

**VARIATION AND ASSOCIATION STUDIES IN MID-GR P
CAULIFLOWER (*Brassica oleracea* var. *botrytis* L)**

THESIS

By

MANOJ KUMAR
(A-2008-30-29)

Submitted to



CHAUDHARY SARWAN KUMAR
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PALAMPUR – 176 062 (H.P.) INDIA

in

Partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE IN AGRICULTURE
(DEPARTMENT OF VEGETABLE SCIENCE AND FLORICULTURE)
(VEGETABLE SCIENCE)

2010

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AFFECTIONATELY DEDICATED
TO
MY REVEREND AND EVERLOVING PARENTS

Who sacrificed their present to make my future better



*We shall not cease from exploration and the end of
all our exploring will be to arrive where we started
and know the place for the first time.....*

Dr K.C. Sharma
Associate Professor
(Vegetables)


Department of Vegetable Science and Floriculture,
College of Agriculture,
CSK Himachal Pradesh Krishi Vishvavidyalaya,
Palampur – 176062 (H.P.) INDIA

CERTIFICATE – I

This is to certify that the thesis entitled “**Variation and association studies in mid-group cauliflower (*Brassica oleracea* var. *botrytis* L.)**” submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the discipline of ‘**Vegetable Science**’ of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Mr. Manoj Kumar (Admission No. A-2008-30-29)** son of Shri Hem Raj Sharma under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

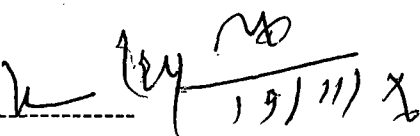
The assistance and help received during the course of this investigation have been duly acknowledged.

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Dated : 21st Oct , 2010



(Dr. K.C. Sharma)
Major Advisor

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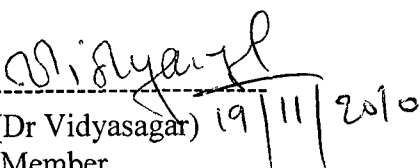
This is to certify that the thesis entitled “**Variation and association studies in mid-group cauliflower (*Brassica oleracea* var. *botrytis* L.)**” submitted by **Mr. Manoj Kumar** (Admission No. A-2008-30-29) son of Shri Hem Raj Sharma to the CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in the discipline of **Vegetable Science** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.



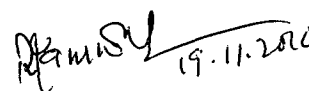
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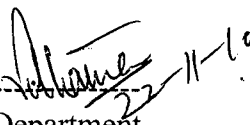
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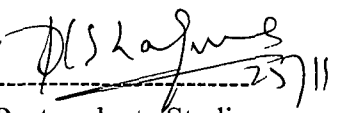
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ACKNOWLEDGEMENTS

Enthusiastic, invaluable guidance and vigilant supervision of Dr. K.C. Sharma, the Chairman of my Advisory Committee has made it possible for me to accomplish this work. My deepest regards and sincere thanks are due to him for his dexterous guidance, remarkable insight, constant care and unfailing help which came to me in abundance. Indeed the words at my command are not adequate either in form or spirit, to convey the depth of my feelings of gratitude to my teacher and member of my Advisory Committee, Dr. Vidyasagar, Professor, Department of Vegetable Science and Floriculture for his everlasting guidance, Scientific acumen and constant inspiration. Heartful thanks to member of my Advisory Committee, Dr. R.S. Jamwal, Senior Vegetable Breeder for his suggestions and timely advice.

I am thankful to esteemed Dean's Nominee of my Advisory Committee, Dr. Shyam Verma, Senior Plant Breeder for his invaluable suggestions, proper guidance and intrinsic help during the entire course of present studies.

Unfailing support by Dr. Pritam Kalia (Head of Division, Division of Vegetable Crops), IARI, New Delhi, Dr. D.S. Cheema (Head of Department, Division of Vegetable crops, Punjab Agricultural University, Ludhiana), Dr. N.K. Pathania (Head of Department, Department of Vegetable Science and Floriculture, CSKHPKV, Palampur) and my dear friend Susheel Sharma (Ph.D. student, Division of Plant Pathology, IARI, New Delhi) in the form of germplasm procurement made it possible to complete this investigation.

I emphatically express my thanks to Dr. Naval Kishor (Scientist, Department of Plant Breeding and Genetics), my seniors Amit Bhushan, Jintu Dutta and Naveen Kharyal who helped me in the analysis of the experiment, which was a difficult task for me. Help and care rendered by Sh. B.R. Dhiman (local Guardian) is also acknowledged.

I bestow my heartfelt gratitude and respect towards Dr. N.K. Pathania, Head of Department, Department of Vegetable Science and Floriculture, CSKHPKV, Palampur for his ever helpful attitude and enthusiasm that enable me to complete the present studies.

The kind words of encouragement of all my teachers Dr. Y.S. Chauhan, Dr. K.S. Chandel, Dr. Akhilesh Sharma, Dr. Sonia Sood, Dr. Des Raj, Dr. Praveen Sharma, Dr. Sanjay Chadha, Dr. Pradeep, Dr. Viveka Katoch, Dr. R.K. Gupta and Dr. S.K. Upadhey will be cherished forever.

I wish to extend my thanks to Dr. R.K. Sharma (Dean, P.G. Studies) and University authorities for providing me the necessary facilities to complete this investigation.

Sincere thanks are also due to my seniors Munish, Prabhakar, Pandey, Anil, Naveen¹, Naveen², Sandeep, Vishal, Amit, Rishi, Palash, Madhu, Nisha¹, Pooja and Jyoti for the affection and proper guidance and juniors Sourabh, Harish, Sankhyan, Bhanu, Bharmandu, Gopal, Lalit and Deepti for the help rendered to me and respect that I always felt.

Time stops ticking, when I think of acknowledging the nice company of my friends Vishal, Suneel, Ajey, Naveen, More, Ashwani, Sharvan, Anku, Vikas, Nisha², Bilashini, Reeta, Arpna and Indu who strengthened my resolve to complete this investigation. I thank you for the nice co-operation and intrinsic help that I received from you during the entire course of my studies and most important for being my good friends forever.

I'm highly thankful to my Nanaji Sh. Sat Pal Sharma (Retd. Teacher) and Dr. S.K. Sharma (Vice-Chancellor) for guiding me right path of the life. Help rendered by Dr. S.K. Sandal (Warden, P.G. Hostel) and residents of Shivalik Hostel is also acknowledged.

I gratefully acknowledge the love and care shown to me by my Grandparents, Parents, Sisters and Jija Ji's, nephew and niece (Shubham and Manya) and cousins (Shishu, Shivi, Mukta, Manu, Sunny, Summy and Keshav).

The Field and Office Staff of the Experimental Farm, HAREC, Bajaura and Department of Vegetable Science and Floriculture, CSKHPKV, Palampur deserve due thanks for the help rendered to me during the entire course of studies.

Last but not the least, I thank Mr. Ajay Kumar Walia for the wonderful look which he has given to this manuscript.

Errors and omissions are mine

Place: Palampur

Date: 21st October, 2010

Manoj

(Manoj Kumar)

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LIST OF ABBREVIATIONS USED

Sr. No.	Abbreviation	Meaning
1	<i>et al.</i>	et alii (and others)
2	i.e	Id est (that is)
3	<i>Viz.,</i>	Vi delictet (namely)
4	p.	Page
5	pp.	Pages
6	°C	Degree celsius
7	g.	gram
8	kg	kilogram
9	cm ²	centimeter square
10	/	Per
11	%	Per cent
12	Fig.	Figure
13	cm.	centimeter
14	ml.	milliliter
15	mg.	milligram
16	mm.	millimeter
17	nm.	nanometer
18	a.i.	active ingredient
19	v/s	against

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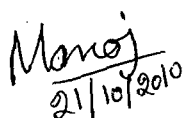
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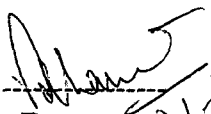
Title of the thesis : Variation and association studies in mid-group cauliflower (*Brassica oleracea* var. *botrytis* L.)
Name of student : Manoj Kumar
Admission number : A-2008-30-29
Major discipline : Vegetable Science
Minor discipline(s) : Plant Breeding
Date of thesis submission : 21st October, 2010
Total pages of the thesis : 61

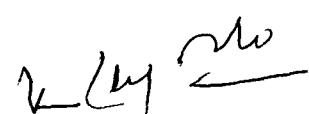
ABSTRACT

The present study was conducted to gather information on genetic variability, correlations and path coefficients in 19 genetically diverse genotypes of mid-group cauliflower. The field experiment was laid out in randomized block design with three replications at the experimental farm of Hill Agricultural Research and Extension Centre, Bajaura, Kullu, Himachal Pradesh during the summer of 2009. Data were analysed as per standard Statistical procedures. A perusal of results revealed that phenotypic coefficients of variation were slightly greater than the genotypic coefficients of variation. The phenotypic and genetic coefficients of variation were high for marketable yield per plant and leaf size. High heritability coupled with high genetic advance was recorded for leaf size, gross weight per plant and marketable yield per plant, thereby indicating the predominance of additive gene action. In general, the genotypic correlations were more pronounced than the phenotypic correlations. The marketable yield per plant exhibited a positive and significant correlation with leaf size, gross weight per plant, curd size index, curd compactness and harvest index at both the phenotypic and genotypic levels. Path coefficient analysis revealed that curd compactness, curd size index and gross weight per plant had the greatest direct positive effects on marketable yield per plant. Three genotypes namely, DC-476, DC-401 and Sel-01 were found to be promising for marketable yield per plant and other component traits viz., gross weight per plant, curd size index and harvest index when compared to standard check. Among the traits, curd compactness, curd size index and gross weight per plant should be given emphasis for developing high yielding and horticulturally superior genotypes of mid-group cauliflower.


21/10/2010

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Introduction

1. INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis* L.) is an important cole crop widely grown in tropics, subtropics and temperate regions of the world. It belongs to the family Brassicaceae and has originated in Eastern Mediterranean region (Vavilov 1951) from wild cabbage through mutations, human selection and adaptation. It is grown for its white tender curd commonly used as a vegetable, in curry, soup and for pickling. It is rich in proteins, carbohydrates, vitamins and minerals like potassium, sodium, iron, phosphorous, calcium and magnesium. When cut, it releases a substance named sulforaphane that triggers liver to produce enzymes, which can remove cancer causing chemicals and even can stop the spread of cancer cells in the later stages of their growth (Anonymous 2010). Cauliflower was introduced in India from England by Dr Jemson 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.

Globally, it is grown in all the continents of the world occupying an area of 10,63,451 ha with the production of 1,80,26,726 tonnes, leading countries being China, India, Spain, Italy and France. In India, cauliflower is grown in an area of 2,27,800 ha with a production of 50,14,500 tonnes (FAO 2008) and ranks first among cole crops in acreage and popularity. The leading cauliflower growing states in the country are Bihar, West Bengal, Karnataka, Punjab, Uttar Pradesh, Orissa, Assam, Haryana, Maharashtra and Rajasthan. In Himachal Pradesh, cauliflower occupies an area of 2,801 ha with a production of 54,512 tonnes (Anonymous 2008).

Cauliflower is highly thermo-sensitive crop requiring different genotypes for commercial cultivation at different periods of the year. Accordingly in Northern India, cauliflower is classified into four maturity groups (Singh *et al.* 1975), viz., I – maturing from late August to early November, II – maturing from mid November to early December, III – maturing from mid December to early January and IV – maturing from mid January to early March. First three groups are the Indian cauliflowers which are early maturing annual types, tolerant to high temperature and humid conditions and have

originated from winter types like Cornish or by inter-crossing of Cornish and other European types. Maturity Group IV is called 'Snowball' varieties or the summer cauliflower of Europe and has been developed from Erfurts and Alpha types. The seeds of first three maturity groups can be freely raised in North Indian plains, such as Rajasthan, Uttar Pradesh, Bihar, Punjab, Haryana, Delhi and in Southern states but the seeds of maturity group IV are raised only in the hills, like Solan and Kullu valley of Himachal Pradesh and Kashmir. Cultivars of cauliflower belonging to the mid-group do well in mid hills of Himachal Pradesh where, these are grown commercially as an off-season crop during summer-rainy season resulting in high economic returns to the farmers. At present, there are only two cultivars of mid-group cauliflower namely Improved Japanese and Palam Uphar recommended for the cultivation in Himachal Pradesh. Therefore, there is an urgent need to develop high yielding cultivars of mid season cauliflower suitable for cultivation in mid hills of Himachal Pradesh.

The extent of genetic variability available for yield and its attributes along with heritability and genetic advance are of immense help to the breeders as the success of selection in any crop improvement programme is determined by these specific genetic parameters. Further, knowledge of correlation coefficients depicting the degree and direction of relationship between yield and its components and path analysis throwing light on direct and indirect effects of various characters on dependent variable will aid the breeders to launch successful crop improvement programmes. Hence, the present study on "Variation and association studies in mid-group cauliflower (*Brassica oleracea* var. *botrytis* L.)" was undertaken with the following objectives:

1. To assess the magnitude of genetic variability in mid-group cauliflower genotypes,
2. To find out inter-relationships among component traits and marketable curd yield and
3. To estimate the direct and indirect contribution of component traits on marketable curd yield through path analysis.



R*ev**e*w**
***o*f**

L*iter**a*tur*****e***

2. REVIEW OF LITERATURE

The relevant reports available in the literature pertaining to various aspects included in the present study are briefly reviewed under the following subheads:

- 2.1 Genetic variability
- 2.2 Correlation coefficients
- 2.3 Path coefficient analysis

2.1 Genetic variability

Genetic variability is the basis of all plant improvement programmes. Sufficient genetic variability, if present, can be exploited for developing superior cultivars. Vavilov (1951) was the first to realize that a wider range of variability in any crop provides a better chance of selecting the desirable types. A knowledge of heritability for different component traits seems to be essential for any crop improvement programme, because the heritable component is the consequence of genotype and is inherited from generation to generation. Wright (1921) reported that heritability components comprised of additive and non-additive portion and it is the former, which responds to selection.

Estimation of expected genetic advance is important to have an idea of effectiveness of selection. Burton and DeVane (1953) suggested that genetic coefficient of variation together with heritability estimates would give reliable indication of the amounts of the extent of improvement expected from selection and further remarked that expected genetic gain under particular system supplies a true practical information which is needed by a breeder. Johnson *et al.* (1955) also found it more useful to estimate the heritability values together with genetic advance in predicting the expected progress to be achieved through selection. The earlier studies on variability, heritability and genetic advance in cauliflower are reviewed as follows:

In cauliflower, the curd (composed of undifferentiated floral buds) is the most desirable economic character contributing towards yield in cauliflower. Solid white curds are liked by consumers everywhere.

Chatterjee and Swarup (1972) observed that the mean curd weight for D-96 and Improved Japanese were 650g and 536g, respectively. Lukovnikova (1973) observed wide variations for the dry matter content, sugar, protein and ascorbic acid in cauliflower, brussels sprout, chinese cabbage and pecking cabbage (*Brassica pekinensis*) suggested good prospects when breeding for these characters.

Korbut *et al.* (1975) found that dry matter content of cabbage grown on medium podzolic soil varied between 7 and 17.8 per cent. Crisp (1977) revealed that curd diameter was important character for capitalizing additive genetic component of variation. Crisp and Kesavan (1978) observed the highest mean curd weight in Autumn Glory (328g) while studying genotypic x environmental effects on curd weight of autumn-maturing cauliflower.

Dhiman (1979) reported that heritability estimates in broad sense were high for days to curd initiation and days to curd maturity but genetic advance was low. For marketable yield, curd size index and gross weight per plant, the heritability was of medium order but genetic gain was high. Thamburaj *et al.* (1980) evaluated a few cauliflower varieties at Coimbatore and found significant differences for curd weight and mean curd yield in early and mid-season varieties of cauliflower. The cultivars viz., Mid-Season, Mid-Season Marvel and Second-Early were the highest yielding genotypes recording mean curd yields of 31.78, 31.52 and 31.24 tonnes per hectare, respectively.

Wurr *et al.* (1981) reported that 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% curd initiation and more than 11 months to mature. They also observed 9-18% dry matter content in the curd of winter cauliflower. Howe and waters (1983) reported that a genotype 'Snowking 65' had a higher percentage of marketable curds (78 %) than any other genotypes and it also gave the highest marketable yield.

Aditya *et al.* (1989) studied genetic variability in 9 characters of 8 cultivars at Mymensingh during 1987-88 and observed highly significant differences among cultivars for all the characters. Early Snowball produced the highest curd weight (895 g) and curd yield (35.8 t/ha). Dutta (1991) evaluated 6 families each having four progenies in cauliflower and observed significant differences for days to marketable maturity from date of planting and curd diameter. The estimates of heritability and genetic advance were high for net curd weight, gross weight, number of leaves per plant and days to curd initiation. Jamwal *et al.* (1992) evaluated 16 varieties of cauliflower during winter seasons of 1988-89 and 1989-90 and reported substantial variability for curd yield per plant (418.50- 875.0 g), gross weight per plant (825.73-1699.56 g), curd size index (110.26-237.02 cm²) and leaf size (386.99-1094.79 cm²). These traits also recorded high genotypic and phenotypic coefficients of variation, heritability and genetic advance.

Radhakrishna (1992) observed that GCV and PCV were highest for net curd weight *viz.*, 18.77 and 23.92%, respectively whereas heritability and genetic advance were high for gross weight, net curd weight, days to marketable maturity and stalk length. Radhakrishna and Korla (1994) studied 17 F₄ progenies derived from the cross of commercial cultivar Pusa Snowball- 1 with the heading broccoli Janavon (resistant to stalk rot) and reported that heritability and genetic advance were high for gross plant weight, net curd weight, harvest index and stalk length.

Khar (1995) reported significant variation among the 17 genotypes of late cauliflower for all the traits. PCV and GCV were high for marketable yield per plant (31.70% and 27.66%) and gross weight per plant (28.20% and 20.59%); moderate for number of leaves per plant (17.79% and 14.25%), leaf area (17.80% and 11.57%) and curd size index (16.99% and 11.64%) whereas low for the remaining traits. He further observed high heritability (76.12%) coupled with high genetic advance (64.10%) for marketable yield per plant.

Malik (1995) evaluated 8 cultivars of cauliflower and reported that a cultivar 'Wilco' recorded maximum curd weight (1.23 kg), number of leaves per plant (32.5), curd diameter (23.77 cm) and yield (35.58 t/ha), whereas 'Early CSS' recorded plant weight (1.20 kg), took minimum number of days (35.75 days) from transplanting to curd

initiation and was early in maturity (33.25 days). Reddy and Varalakshmi (1995) evaluated 92 germplasm accessions of cauliflower at IIHR, Bangalore and observed wide range of variation for most of the characters like plant weight, leaf weight, leaf size and curd weight. They also observed high genotypic coefficient of variation, heritability and genetic advance for plant weight, leaf weight and curd index. Grey and Doyle (1996) evaluated few inbred lines in cauliflower and observed significant differences between the families for mean number of days from sowing to harvest, mean maturity date, mean curd weight, curd size, mean curd diameter and mean curd depth.

Khattri *et al.* (1997) studied 16 genetically diverse lines of sprouting broccoli for various horticultural and quality traits and revealed significant differences for all the traits. PCV and GCV values were low for plant height, number of days from sowing to first harvest and 50% harvest, harvesting span and dry matter content. Estimates of heritability were high for most of the characters except dry matter content. Khar *et al.* (1997) studied variability and heritability in 17 diverse genotypes of cauliflower for 9 yield components and revealed that net curd yield per plant exhibited high genotypic and phenotypic variation, heritability and genetic advance whereas gross weight per plant, curd size index and leaves per plant exhibited moderate values.

Mahajan and Gill (1997) observed the higher phenotypic and genotypic coefficients of variation for disease rating, net weight, gross weight and leaf size index in mid maturity cauliflower. The heritability, genetic advance and GCV were higher for almost all the traits except days to 50% curd formation. Kumar (1998) evaluated 13 genotypes of late and mid-season cauliflower and observed significant differences among genotypes for all the traits. PCV and GCV were high for stalk length while moderate for net curd weight and gross curd weight. The estimates of heritability and genetic advance were high for stalk length, leaf size index, gross weight and net curd weight.

Kumar (1999) studied 25 genetically diverse genotypes of cauliflower and recorded significant differences among genotypes for all the traits studied. The PCV and GCV were high for stalk rot and black rot incidence while moderate for net curd weight and gross curd weight. Genetic advance was high for disease incidence (stalk rot and

black rot), net curd weight and gross curd weight. Kumar and Korla (2001) evaluated 13 genotypes of cauliflower and observed maximum variability for gross curd weight. Phenotypic and genotypic coefficients of variability were high for gross curd weight, curd weight, stalk length and leaf size. Maximum heritability for the number of leaves per plant, whereas genetic advance was highest for stalk length.

Sharma and Verma (2001) studied the genetic variation and divergence in 9 cauliflower cultivars and reported significant differences for all the traits. Cluster means showed maximum values for gross weight per plant, curd yield per plant, curd diameter, leaves per plant and days to curd maturity in cluster 2 while leaves per plant contributed the most to genetic divergence. Thakur and Singh (2001) assessed 6 characters in 5 cultivars of cauliflower and reported that the cultivar SWI-1 had the highest average yield of 387.16 q/ ha and net curd weight of 0.897 and 0.671 kg in two different years. The variety also showed a good curd quality and size as well as the lowest number of outer leaves, while the largest curd size was given by 'White Fox'.

Sharma *et al.* (2001) reported that a variety Pusa Sharad produces long leaves, smaller stalk, matured within 85 days after transplanting having high harvest index and curd yield (26 tonnes/ha). Kumar (2002) studied 22 divergent genotypes of cauliflower and observed significant differences for all the horticultural traits. PCV and GCV were highest for gross curd weight, while they were moderate for number of leaves per plant and net curd weight. Heritability in broad sense was highest for days to marketable maturity while genetic advance was highest for gross curd weight.

Ahmed *et al.* (2003) evaluated 10 cultivars of cauliflower at Hathazari, Chittagong, Bangladesh and observed that 'Shiroyama- 65' gave the highest value for whole plant weight (1916.67 g) and width of biggest leaf (22.17 cm), where as 'Rakhushi Late' recorded the highest values for plant height (68.00 cm), number of leaves at harvest (25.93) and length of biggest leaf (56.03 cm). 'Shiroyama- 65' also gave the highest curd weight (661.67 g) and curd yield (18.38 t/ha). Pathania (2003) studied various characters in 20 divergent genotypes of cauliflower and reported significant differences for all the horticultural and quality traits. He further observed high PCV and GCV for gross curd

weight and net curd weight while moderate for black rot severity and curd compactness. High heritability and genetic advance was recorded for net curd weight.

Jindal and Thakur (2004) evaluated 36 genotypes of cauliflower for various horticultural and quality traits and revealed the existence of wide genotypic differences for all the traits except number of leaves per plant, curd diameter and curd depth. High heritability with high genetic advance was recorded for harvest index and gross weight while high heritability and low genetic advance were recorded for plant spread and days to curd maturity. Garg and Lal (2005) determined the components of genetic variation and genetic parameters for 11 characters in cauliflower and concluded that over dominance was responsible for manifestation of curd characters and plant spread. They further observed that plant height, stalk length and days to curd maturity were controlled by additive gene action.

Sharma *et al.* (2005) evaluated various selections of mid season cauliflower and observed wide variability for curd weight, curd colour, curd compactness, harvest index and days to marketable maturity. They further reported that 'CCS-1' (Cauliflower Composite Selection-1) excelled the other selections for all the characters. Kumar *et al.* (2006) studied genetic parameters and quality traits in 25 diverse genotypes of cauliflower and observed significant differences among different genotypes for all characters. Moderate PCV and GCV were observed for leaf size index, gross curd weight and net curd weight. High heritability with moderate genetic advance was observed for gross curd weight and harvest index whereas high heritability with high genetic advance was recorded for net curd weight.

Sharma *et al.* (2006) studied genetic variability, heritability and genetic advance for yield and yield components in 13 cauliflower cultivars and reported that phenotypic and genotypic coefficients of variation were the highest for net curd weight, stalk length, marketable curd yield per plant, gross plant weight and harvest index. High levels of heritability and genetic advance were recorded for marketable curd yield per plant, net curd weight and stalk length. Singh *et al.* (2006) observed high variability, heritability coupled with high genetic advance for leaf size, curd weight without guard leaves and curd weight with guard leaves. Quamruzzaman *et al.* (2007) evaluated 20 diverse

genotypes of cauliflower and reported that intra-cluster value was the highest in cluster IV and minimum in cluster II. The inter-cluster distance was larger than the intra-cluster distance, which suggested wide genetic diversity among the genotypes of different groups.

Dhatt and Garg (2008) studied 21 genotypes of mid maturity cauliflower for two consecutive years and found that marketable curd weight, gross curd weight and stalk length exhibited considerable genetic variability while days to curd maturity was least variable character. High heritability coupled with high genetic advance was recorded for gross curd weight, marketable curd weight and stalk length during both the years. Kumar *et al.* (2009) evaluated 15 exotic genotypes of cauliflower and reported that genotypes showed a wide range of variability for stalk length in CGN-11089 (5.56 cm) to CCS-06-08 (9.5 cm).

2.2 Correlation coefficients

Correlation coefficient is a measure of the degree of association between the two traits worked out at the same time (Hayes *et al.* 1955). Yield is very complex entity as it is not only polygenically controlled but also subject to the fluctuating environment. Hence, the selection of superior genotypes based on the performance of yield as such is usually not effective. For selecting superior genotypes, the breeder has to choose from the material on the basis of its phenotypic expression. The extent of observed relationship between two characters is indicated by phenotypic correlation which includes both hereditary 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.* 1955).

Dhiman (1979) observed that the number of leaves, curd size index and gross weight per plant were positively associated with marketable yield but the 'r' values were negative for plant height at the genotypic level. Sharma *et al.* (1982) in two years study revealed highly significant correlation of curd yield with curd diameter, dry matter production, leaf number and leaf area index. Thus, yield can be increased with the manifestation of these simple traits in cauliflower. Thamburaj *et al.* (1982) observed significant and positive correlation of plant weight with the curd yield (0.576), plant weight and foliage weight (0.898) and between number of leaves and leaf area (0.569).

Dhiman *et al.* (1983) observed a strong positive association of the number of leaves per plant, curd size index and gross weight per plant with marketable yield per plant in cauliflower while its correlation with plant height at genotypic level was negative. Singh (1984) reported that leaf number/ plant, curd diameter, plant height and leaf weight/ plant were positively and significantly correlated with yield.

Aditya *et al.* (1989) reported that curd weight was positively correlated with all the other characters studied. Dutta (1991) observed that days to curd maturity from curd initiation, curd length, curd diameter, gross weight and harvest index showed positive and significant correlations with net curd weight while negatively significant with days to curd initiation.

Jamwal *et al.* (1992) observed that curd yield/plant was positively and significantly associated with gross weight/plant and curd size index. Leaf size and leaves/plant showed non-significant correlation with each other and with curd yield/plant, whereas days to curd maturity had significant negative correlation with curd yield/plant and curd-size index. Radhakrishna (1992) reported that net curd weight was positively correlated with gross curd weight, curd diameter, curd depth and curd maturity while negatively associated with days to curd initiation. Khar (1995) reported a positive association of marketable yield per plant with gross weight per plant (0.695), curd size index (0.699) and harvest index (0.612). Radhakrishna and Korla (1995) also 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.

Reddy and Varalakshmi (1995) reported that curd size (0.649), curd diameter (0.664), plant weight (0.893), leaf weight (0.546) and curd index (0.552) were positively and significantly correlated with curd weight. Kumar (1998) observed that net weight of curd was positively and significantly correlated with plant frame, leaf size index, curd depth and gross curd weight whereas the correlation of gross weight of curd with plant frame and leaf size index was positive and significant. Kumar (1999) reported that net curd weight showed significant correlations with plant frame, leaf size index, gross curd weight and harvest index.

Kumar (2002) observed a positive and significant correlation of net curd weight with number of leaves per plant, gross curd weight, curd depth and curd compactness. Pathania (2003) observed that net curd weight had positive and significant correlation with days taken to marketable curds (0.711), number of leaves (0.799), gross curd weight (0.915), curd depth (0.796), curd width (0.802) and curd compactness (0.949).

Garg and Lal (2004) studied 36 cauliflower genotypes and reported that net curd weight had positive and significant correlations with equatorial diameter of curd, curd size index, plant spread, polar diameter of curd and curd compactness index. The equatorial diameter of curd was positively correlated with polar diameter of curd while curd compactness index had positive correlation with plant spread. Kumar *et al.* (2004) evaluated 51 genotypes of mid and late group and observed positive and significant correlation of net curd weight with gross curd weight, curd depth and leaf breadth.

Liu *et al.* (2004) reported that the curd yield was significantly correlated with leaf mass, leaf area, plant mass, diameter of curd stem and curd mass. Kumar *et al.* (2005) studied 25 divergent genotypes of cauliflower and reported that genotypes significantly varied for all the horticultural traits. Net curd weight was positively correlated with gross curd weight, plant frame and leaf size index while curd depth was positively correlated with gross curd weight and negatively correlated with harvest index.

Sharma *et al.* (2006) revealed that marketable curd yield per plant exhibited positive correlation with net curd weight, curd size index, number of leaves per plant, curd length, curd breadth and gross plant weight at the genotypic and phenotypic levels. Singh *et al.* (2006) reported that yield was positively and significantly correlated with curd width and curd weight with guard leaves. Among component traits, leaf size had positive correlation with curd weight with guard leaves and head compactness exhibited negatively significant correlation with curd width. Dhatt and Garg (2008) concluded that gross curd weight, marketable curd weight and days to curd initiation positively influenced net curd weight both directly and indirectly.

2.3 Path coefficient analysis

The correlation coefficients provide information regarding the association of different characters among themselves, a better insight into the cause of association is provided by the path coefficient analysis as it allows the partitioning of the correlation coefficients into the direct and indirect effects of the traits contributing towards the dependent variable (Wright 1921). Dewey and Lu (1959) were the first to suggest the use of path coefficient analysis in breeding programmes.

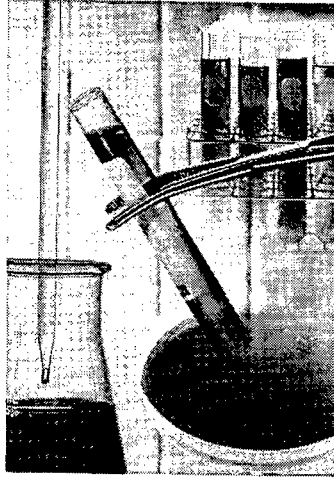
Sharma *et al.* (1982) in a standardised regression coefficient study revealed that the diameter of the curd contributed maximum to the curd yield followed by dry matter production. Thamburaj *et al.* (1982) observed that plant weight had exerted maximum direct and positive effect on curd yield followed by foliage weight but on negative side. They further observed that curd length and curd girth had positive effect on curd yield through plant weight.

Aditya (1991) reported that curd initiation had direct positive effects on curd weight and days to curd maturity indicating that selection based on this trait would be useful for the improvement of curd yield. Dutta (1991) found significant contribution only by gross weight and harvest index on the net curd weight. Radhakrishna (1992) reported the maximum direct and indirect contributions of gross weight, days to curd initiation and days to marketable maturity from curd initiation on net curd weight. Khar (1995) observed that gross weight per plant, harvest index, days to marketable maturity and number of leaves had positive and direct effects on marketable yield.

Reddy and Varalakshmi (1995) reported that curd size (0.662), leaf number (0.141), leaf size (0.181) and harvest index (0.979) had positive direct effects on curd weight. Kumar (1998) revealed that gross curd weight had exerted maximum direct effects (0.962) on marketable yield per plant, followed by harvest index (0.383). Both of these characters also exhibited indirect effects of sufficient magnitude while plant frame and curd depth recorded direct as well as indirect effects of very low magnitude. Kumar (1999) observed that leaf size index, harvest index and leaves per plant had the highest direct positive effects on net curd weight.

Garg and Lal (2004) reported that curd compactness index, curd size index and equatorial diameter of curd had exerted positive direct effects on net curd weight. Kumar *et al.* (2004) observed the maximum positive direct effects of gross curd weight (0.762) and harvest index (0.554) on the net curd weight. Liu *et al.* (2004) observed the significant direct effects of plant mass and curd diameter on curd yield and indirect effects of leaf mass, leaf area and diameter of curd on yield through plant mass and curd diameter. Kumar *et al.* (2005) reported the highest positive direct effects by gross curd weight (0.829) followed by harvest index (0.623) and stalk length (0.110) on net curd weight, whereas the highest indirect effects on net curd weight were recorded by leaf size index via gross curd weight (0.637) followed by plant frame (0.445) and curd depth (0.362).

Sharma *et al.* (2006) observed maximum direct contribution on net curd weight by gross plant weight. Singh *et al.* (2006) observed that highest positive direct effects were exerted by curd weight with guard leaves and curd width, whereas negative effect observed for leaf size. Dhatt and Garg (2008) reported that days to curd maturity showed negative direct and indirect effects of considerable magnitude on net curd weight.



Materials
and
Methods

3. MATERIALS AND METHODS

The present investigation was carried out at the experimental farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Hill Agricultural Research and Extension Centre, Bajaura, (Kullu), Himachal Pradesh during summer season of 2009. The details of materials used and methods employed in the present investigation are presented below:

3.1 Experimental site

3.1.1 Location

Geographically, the experimental farm is situated at 31°8' N latitude and 77° E longitude at an elevation of 1090 m above mean sea level.

3.1.2 Climate

The experimental site fall under mid hill sub-humid zone and represents valley areas of the state which is endowed with mild summers and cool winters with low rainfall during monsoon than winter. The average rainfall of the area is 943 mm per annum. The mean weekly meteorological parameters *viz.*, maximum temperature, minimum temperature, relative humidity, bright sunshine hours, rainfall and rainy days pertaining to the period of experimentation recorded at the Agro meteorological observatory of HAREC, Bajaura have been presented in Appendix 1.

3.2 Materials and layout plan

3.2.1 Experimental materials

The experimental materials consisted of 19 genetically diverse genotypes of mid-group cauliflower. The details are given in Table 1. A perusal of meteorological data (Appendix 1) revealed that during the crop season, mean weekly maximum and minimum temperatures ranged from 15.6 to 31.3 and -0.7 to 20.1°C, respectively. The mean weekly maximum and minimum relative humidity varied from 73 to 91% and 21 to 63%, respectively. The total rainfall received during the entire crop season (August to January was 301.4 mm).

Table 1 Cauliflower genotypes and their sources under study

S.No	Name of the genotype	Source of seed
1	Punjab Giant-26	Punjab Agricultural University, Ludhiana
2	D-19	- do -
3	Punjab Katki	- do -
4	Sel-01	- do -
5	Sel-DS-03	-do-
6	Pusa Synthetic	Indian Agricultural Research Institute, New Delhi
7	Pusa Sharad	- do -
8	DC-476	- do -
9	DC-401	- do -
10	DC-23	- do -
11	Pusa Deepali	- do -
12	Varsha Rani	- do -
13	DC-319	- do -
14	DC-321	- do -
15	DC-334	- do -
16	Early Kunwari	- do -
17	DC-76	- do -
18	DC-312	- do -
19	Palam Uphar	CSKHPKV, Palampur

3.2.2 Layout Plan

The experiment was laid out in a randomized block design with three replications. Each plot (2.4 × 2.25 m) consisted of four rows with row to row and plant to plant spacings of 60 cm and 45 cm, respectively.

3.2.3 Nursery sowing and transplanting

Nursery sowing was done on July 24, 2009 and the transplanting was carried out on August 24, 2009.

3.2.4 Cultural practices

The intercultural operations, irrigation and nutrient application were carried out as per the recommended package of practices to ensure a good crop.

3.2.5 Plant protection measures

a) Nursery

Mancozeb and Chloropyriphos were applied in the nursery beds @ 5g per m² each prior to nursery sowing. Subsequently drenching with Carbendazim (0.1%) and Mancozeb (0.25%) was carried at weekly intervals as a prophylactic measure.

b) In field trial

For the control of cabbage caterpillars (*Pieris brassicae*), three sprays of Endosulphan (1.5 ml/litre on product basis or 0.05% on a.i. basis) at 15 days interval and one spray of Nuvan (0.1%), 10 days before the first harvest were given.

3.3 Recording of the observations

Observations on the characters viz., days to marketable maturity, stalk length (cm), number of leaves per plant, leaf size (cm²), gross weight per plant (kg), marketable yield per plant (kg), curd size index (cm²), curd compactness (g/cm²), harvest index (%) and dry matter content (%) in each replication were recorded. All the observations were recorded on 5 randomly taken/marked plants in each plot. In the process of random labelling the border plants were avoided. Data were recorded as below:

3.3.1 Days to marketable maturity

The number of days taken from the date of transplanting to the day when 50 % curds of a plot obtained marketable maturity. The maturity was judged when curd reached marketable size and was of desirable compactness. At this stage, the younger inner leaves covering the curds just begin to separate.

3.3.2 Stalk length (cm)

Length of the stalk was measured from the uppermost secondary root to the position of first leaf exactly above the secondary root.

3.3.3 Number of leaves per plant

At the time of marketable maturity, fully grown leaves per plant were counted.

3.3.4 Leaf size (cm²)

The length and maximum breadth of three leaves selected after removing first three leaves in each plant were measured. The product of the average length and breadth was taken as leaf size.

3.3.5 Gross weight per plant (kg)

The whole plant at the time of harvest was uprooted and after removing the soil adhering to roots was weighed.

3.3.6 Marketable yield per plant (kg)

Marketable yield per plant refers to the curd weight excluding stalk and leaves up to curd level when harvested at marketable maturity.

3.3.7 Curd size index (cm²)

Polar and equatorial diameters of the curd were measured in (cm) and multiplied to obtain curd size index.

3.3.8 Curd compactness (g/cm²)

Curd compactness was obtained as a ratio of marketable yield per plant to the product of polar (depth) and equatorial (girth) diameters of the curd as per the procedure suggested by Tarsem Lal (1981).

$$\text{Curd compactness} = \text{Net weight of curd} / \text{curd diameter} \times \text{curd depth}$$

3.3.9 Harvest index (%)

Harvest index was calculated as a ratio of marketable yield per plant to the gross weight per plant and expressed in percentage.

3.3.10 Dry matter content (%)

A curd sample of 200g from each genotype was kept in an oven at 60±5°C temperature and weighed after complete drying of the sample, till a constant weight is reached.

3.4 Statistical analysis

Average values for each genotype in each replication for the traits studied were used for statistical analysis. A brief outline of the procedure adopted for estimation of different statistical parameters is given below:

3.4.1 Analysis of variance

The data were statistically analysed as per the following model by Panse and Sukhatme (1984):

$$Y_{ij} = m + g_i + r_j + e_{ij} \text{ for RBD}$$

Where,

$$Y_{ij} = \text{phenotypic observation of the } i^{\text{th}} \text{ genotype in } j^{\text{th}} \text{ replication}$$

$$m = \text{general population mean}$$

- g_i = effect of the i^{th} line
 r_j = effect of the j^{th} replication and
 e_{ij} = error associated with i^{th} genotype in j^{th} replication

Analysis of variance

Source of variation	d.f.	Sum of squares	Mean sum of squares	F cal.	Expected MS
Replication	(r-1)	Sr	Mr (Sr/r-1)	Mr/Me	$\sigma^2 e + g\sigma^2 r$
Genotypes	(g-1)	Sg	Mg (Sg/g-1)	Mg/Me	$\sigma^2 e + r\sigma^2 g$
Error	(r-1)(g-1)	Se	Me (Se/(r-1)(g-1)	-	$\sigma^2 e$
Total	(rg-1)	-	-	-	-

- Where, r = number of replications
 g = number of genotypes
 $\sigma^2 e$ = error variance = Me
 $\sigma^2 g$ = Variance due to genotypes = (Mg-Me)/r
 $\sigma^2 r$ = Variance due to replications = (Mr-Me)/g

The standard error of mean {SE (m)} and critical difference (CD) for comparing the means of any two genotypes were computed as follows:

$$SE (m) \pm = (Me/r)^{1/2}$$

$$SE (d) \pm = (2Me/r)^{1/2}$$

$$CD (5 \%) = SE (d) \times 't' (5\%) \text{ value at error degrees of freedom}$$

$$CV (\%) = Me^{1/2} / \text{generation mean} \times 100$$

The calculated 'F' values were compared with the tabulated 'F' values at 5% level of significance. If the calculated 'F' values equal to or higher than the tabulated, it was considered to be significant. All the characters which showed significant differences among genotypes were further subjected to the analysis for the different parameters.

3.4.2 Estimation of parameters of variability

The genotypic, phenotypic and environmental coefficients of variation were calculated as suggested by Burton and DeVane (1953) as under:

$$\text{Genotypic coefficient of variation (GCV \%)} = (\sigma_g/x) \times 100$$

$$\text{Phenotypic coefficient of variation (PCV \%)} = (\sigma_p/x) \times 100$$

$$\text{Environmental coefficient of variation (ECV \%)} = (\sigma_e/x) \times 100$$

where,

$$\sigma_g = \text{Genotypic standard deviation}$$

$$\sigma_p = \text{Phenotypic standard deviation}$$

$$\sigma_e = \text{Environmental standard deviation}$$

$$x = \text{Grand mean}$$

3.4.3 Heritability

Heritability in broad sense (h^2_{bs}) was calculated as per the following formula given by Burton and DeVane (1953) and Johnson *et al.* (1955).

$$\text{Heritability (\%)} = \sigma^2_g / (\sigma^2_g + \sigma^2_e) \times 100$$

3.4.4 Genetic advance

The expected genetic advance (GA) resulting from the selection of 5% superior individuals was calculated as per Burton and DeVane (1953) and Johnson *et al.* (1955).

$$GA = K \cdot \sigma_p \cdot h^2$$

Where,

K = (selection differential at 5 per cent selection intensity i.e. 2.06)

σ_p = phenotypic standard deviation, and

h^2 = heritability (broad sense)

Genetic advance as percentage of mean = (Expected GA/Grand mean) \times 100

For categorizing the magnitude of different parameters, the following limits were used :

PCV, GCV and ECV	> 30%	-	High
	15 – 30%	-	Moderate
	< 15%	-	Low
Heritability	> 80%	-	High
	50 – 80%	-	Moderate
	< 50%	-	Low
Genetic advance	> 50%	-	High
	25 – 50%	-	Moderate
	< 25%	-	Low

3.4.5 Correlation coefficients

For computing phenotypic, genotypic and environmental coefficients of correlation, analysis of covariance were carried out in all possible pairs of combinations of the characters following Al-Jibouri *et al.* (1958).

Analysis of covariance

Source of variation	df	Mean sum of product	Expected mean sum of product
Replications (r)	(r-1)	Mr_{xy}	$\sigma e_{xy} + g. \sigma r_{xy}$
Genotypes (g)	(g-1)	Mg_{xy}	$\sigma e_{xy} + r. \sigma g_{xy}$
Error (e)	(r-1)(g-1)	Me_{xy}	σe_{xy}

Where,

$\sigma_{g_{xy}}$ = genotypic co-variance of character x and character y and

$\sigma_{e_{xy}}$ = error co-variance of character x and character y

The genotypic, phenotypic and error co-variances were calculated as follows:

Genotypic co-variance ($\sigma_{g_{xy}}$) = $M_{g_{xy}} - M_{e_{xy}}/r$

Phenotypic co-variance ($\sigma_{p_{xy}}$) = $\sigma_{g_{xy}} + \sigma_{e_{xy}}$

Error covariance ($\sigma_{e_{xy}}$) = $M_{e_{xy}}$

The phenotypic, genotypic and environmental coefficients of correlation were computed following Al-Jibouri *et al.* (1958).

Phenotypic coefficient of correlation ($r_{p_{xy}}$)

$r_{p_{xy}} = \sigma_{p_{xy}} / (\sigma^2_{p_x} \times \sigma^2_{p_y})^{1/2}$

where,

$\sigma_{p_{xy}}$ = Phenotypic co-variance between character x and y

$\sigma^2_{p_x}$ = Phenotypic variance of character x

$\sigma^2_{p_y}$ = phenotypic variance of character y

Genotypic coefficient of correlation ($r_{g_{xy}}$)

$r_{g_{xy}} = \sigma_{g_{xy}} / (\sigma^2_{g_x} \times \sigma^2_{g_y})^{1/2}$

where,

$\sigma_{g_{xy}}$ = Genotypic co-variance between character x and y

$\sigma^2_{g_x}$ = Genotypic variance of character x

$\sigma^2_{g_y}$ = Genotypic variance of character y

Environmental coefficient of correlation (re_{xy})

$$re_{xy} = \sigma e_{xy} / (\sigma^2 e_x \times \sigma^2 e_y)^{1/2}$$

where,

σe_{xy} = Environmental co-variance between character x and y

$\sigma^2 e_x$ = environmental variance of character x

$\sigma^2 e_y$ = environmental variance of character y

The significance of phenotypic coefficients of correlations was tested against 'r' values as given by Fisher and Yates (1963) at n-2 degrees of freedom, where, 'n' denotes number of genotypes.

3.4.6 Path coefficient analysis

Path coefficient is a standardized partial regression coefficient which permits the partitioning of coefficients of correlations into direct and indirect effects. The path coefficient analysis of component traits with marketable yield per plant was carried out by following Dewey and Lu (1959) as under:

$$\begin{aligned} P_{y1} + P_{y2} \cdot r_{12} + P_{y3} \cdot r_{13} + \dots + P_{yn} \cdot r_{1n} &= r_{y1} \\ P_{y1} \cdot r_{12} + P_{y2} + P_{y3} \cdot r_{23} + \dots + P_{yn} \cdot r_{2n} &= r_{y2} \\ P_{y1} \cdot r_{13} + P_{y2} \cdot r_{23} + P_{y3} + \dots + P_{yn} \cdot r_{3n} &= r_{y3} \\ \vdots & \\ \vdots & \\ \vdots & \\ \vdots & \\ P_{y1} \cdot r_{n1} + P_{y2} \cdot r_{n2} + P_{y3} \cdot r_{n3} + \dots + P_{yn} &= r_{yn} \end{aligned}$$

Where,

$P_{y1}, P_{y2}, P_{y3}, \dots, P_{yn}$ are the direct path effects of 1, 2, 3,, n variables on the dependent variable "y".

$r_{12}, r_{13}, \dots, r_{(n-1)n}$, are the possible coefficients of correlation between various independent variables and $r_{y1}, r_{y2}, \dots, r_{yn}$ are the coefficients of correlation of independent variables with dependent variable 'y'.

The variation in the dependent variable which remained undetermined by including the given variables was assumed to be due to variable (s) not included in the present investigation. The degree of determination ($p^2 \times R$) of such variable (s) on the dependent variable was calculated as follows:

$$\text{Residual effects (P} \times \text{R)} = (1 - R^2)^{1/2}$$

Where,

$$R^2 = P_{y1}.r_{y1} + P_{y2}.r_{y2} + \dots + P_{yn}.r_{yn},$$

Where, R^2 is the square multiple correlation coefficient and is the amount of variation in yield that can be accounted for by the yield component characters.



***R*esults
and
*D*iscussion**

4. RESULTS AND DISCUSSION

Genetic improvement of crop plants is a continuous process and the plant breeders continuously strive for developing high yielding and widely adaptive quality varieties/hybrids excelling the existing ones. Their successes primarily rely on the available genetic variability existing in the crops, on which they employ different crop improvement tools to achieve their objectives.

The present investigations were carried out in the mid-group cauliflower (*Brassica oleracea* var. *botrytis* L.) for obtaining primary information on genetic variability, association among different economic traits and their relative contribution which inturn will assist the breeders in employing proper breeding programme (s) for exercising effective genetic improvement. Selection, which is basic to every breeding programme, operates only on variation which is of genetic nature (Johannsen 1909). Greater the diversity of germplasm that a breeder handles, better are the chances for selecting superior genotypes (Vavilov 1951).

Cauliflower is an important off-season vegetable crop of hilly areas and the growers are interested in cultivars which have small frame and stalk length and compact snow-white curds of uniform maturity. Thus, a breeder has to make a compromise for selecting suitable genotypes which are not only high yielding but also possess desirable horticultural characters.

In the present study the traits viz., days to marketable maturity, stalk length, number of leaves per plant, leaf size, gross weight per plant, marketable yield per plant, curd size index, curd compactness, harvest index and dry matter content were scored in 19 genetically diverse genotypes of mid-group cauliflower to elicit information on nature and magnitude of genetic variability, association among various traits and the causal factors for the observed association between marketable yield per plant and component traits. The results so obtained are discussed in the light of published work.

4.1 Variability studies

The continuous variation, exhibited by quantitative traits with which the breeders have to deal with, includes the heritable and non-heritable components. According to Fisher (1918), these quantitative traits exhibiting continuous variation are under the control of both heritable and non-heritable factors. Response to selection, however would depend upon the relative proportion of heritable portion of the continuous variation. Though it is very difficult to assess the genotypes directly, it is possible through the assessment of phenotypic expression (which is an outcome of interplay of the genotypes and the environment) of the existing material. Thus, the study of phenotypic variability for marketable yield per plant and its associated traits is of utmost importance.

4.1.1 Analysis of variance

The analysis of variance (Table 2) revealed significant differences among genotypes for all the characters studied viz., days to marketable maturity, stalk length, number of leaves per plant, leaf size, gross weight per plant, marketable yield per plant, curd size index, curd compactness, harvest index and dry matter content, thereby indicating greater scope for their genetic improvement.

Table 2. Analysis of variance for the design of experiment with respect to marketable yield per plant and other traits in cauliflower

Traits	Mean sum of squares			
	Source : df	Replications 2	Genotypes 18	Error 36
Days to marketable maturity		8.26	804.48*	14.19
Stalk length		0.11	1.46*	0.06
Number of leaves per plant		0.82	6.81*	0.55
Leaf size		313.28	163913.30*	2575.49
Gross weight per plant		0.0003	0.31*	0.005
Marketable yield per plant		0.003	0.09*	0.0009
Curd size index		288.88	3031.75*	121.12
Curd compactness		0.12	0.96*	0.06
Harvest index		9.02	82.75*	3.52
Dry matter content		0.31	11.71*	1.59

* Significant at 5 per cent level of significance

4.1.2 Mean performance

Mean values of the genotypes along with their standard error, critical difference and coefficient of variation are presented in Table 3. The results of the present study revealed presence of sufficient genetic variability among the genotypes studied for all the characters *viz.*, days to marketable maturity, stalk length, number of leaves per plant, leaf size, gross weight per plant, marketable yield per plant, curd size index, curd compactness, harvest index and dry matter content. These results are in consonance with the findings of (Aditya *et al.* 1989; Jamwal *et al.* 1992; Khar 1995; Kumar 1998; Kumar 1999; Sharma and Verma 2001; Kumar 2002; Pathania 2003; Jindal and Thakur 2004; Kumar *et al.* 2005; Sharma *et al.* 2005; Kumar *et al.* 2006 and Quamruzzaman *et al.* 2007) who have reported a wide range of variation in mean values of various traits of cauliflower studied by them.

Highly significant differences among the genotypes were observed for days to marketable maturity. All the genotypes except Sel-01 (106.33 days), DC-401 (107.33 days), DC-76 (108.00 days) and DC-312 (115.00 days) were significantly earlier to the standard check variety, Palam Uphar (110.67 days). Sel-DS-03 and Pusa Sharad took the minimum number of days (67.00) to marketable maturity. No genotype was significantly later than the standard check in days to marketable maturity. These results are in accordance with the findings of (Dutta 1991; Grey and Doyle 1996; Ahmed *et al.* 2003 and Sharma *et al.* 2005) but are at variance with the findings of (Dhatt and Garg 2008) who reported that days to marketable maturity was the least variable character. A wide range of variability (1.47-4.02 cm) existed for stalk length among the genotypes under investigation. It was shortest and significantly lesser in DC-312 (1.47cm) as compared to the standard check, Palam Uphar (1.88 cm). Except D-19 (2.03 cm), all other remaining genotypes had stalk length greater than check variety, Palam Uphar. (Kumar and Korla 2001; Dhatt and Garg 2008 and Kumar *et al.* 2009) have also reported a wide range for this trait.

The number of leaves per plant were minimum (17.40) in Early Kuari and maximum (22.93) in DC-321. Eight genotypes *viz.*, Punjab Katki (18.40), Sel-DS-03 (18.60), DC-23 (17.73), Varsha Rani (18.47), DC-319 (18.20), Early Kuari (17.40),

Table 3. Estimate of mean values for marketable yield per plant and other traits in cauliflower

Genotypes	Days to marketable maturity	Stalk length (cm)	Number of leaves per plant	Leaf size (cm ²)	Gross weight per plant (kg)	Marketable yield per plant (kg)	Curd size index (cm ²)	Curd compactness (g/cm ²)	Harvest index (%)	Dry matter content (%)
Punjab Giant	68.67	3.64	19.67	509.03	1.26	0.49	204.10	2.40	38.91	16.12
-26										
D-19	88.67	2.03	20.77	659.27	1.25	0.50	188.95	2.64	39.73	16.32
Punjab Katki	77.67	3.42	18.40	486.78	0.97	0.29	157.43	2.15	29.45	14.52
Sel-01	106.33	2.56	21.60	671.48	1.56	0.69	205.99	3.35	44.26	15.15
Sel-DS-03	67.00	3.19	18.60	423.40	0.87	0.29	156.70	1.88	33.11	16.39
Pusa	85.33	2.37	20.67	1,104.09	1.35	0.50	205.98	2.43	36.75	10.67
Synthetic										
Pusa Sharad	67.00	3.45	20.20	461.22	0.96	0.32	145.19	2.26	33.60	16.22
DC-476	74.00	3.69	20.43	572.07	1.62	0.72	223.41	3.24	44.91	16.46
DC-401	107.33	3.15	20.27	959.99	1.81	0.76	242.20	3.14	42.05	16.13
DC-23	96.00	3.93	17.73	322.76	0.80	0.22	143.86	1.50	27.27	14.90
Pusa Deepali	79.67	3.52	21.67	484.71	0.87	0.30	168.86	1.78	34.94	14.41
Varsha Rani	79.67	3.17	18.47	418.76	0.77	0.22	138.73	1.59	28.85	16.57
DC-319	78.00	3.02	18.20	499.30	0.95	0.29	142.25	2.06	30.28	16.18
DC-321	85.67	3.37	22.93	623.66	0.87	0.30	144.76	2.05	34.31	15.87
DC-334	68.33	2.93	19.30	313.25	1.53	0.58	216.95	2.67	37.89	14.99
Early Kuari	71.00	4.02	17.40	329.71	0.88	0.28	157.76	1.76	31.28	16.71
DC-76	108.00	3.01	18.27	465.85	1.00	0.32	167.38	1.89	32.17	16.08
DC-312	115	1.47	18.40	1,044.96	1.10	0.41	181.62	2.27	37.27	13.00
Palam Uphar	110.67	1.88	20.00	737.82	1.47	0.61	199.53	3.06	41.27	9.67
SE (d)±	3.08	0.20	0.61	41.44	0.06	0.02	8.99	3.00	1.53	1.03
CD (5%)	6.24	0.39	1.23	84.03	0.12	0.05	18.22	0.40	3.11	2.09
CV (%)	4.38	7.82	3.78	8.70	6.38	7.25	6.17	10.36	5.26	8.37

DC-76 (18.27) and DC-312 (18.40) recorded significantly less number of leaves per plant while three genotypes, Sel-01 (21.60), Pusa Deepali (21.67) and DC-321 (22.93) recorded significantly more number of leaves per plant than the standard check variety, Palam Uphar (20.00). Seven genotypes were at par with the standard check. Significant variation for number of leaves per plant is in consonance with the findings of (Wurr *et al.* 1981 and Ahmed *et al.* 2003) but is at variance with (Jindal and Thakur 2004) who reported less variability for number of leaves per plant. Leaf size was found to be the minimum in DC-334 (313.25 cm²) and the maximum in Pusa Synthetic (1,104.09 cm²). Thirteen genotypes, Punjab Giant-26 (509.03 cm²), Punjab Katki (486.78 cm²), Sel-DS-03 (423.40 cm²), Pusa Sharad (461.22 cm²), DC-476 (572.07 cm²), DC-23 (322.76 cm²), Pusa Deepali (484.71 cm²), Varsha Rani (418.76 cm²), DC-319 (499.30 cm²), DC-321 (623.66 cm²), DC-334 (313.25 cm²), DC-76 (465.85 cm²) and Early Kuari (329.71 cm²) had significantly smaller leaf size while three genotypes, DC-401 (959.99 cm²), DC-312 (1,044.96 cm²) and Pusa Synthetic (1,104.09 cm²) recorded significantly bigger leaf size than the standard check variety, Palam Uphar (737.82 cm²). Two of the genotypes *viz.*, D-19 (659.27 cm²) and Sel-01 (671.48 cm²) were at par with the standard check. (Jamwal *et al.* 1992; Reddy and Varalakshmi 1995; Kumar and Korla 2001; Ahmed *et al.* 2003 and Singh *et al.* 2006) have also reported a wide range for leaf size in the genotypes studied by them.

The genotypes differed significantly from each other with respect to gross weight per plant. It was found to be the minimum (0.77 kg) in Varsha Rani and the maximum (1.81 kg) in DC-401. The genotypes DC-476 (1.62 kg) and DC-401 (1.81 kg) had significantly high gross weight per plant than the standard check variety, Palam Uphar (1.47 kg) while two genotypes, Sel-01 (1.56 kg) and DC-334 (1.53 kg) were at par. Fourteen genotypes recorded significantly low gross weight per plant than the standard check. Significant differences for gross weight per plant are in accordance with the findings of (Jamwal *et al.* 1992; Reddy and Varalakshmi 1995; Singh *et al.* 2006 and Dhatt and Garg 2008).

A large amount of variability in marketable yield per plant was exhibited by different genotypes under study. It ranged from 0.22 kg in (DC-23 and Varsha Rani) to 0.76 kg in (DC-401). Three genotypes *viz.*, Sel-01 (0.69 kg), DC-476 (0.72 kg) and DC-

401 (0.76 kg) gave significantly higher marketable yield per plant compared to the standard check, Palam Uphar (0.61 kg) while the genotype DC-334 (0.58 kg) was at par. Remaining fourteen genotypes were significantly inferior to the standard check with respect to marketable yield per plant. Higher variability for marketable yield per plant was also reported by earlier researchers (Thamburaj *et al.* 1980; Jamwal *et al.* 1992; Reddy and Varalakshmi 1995; Grey and Doyle 1996; Kumar and Korla 2001; Ahmed *et al.* 2003; Sharma *et al.* 2005; Singh *et al.* 2006 and Dhatt and Garg 2008).

The product of equatorial and polar diameter was used to work out the curd size index, which ranged from 138.73 cm² in Varsha Rani to 242.20 cm² in DC-401. Two genotypes, DC-476 (223.41 cm²) and DC-401 (242.20 cm²) recorded significantly higher curd size index than the standard check, Palam Uphar (199.53 cm²) while six genotypes *viz.*, DC-312 (181.62 cm²), D-19 (188.95 cm²), Punjab Giant-26 (204.10 cm²), Pusa Synthetic (205.98 cm²), Sel-01 (205.98 cm²) and DC-334 (216.95 cm²) were at par. Remaining 10 genotypes had significantly lesser curd size index than the standard check, Palam Uphar. A high magnitude of genetic variability for curd size index is in accordance with the findings of (Jamwal *et al.* 1992 and Grey and Doyle 1996). Significant variation among genotypes for curd compactness was observed in the present study. It ranged from 1.50 in DC-23 to 3.35 in Sel-01. No genotype showed greater curd compactness than the standard check variety, Palam Uphar (3.06). Four genotypes *viz.*, Sel-01 (3.35), DC-476 (3.24), DC-401 (3.14) and DC-334 (2.67) were at par with the standard check for curd compactness while remaining 14 genotypes had lesser compact curds than the standard check, Palam Uphar. Harvest index varied from 27.27 % in DC-23 to 44.91 % in DC-476. Genotype DC-476 (44.91 %) recorded significantly higher harvest index than the standard check, Palam Uphar (41.27 %) while four genotypes *viz.*, Punjab Giant-26 (38.91 %), D-19 (39.73 %), DC-401 (42.05 %) and Sel-01 (44.26 %) were at par with Palam Uphar with respect to harvest index. Remaining 13 genotypes were inferior to the standard check for harvest index. (Sharma *et al.* 2005) have also reported wide range of variability for curd compactness and harvest index. Dry matter content was the minimum (9.67%) in standard check (Palam Uphar) and the maximum (16.71%) in Early Kuari. The genotype Pusa Synthetic (10.67%) was at par while 16 genotypes had significantly



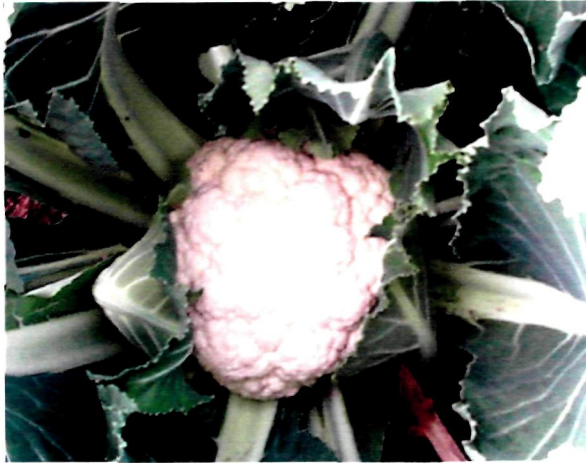
Plate 1 **General view of crop growth at the Experimental Farm, HAREC, Bajaura**

higher dry matter content than the check Palam Uphar. Similar findings were also reported by Wurr *et al.* (1981) who observed dry matter content in the range of 9 to 18 per cent in the curd of cauliflower. Lukovnikova (1973), Korbut *et al.* (1975) and Khattrra *et al.* (1997) have also observed significant variation for dry matter content in cole crops.

Based on the mean performance with respect to various characters of horticultural importance, genotypes DC-476, DC-401 and Sel-01 (Plate 2) were superior or at par for gross weight per plant, marketable yield per plant, curd size index, curd compactness and harvest index when compared to standard check variety Palam Uphar. DC-476 was found to be the best genotype as it exhibited high mean performance for marketable yield per plant and some of its component traits viz., gross weight per plant, curd size index, harvest index and took less days to reach the marketable maturity than the standard check. Marketable yield per plant is an important horticultural trait for producers as well as consumers. Three genotypes viz., DC-401 (0.76 kg), DC-476 (0.72 kg) and Sel-01 (0.69 kg) recorded significantly higher marketable yield per plant as compared to Palam Uphar (0.61 kg) while the genotype DC-334 (0.58 kg) was at par. Breeders are interested to breed early maturing varieties. Results of the present study revealed significant differences for days to marketable maturity. All the genotypes except Sel-01 (106.33 days), DC-401 (107.33 days), DC-76 (108.00 days) and DC-312 (115.00 days) were significantly earlier to the standard check. Generally, compact curds are preferred in cauliflower varieties. Four genotypes viz., Sel-01 (3.35), DC-476 (3.24), DC-401 (3.14) and DC-334 (2.67) were at par with the standard check, Palam Uphar (3.06). A wide variation existed for harvest index among the genotypes under investigation. Genotype DC-476 (44.91 %) recorded significantly higher harvest index than the standard check, Palam Uphar (41.27 %) while four genotypes, Punjab Giant-26 (38.91 %), D-19 (39.73 %), DC-401 (42.05 %) and Sel-01 (44.26 %) were at par.

4.2 Genetic parameters of variability

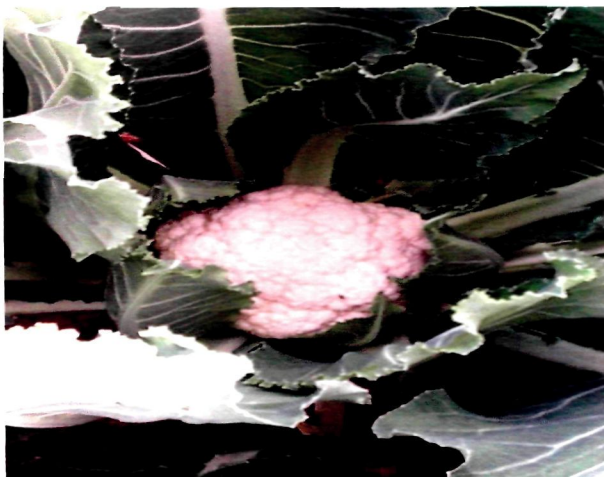
The components of variation viz. grand mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2_{bs}) and genetic advance (GA) for different characters are presented in Table 4.



DC-476



DC-401



Sel-01

Plate 2 Some of the promising mid-group cauliflower genotypes

4.2.1 Range

The range in the mean values- an indicator of variability, revealed sufficient variation for all the characters except for number of leaves per plant.

4.2.2 Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV)

A perusal of the results (Table 4) revealed that PCV was more than GCV in all the characters studied, which indicated close association between phenotype and genotype. PCV and GCV, which are free from the units of measurement, were high for marketable yield per plant (41.82% and 41.19%) and leaf size (40.68% and 39.74%), respectively. High values of PCV and GCV for marketable yield per plant and component traits are in accordance with the studies of earlier researchers for marketable yield per plant (Jamwal *et al.* 1992; Khar 1995; Khar *et al.* 1997; Mahajan and Gill 1997; Kumar and Korla 2001 and Pathania 2003) and for leaf size (Jamwal *et al.* 1992; Mahajan and Gill 1997 and Kumar and Korla 2001) while they were moderate for days to marketable maturity (19.37% and 18.87%), stalk length (23.79% and 22.46%), gross weight per plant (28.25% and 27.52%), curd size index (18.51% and 17.45%) and curd compactness (25.76% and 23.58%). For gross weight per plant (Khar *et al.* 1997; Kumar 1998; Kumar 1999 and Kumar *et al.* 2006), for curd size index (Khar 1995 and Khar *et al.* 1997) and for curd compactness (Pathania 2003) reported moderate values of PCV and GCV for above mentioned characters whereas harvest index showed moderate PCV (15.32%) and low GCV (14.39%) values. The low estimates of PCV and GCV observed for dry matter content (14.78 and 12.18%) and number of leaves per plant (8.27% and 7.36%) indicated that genotypes of mid-group cauliflower included in the present study possessed less genetic variability for these traits. Low PCV and GCV for number of leaves per plant and dry matter content in the present studies favour the findings of Khattra *et al.* (1997).

4.2.3 Heritability (h^2 bs)

A useful measure for considering the ratio of genetic variance to the total variance is heritability, which is of major importance to the development of quantitative genetics. Heritability is useful in predicting the expected progress to be achieved through selection (Burton and DeVane 1953 and Johnson *et al.* 1955) while it is a parameter of tremendous

Table 4. Components of genetic variation in cauliflower

Traits	Grand Mean	Range	Phenotypic coefficient of variation (PCV)	Genotypic coefficient of variation (GCV)	Heritability (h^2_{bs})	Genetic advance as percentage of mean (GA)
Days to marketable maturity	86.00	67.00-115.00	19.37	18.87	94.89	37.87
Stalk length	3.04	1.47-4.02	23.79	22.46	89.20	43.71
Number of leaves per plant	19.63	17.40-22.93	8.27	7.36	79.13	13.48
Leaf size	583.58	313.25-1104.09	40.68	39.74	95.43	79.97
Gross weight per plant	1.15	0.77-1.81	28.25	27.52	94.90	55.22
Marketable yield per plant	0.43	0.22-0.76	41.82	41.19	96.99	83.57
Curd size index	178.51	138.73-242.20	18.51	17.45	88.90	33.89
Curd compactness	2.32	1.50-3.35	25.76	23.58	83.81	44.47
Harvest index	35.70	27.27-44.91	15.32	14.39	88.22	27.85
Dry matter content	15.07	9.67-16.71	14.78	12.18	67.91	20.68

significance to the breeders as its magnitude indicates the reliability with which a genotype can be recognized by its phenotypic expression (Lush 1940). In the present study, high heritability was noticed for marketable yield per plant (96.99%), leaf size (95.43%), gross weight per plant (94.90%), days to marketable maturity (94.89%), stalk length (89.20%), curd size index (88.90%), curd compactness (83.81%) and harvest index (88.22%). In the present study, the characters *viz.*, days to marketable maturity, leaf size, gross weight per plant and marketable yield per plant exhibited more than 90.0% heritability. High heritability in broad sense indicated that large proportion of phenotypic variance was attributable to the genotypic variance and these character differences among the genotypes were real and showed that above mentioned traits with high heritability values were less influenced by the environment. Therefore, selection made for these traits on the basis of phenotypic expression could be relied upon. High heritability for marketable yield per plant and component traits supports the findings of earlier researchers for marketable yield per plant (Dutta 1991; Jamwal *et al.* 1992; Radhakrishna 1992; Radhakrishna and Korla 1994; Khar 1995; Reddy and Varalakshmi 1995; Khar *et al.* 1997; Kumar 1998; Pathania 2003; Kumar *et al.* 2006; Sharma *et al.* 2006; Singh *et al.* 2006 and Dhatt and Garg 2008), for gross weight per plant (Dutta 1991; Jamwal *et al.* 1992; Radhakrishna 1992; Radhakrishna and Korla 1994; Reddy and Varalakshmi 1995; Kumar 1998; Singh *et al.* 2006 and Dhatt and Garg 2008), for leaf size (Jamwal *et al.* 1992; Kumar 1998 and Singh *et al.* 2006), for curd size index (Jamwal *et al.* 1992 and Reddy and Varalakshmi 1995), for days to marketable maturity (Dhiman 1979; Radhakrishna 1992; Khar 1995; Kumar 2002 and Jindal and Thakur 2004), for stalk length (Radhakrishna 1992; Radhakrishna and Korla 1994; Kumar 1998; Sharma *et al.* 2006 and Dhatt and Garg 2008) and for harvest index (Radhakrishna and Korla 1994 and Kumar *et al.* 2006) but are in disagreement with the findings of (Khar 1995 and Kumar and Korla 2001) who have reported higher heritability for number of leaves per plant and (Reddy and Varalakshmi 1995) who have observed low heritability for leaf size. Two characters, namely, number of leaves per plant (79.13%) and dry matter content (67.91%) showed moderate heritability values. Moderate heritability for number of leaves per plant and dry matter content supports the findings of earlier research workers (Khattra *et al.* 1997 and Khar *et al.* 1997).

4.2.4 Genetic advance (GA)

Heritability and genetic advance are two complementary parameters; the former may be used to estimate expected genetic advance through selection. The efficacy of any selection programme depends upon the extent of heritability as well as genetic advance, which usually changes from population to population and environment to environment. Johnson *et al.* (1955) stressed that for estimating the real effects of selection, heritability alone is not sufficient and genetic advance coupled with heritability is more useful. High genetic advance was observed for marketable yield per plant (83.57%), leaf size (79.97%) and gross weight per plant (55.22%) which indicates higher response of these characters to selection. These results are in broad conformity to the earlier researchers for marketable yield per plant (Dhiman 1979; Dutta 1991; Jamwal *et al.* 1992; Radhakrishna 1992; Radhakrishna and Korla 1994; Khar 1995; Reddy and Varalakshmi 1995; Khar *et al.* 1997; Kumar 1998; Kumar 1999; Pathania 2003; Kumar *et al.* 2006; Sharma *et al.* 2006; Singh *et al.* 2006 and Dhatt and Garg 2008), for gross weight per plant (Dhiman 1979; Dutta 1991; Jamwal *et al.* 1992; Radhakrishna 1992; Radhakrishna and Korla 1994; Khar 1995; Reddy and Varalakshmi 1995; Kumar 1998; Kumar 1999; Kumar 2002; Singh *et al.* 2006 and Dhatt and Garg 2008) and for leaf size (Jamwal *et al.* 1992; Kumar 1998 and Singh *et al.* 2006). It was moderate for days to marketable maturity (37.87%), stalk length (43.71%), curd size index (33.89%), curd compactness (44.47%) and harvest index (27.85%) whereas low genetic advance was observed for number of leaves per plant (13.48%) and dry matter content (20.68%). These results are in line with the earlier studies of (Kumar *et al.* 2006) for harvest index but are at variance with (Dutta 1991 and Khar 1995) who observed high genetic advance for number of leaves per plant.

High heritability coupled with high genetic advance indicates additive gene action (Panse 1957) and consequently a high genetic gain is expected from selection under such a situation. In the present studies, high heritability along with high genetic advance was observed for leaf size, gross weight per plant and marketable yield per plant. Similar findings have also been reported for marketable yield per plant (Jamwal *et al.* 1992; Khar

1995; Reddy and Varalakshmi 1995; Khar *et al.* 1997; Pathania 2003; Kumar *et al.* 2006; Sharma *et al.* 2006; Singh *et al.* 2006 and Dhatt and Garg 2008), for gross weight per plant (Dutta 1991; Reddy and Varalakshmi 1995; Jindal and Thakur 2004; Singh *et al.* 2006 and Dhatt and Garg 2008) and for leaf size (Jamwal *et al.* 1992 and Singh *et al.* 2006).

High heritability along with moderate genetic advance for days to marketable maturity, stalk length, curd size index, curd compactness and harvest index may be attributed to the additive gene action linked with non-additive effects and these may be improved through hybridization followed by selection. High heritability along with moderate genetic advance for these component traits is in broad conformity with the results obtained for curd size index (Dhiman 1979; Jamwal *et al.* 1992 and Garg and Lal 2005), for harvest index (Kumar *et al.* 2006) and for curd compactness (Garg and Lal 2005). Moderate heritability and low genetic advance was observed for number of leaves per plant and dry matter content. Characters with low heritability can be improved through hybridization (Liang and Walter 1968).

4.3 Correlation studies

In crop improvement programmes, selection is often made on the basis of one or at the most a few characters. Though a breeder is always interested in the improvement of several characters, it is necessary to know the concurrent change that would result in the unselected economic characters when selection pressure is applied for the improvement of certain other traits. For this purpose, it is beneficial to know the inter-relationship amongst the various economically important characters. This consideration becomes still imperative when one visualizes curd yield as a complex trait and product of the interaction of several component traits. In fact Adam and Grafius (1971) and Adams (1975) have mentioned that yield should be considered as an end-product of a number of characters and breeders should not ignore the principle of balance among these components. In the present investigations, the correlation coefficients of different economic traits *viz.*, days to marketable maturity, stalk length, number of leaves per plant, leaf size, gross weight per plant, marketable yield per plant, curd size index, curd

compactness, harvest index and dry matter content for 19 genotypes were worked out at phenotypic, genotypic and environmental levels. The results so obtained are presented in Table 5.

4.3.1 Phenotypic correlation coefficients

Results of the present study revealed that marketable yield per plant had positive and significant correlations with gross weight per plant (0.965), curd size index (0.908), curd compactness (0.928), harvest index (0.907) and leaf size (0.491) whereas its association was positive and non-significant with days to marketable maturity (0.295) and number of leaves per plant (0.390). There was negative and non-significant association of marketable yield per plant with stalk length (-0.316) and dry matter content (-0.197). Correlation coefficient of days to marketable maturity with leaf size (0.568) was found to be positive and significant while its association was positive and non-significant with number of leaves per plant (0.062), gross weight per plant (0.289), curd size index (0.257), curd compactness (0.278) and harvest index (0.266). It had negative and significant correlation with stalk length (-0.578) followed by negative and non-significant association with dry matter content (-0.407). Stalk length showed significant positive correlation with dry matter content (0.522) while its association was negative and significant with leaf size (-0.651). There was negative and non-significant correlation of stalk length with number of leaves per plant (-0.164), gross weight per plant (-0.315), curd size index (-0.289), curd compactness (-0.356) and harvest index (-0.365). Number of leaves per plant showed positive and significant association with harvest index (0.480) while its association was positive and non-significant association with leaf size (0.321), gross weight per plant (0.332), curd size index (0.295) and curd compactness (0.401). There was negative and non-significant correlation of number of leaves with dry matter content (-0.089). Leaf size was positively and significantly correlated with gross weight per plant (0.473), curd size index (0.495) and harvest index (0.494). Its association was positive and non-significant with curd compactness (0.450) followed by a negative and significant relationship with dry matter content (-0.504).

Table 5. Phenotypic (P), genotypic (G) and environmental (E) correlation coefficients for different pairs of characters in cauliflower

Traits	Type of correlation	Marketable yield per plant	Days to marketable maturity	Stalk length	Number of leaves per plant	Leaf size	Gross weight per plant	Curd size index	Curd compactness	Harvest index
Days to marketable maturity	P	0.295								
	G	0.313								
	E	-0.120								
Stalk length	P	-0.316	-0.578*							
	G	-0.352	-0.618*							
	E	0.208	-0.128							
Number of leaves per plant	P	0.390	0.062	-0.164						
	G	0.448	0.082	-0.150						
	E	-0.026	-0.089	-0.253						
Leaf size	P	0.491*	0.568*	-0.651*	0.321					
	G	0.499*	0.591*	-0.694*	0.384					
	E	0.285	0.114	-0.157	-0.125					
Gross weight per plant	P	0.965*	0.289	-0.315	0.332	0.473*				
	G	1.00*	0.305	-0.350	0.377	0.507*				
	E	0.126	0.007	0.097	0.051	-0.201				
Curd size index	P	0.908*	0.257	-0.289	0.295	0.495*	0.915*			
	G	0.966*	0.261	-0.306	0.356	0.513*	0.979*			
	E	0.191	0.239	-0.151	-0.021	0.305	0.209			
Curd compactness	P	0.928*	0.278	-0.356	0.401	0.450	0.881*	0.728*		
	G	0.982*	0.307	-0.424	0.517*	0.500*	0.975*	0.909*		
	E	0.615	0.048	0.084	-0.107	0.040	0.129	-0.420		
Harvest index	P	0.907*	0.266	-0.365	0.480*	0.494*	0.834*	0.797*	0.869*	
	G	0.957*	0.289	-0.419	0.644*	0.518*	0.914*	0.913*	0.960*	
	E	0.360	0.015	0.063	-0.367	0.247	-0.022	-0.094	0.314	
Dry matter content	P	-0.197	-0.407	0.522*	-0.089	-0.504*	-0.228	-0.209	-0.254	-0.166
	G	-0.235	-0.466*	0.648*	-0.171	-0.604*	-0.255	-0.284	-0.222	-0.231
	E	-0.067	-0.258	0.097	0.141	-0.149	-0.182	0.064	-0.382	0.063

* Significant at 5 per cent level

Correlation coefficient of gross weight per plant was found to be positive and highly significant with curd size index (0.915), curd compactness (0.881) and harvest index (0.834) whereas it was negatively and non-significantly associated with dry matter content (-0.228). There was positive and significant correlation of curd size index with curd compactness (0.728) and harvest index (0.797) whereas it had negative and non-significant association with dry matter content (-0.209). Curd compactness was positively and significantly associated with harvest index (0.869) while it showed negative and non-significant relationship with dry matter content (-0.254). There was negative and non-significant association of harvest index with dry matter content (-0.166).

4.3.2 Genotypic correlation coefficients

The genotypic correlation coefficients among the various traits were worked out after eliminating the environmental interactions which disturbs the real association of traits. Marketable yield per plant showed positive and significant association with leaf size (0.499), gross weight per plant (1.00), curd size index (0.966), curd compactness (0.982) and harvest index (0.957) which favours the earlier findings of (Sharma *et al.* 2006) for its positive and significant association with gross weight per plant and curd size index. Its relationship was positive and non-significant with days to marketable maturity (0.313) and number of leaves per plant (0.448) followed by negative and non-significant correlation with stalk length (-0.352) and dry matter content (-0.235). The correlation coefficient of days to marketable maturity was positive and significant with leaf size (0.591) followed by a positive and non-significant associations with number of leaves per plant (0.082), gross weight per plant (0.305), curd size index (0.261), curd compactness (0.307) and harvest index (0.289). It had negative and significant relationship with stalk length (-0.618) and dry matter content (-0.466). Correlation coefficient of stalk length was positive and significant with dry matter content (0.648) while it was negative and significant with leaf size (-0.694). There was negative and non-significant association of stalk length with number of leaves per plant (-0.150), gross weight per plant (-0.350), curd size index (-0.306), curd compactness (-0.424) and harvest index (-0.419). Number of leaves per plant had positive and significant associations with curd compactness

(0.517) and harvest index (0.644) while it had positive and non-significant associations with leaf size (0.384), gross weight per plant (0.377) and curd size index (0.356). Its association was negative and non-significant with dry matter content (-0.171). There was positive and significant correlation of leaf size with gross weight per plant (0.507), curd size index (0.513), curd compactness (0.500) and harvest index (0.518) followed by negative and significant relationship with dry matter content (-0.604).

Correlation coefficient of gross weight per plant was positive and highly significant with curd size index (0.979), curd compactness (0.975) and harvest index (0.914) whereas it had negative and non-significant association with dry matter content (-0.255). Curd size index showed positive and highly significant correlations with curd compactness (0.909) and harvest index (0.913) whereas, it had negative and non-significant association with dry matter content (-0.284). Curd compactness had positive and significant correlation with harvest index (0.960) followed by a negative and non-significant relationship with dry matter content (-0.222). Harvest index was negatively and non-significantly associated with dry matter content (-0.231).

4.3.3 Environmental correlation coefficients

Correlation coefficients at environmental level, in general, were low in most of the combinations, thus showing that associations of these traits were mostly under the genotypic control and influence of the environment was low however, marketable yield per plant had significant and positive environmental correlation with curd compactness (0.615). Environmental correlation coefficient values were comparatively higher and positive for the character pairs *viz.*, marketable yield per plant v/s leaf size (0.285), stalk length (0.208) and harvest index (0.360); days to marketable maturity v/s curd size index (0.239); leaf size v/s curd size index (0.305) and harvest index (0.247); gross weight per plant v/s curd size index (0.209) and curd compactness v/s harvest index (0.314).

A perusal of results (Table 5) revealed that the genotypic correlations were higher in magnitude in all the cases than the phenotypic correlations thereby, suggesting strong

inherent association among various characters studied. From these associations, it appeared that marketable yield per plant could be improved by increasing leaf size, gross weight per plant, curd size index, curd compactness and harvest index. These findings are in line with those of (Dhiman 1979; Thamburaj *et al.* 1982; Dhiman *et al.* 1983; Dutta 1991; Jamwal *et al.* 1992; Radhakrishna 1992; Khar 1995; Radhakrishna and Korla 1995; Reddy and Varalakshmi 1995; Kumar 1998; Kumar 1999; Kumar 2002; Pathania 2003; Kumar *et al.* 2004; Liu *et al.* 2004; Kumar *et al.* 2005 and Sharma *et al.* 2006) for gross weight per plant, (Dhiman 1979; Dhiman *et al.* 1983; Jamwal *et al.* 1992; Khar 1995; Reddy and Varalakshmi 1995; Garg and Lal 2004 and Sharma *et al.* 2006) for curd size index, (Kumar 2002; Pathania 2003 and Garg and Lal 2004) for curd compactness, (Dutta 1991; Khar 1995; Reddy and Varalakshmi 1995 and Kumar 1999) for harvest index and (Sharma *et al.* 1982; Kumar 1998; Kumar 1999; Liu *et al.* 2004 and Kumar *et al.* 2005) for leaf size. Association of marketable yield per plant was positive and non-significant with days to marketable maturity, which is in accordance with the studies of Radhakrishna (1992) and Pathania (2003). Leaf size was positively and significantly correlated with gross weight per plant (0.473), curd size index (0.495) and harvest index (0.494) which is in agreement with (Kumar 1998 and Singh *et al.* 2006). Correlation coefficient of gross weight per plant was found to be positive and highly significant with curd size index (0.915), curd compactness (0.881) and harvest index (0.834) which supports the earlier findings of Dhiman *et al.* (1983). The study also indicated positive and significant associations among the character pairs *viz.*, days to marketable maturity v/s leaf size; stalk length v/s dry matter content; number of leaves per plant v/s harvest index; leaf size v/s gross weight per plant, curd size index and harvest index; gross weight per plant v/s curd size index, curd compactness and harvest index; curd size index v/s curd compactness and harvest index and curd compactness v/s harvest index.

Therefore, it can be concluded that selection based on leaf size, gross weight per plant, curd size index, curd compactness and harvest index will be effective in selecting genotypes with high marketable yield per plant.

4.4 Path coefficient analysis

Marketable yield is an ultimate product of interaction among its attributes under the influence of environment. These interactions mean indirect effect of these attributes apart from their direct contribution towards marketable yield. Therefore, in addition to determining the inter-relationships among the marketable yield components on one hand and between marketable yield and its components on the other, it is necessary to understand their direct or indirect effects on marketable yield. It is quite likely that contribution of a component sharing high significant association with marketable yield may get diluted through the interactions with other components. Further, the information on relative contribution (direct or indirect) of components to marketable yield helps in giving appropriate weightage for the purpose of selection. Therefore, path coefficients were estimated as suggested by (Dewey and Lu 1959). The results are presented in Table 6.

4.4.1 Estimates of direct and indirect effects at the phenotypic level

Results of the present study revealed that at phenotypic level, all the characters had direct positive contribution towards marketable yield per plant. The highest contribution being by curd compactness followed by curd size index and gross weight per plant along with minor direct positive contributions by harvest index, dry matter content, stalk length, days to marketable maturity, leaf size and number of leaves per plant. Curd compactness exhibited very high direct positive effect (0.4094) and high indirect positive effect via gross weight per plant (0.1858), curd size index (0.2383) and harvest index (0.1013). Curd size index contributed positively and directly (0.3274) towards marketable yield per plant and also indirectly via gross weight per plant (0.1928) and curd compactness (0.2981). Besides high direct positive effect (0.2108), gross weight per plant also had high indirect positive effect via curd size index (0.2994) and curd compactness (0.3608). Harvest index showed positive direct effect (0.1166) and high indirect effect via gross weight per plant (0.1759), curd size index (0.2611) and curd compactness (0.3556). Dry matter content contributed positively and directly (0.0437) towards marketable yield per plant. Stalk length had positive direct effect (0.0429). Days to marketable maturity

Table 6. Estimates of direct and indirect effects of different traits on marketable yield per plant at phenotypic (P) and genotypic (G) levels:

Traits	Days to marketable maturity	Stalk length (cm)	Number of leaves per plant	Leaf size (cm ²)	Gross weight per plant (kg)	Curd size index (cm ²)	Curd compactness (%)	Harvest index (%)	Dry matter content (%)	Correlation with marketable yield per plant
Days to marketable maturity	P <u>0.0402</u> G <u>0.1448</u>	-0.0248 1.1341	0.0005 0.1684	0.0069 -0.6229	0.0610 0.9503	0.0843 0.6829	0.1139 -0.6407	0.0310 -1.0514	-0.0178 -0.4528	0.295 0.313
Stalk length	P -0.0232 G -0.0895	<u>0.0429</u> <u>-1.8351</u>	-0.0013 -0.3055	-0.0079 0.7311	-0.0663 -1.0900	-0.0947 -0.8023	-0.1457 0.8859	-0.0425 1.5229	0.0228 0.6302	-0.316 -0.352
Number of leaves per plant	P 0.0025 G 0.0119	-0.0070 0.2744	<u>0.0077</u> <u>2.0430</u>	0.0039 -0.4042	0.0700 1.1751	0.0966 0.9314	0.1643 -1.0789	0.0560 -2.3389	-0.0039 -0.1663	0.390 0.448
Leaf size	P 0.0228 G 0.0856	-0.0279 <u>1.2731</u>	0.0025 <u>0.7836</u>	<u>0.0122</u> <u>-1.0538</u>	0.0997 <u>1.5797</u>	<u>0.1620</u> <u>1.3450</u>	<u>0.1844</u> -1.0432	0.0576 -1.8834	-0.0220 -0.5871	0.491* 0.499*
Gross weight per plant	P 0.0116 G 0.0441	-0.0135 <u>0.6418</u>	0.0026 <u>0.7703</u>	0.0057 -0.5342	<u>0.2108</u> <u>3.1166</u>	<u>0.2994</u> <u>2.5635</u>	<u>0.3608</u> -2.0351	0.0973 -3.3190	-0.0100 -0.2476	0.965* 1.00*
Curd size index	P 0.0103 G 0.0377	-0.0124 <u>0.5621</u>	0.0023 <u>0.7264</u>	0.0060 -0.5411	<u>0.1928</u> <u>3.0499</u>	<u>0.3274</u> <u>2.6195</u>	<u>0.2981</u> -1.0965	0.0930 -3.3152	-0.0091 -0.2766	0.908* 0.966*
Curd compactness	P 0.0112 G 0.0444	-0.0153 <u>0.7789</u>	0.0031 <u>1.0560</u>	0.0055 -0.5267	<u>0.1858</u> <u>3.0387</u>	<u>0.2383</u> <u>2.3801</u>	<u>0.4094</u> <u>-2.0872</u>	<u>0.1013</u> -3.4865	-0.0111 -0.2159	0.928* 0.982*
Harvest index	P 0.0107 G 0.0419	-0.0157 <u>0.7692</u>	0.0037 <u>1.3152</u>	0.0060 -0.5463	<u>0.1759</u> <u>2.8470</u>	<u>0.2611</u> <u>2.3902</u>	<u>0.3556</u> -2.0029	<u>0.1166</u> <u>-3.6333</u>	-0.0073 -0.2242	0.907* 0.957*
Dry matter content	P -0.0163 G -0.0674	0.0224 -1.1890	-0.0007 -0.3492	-0.0061 0.6361	-0.0480 -0.7935	-0.0684 -0.7448	-0.1042 0.4633	-0.0194 0.8373	<u>0.0437</u> <u>0.9726</u>	-0.197 -0.235

Residual effect : P= 0.0114, G= 0.0124

Underline values denote direct effects and the remaining indirect effects

* Significant at 5 per cent level

exhibited positive direct (0.0402) and indirect effect via curd compactness (0.1139). Leaf size showed low direct positive effect (0.0122) but high indirect effect via curd size index (0.1620) and curd compactness (0.1844). Number of leaves per plant had minor direct effect (0.0077) and indirect effect via curd compactness (0.1643).

Direct and indirect effects obtained at phenotypic level were markedly different from those at genotypic level, which might be due to varying degree of influence of environment on various traits studied. In few characters *viz.*, stalk length, leaf size, curd compactness and harvest index, direct effects were observed to be positive at phenotypic level but negative at the genotypic level. Such a change in direction as well as magnitude from phenotypic level to genotypic level might be due to varying degree of influence of environment on various characters studied. Therefore, the path analysis at the phenotypic level may not provide true picture of direct and indirect causes and it would be advisable to understand the contribution of different traits towards the marketable yield per plant at the genotypic level.

4.4.2 Estimates of direct and indirect effects at the genotypic level

At genotypic level, five characters had exerted positive direct effects on marketable yield per plant. The highest direct effect was observed by gross weight per plant followed by curd size index, number of leaves per plant, dry matter content and days to marketable maturity. Gross weight per plant exhibited high direct (3.1166) and indirect effect via stalk length (0.6418), number of leaves per plant (0.7703) and curd size index (2.5635). Curd size index contributed positively and directly (2.6195) towards marketable yield per plant and also indirectly via stalk length (0.5621), number of leaves per plant (0.7264) and gross weight per plant (3.0499). Number of leaves per plant had direct positive (2.0430) and indirect effect via stalk length (0.2744), gross weight per plant (1.1751) and curd size index (0.9314). Dry matter content showed direct positive (0.9726) and indirect positive effect via leaf size (0.6361), curd compactness (0.4633) and harvest index (0.8373). Days to marketable maturity had direct positive effect (0.1448) and indirect effect via stalk length (1.1341), number of leaves per plant (0.1684), gross weight per plant (0.9503) and curd size index (0.6829).

Four characters had exerted negative direct effects on marketable yield per plant. The highest being by harvest index followed by curd compactness, stalk length and leaf size. Harvest index showed negative direct effect (-3.6333) and positive indirect effect via gross weight per plant (2.8470), curd size index (2.3903), number of leaves per plant (1.3152) and stalk length (0.7692) and negative indirect effect via leaf size (-0.5463), dry matter content (-0.2242) and curd compactness (-2.0029); curd compactness had negative direct effect (-2.0872) and positive indirect effect via gross weight per plant (3.0387), curd size index (2.3801), number of leaves per plant (1.0560) and stalk length (0.7789) while negative indirect effects via harvest index (-3.4865) and leaf size (-0.5267); stalk length exhibited negative direct effect (-1.8351) and positive indirect effect via leaf size (0.7311), curd compactness (0.8859), harvest index (1.5229) and dry matter content (0.6302) while negative indirect effect via gross weight per plant (-1.0900), curd size index (-0.8023) and number of leaves per plant (-0.3055) and leaf size showed negative direct effect (-1.0538) and high positive indirect effect via stalk length (1.2731), number of leaves per plant (0.7836), gross weight per plant (1.5797) and curd size index (1.3450) while negative indirect effect via curd compactness (-1.0432), harvest index (-1.8834) and dry matter content (-0.5871).

Therefore, results of the path coefficients revealed that at phenotypic level, the characters *viz.*, curd compactness, curd size index and gross weight per plant had maximum positive direct as well as indirect contribution towards marketable yield per plant and their corresponding correlation coefficients were also positive and significant. Hence, these traits should be given greater emphasis in the selection programme aimed at developing high yielding mid-group cauliflower varieties. Leaf size had minor direct contribution (0.0122) but its correlation with marketable yield per plant (0.491) was positive and significant because of indirect effects via curd size index and curd compactness. These results are in accordance with earlier researchers (Sharma *et al.* 1982; Reddy and Varalakshmi 1995; and Kumar 1999) who observed positive direct effects for leaf size but are at variance with the findings of (Liu *et al.* 2004; Kumar *et al.* 2005 and Singh *et al.* 2006) who observed indirect effects for leaf size. Gross weight per plant exhibited positive and significant correlation with marketable yield per plant

(0.965) because of its high direct (0.2108) and indirect effects via curd size index and curd compactness. These findings are in agreement with those of (Thamburaj *et al.* 1982; Dutta 1991; Radhakrishna 1992; Khar 1995; Kumar 1998; Kumar *et al.* 2004; Liu *et al.* 2004; Kumar *et al.* 2005; Sharma *et al.* 2006 and Singh *et al.* 2006) who observed positive direct effects of gross weight per plant on marketable yield per plant. Correlation coefficient of curd size index with marketable yield per plant (0.908) was positive and significant because of its own high direct effect (0.3274) and indirect effects via gross weight per plant and curd compactness. These results are in line with Reddy and Varalakshmi (1995) and Garg and Lal (2004). Curd compactness exhibited high positive direct (0.4094) and indirect effects via gross weight per plant, curd size index and harvest index which resulted in its positive and significant relationship with marketable yield per plant (0.928). Garg and Lal (2004) have also observed positive direct effects for curd compactness. Harvest index showed positive and significant relationship with marketable yield per plant because of its own minor positive direct (0.1166) but major indirect effect via gross weight per plant, curd size index and curd compactness. Similar results have also obtained by (Dutta 1991; Khar 1995; Reddy and Varalakshmi 1995; Kumar 1998; Kumar 1999; Kumar *et al.* 2004 and Kumar *et al.* 2005) for harvest index. The contributions of other characters *viz.*, days to marketable maturity, stalk length, number of leaves per plant and dry matter content (direct or indirect) which were almost negligible supports the earlier findings of (Khar 1995; Reddy and Varalakshmi 1995 and Kumar 1999) for number of leaves per plant, (Kumar *et al.* 2005) for stalk length, (Khar 1995) for days to marketable maturity and (Sharma *et al.* 1982) for dry matter content.

At genotypic level, five characters had exerted positive direct effects on marketable yield per plant. The highest contribution was observed by gross weight per plant followed by curd size index, number of leaves per plant, days to marketable maturity and dry matter content. Direct effect of gross weight per plant was positive but comparatively low in magnitude (3.1166) as compared to its correlation coefficient (1.00). It further revealed that indirect effect of gross weight per plant via curd size index, stalk length and number of leaves per plant were positive resulting in a positive and

highly significant correlation of this trait with marketable yield per plant. Curd size index, having positive and significant correlation with marketable yield per plant (0.966), exhibited high direct (2.6195) and indirect effect via gross weight per plant, stalk length and number of leaves per plant. The characters viz., harvest index, curd compactness, stalk length and leaf size had exerted negative direct effects on marketable yield per plant. Harvest index had high negative direct effect on marketable yield per plant (-3.6333) but it exhibited positive and significant correlation with marketable yield per plant (0.957) because of positive indirect effects via gross weight per plant, curd size index, stalk length and number of leaves per plant. Although direct effect of curd compactness on the marketable yield per plant was negative (-2.0872) but it had high positive direct contributions via gross weight per plant, curd size index, stalk length and number of leaves per plant resulting in its positive and significant correlation with marketable yield per plant. Correlation coefficient of leaf size with marketable yield per plant (0.499) was positive and significant because of its own negative direct (-1.0538) but high indirect positive effects via gross weight per plant, curd size index, stalk length and number of leaves per plant.

A low magnitude of residual effects both at phenotypic (0.0114) and genotypic (0.0124) levels indicated that the characters included in the present investigation accounted for most of the variation present in the dependent variable (marketable yield per plant).

Thus, the present study clearly indicated the existence of sufficient amount of genetic variability in the genotypes of cauliflower (mid-maturity group), which could possibly be managed either through selection or hybridization or both. Three genotypes namely, DC-476, DC-401 and Sel-01 were found to be promising for marketable yield per plant and other component traits viz., gross weight per plant, curd size index and harvest index when compared to standard check. Among the traits studied, curd compactness, curd size index and gross weight per plant should be given emphasis while developing high yielding and horticulturally superior genotypes of mid-group cauliflower.



***S*ummary
and
*C*onclusions**

5. SUMMARY AND CONCLUSIONS

The present investigation entitled, “variation and association studies in mid-group cauliflower (*Brassica oleracea* var. *botrytis* L.)” was carried out to gather information on genetic variability, correlation and path coefficients in 19 genetically diverse genotypes of cauliflower obtained from different sources. The field experiment was laid out in randomized block design with three replications at the Experimental Farm, CSK Himachal Pradesh Krishi Vishvavidyalaya, Hill Agricultural Research and Extension Centre, Bajaura, Kullu during summer season of 2009. Data on marketable yield per plant and its component traits viz., days to marketable maturity, stalk length, number of leaves per plant, leaf size, gross weight per plant, curd size index, curd compactness, harvest index and dry matter content were analysed as per standard statistical procedures and then the coefficients of variability, heritability, genetic advance, correlation coefficients and path coefficients were worked out.

Analysis of variance showed significant differences among genotypes for all the traits. On the basis of mean performance, genotypes DC-476, DC-401 and Sel-01 were superior or comparable for marketable yield per plant and some of its component traits viz., gross weight per plant, curd size index, curd compactness and harvest index than the standard check. Genotype DC-476 was found to be the best genotype as it recorded significantly higher marketable yield per plant, gross weight per plant, curd size index, harvest index and took less days to reach the marketable maturity than the standard check.

The estimates of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were high for marketable yield per plant and leaf size while moderate for days to marketable maturity, stalk length, gross weight per plant, curd size index and curd compactness whereas these were low for number of leaves per plant and dry matter content. The character ‘harvest index’ exhibited moderate PCV and low GCV values. Heritability estimates were higher for days to marketable maturity, stalk length, leaf size, gross weight per plant, marketable yield per plant, curd size index, curd

compactness and harvest index while moderate for number of leaves per plant and dry matter content. Genetic advance as per cent of mean was higher for leaf size, gross weight per plant and marketable yield per plant. High heritability coupled with high or moderate genetic advance observed for days to marketable maturity, stalk length, leaf size, gross weight per plant marketable yield per plant, curd size index, curd compactness and harvest index indicated the role of additive gene action for the inheritance of these traits. Hence, these traits could be improved through direct selection. On the other hand, moderate heritability along with low genetic advance was observed for number of leaves per plant and dry matter content indicated the role of non-additive gene action for the genetic control of these traits. Hence, the characters showing this type of behaviour are likely to respond to hybridization and heterosis breeding.

Correlation studies revealed that in general, genotypic correlations were more pronounced than the phenotypic correlations. The marketable yield per plant exhibited positive and significant associations with leaf size, gross weight per plant, curd size index, curd compactness and harvest index both at the phenotypic and genotypic levels, suggesting that above mentioned characters should be taken into consideration while exercising phenotypic selection for higher marketable yield per plant. Among component traits, positive and significant associations of days to marketable maturity and leaf size; stalk length and dry matter content; number of leaves per plant with harvest index and curd compactness; leaf size with gross weight per plant, curd size index, curd compactness and harvest index; gross weight per plant with curd size index, curd compactness and harvest index; curd size index with harvest index and curd compactness and curd compactness with harvest index either on phenotypic or genotypic level or on both levels were observed. The study also indicated negative and significant associations of days to marketable maturity with stalk length and dry matter content; stalk length with leaf size and leaf size with dry matter content.

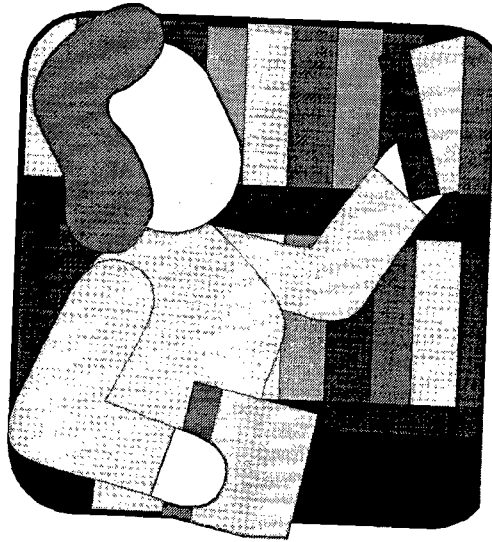
Results of the path coefficients indicated that at phenotypic level, all characters had exerted positive direct effects. However, the characters *viz.*, curd compactness, curd size index and gross weight per plant had the highest positive direct as well as indirect contribution towards marketable yield per plant. At genotypic level, gross weight per

plant, curd size index, number of leaves per plant, dry matter content and days to marketable maturity had positive direct effects on the marketable yield per plant, whereas harvest index, curd compactness, stalk length and leaf size exhibited negative direct effects.

So, an ideal mid-group cauliflower genotype producing high marketable yield per plant will be the one having traits like high curd compactness, curd size index and gross weight per plant.

Conclusion

Thus, the present study clearly indicated the existence of sufficient amount of genetic variability in the genotypes of mid-maturity cauliflower studied which could possibly be managed either through selection or hybridization or both. The genotypes namely DC-476, DC-401 and Sel-01 were superior or at par for gross weight per plant, marketable yield per plant, curd size index, curd compactness and harvest index when compared to standard check variety. The genotype, DC-476 exhibited high mean performance for marketable yield per plant and some of its component traits *viz.*, gross weight per plant, curd size index, harvest index and took less time to reach marketable maturity than the standard check. Hence, could be further tested for direct use as cultivars or can be used in future breeding programmes. Correlation studies indicated that marketable yield per plant could be improved by increasing leaf size, gross weight per plant, curd size index, curd compactness and harvest index while path coefficient analysis revealed that due importance has to be given for the characters namely curd compactness, curd size index and gross weight per plant while developing high yielding and horticulturally superior genotypes of mid-group cauliflower.



***L*iterature
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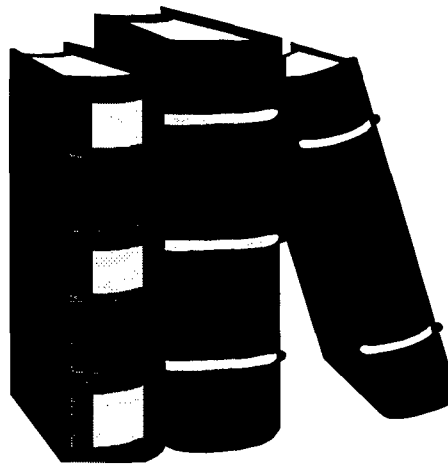
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***A**ppendices*

Appendix 1

Mean weekly meteorological data (23rd July to 31st December, 2009)

Week no.	Period	Temp.		RH (%)		Bright sunshine hours	Total rainfall (mm)	No. of rainy days
		Max.	Min.	M	E			
30	23--29	31.5	22.2	89	57	5.2	36	4
31	30-5 Aug.	31.5	22.1	87	46	6.8	4	2
32	6--12	32.6	22.4	86	46	6.7	11.2	2
33	13-19	30.7	22	89	50	4.4	25.2	4
34	20-26	30.4	18.1	87	48	8.3	0	0
35	27-2 Sep.	29.1	20.4	88	59	4.6	33.6	3
36	3--9	29.3	16	89	54	6.5	23.2	2
37	10--16	23.7	14.8	92	63	4	148.6	4
38	17--23	30.5	15.9	89	44	8.7	0	0
39	24-30 Sep.	31.3	18.1	88	49	7.9	0	0
40	1-07 Oct.	30.6	16.4	87	53	8.1	2.4	1
41	8--14	28.1	7.9	73	22	8.6	0	0
42	15-21	26.6	7.5	89	22	8.3	0	0
43	22-28	25.7	4.3	89	21	8.3	0	0
44	29-4 Nov.	26.3	4.7	89	25	7.4	0	0
45	5--11	23.3	4.8	88	38	6.2	27.4	2
46	12--18	20.1	6.3	91	43	5.4	24.4	5
47	19-25	19.8	1.7	89	33	5.6	0	0
48	26-2 Dec.	19	2.7	90	36	4.5	0	0
49	3-9	19.7	1.6	88	29	5.7	0	0
50	10-16	15.6	6.1	82	45	1.4	1.4	1
51	17-23	16.8	-0.7	89	29	4.8	0	0
52	24-31 Dec.	16.8	-0.4	88	26	4.7	0	0

Source: Meteorological observatory, CSKHPKV, HAREC, Bajaura

Brief Biodata of the student

Name : Manoj Kumar
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Mother's Name : Smt. Pawna Devi
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Educational qualification

Class	Month	Year	School/College	Board/University	Marks (%) / OCPA	Division
10 th	March	2000	Govt. High School, Bhatoli Phakorian	Himachal Pradesh Board of School Education, Dharamshala	66.57	First
12 th	September	2003	Private Candidate	Himachal Pradesh Board of School Education, Dharamshala	57.2	Second
B.Sc. in Agriculture	July	2008	College of Agriculture	CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur	6.73	First