GENETIC EVALUATION OF NEWLY INTRODUCED GENOTYPES OF CAULIFLOWER (*Brassica oleracea* var. *botrytis* L.)

Thesis

by

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CERTIFICATE-I

This is to certify that the thesis titled **"Genetic Evaluation of Newly Introduced Genotypes of Cauliflower (*Brassica oleracea* var. *botrytis* L.)"** submitted in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE (HORTICULTURE) VEGETABLE SCIENCE** in the discipline of **HORTICULTURAL SCIENCES** of Dr. Yashwant Singh Parmar University of Horticulture & Forestry, (Nauni) Solan (HP)– 173 230 is a bonafide research work carried out by **Ms Radhika Kapoor (H-2019-96-M)** daughter of Shri Mahajan Kapoor 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 fully acknowledged.

Place: Nauni-Solan
Date:

Dr Dharminder Kumar
(Major Advisor)

CERTIFICATE – II

This is to certify that the thesis titled, **"Genetic Evaluation of Newly Introduced Genotypes of Cauliflower (*Brassica oleracea*var. *botrytis* L.)"**, submitted by **Ms Radhika Kapoor (H-2019-96-M)** daughter of Shri Mahajan Kapoor to the Dr Yashwant Singh Parmar University of Horticulture & Forestry, (Nauni) Solan (HP) – 173 230 India in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (HORTICULTURE) VEGETABLE SCIENCE** in the discipline **of HORTICULTURAL SCIENCES** has been approved bythe Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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Place: Nauni, Solan
Dated: **(Radhika Kapoor)**

CONTENTS

LIST OF ABBREVIATIONS

%	:	Per cent
<	:	Less than
>	:	Greater than
/	:	Per
±	:	Plus or minus
×	:	Cross
ANOVA	:	Analysis of variance
C.V.	:	Coefficient of variation
CD	:	Critical difference
Cm	:	Centimetre
Cm^2	:	Square centimeter
d.f.	:	Degree of Freedom
et al.	:	co workers
L.	:	Linnaeus
Var.	:	Variety
G	:	Gram
g/cm	:	Gram/ Centimetre
GCA	:	General combining ability
H.P.	:	Himachal Pradesh
Ha	:	Hectare
i.e.	:	*id est* (that is to say)
Amsl	:	Above mean sea level
Me	:	Mean sum of squares due to error
Mr	:	Mean sum of squares due to replications
Mg	:	Mean sum of squares due to genotypes
^oC	:	Degree Celsius
pH	:	Pouvoir hydrogen
RH	:	Relative Humidity
Se	:	Sum of squares due to error
SE ± (d)	:	Standard error of difference
SE ± (m)	:	Standard error of mean
Sr	:	Sum of squares due to replications
Sg	:	Sum of squares due to genotypes
T	:	Number of treatments
T	:	Tonnes
UHF	:	University of Horticulture and Forestry
viz.	:	*Videlicet* (namely)
RHR&TS	:	Regional Horticulture Research &Training Station

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Chapter-1

INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis* L.) a commercially important vegetable crop belongs to the family Brassicaceae. Under a varied agro-climatic conditions, it is the most widely cultivated winter vegetable in the world. Boswell (1949) traced the origin of cauliflower to the island of Cyprus and its virtual spread to countries such as Syria, Turkey, Egypt, Italy, Spain, and North Western Europe. It is believed to have been descended from the wild cabbage (*B. oleracea var. sylvestris* L.) resembling the common kale found in Western Europe and North Africa (Allard, 1960 and Vilmorin, 1956). It has been rightly acclaimed as "Aristocrat of Cole crops" (Nimkar and Korla, 2014).

The cauliflower plant has a peculiar inflorescence that consists of thick, fleshy, heavily ramified flower stalks which form a compact, often almost spherical 'curd' (Joshi *et al*. 2000). The cauliflower curd is a pre-floral fleshy apical meristem in which the lateral buds of the shoot meristem are elongated and heavily branched, and the apices of these branches form the curd structure, of which more than 90% abort before flowering. Cauliflower is the only crop in group of cole crops in which the intermediate stage of curding lies between vegetative and reproductive stage (Nieuwhof, 1969). The majority of cauliflower cultivars are annuals that produce a head in the year of sowing in temperate zones. In addition, there are biennials, which do not reach the generative phase until after a period of low temperatures.

The edible portion i.e. curd is approximately 45 per cent of the plant weight (Rai and Yadav, 2005). It is generally consumed as cooked vegetable and also in form of vegetable curry, soup, pickles, rice, pizza crust or in dehydrated form (Savita *et al.* 2014 and Baloch *et al.* 2015). Cauliflower is a low-calorie food with good dietary fibre, abundant in vitamins (C, B, A, K) and minerals like phosphorus, potassium, sodium, calcium, iron, magnesium, manganese, and molybdenum (Salem *et al.* 2013). The curds are reported to contain high content of carotenoids, flavonoids, isothiocynates, indoles and tocopherols (Jahangir *et al.* 2009). Cauliflower has wide therapeutic applications such as anti-cancer (Lee *et al*. 2008 and Tang *et al*. 2008), anti-diabetic (Sharma and Prasad, 2018) and reduced risk of cardiovascular diseases (Ahmed and Ali, 2013). Its curd contains 1.9 per cent protein, 5 per cent carbohydrate, 95 per cent water, 48.2 mg vitamin C, 199 mg potassium/100 g of edible portion (Gopalan *et al.* 2011).

Globally cauliflower is grown in an area of 1417.81 thousand hectares with a production and productivity of 26,504 thousand metric tonnes and 18.69 metric tonnes per hectare, respectively (FAOSTAT, 2019). India is the second largest producer of cauliflower in the world after China having an area, production and productivity of 469 thousand hectares, 9103 thousand metric tonnes and 19.41 metric tonnes per hectares (NHB, 2019). Even though India fares better in productivity of cauliflower than world's figure, however the country has a potential productivity of 35-40 metric tonnes per hectare as achieved by top cauliflower producing countries of the world (Sharma *et al*. 2018) The leading cauliflower growing states in India are West Bengal, Bihar, Haryana, Gujarat, Assam, Uttar Pradesh, Karnataka, Tamil Nadu and Himachal Pradesh. The mid and high hills of Himachal are very potential zones for growing cauliflower. The high hills are most important to produce the seeds of late group (Snowball type) of cauliflower.

Cauliflower is a thermo sensitive crop with its own specific temperature requirements for growth and curding stages (Verma *et al.* 2017). Different maturity groups of Indian cauliflower have been classified based on the specific temperature requirements for curd initiation and development, viz., early, mid-early, mid-late, and late. Aside from cultivating Indian cauliflower groups, Himachal Pradesh's hilly terrains are ideal for cultivating and seed production of temperate types (Erfurt's and Alpha strains), commonly known as the Snowball group. (Singh and Sharma, 2001). In Himachal Pradesh, the area and production of cauliflower is 5.92 thousand hectares and 129.58 thousand metric tonnes, respectively with the average productivity of at 21.89 metric tonnes per hectare which surpasses the international as well as national average productivity. The top five districts of Himachal Pradesh leading in cauliflower production are Shimla, Mandi, Lahaul Spiti, Kullu and Kangra (Anonymous, 2019).

The nature and extent of genetic variability in available germplasm suggest the possibility for selection to improve various characteristics. Farmers will be able to grow a cauliflower variety that is better suited to HP's low-lying areas as a result of this research. As a result, an attempt was made to estimate the extent of genetic variability and character association among different genotypes of cauliflower obtained from various sources under low hill conditions of Himachal Pradesh.0

OBJECTIVES

i) To estimate the magnitude of genetic variability for yield and its contributing traits in different genotypes of Cauliflower.

ii) Determination of association of yield and different horticultural traits.

Chapter-2

REVIEW OF LITERATURE

The following subheadings review the literature available in cauliflower on genetic evaluation studies:

2.1 Variability Studies

2.2 Correlation and Path analysis studies

2.3 Heritability and Genetic advance

2.4 Quality Characters

2.1 Variability Studies

Plant improvement programs are built on the foundation of genetic variability. If there is enough genetic diversity, it can be used to grow superior cultivars. Vavilov (1951) was the first to recognise that a greater range of variability in any crop allows for better selection of desirable varieties.

Singh *et al*. (2006) concluded highest variability was found in leaf size, curd weight without guard leaves, and curd weight with guard leaves. The genotypes were mainly divided at the first node into clusters of seven and twenty-three genotypes in different classes, according to multivariate cluster analysis using Ward's process.

Dhatt and garg (2008) performed an experiment different cauliflower genotypes and found that marketable, net, and gross curd weight all had a lot of genetic variation, while days to curd maturity was the least variable character in november maturing cauliflower genotypes.

Singh *et al*. (2010) studied 45 different cauliflower genotypes. For all of the characters, the phenotypic coefficient of variation was greater than the genotypic coefficient of variation. It alluded to the influence of the setting on character speech. The heritability of plant height and whole plant weight was higher, as was the genetic advance, indicating additive gene effects. High heritability and low genetic advance were found in plant spread and curd diameter, indicating non additive gene effects.

Kumar *et al.* (2011) found substantial variations between genotypes in early Indian cauliflower and indicated that yield and quality character variability was adequate. With respect to yield and quality characteristics, the genotypes DC-98-4, DC-98-10, and DC-124 were found to be superior. The phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) in the aggregate. The highest heritability was found for days to 50% curd formation (0.992). Curd compactness and net curd weight were estimated to have a high heritability as well as a high genetic advance as a percentage of the mean.

Mehra and Singh (2013) evaluated seven germplasm lines of cauliflower during the year 2010 for estimating genetic variability for curd yield per hectare and its contributing characters revealed that the genotypic and phenotypic coefficient of variation were lowest in days to 50 per cent curd initiation. Plant diameter showed highest heritability (99.99 per cent) with medium genetic advance (24.04) and moderate genetic advance as percentage of mean (29.79 per cent). They found that characters were very important while making selection for high yielding genotypes.

Singh *et al*. (2013b) evaluated 17 genotypes of cauliflower to study the magnitude of genetic variability and character association for growth, yield and quality traits. The current study found that for most traits, both the phenotypic and genotypic coefficients of variation (PVC and GCV) were higher, indicating that environmental influences had a significant impact on the characteristics. For vitamin C, the genotypes Pusa Snowball K-1, PusaSharad, and Pusa Hybrid-2 had the highest genotypic co-efficient of variability, whereas the genotype K-1 had the lowest genotypic and phenotypic coefficient of variability for number of leaves per plant.

Santhosha *et al*. (2014) evaluated the morphological characterization of 51 cauliflower genotypes for horticultural traits. High coefficients of variation (C.V.) were found for yield features such gross curd weight (26.03%), net curd weight (26.02%), and curd size index (24.95%) among fifty one early cauliflower genotypes defined, indicating that these qualities should be given top importance during selection. For the above metrics, genotypes IIHR-272, IIHR-263, IIHR-266, and IIHR-390 performed better, therefore these lines were employed directly for cultivation or as a source of favourable traits in a breeding programme to increase curd yield and quality in cauliflower.

Chittora and Singh (2015) studied genetic variability for 18 quantitative characters and 5 qualitative characters in 40 genotypes of early cauliflower. Except for days to curd initiation, days to curd maturity, and curd depth, analysis of variance revealed significant variations between genotypes for all of the characters. PCF-95, PCF-106, Inb-9-5, and Inb-10-1 genotypes were found to be promising as they had many desirable quantitative and qualitative traits. PCF-95 recorded highest curd yield per hectare (271.87q), while PCF-101 had the earliest curd maturity (115.33 days).

Gaur and Singh (2016) studied variability for yield and quality characters in cauliflower. The overall values of phenotypic coefficient of variation (PCV) were higher than those of genotypic coefficient of variation (GCV). The highest estimate of genotypic coefficient of variation (GCV) was observed for curd size index followed by marketable curd weight, while highest heritability was recorded for plant diameter.

Vanlalneihi *et al*. (2017) evaluated 15 genotypes of cauliflower belonging to mid group in replicated yield trials. Observations on 15 characters revealed significant genetic diversity that could be exploited in breeding programmes, as evidenced by the broad range of traits observed. Plant height, leaf length, leaf width, number of leaves per plant, curd angle, curd diameter, , net curd weight, marketable curd weight and yield all had high heritability (60%) and high genetic advance as percent of mean (20%), indicating the prevalence additive variance and thus direct selection for improvement of specific traits. The genotypes with the highest net curd weight and the greatest positive contribution to curd yield should be taken into consideration, according to path coefficient analysis.

Ansari (2017) studied genetic variability, correlation and path coefficients in 10 genetically diverse genotypes of mid-group cauliflower. The field experiment was conducted in randomized block design with three replications at the experimental farm under All India Co-ordinated Research Project on Vegetable Crops at Horticultural Research cum Institutional Farm, Indira Gandhi Krishi Vishwavidalaya, Raipur (C.G.) during the year 2016-17. Data were analysed as per standard Statistical procedures. A perusal of results revealed that phenotypic coefficients of variation were slightly greater than genotypic coefficients of variation. The phenotypic and genetic coefficients of variation were high for traits viz., marketable curd weight, gross plant weight, net curd weight and marketable curd yield. The genotypes namely 2016/CAUMHYB-10 was found to be promising for marketable yield per plant and other component traits viz., gross weight per plant, curd size index.

Among the traits, curd yield per plot, curd size index and gross weight per plant should be given emphasis for developing high yielding and horticulturally superior genotypes of mid-group cauliflower.

Kumar *et al*. (2017) examined genetic variability in 57 genotypes of mid-season cauliflower for 16 quantitative parameters. Except for plant spread, curd length, and curd size index, analysis of variance revealed significant differences for the bulk of the characters. INBPCF 120, 2013/CAUMVAR-6, PCF-93, PG-5, PCF-7, and INBPCF117 genotypes were identified to be more promising because they possessed multiple desired features. PCF-29 had the shortest days to maturity, but INBPCF 120 had the highest curd yield per hectare (192.5 q) (85). For stalk length, gross plant weight, net curd weight, marketable curd weight, harvest index, and curd size index, significant phenotypic and genotypic coefficients of variation (PCV and GCV) were observed. For number of leaves per plant and days required to maturity, the lowest coefficient of variation (PCV and GCV), heritability in a wide sense, genetic advance, and genetic advance as a percent of mean were recorded.

Sharma *et al.* (2018) examined 25 genotypes of cauliflower for yield and several yield contributing morpho-physiological components in late cauliflower. The presence of significant genetic diversity among the genotypes was shown by the analysis of variance, which revealed that mean squares due to genotypes were significant for all traits. Days from transplanting to curd initiation, date of transplanting to days to marketable curd maturity, curd compactness, curd solidity, and harvest index were found to be superior in the hybrids H1 and H4, while marketable yield per plant, gross weight per plant, and curd diameter were found to be comparable in the standard check Madhuri. For all hybrids except H5, the position of leaves was categorised as Type No. 3 based on visual observation, but the majority of hybrids had semi-incurving leaves to protect them from curd. In terms of curd quality, most of the hybrids had a white colour and were not ricey, which is good for selection.

Zhu *et al*. (2018) studied the phenotypic diversity of 165 cauliflower inbred lines based on ten quantitative and twenty qualitative traits at the Experimental Farm of Wenzhou Academy of Agricultural Science, Wenzhou, Zhejiang Province of China. Extensive variability was observed for most quantitative and qualitative traits.

Topwal *et al*. (2019) evaluated genetic variability in cauliflower crop germplasm, which is essential for any successful breeding programme. Because phenotypic selection was dependent on the range of genetic variability present in the population, determining the magnitude of genetic variability and the extent of heritability of desirable characteristics was critical to improving this crop. The competence to determine the scope for selecting desirable genotypes was improved by studies on the level of variability present in the germplasm. As a result, an attempt was made to investigate the genetic variability across various cauliflower genotypes' horticultural traits.

Nandhini *et al*. (2020) experimented on 13 broccoli genotypes under Randomized Block Design with three replications to assess the genetic variability, heritability and genetic advance for various horticultural traits. For all fourteen traits, analysis of variance revealed that there was considerable variability among genotypes. Leaf length (23.89 and 24.25), curd weight/plant (35.34 and 35.47), and curd yield (33.67 and 34.85) all had high genotypic and phenotypic coefficients of variation. High heritability combined with high genetic advance as percent mean were found for number of leaves (89.60 and 29.08 per cent), leaf length (97.00 and 48.47 per cent), leaf width (84.60 and 24.74 per cent), days to curd initiation (91.50 and 20.74 per cent), curd length (97.00 and 30.36 per cent), curd width (98.10 and 41.07 per cent), curd weight/plant (99.20 and 72.52 per cent), curd yield (93.40 and 67.02 per cent) and ascorbic acid (96.70 and 24.68 per cent).

2.2 CORRELATION AND PATH ANALYSIS STUDIES

Correlation coefficient is a measure of the degree of association between the two traits (Hayes *et al.* 1955). The phenotypic correlation coefficient, which includes both hereditary and environmental influences, indicates the extent of the observed relationship between two characters, while the genotypic correlation coefficient, which can be useful for selection, indicates the true association between the two characters (Johnson *et al.* 1955). Thamburaj *et al.* (1982) observed significant and positive correlation of plant weight with the curd yield, plant weight and foliage weight and between number of leaves and leaf area. Dewey and Lu (1959) were the first to propound the use of path coefficient analysis in breeding programmes.

Kalia *et al*. (2010) reported that total yield had significant positive correlation with net curd weight and harvest index. However, on the other hand yield was negatively correlated with duration of curd availability and days to 50% curd formation. Path coefficient analysis revealed that net curd weight and curd compactness had the highest positive contribution towards the total yield respectively.

Kumar *et al*. (2011) found substantial differences among genotypes of early Indian cauliflower, indicating that there is enough variability for yield and quality traits. In terms of yield and quality traits, the genotypes DC-98-4, DC-98-10, and DC-124 were found to be superior. The net curd weight and harvest index revealed a substantial positive correlation with total yield. Yield, on the other hand, was negatively correlated with curd availability and days to 50% curd formation. Net curd weight and curd compactness had the highest valuable impacts to total yield, according to path coefficient analysis.

Sheemar *et al*. (2012) studied correlation coefficients and their direct and indirect effects on several economic characteristics of cauliflower grown on the North Indian plains. Net curd weight was significantly and positively correlated with total plant weight, according to phenotypic and genotypic correlation coefficient estimates. According to path analysis of correlation coefficients, total plant weight had the highest positive direct effect on net curd weight, harvest index, and curd depth.

Nimkar and Soniya (2013) found that net curd weight was positively and significantly correlated with gross curd weight and gross curd weight was positively and significantly associated with plant frame, number of leaves per whorls and net curd weight. Net curd weight had the highest direct and beneficial effect on gross curd weight in both progenies. Gross curd weight had the highest positive direct effect on net curd weight in both progenies.

Singh and Dogra (2013) evaluated biometric traits in cauliflower (*Brassica oleracea* L. var. *botrytis* L.). Net and gross curd weight were found to have a significant positive correlation, followed by net curd weight and leaf area. Plant frame and leaf area showed a positive significant relationship with days to curd maturity. The most important feature was found to be gross weight, which was useful in both direct and indirect selection of superior genotypes with high net curd weight.

Jha *et al.* (2014) performed correlation and path coefficient analysis on ‘Pushi’ variety of cauliflower. Significant positive correlation of yield with all the horticultural characters namely curd diameter, curd weight, curd depth, number of leaves, leaf area, plant spread and plant height was acknowledged. Maximum direct positive effect of leaf count followed by plant height, curd weight and curd depth on yield was calculated. Whereas negative effect was due to leaf area, curd diameter and plant spread.

Singh *et al.* (2014) studied correlation and path coefficient analysis on 'Pushi' variety of cauliflower. Yield was found to be highly and significantly positively correlated with all the ancillary characters curd weight, number of the leaves, leaf area, curd diameter, plant spread and height and curd depth. All the ancillary characters showed significantly positive correlations among themselves. The path coefficient analysis values also indicated that the maximum positive direct effect accrued due to leaf count followed by curd weight, plant height and curd depth.

Kannan *et al.* (2015) conducted study on correlation coefficients for 12 characters in various genotypes of cauliflower. The positive and significant association of yield was observed with all the characters in genotypes in curd weight significant and positive correlation with curd length, number of leaf, plant height, leaves per plant, petiole length, days to curd formation and days to fifty per cent maturity.

Gaur and Singh (2016) studied correlation coefficient in cauliflower and revealed that total yield had significant positive genotypic and phenotypic correlation with marketable curd weight, followed by net curd weight and curd depth. However, yield was negatively genotypic correlated with plant diameter. Path coefficient analysis revealed that marketable curd weight and days to curd initiation had the highest positive contribution towards the total yield.

Ansari *et al.* (2017) studied that the genotypic correlation coefficient was higher than the corresponding phenotypic correlation coefficient for all the traits in cauliflower. Curd yield per hectare was found to be highly positive and significantly correlated with marketable curd and net curd weight, curd diameter, number of leaves per plant, and gross plant weight based on phenotypic and genotypic correlation estimates. Net curd weight had a high positive direct effect on total yield, but harvest index had a negative direct effect on curd yield per hectare, according to path coefficient analysis.

Kumar *et al.* (2017) evaluated 57 genotypes of cauliflower for correlation coefficient and path coefficient analysis. For all of the parameters, the genotypic correlation coefficient was higher than the phenotypic correlation coefficient. Curd yield per hectare was found to be highly positive and significantly correlated with marketable and net curd weight, curd diameter, number of leaves per plant, and gross plant weight based on phenotypic and genotypic correlation estimates. Net curd weight had a significant positive direct effect on total yield, but harvest index had a negative direct effect on curd yield per hectare, according to path coefficient analysis.

Vanlalneihi *et al*. (2017) observed positive and significant correlation between all the horticultural traits like plant height, marketable curd weight, curd polar diameter, curd yield and net curd weight. Both phenotypically and genotypically, there was a significant and positive correlation between curd polar and equatorial diameter and marketable curd weight and net curd weight. Net curd weight had the most direct and beneficial impact on curd yield.

Chatterjee *et al.* (2018) studied correlation which revealed that marketable yield per plant was positively and significantly associated with gross weight per plant, days to marketable curd maturity, curd solidity, curd size index, curd depth, leaf number per plant and stalk length whereas negatively and significantly with leaf size index. The path coefficient analysis depicted that leaf number per plant had the maximum positive direct effect on marketable yield per plot.

Sharma *et al*. (2018) conducted the investigation during the 2014-15 rabi season to determine the heterogeneity, heritability and genetic progression in the cauliflower. Curd solidity has high PCV and GCV values, indicating that there is plenty of possibility for improvement through selection. The phenotypic coefficient of variation (PCV) was considerably higher than the genotypic coefficient of variation (GCV) for several parameters, indicating apparent heterogeneity owing to genotypes in addition to environmental effect. Through the identification of these traits, the importance of additive gene activity was highlighted for improvement.

Gulyas *et al*. (2019) evaluated genotypes of cauliflower (Abeni, SV577AC and Telergy F1) on the basis of different growing methods such as plastic tunnel and on open field. The curd's width and height were determined using the data collected. In comparison to plastic tunnels, open field conditions resulted in broader curds with longer ends, resulting in lower product consistency and poorer parameter correlation. The relationship between several morphological features was evaluated using plastic tunnel correlation analysis. Therefore, on the open field, the mean of the varieties with various consistency characteristics was found to be higher than in the plastic tunnels. The curds generated in the covered environment were of greater quality and yielded superior results.

Refai *et al*. (2019) assessed correlation coefficients during three consecutive winter seasons. All of the undertaken characteristics' genetic association coefficients were low and negatively associated with days to harvest, while high and positively correlated with curd diameter.

Singh *et al*. (2019) found a strong and significant positive relationship between yield and all other horticultural parameters, including curd depth (0.9180), curd weight (0.8990) and plant weight (0.8990). The experiment was carried out on the cultivar Pusa Deepali.

2.3 HERITABILITY AND GENETIC ADVANCE

Mehra (2012) found that plant diameter has the maximum heritability (99.99 %). Heritability below this accounted for leaf length, leaf width and plant height, while curd depth had the lowest (70.17 %).

Mehra and Singh (2013) demonstrated lowest heritability and genetic advance of curd depth during evaluation of 7 germplasm lines of cauliflower. Maximum heritability and medium genetic progress were accounted for by 99.99 % and 24.04 %, respectively.

Singh *et al*. (2013) studied 16 genotypes of cauliflower for the estimation of heritability and genetic advance. According to his study, curd weight and vitamin C have high broad sense heredity, but stem diameter has moderate broad sense heredity. High heritability with genetic advance was also observed for curd weight.

Soni *et al*. (2013) evaluated high broad sense heritability for days to maturity (98.90%), leaf width (83.40%), yield (87.20%), head weight (87.30%) and leaf length (83.20%) whereas characters like stalk length (71.20%), plant height (78.20%) and number of non wrapper leaves (66.00%) showed moderate heritability. For plant spread in cabbage, the genetic advance ranged from 6.04 % to 50.09 %.

Chittora and Singh (2015) completed their research by determining the curd maturity with the lowest heritability, coefficient of variance, and genetic progress. Net curd weight, curd yield, gross plant weight, and harvest index all showed broad sense heritability.

Vanlalneihi *et al.* (2017) observed high heritability accompanied with high genetic advance (>60 and >20 per cent) in characters like plant height, leaf number, length and width of leaf, curd diameter, marketable and net curd weight and yield. His research revealed that additive variance was frequent therefore direct selection was used to improve traits in a unique way.

Kaur *et al*. (2018) found that curd diameter, harvest index, curd yield, gross plant weight, curd depth and leaf length had high heredity estimates while stalk length (76 %) and plant height have moderate heredity values (71 %). The highest genetic advance was found in net curd weight (45.96 %) and curd yield was moderate.

Kumar *et al*. (2018) studied heritability and genetic advance in an experiment of 19 genotypes of cauliflower. Characters including net and marketable curd weight, curd compactness, and harvest index showed the combined effect of high heritability and genetic advance. This demonstrated the importance of additive gene action in selection-based productivity improvement.

Chatterjee *et al*. (2018) studied the nature of heritability and genetic gain in 20 mid late and late cauliflower genotypes during rabi season. In addition to high genetic gain (53.51) the curd size index also had a high heritability (95.99). Curd size index had high heritability (95.99) besides high genetic gain (53.51). High heritability (95.99) with moderate genetic gain was observed in curd depth, number of leaves per plant, gross curd weight and marketable yield per plant. This resulted in a greater level of transmissibility of these characteristics.

Kumar *et al*. (2019) presented supplementary role of heritability and genetic advance in curd diameter, net curd weight, curd yield, marketable curd weight and gross curd weight. Except for the number of leaves per plant (43.75) and stalk length (49.51), the most of the characters showed high broad sense heritability. The genetic advance of net curd weight (75.19), marketable curd weight (57.63), curd yield (55.56), harvest index (46.43), and gross curd weight (39.36) was high thereby suggested selection for crop improvement.

Refai *et al*. (2019) studied genetic advance and heritability in cauliflower for three consecutive winter seasons from 2015 to 2017. He showed that several factors affect the genetic advance of a trait under selection. Total variation, selection pressure, and heritability were all incorporated in. With selection of 1.72 % in C1 and 2.54 % in C2, a new record for curd maturity was accomplished with high heritability (95 percent). Curd diameter showed lower genetic advance values.

Singh *et al.* (2019) worked out on the role of additive and non additive gene action in cauliflower resulted due to high heritability and genetic advance in CUPRAC, FRAP, carotenoids and high heritability and low genetic advance in ascorbic acid. In the presence of high heritability, more genotypic variance and less environmental effect lead to significant phenotypic variation.

2.4 QUALITY CHARACTERS

2.4.1 Leaf Colour

Singh *et al.* (2013) evaluated 15 cauliflower genotypes and divided them into three groups based on leaf colour: light green, dark green, and bluish. Except for Pusa Paushja, which had bluish leaves, the majority of the cultivars were found to be light and dark green leaves.

Santhosha *et al.* (2014) evaluated 51 genotypes of cauliflower and observed that majority of the genotypes had glossy dark green leaves.

2.4.2 Curd Colour

Kalpana (2006) showed that KT-25 was the only genotype having completely snow white curds, while Lawyana was the only genotype with completely dull curds. The majority of cultivars produced curds which were either snow white or white in colour.

Kanwar and Korla (2002) observed that out of 20 biparental progenies white colour of the curd was exhibited by majority of the biparental progenies except 3, 4 and 10 which gave white to creamish yellow colour.

Singh *et al.* (2013) reported that out of 15 genotypes Pusa Paushja, Pusa Sharad, PSBK-1 and PSBK-25 exhibited white colour whereas, rest of the varieties showed creamy white colour

Chatterjee *et al.* (2018) observed snow white curds in the genotypes Hermia, Kt-25, Kt-20, Snowball-16, DC-76, EC-683461, Pusa Himjyoti, PSBK-I. White curd was produced by the genotypes UHF-C-2, Palam Uphar, King King, EC-683466, EC-162587, Kt22, Sel-I, Sel-II, Pant Shubhra. Kt-19, Mukutamani, and Kt-18 were the only germplasms that produced dull-colored curds.

Sharma *et al*. (2018) observed that out of 25 hybrids, H 3, H 10, H 11 and H 22 were snow white in colour and rest of the hybrids showed white coloured curds.

2.4.3 Curd Compactness

Singh *et al*. (2013) classified Pusa Deepali and Pusa Himjyoti as medium compact varieties whereas Pusa Snowball K-25 as compact variety.

Chittora *et al.* (2016) revealed that out of 35, seventeen genotypes had compact curd while remaining eighteen genotypes possessed loose curd.

Shree *et al*. (2019) found wide variation in curd compactness while analysing variance for 13 genotypes of cauliflower.

2.4.4 Riceyness

Kanwar and Korla (2002) concluded that majority of the biparental progenies showed non-ricey curds however 3, 4 and 18 gave considerable percentage of ricey curds.

Sharma *et al.* (2018) recorded that all the curds of twenty five hybrids were free from riceyness except one hybrid i.e. H 5 exhibited ricey curds.

Chittora *et al*. (2016) recorded riceyness in nine genotypes while it was absent in other twenty genotypes.

Chapter-3

MATERIALS AND METHODS

The current investigation accredited "**Genetic Evaluation of Newly Introduced Genotypes of Cauliflower (*Brassica oleracea* var. *botrytis* L.*)***" was carried out during winter 2020-21 at the experimental farm of Regional Horticultural Research & Training Station, Jachh (Nurpur), District- Kangra, Himachal Pradesh. The details of experimental materials used and procedures followed during the course of investigation have been described below:

3.1 GENERAL FEATURES OF EXPERIMENTAL SITE

3.1.1 Location

The experimental Farm of the Research Station Jachh, Nurpur is situated on Pathankot- Mandi highway at an altitude of 428 m above mean sea level lying between 32° 18' N latitude and longitude of 75° 55' E under sub- mountain low hill sub tropical areas, zone 1 of Himachal Pradesh, India. The field evaluation of the genotypes were carried out in the Experimental farm of the research station.

3.1.2 Climate

Research station experiences low hill sub tropical agro- climatic conditions with mild climate during summers and low temperatures in winters. The temperature goes as high as 43.50°C in summers and as low as -0.1°C during winter months. The mean annual rainfall experienced in this area is 1500mm. However, the mean summer and winter temperatures average at 29.30°C and 13.60°C, respectively.

3.1.3 Soil

The soil of the experimental farm was sandy loam to clayey loam with pH of nearly 6.8.

3.2 EXPERIMENTAL MATERIAL

The experimental material for the present investigation carried out comprised of 24 genotypes of cauliflower (*Brassica oleracea* var. *botrytis* L.) out of which two are commercially grown cultivars PSBK-1 (Check) and Pusa Shukti from IARI, Regional Station, Katrain, Kullu valley, Kullu (H.P) and IARI, New Delhi respectively. These genotypes were transplanted on 04.11.2020 during 2020 in a Randomized Block Design with three replications at a spacing of 60 cm × 45 cm. Recommended package of practices were followed during growth period of the crop. The list of genotypes along with source is as under.

Sr. No	Name of genotypes	Source
1	EC-162587	IARI,Regional Station, Katrain
2	EC-656627	IARI,Regional Station, Katrain
3	EC-683451	IARI,Regional Station, Katrain
4	EC-683455	IARI,Regional Station, Katrain
5	EC-690942	IARI,Regional Station, Katrain
6	EC-690967	IARI,Regional Station, Katrain
7	EC-702493	IARI,Regional Station, Katrain
8	EC-716550	IARI,Regional Station, Katrain
9	EC-716613	IARI,Regional Station, Katrain
10	EC-716638	IARI,Regional Station, Katrain
11	EC-716642	IARI,Regional Station, Katrain
12	EC-716672	IARI,Regional Station, Katrain
13	EC-716673	IARI,Regional Station, Katrain
14	EC-716679	IARI,Regional Station, Katrain
15	EC-791397	IARI,Regional Station, Katrain
16	EC-808731	IARI,Regional Station, Katrain
17	EC-808737	IARI,Regional Station, Katrain
18	EC-808738	IARI,Regional Station, Katrain
19	EC-808748	IARI,Regional Station, Katrain
20	EC-808750	IARI,Regional Station, Katrain
21	EC-808779	IARI,Regional Station, Katrain
22	PUSA SHARAD	IARI, New Delhi
23	PUSA SHUKTI (C)	IARI, New Delhi
24	PSBK-1 (C)	IARI,Regional Station, Katrain

(C)Check Cultivars

3.3 SEED SOWING AND NURSERY

The seed sowing of all genotypes was carried out on 29.09.2020 in raised bed nursery. Recommended cultural practices were followed for raising the healthy nursery.

3.4 EXPERIMENT DESIGN AND LAYOUT

The experiment was laid out in the Randomized Complete Block Design involving three replications. The experiment was held during winter season. The details of experimental layout are given below:

Plate 1. View of experimental field at RHR&TS, Jachh

- **Number of genotypes:** 24 (including 2 checks)
- **Date of sowing:** 29^{th} September, 2020
- **Date of Transplanting:** 4^{th} November, 2020
- **Design:** Randomized Complete Block Design (R.C.B.D.)
- **Replication (s):** 3
- **Spacing:** 60 cm × 45 cm.
- **Plot Size:** 3 m × 1.8 m
- **Number of plants per plot:** 20

The standard cultural practices for raising a healthy crop of cauliflower as recommended in the "Package of Practices" for Vegetable Crops, published by the Directorate of Extension Education, YSPUHF, Nauni, Solan (HP) was followed during the course of investigation.

3.5 OBSERVATIONS RECORDED

Observations with respect to following characters were recorded on five randomly selected plants from each plot and their means were worked out for statistical analysis.

3.5.1 Plant height (cm)

The height of each plant were measured from the ground level to the tip of the highest leaf at the time of curd harvest and mean was worked out.

3.5.2 Days to 50 per cent marketable maturity

The number of days taken were counted from the date of transplanting to the date when 50 per cent plants had attained the marketable curd size.

3.5.3 Number of leaves per plant

Fully grown leaves of five plants per plot were counted at the time of curd maturity,

3.5.4 Leaf length (cm)

Lengths of fully developed leaves from different whorls of randomly selected five plants were recorded and mean values were calculated.

3.5.5 Leaf breadth (cm)

Leaf breadth of fully developed leaves from different whorls of randomly selected five plants per plot were recorded where it was maximum and mean value were calculated.

3.5.6 Leaf size index (cm^2)

The length and maximum breadth of five leaves from selected plants were measured in centimetres at the time of marketable curd maturity. The product of the average length and breadth was taken as leaf size index.

3.5.7 Plant Frame (cm^2)

Maximum width of plant measured at the widest part from leaf tip to leaf tip both in East West and North South direction were recorded and multiplied to get the average.

3.5.8 Stalk length (cm)

Stalk length were measured from first secondary root level to the position of first leaf whorl.

3.5.9 Curd equatorial length (cm)

Five randomly selected curds at maturity were cut into equal half and curd width measured with measuring scale on the broadest side from one end to the other.

3.5.10 Curd polar length (cm)

Five randomly selected curds at maturity were cut into equal half and curd length measured with measuring scale from top inflorescence bud to the point of emergence of first inflorescence segment.

3.5.11 Curd size index (cm^2)

The equatorial length and polar length of the curd were multiplied to get the curd size index (cm^2)

3.5.12 Curd solidity (g/cm)

It was measured as the ratio of net curd weight and curd (polar) length.

3.5.13 Gross plant weight (g)

The whole plant weight including weight of curd along with leaves and stalk were recorded for randomly selected plants and average worked out.

3.5.14 Marketable curd weight (g)

After trimming all the leaves while keeping intact whorl of leaves which terminated up to the level of curd and removing the stalk, the marketable curds were weighed to record the weight in grams.

3.6 QUALITY TRAITS

3.6.1 Leaf colour

Leaf colour was observed visually and genotypes grouped into three categories:

i) Light green
ii) Dark green
iii) Bluish green

3.6.2 Curd colour

Curd colour was observed visually and grouped into four classes: -

i) Snow white
ii) White
iii) Creamy white
iv) Purple

3.6.3 Curd compactness

It was observed by applying thumb pressure and genotypes grouped into three categories:

i) Loose
ii) Medium
iii) Compact

3.6.4 Riceyness

It was observed visually and genotypes grouped into two categories:

i) Absent
ii) Present

3.7 STATISTICAL ANALYSIS

3.7.1 Analysis of Variance (ANOVA)

Experiments were conducted in three replications with appropriate control. Results were statistically analysed by using Randomized Complete Block Design given by Gomez and Gomez, (1984). The analysis of variance (ANOVA) for RBD shall be as follows:

ANOVA for RCBD shall be as follows:

Source of Variation (SV)	**Degree of Freedom (df)**	**Sum of Square (SS)**	**Mean Sum of Square (MSS)**	**Calculated F value**
Replication (r)	r-1	Sr	Sr/(r-1) =Mr	Mr/Me
Genotypes(g)	g-1	Sg	Sg/(g-1) =Mg	Mg/Me
Error (e)	(r-1) (g-1)	Se	Se/(r-1) (g-1) =Me	

Where,

r = Number of replications

g = Number of genotypes

Sr = Sum of squares due to replications

Sg = Sum of squares due to genotypes

Se = Sum of squares due to error

Mr = Mean sum of squares due to replications

Mg = Mean sum of squares due to genotypes

Me = Mean sum of squares due to error

The calculated 'F' values were compared with tabulated 'F' values whenever, values was found significant, Critical Difference (CD), Standard Error (SE) and Coefficient of Variation (CV) was calculated to find out the superiority of one entry over the others.
The standard error and critical differences shall be calculated as follows:

$$SE(m) \pm = \sqrt{Me/r}$$

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

$$CD_{(0.05)} = SE(d) \times t_{(0.05)} \text{ at error degree of freedom}$$

Where,

SE (m) ± = Standard error of mean

SE (d) ± = Standard error of difference

$CD_{(0.05)}$ = Critical difference at 5% level of significance

All the earlier characters which showed significant differences among the genotypes were subjected to analysis for the following parameters.

3.7.2 Coefficient of variability
3.7.3 Heritability
3.7.4 Genetic Advance
3.7.5 Genetic Gain
3.7.6 Correlation coefficients
3.7.7 Path coefficients analysis

3.7.2 Coefficient of variability

Variability for different characters was estimated as suggested by Burton and De Vane (1953). The coefficient of variability at genotypic (GCV), phenotypic (PCV), and environmental (ECV) levels were estimated as follows:

a) Phenotypic Coefficient of Variation (PCV)

$$\text{PCV (\%)} = \frac{\sqrt{\text{Phenotypic Variance (Vp)}}}{\text{General Mean of Population (GM)}} \times 100$$

b) Genotypic Coefficient of Variation (GCV)

$$\text{GCV (\%)} = \frac{\sqrt{\text{Genotypic Variance (Vg)}}}{\text{General Mean of Population}} \times 100$$

Where:

V_e = M_e

V_g = Genotypic variance $(M_{g-} M_e)/r$

V_p = Phenotypic variance $(V_g + V_e)$

For categorizing the magnitude of PCV and GCV for different parameters the following limits were used (Sharma, 1994):

PCV and GCV	>30%	High
	15-30%	Moderate
	<15%	Low

3.7.3 Heritability

Heritability in broad sense was calculated by the formulae as suggested by Burton and De-Vane (1953) and Allard (1960).

$$\text{Heritability (\%)} = \frac{Vg}{Vp} \times 100$$

Where,

V_g = Genotypic variance $[V_g = (M_g\text{-}M_e)/r]$

V_p = Phenotypic variance $(V_{g\,+}V_e)$

The following categorization was made as given by Sharma, (1994) w.r.t heritability:

Heritability	>80%	High
	50-80%	Moderate
	<50%	Low

3.7.4 Genetic Advance

The expected genetic advance (GA) which resulted from selecting five per cent superior individuals was calculated by Allard (1960).

$$\text{Genetic Advance} = H \times \sigma p \times K$$

Where,

H = Heritability (%)

Σp = Phenotypic standard deviation

K = Selection differential at 5% selection intensity K = 2.06

3.7.5 Genetic gain

Genetic gain is calculated by per cent ratio of genetic advance and population mean as per suggested by Johnson *et al.* (1955).

$$\text{Genetic Gain (\%)} = \frac{GA}{GM} \times 100$$

Where,

GA = Genetic advance

GM = Population mean

The genetic gain as per cent over mean was classified as below (Sharma, 1994)

Genetic Gain	>50%	High
	25-50%	Medium
	<25%	Low

3.7.6 Correlation Coefficients

The correlation coefficients (genotypic and phenotypic) were calculated by the method of analysis of variance and covariance matrix as per Al-Jibouri *et al*. (1958) which involved splitting of total variability into replications, genotypes and errors. All the components of variance were calculated from the analysis of variance table and those of co-variance from the analysis of co-variance as given below:

Source of Variation	**Degree of Freedom**	**Mean sum of square**		**Variation Ratio (F- value)**
		X	**Y**	
Replication (r)	(r-1)	Mrx	Mry	Mrxy
Genotypes (g)	(g-1)	Mgx	Mgy	Mgxy
Error (r)	(r-1) (g-1)	Mex	Mey	Mexy

Genotypic and phenotypic co-variances between X and Y characters were worked out as under:

Genotypic variance (V_g) = (M_g- M_e)/r

Phenotypic variance (V_p) = (V_g + V_e)

1. Phenotypic correlation coefficient between characters x and y :

$$rp = \frac{Vpxy}{\sqrt{Vpx \times Vpy}}$$

Where:

Vpxy = Phenotypic co- variance between x and y

Vpx = Phenotypic variance of character x

Vpy = Phenotypic variance of character y

2. Genotypic correlation coefficient between X and Y :

$$rg = \frac{Vgxy}{\sqrt{Vgx}\times Vgy}$$

Where:

Vgxy = Genotypic co- variance between x and y

Vgx = Genotypic variance of character x

Vgy = Genotypic variance of character y

The correlation coefficients (rg and rp) were compared with the tabulated 'r' value at (n-2) degree of freedom (Fisher and Yates, 1963). If the calculated value of correlation coefficients were found to be greater than tabulated value at 5 per cent level of significance the correlation was said to be significant, otherwise non-significant.

3.7.7 Path Coefficient Analysis

The path coefficient analysis of phenotypic and genotypic correlation was used to determine the direct and indirect contribution towards marketable curd weight.

The direct and indirect paths were obtained by the formula given by Dewy and Lu (1959). The path coefficients were obtained by the simultaneous selection of following equations, which expressed the basic relationship between genotypic correlation (r) and path coefficient (P).

$$r_{14} = P_{14} + r_{12} P_{24} + r_{13} P_{34}$$
$$r_{24} = r_{21}P_{14} + P_{24} + r_{23} P_{34}$$
$$r_{34} = r_{31} P_{14} + P_{32} + r_{24} P_{34}$$

where,

r_{14}, r_{34} and r_{24} are genotypic correlation of components characters with marketable curd weight (dependent variable) and r_{13}, r_{23} and r_{24} are genotypic correlations among the component characters (independent variable) and $r_{12}P_{24}$, $r_{13}P_{34}$, $r_{21}P_{14}$, $r_{23}P_{34}$, $r_{31}P_{14}$ and $r_{24}P_{34}$ are indirect effects.

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

$$P_{14} = C_{11} r_{14} + C_{12} r_{24} + C_{13} r_{34}$$
$$P_{24} = C_{21} r_{14} + C_{22} r_{24} + C_{23} r_{34}$$
$$P_{34} = C_{31} r_{14} + C_{32} r_{24} + C_{24} r_{34}$$

Where C_{11}, C_{12}, C_{23} and C_{33} are constants derived by using abbreviated Doultittle's technique as explained by Goulden (1959) and P_{14}, P_{24} and P_{34} are the estimates of direct effects.

3.7.7.1 Residual effect

It measures the role of other possible independent variables which were not included in the study on dependent variable. The variation in the dependent variable that remained undetermined by including all the variables were assumed to be due to variable (s) not included in the present investigation. The residual effect is estimated with the help of direct effect and simple correction coefficient as given below:

$$I = P^2 x_4 + P^2_{14} + P^2_{24} + P^2_{34} + 2P_{14} r_{12} P_{24} + 2P_{14}r_{13} P_{34}+ 2P_{24}r_{22}P_{34}$$

Chapter-4

RESULTS AND DISCUSSION

The current investigation accredited **"Genetic Evaluation of Newly Introduced Genotypes of Cauliflower (*Brassica oleracea* var. *botrytis* L.)"** were undertaken at Regional Horticulture Research & Training Station, Jachh (Nurpur), Kangra, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. Twenty four genotypes of cauliflower were evaluated for different horticultural traits. The results so obtained are documented under the following sections.

4.1 Variability studies

4.1.1 Mean performance of genotypes

4.1.2 Parameters of variability

4.2 Association studies

4.2.1 Correlation studies

4.2.2 Path coefficient analysis

4.1 VARIABILITY STUDIES

4.1.1 Mean performance of genotypes

The analysis of variance for different characters indicated significant variation among the genotypes under study (Appendix-I). The calculated 'F' values revealed significant differences among the different horticultural traits which are discussed below;

4.1.1.1 Plant height (cm)

Having a glance over Table 1 the mean performance recorded for the plant height showed a range from 27.17 to 46.20. Maximum plant height was recorded for EC-716672 (46.20) which was found to be at par with EC-690942 (46.17) , EC-683455 (45.53), EC-808738 (44.90), EC-702493 (43.87), Pusa Sharad (43.77), EC- (43.60), Pusa Shukti (41.70), EC-791397 (41.63) and EC-716679 (41.57) while minimum plant height was recorded for EC-716673 (27.17) which was at par with EC-716613 (28.90), EC-162587 (31.20) and EC-716642 (31.93). The commercial check varieties Pusa Shukti and PSBK-1 shows plant height of 43.77 and 40.50 respectively. On an average mean of plant height recorded for all the genotypes was 38.83 cm. The data here was in accordance to Shree *et al.* (2019). A significant amount of variability among the genotypes regarding the trait under study was found and the same result was also found by Jindal and Thakur (2004), Ahirwar *et al*. (2013), Singh *et al*. (2013), Kalia *et al*. (2014), Chittora and Singh (2015), Kaur *et al.* (2018).

4.1.1.2 Days to marketable maturity

Significant variations were observed among all the genotypes for days to marketable maturity (Table 1). The differences between the genotypes for this horticultural trait range varied from 65.56 to 96.57. EC-716673 took minimum number of days to reach marketable maturity (65.56) which was found to be statistically at par with EC-808750 (67.67), EC-808731 (70.33), EC-716672 (70.78), EC-683455 (73.00), EC-716642 (73.45), EC-808738 (74.23), EC-690942 (75.11), EC-690967 (75.11). Maximum number of days to reach marketable maturity was taken by EC-716550 (96.57) which was found to be statistically at par with PSBK-1 (96.11), EC-791397 (94.33), EC-656627 (92.11), Pusa Shukti (90.78), EC-716613 (88.77), EC-702493 (86.89), and EC-808748 (86.22). The standard cultivars Pusa Shukti took 90.78 days while PSBK-1 took 96.11 days to reach marketable maturity. On an average all the genotypes took 81.19 days to reach maturity (Table 4.1). Tremendous variability with respect to this trait was also reported by Jindal and Thakur (2004), Garg and Lal (2006), Singh and Dogra (2013), and Kalia *et al*. (2014), Santhosha *et al.* (2014), Chittora and Singh (2015), Sharma *et al.* (2018).

4.1.1.3 Number of leaves per plant

Number of leaves per plant revealed significant variability among the twenty four genotypes studied (Table 1). The range varied between 12.27 to 21.37. EC-716550 had minimum number of leaves per plant (12.27) which were found to be statistically at par with EC-716613 (14.10), EC-716638 (14.13), EC-656627 (14.73) and EC-808731 (14.83). EC-808738 had maximum number of leaves per plant (21.37) which were found to be statistically at par with Pusa Shukti (20.57), EC-683455 (20.40), Pusa Sharad (20.07), EC-716679 (19.67), EC-162587 (19.63), EC-683451 (19.50), EC-702493 (19.50), EC-808737 (19.47) and PSBK-1 (19.33). Nearly all the genotypes had 17.72 number of leaves per plant on an average which was also inferenced by Santhosha *et al.* (2015). A good amount of variability regarding this trait was also reported by Garg and Lal (2006), Sharma (2006), Ahirwar *et al.* (2013), Santhosha *et al.* (2014) and Chittora and Singh (2015) and Kumar *et al*. (2017).

Table 1. Mean performance of different genotypes of cauliflower for Days to Marketable maturity, Number of leaves per plant and Plant height

Genotypes	Plant height (cm)	Days to marketable maturity (days)	Number of Leaves per plant
EC-162587	31.20	80.11	19.63
EC-656627	32.90	92.11	14.73
EC-683451	43.60	85.23	19.50
EC-683455	45.53	73.00	20.40
EC-690942	46.17	75.11	18.17
EC-690967	40.57	75.11	18.50
EC-702493	43.87	86.89	19.50
EC-716550	41.10	96.57	12.27
EC-716613	28.90	88.77	14.10
EC-716638	37.23	77.89	14.13
EC-716642	31.93	73.45	16.53
EC-716672	46.20	70.78	18.20
EC-716673	27.17	65.56	15.60
EC-716679	41.57	85.33	19.67
EC-791397	41.63	94.33	18.50
EC-808731	33.87	70.33	14.83
EC-808737	37.23	80.00	19.47
EC-808738	44.90	74.23	21.37
EC-808748	39.90	86.22	15.10
EC-808750	36.10	67.67	18.17
EC-808779	34.27	80.78	17.03
PUSA SHARAD	43.77	82.33	20.07
PUSA SHUKTI (C)	41.70	90.78	20.57
PSBK-1 (C)	40.50	96.11	19.33
Mean	**38.83**	**81.19**	**17.72**
SE ± (m)	**1.69**	**3.91**	**0.97**
C.V. (%)	**7.52**	**8.32**	**9.50**
CD (0.05)	**4.81**	**11.14**	**2.78**

4.1.1.4 Leaf length (cm)

A significant range of variability was observed for leaf length among twenty four genotypes (Table 2) from 27.78 to 42.56. The commercial check cultivar Pusa Shukti and PSBK-1 had 41.78 and 39.67. Average leaf length among the genotypes was recorded 38.17.

Fourteen genotypes *viz.* EC-702493 (42.55), EC-716672 (42.44), Pusa Sharad (41.89 cm), EC-683451 (41.78), Pusa Shukti (41.78), EC-808748 (41.56), EC-683455 (41.44), EC-808737 (40.99), EC-808738 (40.11), EC-162587 (39.78), PSBK-1 (39.67), EC-716550 (38.89), EC-716679 (38.56) and EC-791397 (38.22) were found to be statistically at par with (42.56) showing maximum leaf length while genotypes EC-808731 (30.89) was statistically at par with (27.78 cm) recording minimum leaf length. The mean here was in line with the findings of Kanwar and Korla (2002), Kumar *et al*. (2017), Kaur *et al.* (2018).

4.1.1.5 Leaf breadth (cm)

Evaluation done among all the genotypes for leaf breadth stated a range between 12.56 to 17.78 (Table 2) respectively. 16.00 and 15.67 leaf breadth was observed in the commercial check cultivar Pusa Shukti and PSBK-1 respectively. The mean leaf breadth recorded for all the genotypes was 15.00. EC-702493 (17.44), Pusa Sharad (17.33), EC-716679 (16.67), EC-162587 (16.56), EC-716638 (16.11), EC-EC-683451 (16.00), EC-808779 (16.00), Pusa Shukti (16.00), EC-808737 (15.89), PSBK-1 (15.67), EC-716550 (15.56) were statistically at par with EC-7166672 showing maximum leaf breadth (17.78). Twelve genotypes namely EC-808731 (15.22), EC-656627 (14.89), EC-808748 (14.55 cm), EC-690967 (13.67), EC-808750 (13.67), EC-683455 (13.44), EC-690942 (13.11), EC-791397 (13.11), EC-716613 (13.00), EC-716642 (13.00) and EC-716673 (12.89) were at par with having minimum leaf breadth (12.56 cm). The above findings were in line with Kanwar and Korla (2002), Dhatt and Garg (2008), Santhosha *et al.* (2015), Kumar *et al*. (2017) and Kaur *et al. (*2018).

4.1.1.6 Leaf size index (cm^2)

Data pertaining to this trait revealed significant variations among genotypes (Table 2). Leaf size index ranged from 360.33 to 754.67. Seven genotypes viz., EC-716679 (640.78), EC-808737 (649.11), EC-162587 (659.44), EC-683451 (668.33), Pusa Shukti (670.00 cm^2), Pusa Sharad (728.22) and EC-702493 (738.67) were found to be statistically at par with EC-716672 (754.67) which showed maximum leaf size index. Four genotypes viz., EC-716642 (425.56), EC-690967 (444.33), EC-716613 (464.78) and EC-808731 (470.33) were found to be statistically at par with EC-716673 (360.33) which showed minimum leaf size index. The commercial check varieties Pusa Shukti and PSBK-1 had leaf size index of 670.00 and 621.67 respectively. The general population mean was found to be 575.51.

Table 2. Mean performance of different genotypes of cauliflower for Leaf length, Leaf breadth and Leaf size index

Genotypes	Leaf length(cm)	Leaf breadth(cm)	Leaf size index (cm^2)
EC-162587	39.78	16.56	659.44
EC-656627	37.89	14.89	564.22
EC-683451	41.78	16.00	668.33
EC-683455	41.44	13.44	556.00
EC-690942	42.56	13.11	558.11
EC-690967	37.99	13.67	520.33
EC-702493	42.55	17.44	738.67
EC-716550	38.89	15.56	606.33
EC-716613	36.00	13.00	464.78
EC-716638	34.22	16.11	561.89
EC-716642	32.67	13.00	425.56
EC-716672	42.44	17.78	754.67
EC-716673	27.78	12.89	360.33
EC-716679	38.56	16.67	640.78
EC-791397	38.22	13.11	501.89
EC-808731	30.89	15.22	470.33
EC-808737	40.99	15.89	649.11
EC-808738	40.11	12.56	502.66
EC-808748	41.56	14.55	604.56
EC-808750	32.56	13.67	444.33
EC-808779	33.78	16.00	540.11
PUSA SHARAD	41.89	17.33	728.22
PUSA SHUKTI (C)	41.78	16.00	670.00
PSBK-1 (C)	39.67	15.67	621.67
Mean	**38.17**	**15.00**	**575.51**
SE ± (m)	**1.56**	**0.94**	**44.13**
C.V. (%)	**7.07**	**10.89**	**13.28**
CD (0.05)	**4.45**	**2.69**	**126.02**

4.1.1.7 Stalk length (cm)

Stalk length varied significantly from 2.78 to 6.99 (Table 3). The commercial check varieties Pusa Shukti and PSBK-1 showed 2.78 and 3.22. Across all twenty-four genotypes, the average stalk length was 3.92 (Table 4.3). Maximum stalk length was recorded in EC-690942 (6.99) whereas Pusa Shukti, EC-716638, EC-162587 showed the minimum stalk length (2.78) which was found to be at par with EC-808750 (3.00), EC-808737 (3.22), PSBK-1 (3.22), EC-716673 (3.22), EC-716642 (3.22), Pusa Sharad (3.56), EC-656627 (3.67), EC-731397 (3.67), and EC-716613 (3.79). Near about inference was drawn by Garg and Lal (2006), Sharma *et al*., (2006), Mehra (2012), Singh and Dogra (2013), Ahirwar *et al.* (2013), Singh *et al.* (2013) and Vanlalneihi *et al.* (2017), Kanwar and Korla (2002), Santhosha *et al*. (2014) and Sharma *et al*. (2018).

4.1.1.8 Plant frame (cm^2)

Plant frame revealed significant differences among the various genotypes studied (Table 3). It ranged from 34.28 (EC-716613) to 58.22 (Pusa Sharad) with general population mean of 48.21. The commercial check varieties Pusa Shukti and PSBK-1 had 50.28 and 53.22 plant frame. Five genotypes viz., EC-716672 (55.11), EC-162587 (54.67), EC-808738 (54.00), EC-702493 (53.72), PSBK-1 (53.22) and EC-808737 (52.95) were found to be at par with Pusa Sharad (58.22) having maximum plant frame. Only one genotype namely EC-656627 (35.95) was found to be statistically at par with EC-716613 (34.28) having minimum plant frame. These results are in accordance with the findings of Mihov and Antonova (2009).

4.1.1.9 Curd solidity (g/cm)

Data pertaining to this trait revealed significant variations among genotypes (Table 3). Curd solidity ranged from 15.59 to 46.21 in EC-808779 and PSBK-1. The average population mean was found to be 27.77, whereas the commercial check variety Pusa Sharad and PSBK-1 showed the value of 27.01 and 46.21 regarding this very trait. Two genotypes namely EC-808773 (42.22) and EC-716672 (42.13) were found to be at par with PSBK-1 (46.21) having maximum curd solidity. Eight genotypes viz., EC-716550 (17.41), EC-683451 (18.89), EC-716673 (19.41), EC-716642 (19.46), EC-690942 (20.75), EC-683455 (21.02), EC-791397 (21.79), EC-716679 (22.37) and Pusa Sharad (22.71) were found to be at par with EC-808738 (15.59) which had minimum value regarding this trait.

Table 3. Mean performance of different genotypes of cauliflower for Stalk length, Plant frame and Curd solidity

Genotypes	Stalk length (cm)	Plant frame (cm^2)	Curd solidity(g/cm)
EC-162587	2.78	54.67	33.16
EC-656627	3.67	35.95	35.24
EC-683451	4.00	44.27	18.89
EC-683455	5.44	47.94	21.02
EC-690942	6.99	48.77	20.75
EC-690967	3.00	51.50	30.99
EC-702493	3.89	53.72	28.42
EC-716550	4.67	41.67	17.41
EC-716613	3.79	34.28	28.77
EC-716638	2.78	44.22	33.30
EC-716642	3.22	47.00	19.46
EC-716672	4.00	55.11	42.13
EC-716673	3.22	43.61	19.41
EC-716679	4.89	52.67	22.37
EC-791397	3.67	49.94	21.79
EC-808731	4.22	43.67	35.61
EC-808737	3.22	52.95	27.77
EC-808738	4.66	54.00	15.59
EC-808748	4.33	46.05	27.85
EC-808750	4.00	48.28	28.47
EC-808779	4.11	45.00	42.22
PUSA SHARAD	3.56	58.22	22.71
PUSA SHUKTI (C)	2.78	50.27	27.00
PSBK-1 (C)	3.22	53.22	46.21
Mean	**3.92**	**48.21**	**27.77**
SE ± (m)	**0.37**	**1.90**	**2.96**
C.V. (%)	**16.61**	**6.83**	**18.49**
CD (0.05)	**1.07**	**5.43**	**8.47**

4.1.1.10 Curd polar length (cm)

Having a glance over twenty four genotypes under study (Table 4) minimum curd polar length was demonstrated by EC-808748 (5.22) and maximum curd polar length by EC-690942 (9.67) which was statistically at par with EC-716550 (8.55). Five genotypes EC-162587 (5.78), EC-716613 (6.00), EC-656627 (6.11), EC-808779 (6.11) and EC-808731 (6.22) was statistically at par with EC-808748 (5.22) which had maximum curd polar length. The mean recorded while evaluating these genotypes was 6.99. The standard cultivars Pusa Shukti and PSBK-1 had 7.00 and 7.55 curd polar length (Table 4). Findings were in close proximity to Santosha *et al*. (2014), Kumar *et al*. (2017), Kumar *et al*. (2019) and Singh *et al.* (2019).

Table 4. Mean performance of different genotypes of cauliflower for Curd polar length, Curd equatorial length and Curd size index

Genotypes	Curd polar length (cm)	Curd equatorial length (cm)	Curd size index (cm^2)
EC-162587	5.78	9.33	53.80
EC-656627	6.11	10.53	64.23
EC-683451	7.00	9.67	64.17
EC-683455	7.55	8.67	63.90
EC-690942	9.67	11.33	108.53
EC-690967	7.11	11.13	77.15
EC-702493	6.89	10.09	70.81
EC-716550	8.55	10.12	83.40
EC-716613	6.00	9.77	67.80
EC-716638	6.89	11.50	77.07
EC-716642	6.44	8.78	53.25
EC-716672	7.22	10.33	77.83
EC-716673	6.67	9.77	66.82
EC-716679	7.77	11.33	86.52
EC-791397	8.11	10.01	81.60
EC-808731	6.22	8.67	53.60
EC-808737	6.78	10.35	65.10
EC-808738	7.78	9.00	71.52
EC-808748	5.22	8.55	44.85
EC-808750	6.66	10.22	66.52
EC-808779	6.11	9.91	58.47
PUSA SHARAD	6.55	9.44	61.15
PUSA SHUKTI (C)	7.00	9.56	67.17
PSBK-1 (C)	7.55	9.67	72.60
Mean	**6.99**	**9.91**	**69.10**
SE ± (m)	**0.42**	**0.37**	**6.43**
C.V. (%)	**10.52**	**6.53**	**16.11**
CD (0.05)	**1.21**	**1.06**	**18.35**

4.1.1.11 Curd equatorial length (cm)

A significant range of variability was observed among all the twenty four genotypes undertaken (Table 4). 8.55 to 11.50 of range varied among the genotypes. The minimum curd depth was expressed in EC-808748 (8.55) whereas maximum was in EC-716638 (11.50) which was statistically at par with EC-690942 (11.33), EC-716679 (11.33) and EC-808750 (11.13). Nearly the mean for all the genotypes was around 11.92. Seven genotypes *viz.*, EC-683455 (8.67), EC-808731 (8.67), EC-716642 (8.78), EC-808738 (9.00), EC-162587 (9.33 cm), Pusa Sharad (9.44) and Pusa Shukti (9.56) were statistically at par with EC-808748 (8.55). The standard cultivars Pusa Shukti and PSBK-1 had 9.56 and 9.67 curd equatorial length On an average the mean of all the genotypes was around 9.91. This was in close proximity to Santhosha *et al.* (2014) and Santhosha *et al*. (2015)

4.1.1.12 Curd size index (cm^2)

Significant variations for curd size index were observed among the genotypes under study (Table 4). The differences between the genotypes for this trait ranged from 44.85 to 108.53. On an average all genotypes had curd size index of 69.08. The commercial check varieties Pusa Shukti and PSBK-1 had curd size index of 67.17 and 72.60. The genotype EC-690942 (108.53) has maximum curd size index whereas EC-808748 (44.85) recorded minimum curd size index which was statistically at par with EC-716642 (53.25), EC-808731 (53.60), EC-162587 (53.80), EC-808779 (58.47), and Pusa Sharad (61.15). These results collaborate with the findings of Dubey *et al*. (2003), Sharma *et al*. (2006), Kumar *et al*. (2017) and Sharma *et al*. (2018) who had also reported significant variation for the curd size index among the different genotypes.

4.1.1.13 Gross plant weight (g)

Data pertaining to this trait demonstrated significant variation among all the genotypes (Table 5). The range recorded here was 726.66 to 1492.33. The mean value recorded here was 995.89. Two checks Pusa Shukti and PSBK-1 recorded 1009.98 and 1149.46 gross plant weight. EC-716672 recorded the maximum gross plant weight (1492.33) whereas EC-716613 recorded the minimum gross plant weight (726.66) which was statistically at par with EC-716673 (766.10) and EC-716642 (784.44). Approximate results were given by Singh *et al.* (2006), Dhatt and Garg (2008), Chittora and Singh (2015) and Kumar *et al*. (2017).

4.1.1.14 Marketable curd weight (g)

Evaluation done among all the twenty four genotypes under study for marketable curd weight revealed a range of 522.21 to 713.87 (Table 5). The average population mean was 589.76. It was minimum in EC-716642 (522.21), statistically at par with EC-716673 (525.57), EC-808738 (530.58), EC-683451 (535.01), EC-808748 (550.54), EC-716550 (553.36), EC-683455 (554.43), EC-716613 (574.44), Pusa Sharad (574.47) and EC-716679 (575.54) while maximum in EC-716672 (513.87) which was statistically at par with PSBK-1 (681.67) and EC-808779 (660.00). The standard cultivars Pusa Shukti and PSBK-1 had 586.67 and 681.67 marketable curd weight. These were in consonance with the findings of Chatterjee *et al*. (2018).

Table 5. Mean performance of different genotypes of cauliflower for Gross plant weight and Marketable curd weight

Genotypes	Gross plant weight (g)	Marketable curd weight (g)
EC-162587	1077.77	591.10
EC-656627	850.90	627.76
EC-683451	1010.56	535.01
EC-683455	927.79	554.43
EC-690942	1097.79	600.00
EC-690967	965.56	608.33
EC-702493	1121.68	600.33
EC-716550	956.67	553.36
EC-716613	726.66	574.44
EC-716638	938.88	621.12
EC-716642	784.44	522.21
EC-716672	1492.33	713.87
EC-716673	766.10	525.57
EC-716679	1058.32	575.54
EC-791397	1009.46	578.89
EC-808731	966.68	602.21
EC-808737	1034.45	598.32
EC-808738	983.33	530.58
EC-808748	858.87	550.54
EC-808750	929.98	587.77
EC-808779	1082.23	660.00
PUSA SHARAD	1101.68	574.47
PUSA SHUKTI (C)	1009.98	586.67
PSBK-1 (C)	1149.46	681.67
Mean	**995.89**	**589.76**
SE ± (m)	**33.28**	**18.95**
C.V. (%)	**9.67**	**17.29**
CD (0.05)	**95.04**	**54.12**

4.1.1.15 Leaf colour

It was observed visually at the time of harvesting (Table 6). The genotypes under study were found to produce light green, dark green and bluish green leaf colour. The majority of the genotypes were found to be light green leaves and the result was also found by Singh *et al*. (2013). The genotypes namely EC-656627, EC-683451, EC-683455, EC-690942, EC-716550, EC-716613, EC-716642, EC-716672, EC-791397, EC-808731, EC-808748, EC-808779, EC-808750 and EC-690967 were found to have light green leaves. Whereas the genotypes namely Pusa Shukti, Pusa Sharad, EC-808737, EC-808738, EC-716679, EC-716673 and EC-702493 showed bluish green leaves. Only three genotypes viz., EC-162587, EC-716638 and PSBK-1 showed dark green leaves.

Table 6. Classification of different genotypes of cauliflower on the basis of leaf colour

Sr. No.	Leaf colour	Name of the genotypes
1	Light green	EC-656627, EC-683451, EC-683455, EC-690942, EC-716550, EC-716613, EC-716642, EC-716672, EC-791397, EC-808731, EC-808748, EC-808779, EC-808750, EC-690967
2	Dark green	EC-162587, EC-716638, PSBK-1
3	Bluish green	Pusa Shukti, Pusa Sharad, EC-808737, EC-808738, EC-716679, EC-716673 EC-702493

4.1.1.16 Curd colour

It was observed visually at the time of harvesting (Table 7). In the present study four different curd colour were observed snow white, white, creamy white and purple. PSBK-1 was the only genotype which had completely snow white curds. The majority of the genotypes gave either white or creamy white curds and that result was also found by Singh *et al*. (2013). Creamy white curds were observed in the genotypes namely EC-683451, EC-683455, EC-690942, EC-702493, EC-716638, EC-716642, EC-716672, EC-716679, EC-808731, EC-808738, EC-808748, EC-808779, EC-808750, EC-690967 and Pusa Shukti. Whereas the genotypes namely EC-162587, EC-656627, EC-716550, EC-716613, EC-808737 and Pusa Sharad produced white coloured curds. Only two genotypes EC-716673 and EC-791397 produced purple coloured curds.

Table 7. Classification of different genotypes of cauliflower on the basis of curd colour

Sr. No.	Curd colour	Number of genotypes	Name of the genotypes
1	Snow white	1	PSBK-1
2	White	6	EC-162587, EC-656627, EC-716550, EC-716613, EC-808737, Pusa Sharad
3	Creamy white	15	EC-683451, EC-683455, EC-690942, EC-702493, EC-716638, EC-716642, EC-716672, EC-716679, EC-808731, EC-808738, EC-808748, EC-808779, EC-808750, EC-690967, Pusa Shukti.
4	Purple	2	EC-716673, EC-791397

4.1.1.17 Curd compactness

It was observed manually by exerting thumb pressure on the curd which was made at the time of harvesting. Among all the genotypes, only two of them showed medium compactness (Table 8) namely EC-683455 and EC-716613. Maximum genotypes expressed compact curd (Chittora *et al.* 2016) namely EC-162587, EC-656627, EC-702493, EC-716550, EC-716638, EC-716642, EC-716672, EC-716673, EC-716679, EC-791397, EC-808738, EC-808750, EC-808737, PSBK-1 and Pusa Shukti. Loose compactness was spotted only in the seven genotypes which included EC-683451, EC-690942, EC-808731, EC-808748, EC-808779, EC-690967 and Pusa Sharad. These results were in accordance with those of Chittora and Singh (2015), Ansari (2017) and Sahu (2017)

Table 8. Classification of different genotypes of cauliflower on the basis of curd compactness

Curd compactness	Genotypes
Compact	EC-162587, EC-656627, EC-702493, EC-716550, EC-716638, EC-716642, EC-716672, EC-716673, EC-716679, EC-791397, EC-808738, EC-808750, EC-808737, PSBK-1, Pusa Shukti
Medium	EC-683455, EC-716613
Loose	EC-683451, EC-690942, EC-808731, EC-808748, EC-808779, EC-690967, Pusa Sharad

4.1.1.18 Riceyness

Majority of the genotypes under study were found to produce non ricey curds (Table 9). Among the twenty four genotypes under study twenty one genotypes namely EC-162587, EC-656627, EC-683451, EC-683455, EC-702493, EC-716550, EC-716613, EC-716638, EC-716642, EC-716673, EC-716679, EC-791397, EC-808731, EC-808738, EC-808748, EC-808750, EC-690967, EC-808737, Pusa Sharad, Pusa Shukti and PSBK-1 produced non ricey curds whereas three genotypes namely EC-690942, EC-716672 and EC-808779 produced ricey curds.

Table 9. Classification of different genotypes of cauliflower on the basis of occurrence of riceyness

Sr. No.	Riceyness	Number of genotypes	Name of the genotypes
1	Non ricey curds	21	EC-162587, EC-656627, EC-683451, EC-683455, EC-702493, EC-716550, EC-716613, EC-716638, EC-716642, EC-716673, EC-716679, EC-791397, EC-808731, EC-808738, EC-808748, EC-808750, EC-690967, EC-808737, Pusa Sharad, Pusa Shukti, PSBK-1
2	Ricey curds	3	EC-716672, EC-690942, EC-808779

Parameters of variability

Genetic variability is the basis of all plant upgrading programmes. If present, adequate genetic diversity can be exploited for the production of superior cultivars.

Vavilov (1951) was the first to understand that a wider range of variation in any crop offers greater opportunities to choose the desirable forms. Achievement of any breeding programme is proportional to the amount of variability collected. This is hence measured in terms of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability, genetic advance and genetic gain were estimated as shown in table 4.6.

Coefficient of variability

Table 10 demonstrated higher phenotypic coefficients of variability as compared to genotypic coefficients of variability for all the horticultural traits undertaken in this study. Same conclusion was drawn by Dhatt and Garg (2008), Singh *et al*. (2010), Mehra and Singh (2013), Santhosha *et al.* (2014) Sharma *et al.* (2018) Singh *et al*. (2020), Shree *et al*. (2019). The range of PCV was from 10.17% (Curd equatorial length) to 33.65% (Curd solidity). The range of GCV was from 7.79% (Curd equatorial length) to 28.10% (Curd solidity).

Highest value for phenotypic and moderate value for genotypic coefficients of variability was observed for curd solidity (33.65% and 28.10%). Sharma *et al*. (2018) observed High estimates of PCV and GCV for curd solidity indicated that there is substantial variability ensuring ample scope for improvement of this trait through selection The difference between phenotypic coefficient of variation and genotypic coefficient of variation indicate the difference of environmental factors. The next traits which recorded the moderate phenotypic coefficient of variability and genotypic coefficients of variability were stalk length (27.96% and 22.48%) and gross plant weight (16.27% and 15.21%). Curd size index (23.27% and 16.78%), leaf size index (20.97% and 16.24%) showing moderate values for phenotypic and genotypic coefficients of variability which were in consonance with Sharma (2006), Chittora and Singh (2015) and Chittora *et al*. (2016). Chatterjee *et al*. (2018) recorded moderate estimates of GCV in leaf size index, curd size index, gross weight per plant. Kumar *et al*., (2011) observed moderate phenotypic coefficient of variability and genotypic coefficients of variability in stalk length which are in line with the above findings. Moderate PCV but low GCV were recorded in curd polar length (16.23% and 12.36%), number of leaves per plant (16.00% and 12.88%) and plant height (15.77% and 13.86%). Moderate PCV and GCV for marketable curd weight have also been reported by Kanwar *et al*. (2010).

Low values for phenotypic and genotypic coefficients of variability was seen in marketable curd weight (9.26% and 7.40%), curd equatorial length (10.17% and 7.79%), leaf length (12.34% and 10.11%), days to 50% marketable maturity (13.12% and 10.14%), leaf breadth (14.10% and 8.95%) and plant frame (13.56% and 11.71%). Lowest coefficient of variation was also observed for days to 50% marketable maturity by Chittora and Singh (2015). The low GCV was observed for days to 50 % marketable curd maturity and curd equatorial length by Kumar *et al*. (2018). Whereas, Kumar *et al*. (2019) recorded low GCV and moderate PCV for the characters like curd polar length and number of leaves per plant The estimates of these parameters for days to 50% marketable maturity are in line with the findings of Kumar (2002), Pathania (2003), Sahu (2017) and Shree *et al*. (2019).

Heritability and genetic advance as per cent of mean

The combined role effect of heritability and genetic advance helps a breeder to go for better selection of the genotypes at the phenotypic level. A broad sense heritability estimate provides information on relative magnitude of genetic and environmental variation in germplasm pool. Heritability is defined as proportion of phenotypic variance among individuals in a population that accounts due to heritable genetic effects. Broad sense heritability reliably features the recognisation of genotype through phenotypic expression (Lush, 1940) whereas narrow sense heritability is estimated from additive gene variance. The heritability estimate varied from 40.28 per cent in leaf breadth to 87.35 per cent in gross plant weight (Table 10). An attempt has been made in the present investigation to estimate heritability in broad sense which is categorized as low (< 50%), moderate (50-70%) and high (>70%) as suggested by Sharma (1994).

The high heritability was observed in gross plant weight (87.35%). This was in line with Kumar *et al.* (2011), Singh *et al*. (2010), Singh *et al.* (2006), Dubey *et al.* (2003). Moderate heritability was observed in plant frame (74.64%), plant height (77.28%),curd solidity (69.77%), leaf length (67.19%), number of leaves per plant (64.75%), stalk length (64.68%), marketable curd weight (63.88%), leaf size index (59.91%), days to 50 per cent marketable maturity (59.79%), curd equatorial length (58.74%), curd polar length (57.97%), curd size index (52.05%). Low heritability was observed in leaf breadth (40.28%).

Table 10. Estimation of Population range, Mean, Phenotypic and Genotypic coefficients of variation, Heritability, Genetic advance and Genetic gain for various characters in cauliflower

Characters	Range	Mean	Coefficients of Variability (%)		Heritability (%)	Genetic advance	Genetic Gain (%)
			Genotypic	Phenotypic			
Plant height (cm)	27.17-46.20	38.83	13.86	15.77	77.28	9.75	25.11
Days to 50% marketable maturity	65.56-96.57	81.19	10.14	13.12	59.79	11.31	16.15
Number of leaves per plant	12.27-21.37	17.72	12.88	16.00	64.75	3.78	21.35
Plantframe (cm^2)	34.28-58.22	48.21	11.71	13.56	74.64	10.05	20.84
Leaf length (cm)	27.78-42.56	38.17	10.11	12.34	67.19	6.52	17.08
Lead breadth (cm)	12.56-17.78	15.00	8.95	14.10	40.28	1.76	11.70
Leaf size index (cm^2)	360.33-754.67	575.51	16.24	20.97	59.91	148.98	25.89
Stalk length (cm)	2.78-7.00	3.92	22.48	27.96	64.68	1.46	37.25
Curd polar length (cm)	5.22-9.67	6.99	12.36	16.23	57.97	1.35	19.38
Curd equatorial length (cm)	8.55-11.50	9.91	7.79	10.17	58.74	1.22	12.30
Curd size index (cm^2)	44.85-108.53	69.18	16.78	23.27	52.05	17.24	24.95
Curd solidity (g/cm)	15.59-46.21	27.77	28.10	33.65	69.77	13.43	48.36
Gross plant weight (g)	726.66-1492.33	995.90	15.21	16.27	87.35	291.60	29.28
Marketable curd weight (g)	422.21-713.87	606.42	7.403	9.26	63.89	71.88	12.19

Collective understanding of genetic advance with heritability undoubtedly aids in better selection of a trait. High heritability and genetic variability is essential for higher genetic gain (Kumari *et al*. 2016). Johnson *et al.* (1955) was of the opinion that heritability without genetic advance was inefficient for crop improvement selection. None of the characters had shown high genetic gain, moderate genetic gain was expressed in five characters while low genetic gain was seen in nine characters (Table 10). and showed highest genetic gain which are in accordance with Singh *et al*., (2010), Sharma *et al*., (2018). Gross plant weight (29.28%), curd solidity (48.36%), stalk length (37.25%), leaf size index (25.89%), plant height (25.11%), showed moderate genetic gain which are in accordance with Kanwar *et al*. (2010). The findings are in line for curd size index Singh *et al*., (2006) and curd equatorial length Dubey *et al*. (2003). Earlier workers have also reported moderate genetic again for curd size index (Dubey *et al*. 2003), and plant height (Shree *et al*. 2019). Category of low genetic gain enlisted curd size index (24.95%), number of leaves per plant (21.35%), plant frame (20.84%), curd polar length (19.38%), leaf length (17.08%), marketable curd weight (12.19%), leaf breadth (11.70%), curd equatorial length (12.30%) and days to 50 per cent marketable maturity (16.15%). The findings are in line with Atter *et al.* (2009).

Additive gene action due to high heritability and genetic advance promotes successful selection for betterment of crop (Panse, 1957). Similar inference was drawn by Singh *et al.* (2013), Kumar *et al.* (2018) and Singh *et al.* (2019). High heritability and low genetic advance interpreting the presence of non additive gene action thereby lesser selection. This was winded up by Dhatt and Garg (2008) and Singh *et al.* (2010). Moderate heritability and low genetic advance combination for any trait demonstrated dominance and epistatic effect permitting betterment only by recombination (Panse, 1957).

4.2 CORRELATION STUDIES

Crop improvement programme largely depends on availability of sufficient variability and association among different characters which are pre-requisite for executing an effective selection programme. The correlation studies are one of the tools which help in measuring the degree and magnitude of association between two characters. The measure of degree of association between the two traits simultaneously is coined as correlation coefficient (Hayes *et al.* 1955). The association of different horticultural traits is of tremendous value for any strategic breeding programme besides yield betterment. 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). Unfavourable association in several traits for yield often leads to genetic slippage (Dickerson, 1955). Thus, it becomes necessary to find out the direction and degree of association between two characters at phenotypic and genotypic levels.

In the present investigation, in general, genotypic correlation coefficients were higher as compared to phenotypic correlation coefficients in all the traits. This was also in accordance to earlier findings of Shree *et al.* (2019), Chittora and Singh (2017), Ansari *et al.* (2017) and Meena *et al.* (2013). The little variation between the values of both correlation coefficients reflected strong inheritance among several characters studied (Table 11).

4.2.1.1 Plant height (cm)

The trait plant height was found to be positively correlated with days to 50% marketable maturity (0.45 and 0.25), number of leaves per plant (0.57 and 0.49), plant frame (0.61 and 0.46), leaf length (0.82 and 0.70), leaf size index (0.66 and 0.51), stalk length (0.49 and 0.46), curd polar length (0.74 and 0.51), curd size index (0.58 and 0.38) and gross plant weight (0.65 and 0.55) under both genotypic and phenotypic level. Plant height has significant positive association with leaf breadth (0.33) at genotypic level. However, significant negative correlation was observed with curd solidity (-0.24) at genotypic level. Kumar *et al*., (2017) observed that plant height showed a positive and significant correlation with gross plant weight, marketable curd weight, plant frame. Earlier workers have also observed positive and significant association of the plant height with curd polar length (Kanwar and Korla, 2002), number of leaves per plant (Kumar *et al*. 2011 and Kumar *et al*. 2017).

4.2.1.2 Days to 50% marketable maturity

Days to 50% marketable maturity imposed positive significant correlation on gross plant weight (0.59 and 0.45), curd size index (0.56 and 0.41), leaf length (0.56 and 0.30), leaf breadth (0.49 and 0.34), leaf size index (0.61 and 0.40) and curd polar length (0.55 and 0.35) at both genotypic and phenotypic level. Dhatt and Garg (2008) reported days to marketable maturity was positively correlated with gross plant weight, leaf length and marketable curd weight and Sahu (2017) observed with curd size index. Days to 50% marketable maturity was found to be positively and significantly correlated with curd equatorial length only at genotypic level.

4.2.1.3 Number of leaves per plant

Both genotypic and phenotypic positive and significant correlation was displayed by number of leaves per plant with gross plant weight (0.50 and 0.41), plant frame (0.89 and 0.64), leaf length (0.56 and 0.48) and leaf size index (0.46 and 0.33). Despite this, a positive significant at genotypic level was observed with curd polar length (0.28) and leaf breadth (0.24). Sahu (2017) reported positive significant correlation of number of leaves per plant with curd size index at genotypic level. Kumar *et al*., (2017) found that number of leaves per plant varies positively and significantly with gross plant weight, leaf length and number of leaves per plant with curd polar length was reported by Manaware *et al*. 2017.

4.2.1.4 Plant frame (cm^2)

Plant frame showed positive and significant correlation with gross plant weight (0.70 and 0.63), leaf size index (0.58 and 0.44), leaf length (0.51 and 0.42) and leaf breadth (0.48 and 0.29) both at phenotypic and genotypic level. At genotypic level plant height displayed positive and significant correlation with marketable curd weight (0.25) and curd polar length (0.33). Kumar *et al*. (2017) showed significant and positive correlation of plant frame with gross plant weight, marketable curd weight, curd yield, net curd weight, curd breadth, curd size index and number of leaves,

4.2.1.5 Leaf length

Leaf length showed significant positive association with gross plant weight (0.58 and 1.47), leaf size index (0.86 and 0.76) and leaf breadth (0.47 and 0.29) both at phenotypic and genotypic level. A positive significant at genotypic level only was observed with stalk length (0.33), curd polar length (0.45) and curd size index (0.33). Kumar *et al*. (2017) observed that leaf length was significantly and positively correlated with leaf breadth, gross plant weight, plant height and curd size index,

4.2.1.6 Leaf breadth

Leaf breadth was found to be positively correlated with leaf size index (0.86 and 0.85), gross plant weight (0.78 and 0.56) which was highly significant, both at phenotypic and genotypic level. Leaf breadth was significantly and positively associated with marketable curd weight (0.63 and 0.39), curd solidity (0.52 and 0.38) at genotypic and phenotypic level. Whereas leaf breadth had significant and positive association with curd equatorial length (0.27) at genotypic level. However, significant negative correlation was observed with stalk length (-0.27 and -0.24) at both genotypic and phenotypic level. Sahu (2017) reported negative significant correlation of leaf breadth with stalk length at genotypic level only.

4.2.1.7 Leaf size index

Leaf size index showed significant positive association with marketable curd weight (0.44 and 0.33) and gross plant weight (0.79 and 0.65) both at genotypic and phenotypic level. Singh *et al*. (2006) observed that leaf size index had positive correlation with marketable curd weight.

4.2.1.8 Stalk length

A significant positive correlation at phenotypic and genotypic level was observed with curd size index (0.60 and 0.39) and curd polar length (0.69 and 0.50). A significant negative correlation at phenotypic and genotypic level was observed with curd solidity (-0.35 and -0.29). Kumar *et al*. (2017) and Sahu (2017) observed that stalk length had positive and significant association with curd size index and curd polar length.

4.2.1.9 Curd polar length

Curd polar length showed highest positive and significant correlation at genotypic and phenotypic level with curd size index (0.92 and 0.86) and curd equatorial length (0.43 and 0.44). Curd polar length had significant and positive association with gross plant weight (0.36) at genotypic length. Whereas curd polar length had significant negative association at genotypic and phenotypic level with curd solidity (0.54 and 0.49). Kumar *et al*. (2017) reported that curd polar length was significantly and positively correlated with curd size index.

4.2.1.10 Curd equatorial length

A significant positive association at phenotypic and genotypic level was observed with marketable curd weight (0.37 and 0.35), curd size index (0.73 and 0.77) and significant positive association at genotypic level with gross plant weight (0.25). Kumar *et al*. (2017) showed that curd equatorial length established a positive and significant correlation with curd size index. Significant and positive correlation of curd breadth with number of leaves and days to curd formation by Singh *et al*. (2014).

4.2.1.11 Curd size index

Curd size index recorded significant positive phenotypic and genotypic correlation with gross plant weight (0.35 and 0.25). A significant negative association at phenotypic and genotypic level was observed with curd solidity (-0.32 and -0.28).

4.2.1.12 Curd solidity

Curd solidity was found to be positive correlated with gross plant weight (0.42 and 0.41) and marketable curd weight (0.91 and 0.86) which was highly significant, both at phenotypic and genotypic level.

4.2.1.13 Gross plant weight

A significant positive association at phenotypic and genotypic level was observed with marketable curd weight (0.73 and 0.62). Kumar *et al*. (2017) and Sahu (2017) observed significant and positive correlation with marketable curd weight.

4.2.1.14 Marketable curd weight

Correlation studies revealed that marketable curd weight had significant positive correlation with gross plant weight (0.73 and 0.62), curd solidity (0.91 and 0.86), curd equatorial length (0.37 and 0.35), leaf size index (0.44 and 0.33), leaf breadth (0.63 and 0.39) and days to 50% marketable maturity (0.45 and 0.29) both at phenotypic and genotypic level, indicating that selection of these traits would also lead to improvement in yield. Whereas marketable curd weight showed significant and positive correlation with plant frame (0.25) at genotypic level. Earlier researchers have also reported significant and positive association of marketable curd weight with, curd equatorial length (Sharma *et al*. 2006 and Santhosha *et al*. 2015). Santhosha *et al*. (2015) also reported high significant and positive association of marketable curd weight with gross plant weight, leaf breadth and curd size index at both genotypic and phenotypic levels.

However, plant height (0.14 and 0.11), leaf length (0.16 and 0.13) and curd size index seed length (0.06 and 0.16) observed non-significant positive correlation with marketable curd weight. Marketable curd weight showed non-significant and positive association with plant frame (0.09) and number of leaves per plant (0.05) at phenotypic level.

A non-significant negative association at phenotypic and genotypic level was observed with marketable curd weight and characters *viz.*, stalk length (-0.14 and -0.11) and curd polar length (-0.14 and -0.05). A non-significant negative association at phenotypic level was observed with number of leaves per plant (-0.02).

Kumar *et al*. (2017) reported that marketable curd weight was correlated positively and significantly with net curd weight and curd equatorial length.

The inter-correlations estimated for the curd weight components indicate the possibility of simultaneous improvement of these traits by selection. If the correlation existing between the characters is positive, simultaneous improvement of these traits by a single selection programme is possible, but when negative association exists, it would be difficult to exercise simultaneous selection of these characters in developing a variety (Newell and Eberhart, 1961).

Overall, the important curd weight attributing traits in the current study namely, gross plant weight, curd solidity, curd equatorial length, leaf size index, leaf breadth and days to 50% marketable maturity, were found to exhibit significant positive correlation among them. It may be concluded that these traits strongly influenced marketable curd weight. In the breeding programme due weightage for these traits may be given for improvement of curd weight. Again, since the traits are inter correlated between themselves, selection in any one of these characters will result in the improvement of other trait thus, resulting in increasing in marketable curd weight.

PATH COEFFICIENT ANALYSIS

Clarified approach is followed by path coefficient analysis during association of several horticultural traits.

Table 11. Genotypic and Phenotypic coefficients of correlation for different characters in cauliflower

CHARACTERS		PH	DMCM	NLPP	PF	LL	LB	LSI	SL	CPL	CEL	CSI	CS	GPW	MCW
PH	**G**	**1.00**	0.45*	0.57*	0.61*	0.82*	0.33*	0.66*	0.49*	0.74*	0.13	0.58*	-0.24*	0.65*	0.14
PH	**P**	**1.00**	0.25*	0.49*	0.46*	0.70*	0.17	0.51*	0.46*	0.51*	0.15	0.38*	-0.17	0.55*	0.11
DMCM	**G**		**1.00**	0.14	0.22	0.56*	0.49*	0.61*	0.11	0.55*	0.33*	0.56*	0.12	0.59*	0.45*
DMCM	**P**		**1.00**	0.02	0.11	0.30*	0.34*	0.40*	0.06	0.35*	0.23	0.41*	0.06	0.45*	0.29*
NLPP	**G**			**1.00**	0.89*	0.56*	0.24*	0.46*	0.03	0.28*	-0.11	0.11	-0.19	0.50*	-0.02
NLPP	**P**			**1.00**	0.64*	0.48*	0.08	0.33*	0.05	0.17	-0.05	0.06	-0.05	0.41*	0.05
PF	**G**				**1.00**	0.51*	0.48*	0.58*	-0.07	0.33*	0.03	0.19	0	0.70*	0.25*
PF	**P**				**1.00**	0.42*	0.29*	0.44*	-0.04	0.17	-0.01	0.09	-0.02	0.63*	0.09
LL	**G**					**1.00**	0.47*	0.86*	0.33*	0.45*	0.01	0.33*	-0.16	0.58*	0.16
LL	**P**					**1.00**	0.29*	0.76*	0.20	0.19	0.11	0.19	-0.03	0.47*	0.13
LB	**G**						**1.00**	0.86*	-0.27*	-0.05	0.27*	0.00	0.52*	0.78*	0.63*
LB	**P**						**1.00**	0.85*	-0.24*	-0.20	0.12	-0.09	0.38*	0.56*	0.39*
LSI	**G**							**1.00**	0.01	0.23	0.15	0.19	0.19	0.79*	0.44*
LSI	**P**							**1.00**	-0.07	-0.03	0.14	0.05	0.23	0.65*	0.33*
SL	**G**								**1.00**	0.69*	0.09	0.60*	-0.35*	0.14	-0.14
SL	**P**								**1.00**	0.50*	0.05	0.39*	-0.29*	0.09	-0.11
CPL	**G**									**1.00**	0.43*	0.92*	-0.54*	0.36*	-0.14
CPL	**P**									**1.00**	0.44*	0.86*	-0.49*	0.21	-0.05
CEL	**G**										**1.00**	0.73*	0.14	0.25*	0.37*
CEL	**P**										**1.00**	0.77*	0.06	0.22	0.35*
CSI	**G**											**1.00**	-0.32*	0.35*	0.06
CSI	**P**											**1.00**	-0.28*	0.25*	0.16
CS	**G**												**1.00**	0.42*	0.91*
CS	**P**												**1.00**	0.41*	0.86*
GPW	**G**													**1.00**	0.73*
GPW	**P**													**1.00**	0.62*
MCW	**G**														**1.00**
MCW	**P**														**1.00**

*Significant at 5% level of significance

Where, DMCM= Days to marketable maturity, NLPP= Number of leaves per plant, PH= Plant height, LL= Leaf length, LB= Leaf breadth, PF= Plant frame, LSI= Leaf size index, SL= Stalk length, PCL= Polar curd length, ECL= Equatorial curd length, CSI= Curd size index, CS= Curd solidity, GPW= Gross plant weight

Correlation values only guide us through positive and negative significant, non-significant knowledge and devoid of any direct or indirect dependence (Shekhawat *et al.* 2014). Path coefficient analysis renders the bifurcation of phenotypic and genotypic correlation coefficients together in terms of direct and indirect effects (Sheemar *et al.* 2012). Dewey and Lu (1959) were the first to suggest the use of path coefficient analysis in breeding programmes. In order to understand the effects of different independent characters or in combination with other characters on marketable curd weight, the estimates of direct and indirect effects were computes through path coefficient analysis in the present studies and results are presented in table 12.

Table 12 presented that leaf size index had highest positive direct effect (2.166) on marketable curd weight followed by curd size index (1.699), curd solidity (1.210), plant height (0.424), number of leaves per plant (0.282), days to 50 per cent marketable maturity (0.124) and stalk length (0.054). On the other hand maximum negative direct effect was shown by plant frame (-0.009), gross plant weight (-0.497), curd equatorial length (-0.677), leaf breadth (-0.851), curd polar length (-0.93) and leaf length (-1.55) on marketable curd weight.

Positive indirect effect on marketable curd weight via plant height was recorded for the traits viz., leaf length (0.349), curd polar length (0.312), leaf size index (0.281), number of leaves per plant (0.240), gross plant weight (0.275), curd size index (0.246), days to 50 per cent marketable maturity (0.189) and plant frame (0.259). The trait days to50 per cent marketable maturity through plant height (0.055), number of leaves per plant (0.017), plant frame (0.027), leaf length (0.069), leaf breadth (0.061), leaf size index (0.075), stalk length (0.013), curd polar length (0.069), curd equatorial length (0.041), curd size index (0.069), curd solidity (0.015) and gross plant weight (0.073) showed positive indirect effect on marketable curd weight.

Number of leaves per plant imposed positive indirect effect through plant height (0.159), days to marketable maturity (0.039), plant frame (0.251), leaf length (0.157), leaf breadth (0.067), leaf size index (0.131), stalk length (0.009), curd polar length (0.080), curd size index (0.031) and gross plant weight (0.142) on the marketable curd weight. On the other hand leaf size index imposed positive indirect effect through plant height (1.435), days to 50 per cent marketable maturity (1.313), number of leaves per plant (1.005), plant frame (1.263), leaf length (1.851), leaf breadth (1.865), stalk length (0.022), curd polar length (0.488), curd equatorial length (0.333), curd size index (0.414), curd solidity (0.403) and gross plant weight (1.700) showed positive indirect effect on marketable curd weight.

Positive indirect effect on marketable curd weight via stalk length was recorded for the traits viz., plant height (0.026), days to 50 per cent marketable maturity (0.006), number of leaves per plant (0.002), leaf length (0.018), leaf size index (0.001), curd polar length (0.037), curd equatorial length (0.005), curd size index (0.032), and gross plant weight (0.007).

Curd size index imposed positive indirect effect through plant height (0.985), days to 50 per cent marketable maturity (0.956), number of leaves per plant (0.191), plant frame (0.329), leaf length (0.567), leaf size index (0.324), stalk length (1.025), curd polar length (1.569), curd equatorial length (1.235), and gross plant weight (0.597) showed positive indirect effect on marketable curd weight. On the other hand curd solidity imposed positive indirect effect through days to 50 per cent marketable maturity (0.143), leaf breadth (0.624), leaf size index (0.225), curd equatorial length (0.166), and gross plant weight (0.502) showed positive indirect effect on marketable curd weight.

Chittora *et al.* (2017) and Chatterjee *et al*. (2018) showed positive direct effect via curd depth, days to marketable maturity and plant height. Close proximity was depicted by Jha *et al.* (2014) in curd depth and plant height. Whereas Singh *et al*. (2014) showed direct negative effect plant frame and curd equatorial length which was in accordance with the above findings.

The contribution of different traits towards the marketable curd weight have also been reported by Khar and Pathania (1998) for days to 50% marketable curd maturity, Kanwar and Korla (2002) and Garg and Lal (2004) for curd size index, Sharma *et al*. (2006) and Sheemar *et al*. (2012) for curd polar length and Kanwar and Korla (2002) and Kumar *et al*. (2011) for stalk length, Shree *et al*. (2019) for leaf length and leaf breadth. Marketable curd weight, curd equatorial length, number of leaves per plant, curd size index, and gross plant weight are the important traits for selection for improvement in early cauliflower (Chittora and Singh, 2017).

The residual effect at genotypic level was observed to be 0.00609.

Table 12. Estimates of direct and indirect effects of different characters on marketable curd weight of cauliflower

Characters	PH	DMCM	NLPP	PF	LL	LB	LSI	SL	CPL	CEL	CSI	CS	GPW	GCC
PH	**0.424**	0.055	0.159	-0.005	-1.276	-0.279	1.435	0.026	-0.684	-0.090	0.985	-0.293	-0.322	0.14
DMCM	0.189	**0.124**	0.039	-0.002	-0.868	-0.418	1.313	0.006	-0.512	-0.221	0.956	0.143	-0.294	0.45
NLPP	0.240	0.017	**0.282**	-0.008	-0.864	-0.202	1.005	0.002	-0.264	0.075	0.191	-0.240	-0.249	-0.02
PF	0.259	0.027	0.251	**-0.009**	-0.790	-0.405	1.263	-0.004	-0.306	-0.016	0.329	-0.005	-0.349	0.25
LL	0.349	0.069	0.157	-0.004	**-1.55**	-0.402	1.851	0.018	-0.417	-0.003	0.567	-0.185	-0.290	0.16
LB	0.139	0.061	0.067	-0.004	-0.734	**-0.851**	1.865	-0.014	0.049	-0.182	-0.007	0.624	-0.386	0.63
LSI	0.281	0.075	0.131	-0.005	-1.325	-0.732	**2.166**	0.001	-0.210	-0.104	0.324	0.225	-0.390	0.44
SL	0.208	0.013	0.009	0.001	-0.505	0.227	0.022	**0.054**	-0.639	-0.061	1.025	-0.422	-0.068	-0.14
CPL	0.312	0.068	0.080	-0.003	-0.695	0.045	0.488	0.037	**-0.93**	-0.290	1.569	-0.649	-0.177	-0.14
CEL	0.057	0.041	-0.031	-0.000	-0.008	-0.229	0.333	0.005	-0.398	**-0.677**	1.235	0.166	-0.123	0.37
CSI	0.246	0.069	0.031	-0.001	-0.517	0.004	0.414	0.032	-0.859	-0.492	**1.699**	-0.389	-0.175	0.06
CS	-0.103	0.015	-0.056	0.000	0.240	-0.438	0.403	-0.018	0.499	-0.093	-0.546	**1.21**	-0.207	0.91
GPW	0.275	0.073	0.142	-0.006	-0.904	-0.662	1.700	0.007	-0.331	-0.167	0.597	0.502	**-0.497**	0.73

At genotypic level, the residual effect = 0.00609

Where, DMCM= Days to marketable maturity, NLPP= Number of leaves per plant, PH= Plant height, LL= Leaf length, LB= Leaf breadth, PF= Plant frame, LSI= Leaf size index, SL= Stalk length, PCL= Polar curd length, ECL= Equatorial curd length, CSI= Curd size index, CS= Curd solidity, GPW= Gross plant weight

Chapter-5

SUMMARY AND CONCLUSION

The study accredited, **"Genetic Evaluation of Newly Introduced Genotypes of Cauliflower (*Brassica oleracea* var. *botrytis* L.)"**, was conducted at experimental farm of Regional Horticultural Research & Training Station, Jachh (Nurpur), district- Kangra, Himachal Pradesh. The experiment was laid out in the Randomized Complete Block Design (RCBD) in Rabi, 2020. It included twenty four genotypes with two check cultivars *viz.*, Pusa Shukti and PSBK-1. The nature and magnitude of variability, heritability, genetic advance and genetic gain was worked upon for selection of favourable traits. Correlation and path coefficient analysis was also done to stratify the superior genotypes for the present programme besides facilitate the farmers with varieties suitable to low lying areas.

Fourteen characters were evaluated namely days to marketable maturity, number of leaves per plant, plant height (cm), leaf length (cm), leaf breadth (cm), leaf size index (cm^2), plant frame (cm), gross plant weight (g), stalk length (cm), marketable curd weight (g), curd polar length (cm), curd equatorial length (cm), curd size index (cm^2), curd solidity (g/cm).

Parameters of variability, correlation and path coefficient analysis was done for marketable curd weight with rest of the traits. Significant variations were observed for almost all the traits. Least number of days to mature was taken by EC-716673 (65.56), EC-808750 (67.67) and EC-808738 (70.33) whereas EC-716550 took maximum days to mature (96.57). EC-808738 (21.37) followed by Pusa Shukti (20.57) and EC-683455 (20.40) had maximum number of leaves per plant. EC-716550 had minimum number of leaves per plant (12.27). Plant height was found maximum in EC-716672 (46.20 cm), EC-690942 (46.17 cm) and EC-683455 (45.53 cm) while minimum in EC-716673 (27.17 cm). Maximum stalk length was observed in EC-690942 (6.99 cm) followed by EC-683455 (5.44 cm) and EC-716679 (4.89 cm) while minimum stalk length observed in EC-162587 (2.78 cm), EC-716638 (2.78 cm) and Pusa Shukti (2.78 cm). EC-690942 (42.56 cm), EC-702493 (42.55 cm) and EC-716672 (42.44 cm) had maximum leaf length than EC-716673 having minimum leaf length (27.78 cm). Leaf breadth was observed maximum in EC-716672 (17.78 cm) followed by EC-702493 (17.44 cm) and Pusa Sharad (17.33 cm). Minimum leaf breadth was observed in EC-808738 (12.56 cm). Leaf size index was found maximum in EC-716672 (754.67 cm^2)

followed by EC-702493 (738.67 cm^2) and Pusa Sharad (728.22 cm^2) whereas minimum was found in EC-716673 (360.33 cm^2). Pusa Sharad (58.22 cm^2), EC-716672 (55.11 cm^2) and EC-162587 cm^2) had maximum plant frame while minimum was observed in EC-716613 (34.28 cm^2). The maximum curd polar length was observed in EC-690942 (9.67 cm) followed by EC-716550 (8.55 cm) and EC-791397 (8.11 cm). EC-808748 had least value for curd polar length (5.22 cm). EC-808748 recorded the minimum value for equatorial length (8.55 cm) while EC-716638 lead all the genotypes (11.50 cm) proceeded by EC-716679 (11.33 cm) and EC-690942 (11.33 cm). Three genotypes namely PSBK-1 (46.21 g/cm), EC-808779 (42.22 g/cm) and EC-716672 (42.13 g/cm) had maximum curd solidity. Contrastingly minimum curd solidity was recorded in EC-808738 (15.59 g/cm). Gross plant weight in EC-716672 was largest (1492.33 g) followed by PSBK-1 (1149.46 g) and EC-702493 (1121.68 g). EC-716613 had minimum gross plant weight (726.66 g). EC-716672 had highest marketable curd weight (713.87 g) followed by PSBK-1 (681.67 g) and EC-808779 (660.00 g). On the other hand EC-716642 had minimum marketable curd weight (522.21 g). Maximum genotypes expressed compact curd namely EC-162587, EC-656627, EC-702493, EC-716550, EC-716638, EC-716642, EC-716672, EC-716673, EC-716679, EC-791397, EC-808738, EC-808750, EC-808737, PSBK-1 and Pusa Shukti. However medium compactness was observed in EC-683455 and EC-716613. While seven genotypes of cauliflower had less compact curds. PSBK-1 was the only genotype which had snow white curds. The majority of the genotypes gave either white or creamy white curds while two genotypes produced purple coloured curds. The majority of the genotypes were found to be light green leaves followed by bluish green leaves. Only three genotypes EC-162587, EC-716638 and PSBK-1 showed dark green leaves. Three genotypes namely EC-690942, EC-716672 and EC-808779 produced ricey curds and rest showed non-ricey curds.

After the evaluation of all the characters, higher values were spotted for phenotypic coefficient of variation than genotypic coefficient of variation. Curd solidity had highest values for both phenotypic and genotypic coefficient of variation. Moderate phenotypic and genotypic coefficients of variation was found in stalk length, gross plant weight, curd size index, leaf size index and marketable curd weight, curd equatorial length, leaf length, days to 50 per cent marketable maturity, leaf breadth, plant frame showed low genotypic and phenotypic coefficients of variability. High heritability was recorded in gross plant weight. On the other hand moderate heritability was observed in plant frame, plant height, curd solidity, leaf length, number of leaves per plant, stalk length, marketable curd weight, leaf size index, days to 50 per cent marketable maturity, curd polar length, curd equatorial length and curd size index. High heritability coupled with moderate genetic gain was found in curd solidity enabling improvement of such traits through selection. Plant frame, leaf length, leaf breadth, number of leaves per plant, marketable curd weight, days to 50 per cent marketable maturity, curd polar length, curd equatorial length and curd size depicted moderate heritability and low genetic gain which favoured selection only by recombination. Generally, genotypic correlation coefficients were found to be higher than phenotypic correlation coefficients. Results indicated that marketable curd weight had positive and significant correlation with the days to 50 per cent marketable maturity, plant frame, leaf breadth, leaf size index, curd equatorial length, curd solidity and marketable curd weight. Hence, there is ample scope of selection for these traits.

Since correlation coefficients only demonstrates about positive- negative, significant-non significant expression therefore path coefficient analysis plays a major role in classifying direct and indirect effect of characters. This study revealed that maximum positive direct effect towards marketable curd weight was contributed by leaf size index, curd size index, curd solidity, plant height, number of leaves per plant, days to marketable curd maturity and stalk length, thus, indicating direct selection of these traits as a criteria for improvement in cauliflower.

CONCLUSION

- From the present investigation, it can be concluded that genotypes EC-716672, PSBK-1, EC-702493 and EC-808779 gave more gross plant weight and marketable curd weight than one of the check cultivar Pusa Shukti, hence shall be preferred in further breeding programmes.
- In the present investigation, it can be concluded that genotypes PSBK-1, EC-716550 belongs to late maturity group, two genotypes namely EC-716673 and EC-808750 belongs to early maturity group. The genotypes EC-683455, EC-690942, EC-690967, EC-716638, EC-716642, EC-716672, EC-808731, EC-808738, EC-808737, EC-808779, Pusa Sharad, EC-162587 belongs to mid early maturity group and EC-683451, EC-702493, EC-716613, EC-716679, EC-791397, EC-808748, Pusa Shukti belongs to mid late maturity group.
- Curd solidity showed highest phenotypic and moderate genotypic coefficients of variability among all the horticultural traits. Both the coefficients had moderate

values for leaf size index, stalk length, curd size index and gross plant weight. Successful selection in the crop can be accomplished for the trait like gross plant weight as it had high heritability coupled with moderate genetic gain. Moderate heritability along with moderate genetic gain was seen in plant height, leaf size index, stalk length, curd solidity and gross plant weight giving a scope of improvement through selection. Moderate heritability and low genetic gain in days to marketable maturity, number of leaves per plant, plant frame, leaf length, leaf breadth, curd polar length, curd equatorial length, curd size index and marketable curd weight favours selection only by recombination.

Table 13. Three best genotypes with respect to different traits in cauliflower

Characters	Genotypes
Plant height (cm), Plant frame (cm^2), Leaf length (cm), Leaf breadth (cm), Leaf size index (cm^2), Curd solidity (g/cm), Gross plant weight (g), Marketable curd weight (g)	EC-716672
Curd solidity (g/cm), Gross plant weight (g), Marketable curd weight (g)	PSBK-1
Plant height (cm), Leaf length (cm), Stalk length (cm), Curd polar length (cm), Curd equatorial length (cm), Curd size index (cm^2)	EC-690942

- High positive and significant correlation of marketable curd weight was observed with the days to 50 per cent marketable maturity, plant frame, leaf breadth, leaf size index, curd equatorial length, curd solidity and marketable curd weight.
- Maximum positive direct effect on marketable curd weight was expressed by leaf size index, curd size index, curd solidity, plant height, number of leaves per plant, days to marketable curd maturity and stalk length. Maximum positive indirect effect towards marketable curd weight was recorded by leaf breadth through leaf size index, gross plant weight through leaf size index and curd polar length through curd size index.
- Fifteen genotypes showed compact curds. Two genotypes showed medium compactness while seven genotypes expressed loose compactness.
- Light green leaves were observed in fourteen genotypes out of 24. Seven genotypes showed bluish green leaves white only three genotypes showed dark green leaves.
- Majority of the genotypes showed creamy white colour including check cultivar Pusa Shukti and snow white colour was observed only in check cultivar PSBK-1. Six genotypes showed white colour curds while two showed purple colour.

EC-716672

EC-683455

EC-690942

Pusa Shukti (C)

PSBK-1 (C)

Plate 2. Promising genotypes of cauliflower along with check variety

- Riceyness was present in the genotypes EC-690942, EC-808779 and in some plants of the genotype EC-716672.
- Under Jachh conditions EC-716672, PSBK-1 and EC-690942 were the best three genotypes but further improvement is necessary before coming to any conclusion.

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APPENDIX-I

Analysis of variance for various horticultural characters in cauliflower

Source	Mean sum of squares			
Characters	**Replications**	**Genotypes**	**Error**	**F cal.**
df	**2**	**23**	**46**	
Plant height (cm)	5.988	95.439	8.517	11.206
Days to 50% marketable maturity	516.937	249.084	45.612	5.461
Number of leaves per plant	5.344	18.467	2.836	6.512
Plant spread (cm^2)	27.249	106.455	10.828	9.831
Leaf length (cm)	10.352	51.981	7.276	7.144
Lead breadth (cm)	2.306	8.077	2.671	3.023
Leaf size index (cm^2)	1,145.66	32,030.71	5,841.19	5.484
Stalk length (cm)	0.203	2.757	0.424	6.495
Curd polar length (cm)	0.347	2.777	0.54	5.138
Curd equatorial length (cm)	0.695	2.205	0.418	5.271
Curd size index (cm^2)	136.324	527.332	123.862	4.257
Curd solidity (g/cm)	85.278	209.177	26.393	7.925
Gross plant weight (g)	4,475.33	72,139.90	3,322.36	21.713
Marketable curd weight (g)	2,829.82	6,795.59	1,077.55	6.307

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Title of thesis	"**Genetic Evaluation of Newly Introduced Genotypes of Cauliflower (*Brassica oleracea* var. *botrytis* L.)**"
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Number of words in abstract	346

ABSTRACT

The current investigation accredited **"Genetic Evaluation of Newly Introduced Genotypes of Cauliflower (*Brassica oleracea* var. *botrytis* L.)"** was undertaken at experimental farm of Regional Horticulture Research & Training Station, Jachh (Nurpur), District- Kangra, Himachal Pradesh during 2020. Twenty four genotypes of cauliflower including PSBK-1 and Pusa Shukti as check were laid out in RCBD with three replications during Rabi season. Analysis of variance showed significant differences among all the genotypes for all the horticultural traits namely days to marketable maturity, number of leaves per plant, plant height, stalk length, plant frame, leaf length, leaf breadth, leaf size index, curd polar length, curd equatorial length, curd size index, curd solidity, gross plant weight and marketable curd weight. EC-716672, PSBK-1 and EC-808779 had highest marketable curd weight than the Pusa Shukti and other genotypes as well and hence shall be preferred for further breeding programmes. Fifteen genotypes were compact, two genotypes had medium compactness whereas, seven genotypes had less compact curds. The genotypes PSBK-1, EC-716550 belonged to late maturity group, two genotypes namely EC-716673 and EC-808750 belonged to early maturity group. The genotypes EC-683455, EC-690942, EC-690967, EC-716638, EC-716642, EC-716672, EC-808731, EC-808738, EC-808737, EC-808779, Pusa Sharad, EC-162587 belonged to mid early maturity group and EC-683451, EC-702493, EC-716613, EC-716679, EC-791397, EC-808748, Pusa Shukti belonged to mid late maturity group. Light green leaf colour was observed in fourteen genotypes, seven genotypes showed bluish green leaves while three genotypes were dark in colour. Majority of the genotypes showed either white or creamy white curd colour and two genotypes showed purple colour curd whereas, PSBK-1 displayed snow white colour. Riceyness was present in EC-690942, EC-716672 and EC-808779 only. Curd solidity had highest values for both phenotypic and genotypic coefficient of variation.High heritability in complement to moderate genetic gain was found only in gross plant weight while moderate heritability and moderate genetic gain was observed in plant height, leaf size index, stalk length and curd solidity. Curd solidity had the highest positive significant correlation with marketable curd weight. Path coefficient analysis revealed highest positive direct effect of leaf size index on marketable curd weight.

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