid group cultivars/lines. Progenies were raised in a Randomized Block Design with three replications and observed for stalk length, number of leaves per plant, plant frame, leaf size index, curd depth, gross curd weight, net curd weight, day for marketable maturity and harvest index, curd colour, curd compactness, riceyness and leafyness.

Analysis of variance revealed significant differences among genotypes/progenies for all the traits. The mean performance of different characters indicated that Monopreco-1MP, PSBK1-2, KJ47-3MP were the best for yield and most of its component and quality characters. The phenotypic and genotypic coefficients of variability were high for stalk length; moderate for net curd weight and gross curd weight and low for the remaining characters viz., plant frame, harvest index, leaves per plant and for days to marketable maturity. The estimates of heritability were high for leaves per plant, stalk length, plant frame and moderate for harvest index, whereas genetic advance was maximum in stalk length followed by leaf size index and moderate for net curd weight, gross curd weight and low for remaining characters. High genotypic coefficient of variability, heritability and genetic gain were observed for stalk length, leaf size

index, gross weight and net curd weight while either of these estimates were low for the remaining characters.

In general, genotypic correlation were higher in magnitude than the phenotypic ones. Net weight of curd was positively and significantly correlated with plant frame, leaf size index, curd depth and gross curd weight, leaves per plant gave negative association with stalk length and harvest index whereas the correlation of gross weight with plant frame and leaf size index was positive and significant.

Path coefficient analysis depicted that gross curd weight was having maximum direct effect on net curd weight followed by harvest index. Both of these characters also exhibited indirect effects of sufficient magnitude resulting in the positive correlation with net curd weight. Plant frame and curd depth gave direct as well as indirect effects of very low magnitude.

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* *Original not seen.*

APPENDIX-I

MEAN PERFORMANCE OF DIFFERENT CHARACTERS UNDER BUD (BP) AND MIX (MP) POLLINATION

Genotypes/ progenies	Stalk length (cm)		Leaves per plant		Plant frame (cm)		Leaf size index (cm^2)		Curd depth (cm)	
	BP	MP	BP	MP	BP	MP	BP	MP	BP	MP
KJ38-1	1.17	-	22.00	-	53.57	-	740.24	-	2.73	-
KJ38-3	1.27	-	20.93	-	44.10	-	557.43	-	3.07	-
KJ38-3 (MP)	-	1.50	-	22.40	-	44.87	-	584.71	-	3.31
KJ38-4	1.59	-	18.00	-	47.85	-	690.39	-	2.93	-
KJ38-4 (MP)	-	1.27	-	20.73	-	50.97	-	522.46	-	3.73
KJ38-5	1.07	-	21.00	-	45.31	-	558.85	-	3.37	-
KJ38-6 (MP)	-	1.97	-	17.73	-	51.14	-	803.74	-	3.53
KJ38-7	1.05	-	20.67	-	42.41	-	462.24	-	3.91	-
KJ47-2	1.27	-	19.73	-	49.67	-	724.24	-	2.99	-
KJ47-2(MP)	-	2.54	-	19.27	-	40.52	-	570.94	-	2.62
KJ47-3	1.41	-	20.27	-	42.63	-	490.92	-	3.27	-
KJ47-3 (MP)	-	1.31	-	20.67	-	47.25	-	1213.35	-	3.23
KJ47-4	1.79	-	20.00	-	54.67	-	1047.72	-	3.57	-
KJ47-5	1.30	-	22.13	-	43.83	-	716.39	-	3.17	-
KJ47-5 (MP)	-	1.39	-	19.40	-	45.19	-	558.78	-	3.00
KJ47-6	1.05	-	23.60	-	57.39	-	798.86	-	3.90	-
KJ47-6 (MP)	-	1.19	-	19.33	-	49.43	-	644.80	-	2.79
KJ47-7	1.16	-	23.40	-	40.58	-	582.69	-	3.60	-
KJ47-7 (MP)	-	1.83	-	21.27	-	59.11	-	785.41	-	3.07
Janavon-1	1.63	-	17.27	-	44.92	-	529.89	-	3.57	-
Janavon-2	1.58	-	19.80	-	59.13	-	896.71	-	3.20	-
Janavon-2 (MP)	-	1.35	-	19.57	-	44.98	-	668.72	-	3.47
EC162587-1	1.16	-	23.40	-	40.58	-	582.69	-	3.60	-
KK104-1	1.14	-	21.20	-	43.72	-	578.30	-	3.13	-
KK104-1 (MP)	-	1.25	-	21.60	-	50.69	-	873.03	-	2.17
Pusa Himjyoti-4	3.69	-	15.13	-	44.67	-	499.77	-	3.20	-
Pyramis-2	1.61	-	20.20	-	55.56	-	780.19	-	2.82	-
KM1-1	1.26	-	18.80	-	53.08	-	561.23	-	3.21	-
KM1-4 (MP)	-	1.17	-	21.93	-	66.63	-	504.64	-	3.45
KM1-5	1.28	-	18.67	-	58.20	-	889.79	-	3.23	-
KT-9-2	1.13	-	20.77	-	45.09	-	364.42	-	3.60	-
PSBK1-1	1.08	-	20.53	-	50.94	-	648.04	-	2.99	-
PSBK1-2	1.25	-	18.73	-	55.31	-	1019.21	-	3.63	-
PSBK1-2 (MP)	-	3.33	-	15.67	-	35.60	-	604.78	-	3.23
Monopreco-1	1.33	-	19.33	-	45.53	-	797.52	-	2.30	-
Monopreco-1 (MP)	-	1.62	-	18.60	-	59.68	-	840.12	-	3.30
Monopreco-2	1.28	-	17.40	-	41.66	-	765.64	-	2.50	-
Monopreco-2 (MP)	-	1.40	-	19.20	-	54.99	-	781.34	-	3.07
Pusa Synthetic 1	1.40	-	19.45	-	46.31	-	633.20	-	3.27	-
Mean	1.38	1.64	20.32	19.46	48.31	47.11	699.70	699.60	3.27	3.06

Contd. .....

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Date of Birth : 16.07. 1973

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Marital Status : Unmarried

Nationality : Indian

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XII	Second	-do-	1991
B.Sc. (Ag.)	First	HPKV, Palampur	1996

Whether sponsored by some state/ Central Govt./Univ./SAARC : No

Scholarship/ Stipend :

M.Sc. : Yes