"Germplasm Evaluation, Correlation and Path Analysis in Coriander (*Coriandrum sativum* L.) in High Hills of Uttarakhand"

Thesis

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By
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CERTIFICATE

This is to certify that the thesis **"Germplasm Evaluation, Correlation and Path Analysis in Coriander (*Coriandrum sativum* L.) in High hills of Uttarakhand"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Horticulture** with major in **Spices and Plantation crops, Medicinal and Aromatic Plants** of the College of Horticulture, VCSG Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal (UK), is a record of ***bona fide*** research carried out by **Mr. Jaidev Chauhan, Id. No. 14146**, under my supervision, and no part of the thesis has been submitted for other degree or diploma.

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(Dr. B. P. Nautiyal)

Chairman
Advisory Committee

CERTIFICATE

We, the undersigned, members of the Advisory Committee, of **Mr. Jaidev Chauhan, Id. No. 14146**, a candidate for the degree of **Master of Science in Horticulture** with major in **Spices and Plantation Crops, Medicinal and Aromatic Plants,** agree that the thesis entitled **"Germplasm Evaluation, Correlation and Path Analysis in Coriander (*Coriandrum sativum* L.) in High hills of Uttarakhand"** may be submitted in partial fulfillment of the requirements for the degree.

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(Co-advisor)	Member	Member	Member

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ABBREVIATIONS

%	Per cent
&	And
°C	Degree centigrade
A D	After death / Anno Domini
BC	Before Christ
CAN	Calcium Ammonium Nitrate
CD	Critical difference
cm	Centimetre
cm^2	Square Centimetre
et al.,	And others
E	East
Fig.	Figure
g	Gram
GA	Genetic Advance
GG	Genetic Gain
GCV	Genetic Coefficient of Variation
ha	Hectare
i.e.,	That is
I.U	International unit
ISO	International organization for Standardization
Kg	Kilogram
m	Metre
m^2	Square metre
mg	Milligram
mm	Millimetres
MOP	Murate Of Potash

mt	Metric tone
NRCSS	National Research Centre on Seed Spices
N	North
PCV	Phenotypic Coefficient of Variation
q	Quintal
RCBD	Randomized Complete Block Design
SEd	Standard error of the difference
S	South
t	Tonne
Viz,	which is/are
VCSG	Veer Chandra Singh Garhwali
W	West

CHAPTER-1
INTRODUCTION

Coriander (*Coriandrum sativum* L.), (2n=2x=22) is an annual herb belonging to family Umbelliferae. Coriander was originated from the Mediterranean region between the Eastern Mediterranean and Caucasus mountains (Vaidya, 2000). The whole plant and especially the unripe fruit is characterized by a strong disagreeable odour. Its name has been derived from the Greek word "Koris" meaning bed bug because of unpleasant seed coat colour. (Gruenwalded, 2004).

Coriander was first used in Egypt for culinary purpose as early as 1550 BC and is mentioned in the Eberspapyrus. It is also mentioned in Sanskrit as a drugs implored by Hippocrates about 400 BC. Coriander is mostly used for pleasant aromatic odour. The entire plant, when young is used for preparing chutneys, sauces and leaves are used for flavoring curries and soups. The coriander oil contains coriandrol. It is a herb with thin stem, bushy appearance and 90-100 cm in height. Leaves are alternate, compound and petiole has a pair of stipules sheathing the stem base. The lower leaves are broad, pinnate and have long petioles with crenately lobed margins. The upper leaves are cut with linear lobes and are bi or tri-pinnate. The flowers are pink or white. The seeds are green round (botanically fruit) attain greyish brown colour at maturity.

The coriander seed is used as spice in the preparation of curry powder, pickling spices, sauces and seasoning. They are used for flavouring pastry, cookies, cakes etc. It is one of the important ingredient in the manufacture of food flavourings, bakery products, meat, fish and salads, soda and syrups, candy preserves. It is also used for flavouring liquor, particularly gin. The young tender plant is used in preparing chutneys and sauces and the leaves are used for flavouring curries and soups.

It requires a relatively cool and humid climate. It is largely confined to the arid and dry areas of India Such as Rajasthan and Gujarat. In Uttarakhand region, Coriander is one of the important seed spice grown over an area of 0.90 thousand hectare with an annual production of 3.80 thousand tons. Because of economic importance, production of coriander is still low in the country having area of 447.13 thousand hectare and production of 313.77 thousand tons (Horticulture statistics at a glance, 2015).The coriander leaves have a pleasant aroma and medicinal purpose. Hundred gram coriander seeds contain moisture 6.3g, Iron 0.006g, carbohydrate 24.0g, Potassium 1.2g, protein 1.3g, vitamin A 175U, fat 19.6g, riboflavin 0.26mg, fibre 31.5g, thiamine 0.23mg, mineral matter 5.3g, Niacin 3.2mg, Calcium 0.8g, vitamin C 12.0mg, Phosphorus 0.44g, volatile oil 0.3g , Sodium 0.82g and non-volatile oil 22.0g (Pruthi, 1979).

All parts of the plant are edible but the fresh leaves and the dried seeds are the most common parts used in cooking. In the Indian traditional medicine, a coriander is used in disorders of digestive, respiratory and urinary system, as it has diaphoretic, diuretic, carminative and stimulant (Abidhusen *et al*, 2012).

India is a major seed spices producer in the world because of its favourable climatic and soil conditions for growing spices and other tropical herbs, therefore it is known as the “Home of Spices or land of Spices”. The great Vasco De Gama discovered sea route to India with main aim for spices trade. International organization for Standardization (ISO) has listed 109 spices worldwide. In India around 63 spices are grown including seed spices. Out of 63 spices, 20 are classified as seed spices (Anwer *et al*, 2011). Out of 20 seed spices 10 are mandate and main seed spices of the National Research Centre on Seed Spices (NRCSS) Ajmer, India. These are coriander, cumin, fennel, fenugreek, dill, ajowain, celery, anise, nigella and caraway. From north of India, Jammu and Kashmir to South, Kerala (Spices State of India), in West, Gujarat and Rajasthan (Seed Spices Bowl) to Eastern States. Coriander is commercially cultivated in India, Bulgaria, Iran, Canada, China, Morocco, Syria, Romania, Egypt, Russia, Japan and Pakistan (K.V Peter). In India coriander occupies the pride of place among the seed spices. Its commercial cultivation is limited to a few states, which include Rajasthan, Madhya Pradesh, Karnataka, Andhra Pradesh, Tamilnadu and Bihar.

For getting higher production selection of promising genotypes in a breeding programme is based on various criteria, most importantly final crop yield and its quality. Relationships among yield and yield-contributing traits also play an important role (Diz *et al,* 1994; Guler *et al*, 2001; Mohammad *et al*, 2003; Rabiei based on other plant and/or crop features, such as, early maturity (Ahmad *et al,* 1991), industrial crop yield (*e.g.* oil yield), (Baye & Becker 2005), crop resistance (Bridge, 2000 and Singh *et al*, 2004) and yield quality features (Gravois 1998; Topal *et al*, 2004). Whatever criteria are used, there is always a final trait (seed yield) or several final traits (seed yield and quality) to which the most attention is paid.

The correlation gives the idea about the extent of association existing between yield and yield components. Moreover, the information related to the nature and extent of association among various yield attributes and direct and indirect influence of each component traits on the yield could prove helpful in formulating effective breeding strategy. Further, path analysis explores the relative contribution of both direct and indirect effects of yield components on the yield. Wright (1921) gave the theory of path coefficient for statistical analysis of cause and effects, which gives a critical examination of specific forces acting to produce correlation. Thus, it becomes imperative to get information on the nature and magnitude of association between different yield components and to resolve and quantify their mode of contribution towards yield. To group the genotypes and in turn, to find the best group of the genotypes, cluster analysis (Everitt *et al*, 2001; Fraley and Raftery 1998) may be applied.

Germplasm is a vital source in generating new plant types having desirable traits that help in increasing crop production with quality and thus improve the level of human nutrition. In order to maintain, evaluate and utilize germplasm efficiently and effectively, it is important to investigate the extent of genetic diversity, it contains (Smith and Smith, 1989). The crop has promising future. And therefore, the present investigation was made to know about best performing and adaptable germplasm of coriander in near temperate high hills of Garhwal Himalayan region with the following objectives:

1. To assess the variability, heritability and genetic advance among the elite cultivars.
2. To analyse association among various horticultural traits, and direct and indirect effect of horticultural traits on yield.

CHAPTER-2

REVIEW OF LITERATURE

In this chapter an attempt has been made to review the relevant literatures under the following sub-heads:

4.1 Genetic variability

4.2 Correlation and path-coefficient studies

4.3 Multivariate and cluster analysis for identification of superior germplasm lines.

4.1Genetic variability

Sharma and Sharma (1989) studied of 200 lines of coriander (*Coriandrum sativum* L.) showed significant variability for plant height, branches per plant, days to flowering and maturity, umbels and umbellates per plant, grains per umbellate, 1000- grain weight, straw and grains yield per plant. The heritability estimate was high for 1000-grain weight, days to flowering and maturity, and low for umbels per plant, umbellates per plant, and grains yield per plant. Grains yield per plant had positive and significant correlation with plant height per plant, number of branches per plant, number of umbels per plant, and number of umbellates per plant, grains per umbellate and straw yield per plant. Path coefficient analysis revealed that umbellates per plant. 1000-grain weight, and branches per plant were the most important characters for selection of high yielding genotypes, as they had direct positive effect as well as positive (except 1000-grain weight) association with grain yield per plant.

Shridhar *et al* (1990) studied on genetic variability, heritability and genetic advance is derived from data on 13 characters in 19 indigenous and exotic genotypes grown in 1988-89. Considerable variation was noted for number of leaves, secondary branches, fresh weight of plant, days to 50% flowering, 1000-seed weight and seed yield per plant.

Megeji and Korla (2002) evaluated 30 genotypes of coriander in a field experiment conducted in Solan, Himachal Pradesh, India. Analysis of variance indicated significant differences in all the characters studied. Genotypic and phenotypic coefficients of variation were high for leaf yield, seed vigour and seed yield. Heritability was highest for thousand seed weight, followed by germination per cent and seed vigour. Leaf yield, 1000-seed weight, germination per cent and seed vigour recorded high genetic advance.

Kalra *et al* (2003) studied the 120 Indian accessions of coriander (*Coriandrum sativum* L.) and these were screened under late planting conditions in Lucknow, Uttar Pradesh, India during 1998-99 for time taken before flowering and fruit maturity, seed yield, seed size, essential oil content of seeds, oil yield and susceptibility to powdery mildew and stem gall diseases. High levels of variability were observed for all the characters. In the same study, they found that a negative correlation between seed yield, and essential oil content and susceptibility to stem gall disease, and a significant positive relationship between days to flower and days to maturity, oil yield and late maturity. One of the accessions - CIMAP 2053 - was early maturing, high seed-yielding, had large fruits and exhibits a fair degree of tolerance to powdery mildew and stem gall diseases. The accession CIMAP 2096 was early maturing with a high degree of tolerance to major diseases and seeds rich in essential oil. It was concluded that these accessions would be suitable for cultivation under late sown conditions in Indo Gangetic plains for higher yield of seeds and essential oil.

Rajput and Singh (2003) studied the 20 genetically diverse genotypes of coriander during Rabi 2001-02 in Jobner, Rajasthan, India. For genetic variability for 7 characters days to flowering, plant height, branches per plant, umbels per plant, umbellates per umbel, seeds per umbel and seed yield. In the same study estimates of genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance were recorded for seed yield, umbels per plant, seeds per umbel and plant height, suggesting the probable role of additive gene effects on character expression. Superior genotypes for different characters were identified that could be exploited for intervarietal hybridization (reciprocal recurrent selection) for developing a high-yielding cultivar with other desirable characters.

Shah *et al* (2003) studied 20 coriander cultivars grown in Udaipur, Rajasthan, India during the Rabi season of 2000-2001 under 3 environments: E1 (early sowing; 23 October), E2 (optimum sowing; 4 November) and E3 (late sowing; 16 November).The genetic variation and correlation analyses for 11 traits were studied .The genotype x environment interaction was significant for days to flowering, plant height, 1000-seed weight, harvest index and oil content. The phenotypic coefficient of variation was generally higher than the genotypic coefficient of variation. High estimates of heritability were recorded for oil content, 1000-seed weight, number of days to flowering, number of days to maturity and plant height. Higher magnitude of genetic gain was recorded for oil content, 1000-seed weight, plant height, number of umbels per plant and seed yield per plant. Oil content, 1000-seed weight, plant height and days to flowering were characterized by high heritability coupled with high genetic gain. At the genotypic and phenotypic levels, seed yield per plant was highly correlated with harvest index. The number of seeds per umbel and number of umbels per plant were significantly correlated with seed yield per plant under all the three environments. The number of primary branches per plant and plant height was positively associated with seed yield under E2 only. The number of primary branches and number of umbels per plant had a negative association with seed yield. The significant positive direct effect on seed yield was exhibited by the number of primary branches per plant. The number of seeds per umbel showed a direct negative effect on seed yield. Harvest index, 1000-seed weight and number of primary branches per plant comprised the major yield contributing characters.

Singh and Shah (2003) evaluated 20 genetically different genotypes of coriander for their stability with respect to their seed yield, its contributing traits and oil content. The genotypes were evaluated in 3 environments .The environments differed significantly as revealed by significant mean square due to environment, for all the traits studied. The genotype x environment interactions was significant for days to flowering, plant height, 1000-seed weight, harvest index and oil content. Whereas, non-significant mean square genotype x environment interaction for remaining traits showed linear response of genotypes to varying environments. Linear and non- linear interactions were significant for plant height, 1000-seed weight, harvest index and oil content, whereas for seed yield only linear component was significant. The genotypes with good yield potential, average plant height and medium maturity were G.Cori-1, RCr-20, UD-262, RCr-446, UD-744, CS-2, RCr-41 and G.Cori-2 these germplasm suited for favorable environments, while Patan Mandi-1 and UD-447 with regression coefficient <1.0 were suitable for a low yielding environment.

Patel *et al* (2008) carried out variability analysis for 15 characters in 36 diverse genotypes of fennel (*Foeniculum vulgare*) at Jagudan (Gujarat) which revealed highly significant differences among genotypes for all the characters studied. High genotypic and phenotypic variances were observed for days to 50 per cent flowering, days to 50 per cent maturity, plant height, plant height up to main umbel, total branches per plant, and seeds per umbel and seed yield per plant. The highest genotypic coefficient of variation was observed for volatile oil content in seed followed by total branches per plant and number of seeds per main umbel. Heritability estimates were high for seed yield per plant, days to 50 per cent flowering, number of primary branches per plant, total branches per plant, test weight and volatile oil content. High genetic advance as per cent of mean was recorded for seed yield per plant, days to 50 per cent flowering; primary branches per plant, total branches per plant, effective umbels per plant, number of umbellate per umbel, number of seeds per main umbel, test weight and volatile oil content, suggesting that phenotypic selection for these traits would be effective. Overall, it is suggested that for improving yield in fennel, more emphasis should be given to plant height, primary branches per plant, total branches per plant and effective umbels per plant.

Selvarajan *et* al (2008) Evaluated nine genotypes of coriander (*Coriandrum sativum* L.), i.e. CS 97, CS 102 and CS 123 from Jobner (Rajasthan, India); CS 12 and CS 203 from Coimbatore (Tamil Nadu, India); and CS 8, CS 101, CS 208 from Hissar (Haryana, India), were evaluated to identify the suitable types for cultivation in Tamil Nadu under irrigated conditions. The results of the pooled analysis of the 3-year (1998- 2000) data indicated that CS 12 was the best with the highest yield of 579.3 kg per ha, followed by CS 102, recording yield of 561.0 kg per ha. The increase in yield for CS 12 was 10 per cent over the control cultivar CO3, which recorded yield of 529.6 kg per ha.

Bhagat *et al* (2010) evaluated 13 genotype of coriander received from various centers under AICRP on spices. The experiment was laid in randomized block design with three replications. The ancillary data with yield were observed and recorded. Among the entries, maximum yield was recorded in COr-31 (950.35 kg/ha) followed by COr-28 (872.57 kg/ha) and COr-32 (865.63 kg/ha).

Bhagat *et al* (2010) studied 14 genotype of fenugreek obtained from different coordinated centers of AICRP on spices during Rabi 2009 in randomized block design with 10 blocks and three replications. Data on plant height, number of pods per plant, seeds per pods, yield per plot and yield kg per ha were recorded. Among the entries, FGK-27 recorded maximum seed yield (618.06 kg per ha) followed by FGK-34 (375.00 kg per ha) and FGK-37 (348.61 kg per ha).

Meena *et al* (2010) studied 13 diverse varieties of fennel (*Foeniculum vulgare* Mill.) at Ajmer experiment during 2006-08 on nature and variability with released varieties of fennel for yield and yield attributes character. Analysis of variability was carried out for 12 characters in showed highly significant differences among varieties for all the characters. High genotypic and phenotypic variances were observed for umbels per plant, umbellates per umbels and seed yield per plant. The highest genotypic coefficient of variation was observed for yield per plot, followed by umbels per plant, umbellate per umbel and test weight. High genetic advances as per cent of mean was recorded for seed yield per plot, umbels per plant, umbellates per umbel, test weight, number of branches per plant, angle of primary branches, seed per umbels and plant height suggesting that phenotypic selection for these traits would be effective.

Prajapati *et al* (2010) evaluated 43 germplasm lines of Ajawain (*Trachyspermum ammi*) along with released varieties collected from different districts of Gujarat and studied eight quantitative and one qualitative traits during Rabi 2008-09. Wide variability existed among genotypes for all morphological and economic traits. Days to 50 per cent flowering, days to maturity, plant height, number of umbels, number of umbellates, number of seeds, 1000 seed weight and seed yield per plot are highly variable based upon range.

Prajapati *et al* (2010) evaluated 50 germplasm of dill (*Anethum sowa* Kurtz) consisting released varieties and local entries, collected from different districts of Gujarat. The study was based on eight quantitative and two qualitative traits. Wide variability existed among the genotypes for all the morphological and economic traits. Days to 50 per cent flowering, days to maturity, plant height number of umbellates, number of seeds, 1000-seed weight and yield per plot are highly variable based on the variance. The correlation coefficients of the grains yield and some of yield attributing character *viz.* number of branches, number of umbels, number of umbellates and 1000-seed weight revealed that high positive correlation. Number of seeds showed high positive correlation with number of umbels and number of umbellates.

Shoba *et al* (2010) studied 22 coriander accessions for drought tolerance at Tamil Nadu Agriculture University, Coimbatore. The study revealed that out of 22 genotypes evaluated under three phase vegetative phase, reproductive phase and non stress condition, the genotype CS-127 registered the highest plant height, higher root length and earliness in flowering irrespective of moisture stress at vegetative phase, reproductive phase and non-stressed condition. In case of total dry matter production, number of umbels per plant and number of umbellates were high in non-stress condition followed by stress during vegetative growth phase and stress during the reproductive phase, respectively. Whereas, in the case of seed yield, and harvest index, CS-127 registered the highest value under non-stressed condition followed by stress at reproductive growth phase and stress during the vegetative growth phase respectively.

Correlation and Path coefficient analysis

Yield in coriander, as in other crops is a very complex character and is dependent on many other traits. A study of correlation between different quantitative characters provides us with an idea of association that could be effectively utilized in selecting a better plant type in coriander breeding programme. Path coefficient analysis measures direct influence of a variable upon another and permits separation of correlation coefficient into component of direct and indirect effect.

Arumugam and Muthurkrishnan (1979) studied five agronomic traits in 42 lines selected from among 244 lines, estimates of heritability and genetic advance were shown to be high for plant height and number of mericarps per plant. These characters together with number of umbellates per umbel were positively correlated with seed yield.

Suthanthirapandian *et al* (1980) evaluated in 60 types from the germplasm collected from the Tamil Nadu Agriculture University Coimbatore. Height and number of umbels per plant showed wide variation. High heritability estimates were observed for all the characters studied, ranging from 66.48 per for number of primary branches to 84.93 per cent for yield per plant. Genetic advance was high for all characters except number of secondary umbels per umbel.

Rao *et al* (1981) studied 52 varieties of coriander for the number of secondary branches, number of umbels per plant and number of fruits per umbel had high genotypic and phenotypic coefficients of variation. High heritability and high genetic advance were noticed for number of secondary branches and number of umbels per plant. Yield had a significant positive association with height and number of umbels per plant. Path analysis indicated that height, number of umbels per plant and seed weight had the most important direct effect on yield

Jindla *et al* (1985) carry out and recorded the observation on days to flowering, plant height, umbels per plant, umbellate per umbel, seeds per umbellates and seed yield per plot. Plant height, umbels per plant and seeds per umbellates exhibited high heritability and genetic advance. Almost all the characters studied were positively correlated with each other. Path-coefficient analysis indicated that days to flowering, plant height and umbellates per umbel were important characters in making selection for seed yield.

Bhandari and Gupta 1991 evaluated 200 genotypes of (*Coriandrum sativum* L.) exhibited genetic variation for plant height, primary branches per plant and effective branches per plant, days to flowering and maturity, umbels and umbellates per plant, grains per umbellates, 1000 seed weight, straw yield and grain yield per plant and harvest index. Heritability estimates were high for days to flowering, 1000 seed weight and days to maturity; moderate for plant height, straw yield, umbels per plant, umbellate per plant and number of primary branches per plant and low for harvest index, effective branches, grain yield per plant and grains yield per umbellate. Phenotypic correlations of grain yield per plant were highly significant and positive with umbellate per plant, umbels per plant, number of effective branches per plant , straw yield per plant, number of primary branches per plant, plant high per plant, number of grains per umbellate and harvest index. Maximum direct contribution to grain yield per plant was made by umbellate per plant, followed by straw yield per plant, umbels per plant and grains per umbellate, Umbellate per plant made sizeable indirect effect via straw yield per plant. Straw yield per plant made sizeable indirect contribution via umbellate per plant.

Srivastava *et al* (2000) studied path coefficient analysis for 40 genotypes of coriander to determine the direct and indirect effects on seed yield of plant height, number of primary branches, number of secondary branches, days to flowering, days to maturity, number of umbels, number of umbellate per umbel number of seed per plant.

Tripathi *et al* (2000) studied forty genotypes of coriander including controls and reported phenotypic and genotypic coefficient of variations (PCV, GCV), heritability, genetic advance (GA) and correlation coefficients for 10 matrix traits. High estimates of PCV, GCV, heritability and GA indicated substantial genetic variability and scope for selection for days to maturity, secondary branches, days to flowering and 1000 seed weight. There was little variability and scope for improvement through selection for number of umbellates per umbel, primary branches per plant and plant height. Correlation studies indicated that plant height, number of secondary branches, days to flowering, days to maturity and number of umbel per plant were the major yield components whereas number of primary branches, number of umbellates per umbel and number of seeds per umbel, being negatively correlated with yield were less important.

Gurbuz (2001) studied correlation and path analysis among yield components in 25 winter resistant lines of coriander (*Coriander sativum* L.). The highest correlations were found between single plant yield and single plant weight, and number of branches with seeds yield. Path analysis indicated the highest direct and positive effect of single plant weight on single plant yield. Plant height had the highest negative effect on single plant yield.

Choudhary and Ramkrishna (2003) carried out mutagenic studies on polygenic variation for yield and yield components (plant height, number of primary branches per plant, number of umbels per plant, number of umbellates per plant, 1000- seed weight, seed set per umbel and number of seeds per umbel was studied in the M4 progenies of 3 Coriander sativum cultivars (RCr-41, RCr-436 and RCr-20). The M2 progenies were developed through intermating the progenies of the M2 and M2 generations. However, only the M2 progenies recording higher yields that their parents were advanced to the M4 generation without evaluating the M3 generation. A total of 63, 64 and 23 M4 progenies were obtained from RCr-41, RCr-436 and RCr-20, respectively. The between-progeny component of the genetic variance was significant, whereas the within-progeny component of the genetic variance was not significant for all the traits. For yield per plant, none of the progenies of RCr-20 was superior to their parent. However, 1 progeny of RCr-41 and 8 progenies of RCr-436 were superior in 5 of the 7 traits. Most of the progenies of RCr-20 and RCr-41 had undergone inbreeding depression, whereas those of RCr-436 frequently out yielded the control. In RCr-436, the parent and M4 progenies showed high coefficients of variation for yield per plant and number of umbels per plant.

Jain *et al* (2003) studied correlation and path analyses for seed yield and yield components number of days to 50 per cent flowering, height up to the base of the main umbel, total plant height, number of branches per plant, number of umbellates per umbel, number of umbellates per plant, number of seeds per umbel and 1000-seed weight) were conducted for 106 genotypes of coriander (*Coriandrum sativum* L.) and 7 controls (selected from the germplasm collection maintained in Jobner, Rajasthan, India) grown during the rabi season of 2001. Seed yield was positively and significantly correlated with all the traits except number of days to 50% flowering. Total plant height was positively associated with number of umbels per plant, height up to the base of the main umbel, number of branches per plant, number of umbellates per umbel, number of seeds per umbel, and 1000-seed weight. Path analysis revealed that total plant height had the greatest positive direct effect on seed yield, followed by number of umbels per plant and 1000-seed weight. The number of days to 50 per plant flowering had a significant negative correlation with seed yield. The results suggest that selection for greater total plant height, number of umbels per plant and 1000-seed weight, earliness, and less height up to the base of the main umbel will be effective for the improvement of the seed yield of coriander.

Davila *et al* (2004) evaluated 4 genotypes of vegetable coriander under 5 environments in Coahuila, Mexico with an objective to generate models of prediction of flowering using regression, correlation and path analysis. The results showed that the methodologies utilized had capacity to generate models with a high predictive value for each environment of production. The models derived from the variables leaf area at 24 days after sowing, dry weight at 38 days after sowing , relative rate of leaf area at 24 days after sowing , relative rate of leaf growth at 52 days after sowing and duration of leaf area at 38 days after sowing successfully estimated the days to flowering in coriander.

Singh *et al* (2008) studied of 70 germplasm lines of coriander (*Coriandrum sativum* L.) grown on sodic soil for variability, heritability and correlation coefficients of seed yield and its component characters. A wide range of variability was noticed for plant height, branches per plant, umbels per plant, seeds per umbel and seed yield. Ten genotypes were identified more promising for sodic soil yielding above 30 g seed per plant. The high heritability coupled with high genetic advance and coefficient of variability was for plant height, inter-nodal distance, seed yield per plant, test weight and umbels per plant. Branches per plant, leaves per plant, umbels per plant and seeds per umbel exhibited positively significant genotypic correlation among themselves and all were positively and significantly associated with seed yield per plant. A positive significant correlation with seed yield per plant and its main components seeds per umbel and umbels per plant were also noticed. Considering the direct and indirect selection parameters of major contributors a plant ideotype has been discussed to enhance seed yield on one hand and leafy vegetable on the other.

Dutta (2006) studied of 15 coriander genotypes for Correlation coefficients of different growth and yield attributing characters with respect to yield revealed that primary branches per plant, secondary branches per plant, umbellate per umbel and seeds per umbel were positively and significantly correlated with yield.

Singh *et al* (2006) evaluated of 360 lines of coriander (*Coriandrum sativum* L.) at Jobnor (Rajasthan) indicated high variability for seed yield (22.2%), umbels per plant·, (28.65%) and seeds per umbel (21.63%) and low variability for days to 50 % flowering (12.39%) and umbellates per umbel" (13.30%). High broad sense heritability (91.94%) and genetic advance (56.55%) were obtained for umbels per plant and seeds per umbels. Correlation and path coefficient analysis indicated that umbels per plant and branches per plant were the most important traits as they exerted positive direct effect on seed yield.

Singh *et al.* (2011) evaluation on nine genotypes namely 2007, 8918, 2002,9903, 9106, 9807, 2015, 2108 (germplasm lines) including check variety Azad Dhania- 1 of coriander (*Coriandrum sativum* L.). The materials were evaluated in an augmented Randomized Block Design with three replications during the rabi season of 2009–10. Efforts have been made to study the association of component traits with seed yield. It came into account that seed yield was significantly and positively correlated with its component characters like the number of primary branches per plant (rg = 0.750** and rp = 0.581**), number of secondary branches per plant (rg = 0.471* and rp = 0.431*), number of umbels per plant (rg = 0.932** and rp = 0.801**), number of umbellates per plant (rg = 0.806** and rp = 573**), number of seeds per umbels (rg = 667** and rp = 0.569**) and umbel diameter (rg = 851** and rp = 0.703**) both at the genotypic and phenotypic levels. Thus, the data revealed that the highest positive correlation (0.932) was appeared between number of umbels per plant and seeds yield (gm) whereas the lowest positive correlation (0.031) was expressed between number of umbellates per plant and 1000-seeds weight. Hence, the study will help the breeder to know the degree of association between traits, which can be used for crop improvement through selection of component traits.

Multivariate and cluster analysis for identification of superior germplasm lines.

Principal component analysis is appropriate when you have obtained measures on a number of observed variables and wish to develop a smaller number of artificial variables (called principal components) that will account for most of the variance in the observed variables. The principal components may be used as predictor or criterion variables in subsequent analyses

Principal component analysis is a variable reduction procedure. It is useful when you have obtained data on a number of variables (possibly a large number of variables), and believe that there is some redundancy in those variables. In this case, redundancy means that some of the variables are correlated with one another, possibly because they are measuring the same construct. Because of this redundancy, you believe that it should be possible to reduce the observed variables into a smaller number of principal components (artificial variables) that will account for most of the variance in the observed variables.

Patel *et al* (2000) studied of Forty eight genotypes of (*Coriandrum sativum* L.) were collected from different villages of an important and major coriander growing district-Guna (Madhya Pradesh). Data were recorded on 10 different characters. D^2 values between pairs of genotypes ranged from 2.50 to 96.96. By using D^2 analysis the genotypes were grouped into nine clusters. The clustering was at random and without any relationship between genetic diversity and geographic diversity. Seed yield per plant had highest contribution towards genetic divergence followed by secondary branches and umbellates per plant.

Ali *et al* (2000) evaluated twenty genotypes of coriander grown for three consecutive seasons. The pooled data for yield and its attributes were subjected to study the genetic divergence using Mahalanobis D^2 statistics. Twenty genotypes were classified into seven clusters. The cluster I contained the maximum of 13 genotypes belonging to different geographical origins. Cluster II contained two genotypes. The clusters III, IV, V, VI and VII contained one genotype each. Genotypes CS-193 and Tekamah Local were quite divergent and appeared promising for further improvement.

Srivastava *et al* (2000) studied 40 genotypes of coriander was subjected to multivariate analysis using D^2 statistics. The characters studied were plant height, primary branches, secondary branches, days to flowering, days to maturity, number of umbel, number of umbellates per umbel, number of seeds per umbel, 1000 seed weight and seed yield. The assessment revealed considerable variability among the stock for all characters except primary branches, umbellate per umbel and 1000-seed weight. The 40 genotypes were grouped into four clusters depending on similarities of their D^2 values. Cluster number I had 12 genotypes, III retained 11. Cluster numbers II and IV captured 10 and 7 genotypes. The inter- cluster D^2 values ranged from 0.62 to 30.7, suggesting considerable diversity among the groups of the genotypes. Based on cluster means, characters such as days to flowering, days to maturity and number of secondary branches were major factors of differentiation among genotypes, which may be taken into account while selecting parents for hybridization programme. The clustering pattern of strains did not follow the geographical distribution exactly.

Ravi *et al* (2007) studied of coriander (*Coriandrum sativum* L.) seeds from eight regions of India, labelled as S1 to S8 were examined for their volatile constitutents by gas chromatography-mass spectroscopy (GC-MS). GC-olfactometry (GC-O) was carried out for major compounds and odour profiling was done by trained panelists. Essential oil content of coriander samples ranged from 0.18 to 0.39%. The GC-MS analysis revealed presence of 30 compounds in coriander oil and around 98% of the compounds were identified in all the samples. Linalool which has floral and pleasant odour notes was the major compound (56.71-75.14%) in the essential oil, but the variation in the linalool content did not significantly affect the pleasantness of samples as perceived by the panelists. Higher a-pinene content of S7 and S8 could be related to the higher turpentine note. Sweet and rose-like odour notes of S1 could be due to occurrence of higher levels of geranyl acetate and lemonol. The odour profiling depicted the overall odour perceived, while the GC-O represented the odour notes of specific volatile compounds of coriander. Principal component analysis showed that samples S7 and S8 loaded with a-pinene, myrcene and undecanal. The results of GCO, sensory and PCA indicated possible association of major compounds with the intensity of characteristic odour notes perceived by the trained panel. Electronic nose pattern matching further complimented sensory and GC-MS results by showing segregation of samples. The study provides description of a few aroma notes in the coriander essential oil and the possibility of discriminating the aroma by sensory and instrumental methods.

Beemnet *et al* (2011) studied the genetic divergence among 49 Ethiopian coriander (*Coriandrum sativum* L.) accessions employing Mahalanobi's distance (D^2) analysis based on 15 characters. The accessions were grouped in to eight clusters. Cluster II and III were the largest each with 12 accessions, followed by clusters I and V each consisting of seven accessions. The highest inter-cluster distance (480.5) was observed between clusters I and VIII, followed by clusters V and VIII (462.2), and then clusters II and VIII (336.1). Hence, crossing between accessions included in these clusters may give high heterotic response, and thereby better sergeants. Maximum contribution toward total genetic divergence was possessed by 1000 seed weight (15.67%), followed by basal leaf number (13.48%), plant height (10.29%), seeds per umbellates (9.81%) and number of umbel per plant (7.84%). Based on means of all characters, accessions in clusters III, VII and VIII could be regarded as useful sources of genes for yield and its components, and the accessions from these clusters, therefore, could be used in improvement programmes to develop desirable types in coriander.

Singh *et al* (2005) evaluation of Seventy germplasm lines of coriander (*Coriandrum sativum* L.) of diverse eco-geographical origin were undertaken in present investigation to determine the genetic divergence following multivariate and canonical analysis for seed yield and its 9 component traits. The 70 genotypes were grouped into 9 clusters depending upon the genetic architecture of genotypes and characters uniformity and confirmed by canonical analysis. Seventy percent of total genotypes (49/70) were grouped in 4 clusters (V, VI, VIII and IX), while apparent diversity was noticed for 30 percent genotypes (21/70) that diverged into 5 clusters (I, II, III, IV, and VII). The maximum inter cluster distance was between I and IV (96.20) followed by III and IV (91.13) and I and VII (87.15). The cluster VI was very unique having genotypes of high mean values for most of the component traits. The cluster VII had highest seeds per umbels (35.3 ± 2.24), and leaves per plant (12.93 ± 0.55), earliest flowering (65.05 ± 1.30) and moderately high mean values for other characters.

Marangoni and Moura (2011) The descriptive terminology and sensory prolife of four samples of Italian salami were determined using a methodology based on the Quantitative Descriptive Analysis (QDA). A sensory panel consensually defined sensory descriptors, their respective reference materials, and the descriptive evaluation ballot. Twelve individuals were selected as judges and properly trained. They used the following criteria: discriminating power, reproducibility, and individual consensus. Twelve descriptors were determined showing similarities and differences among the Italian salami samples. Each descriptor was evaluated using a 10 cm non-structured scale. The data were analyzed by ANOVA, Tukey test, and the Principal Component Analysis (PCA). The salami with coriander essential oil (T3) had lower rancid taste and rancid odor, whereas the control (T1) showed high values of these sensory attributes. Regarding brightness, T4 showed the best result. For the other attributes, T1, T2, T3, and T4 were similar.

Kumar *et al* (2017) Evaluated Ninety genotypes and three checks (Pant Haritima, Hisar Anand and ACr-728) of coriander (*Coriandrum sativum* L.) in Augmented Block Design during Rabi season of 2009-10 and 2010-11 at Vegetable Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar to study the genetic variation for thirteen growth and yield characters namely, days to 50 % flowering, plant height up to main umbel, plant height including main umbel, number of primary branches per plant, number of secondary branches per plant, number of umbels per plant, number of umbellates per umbel, number of fruits per umbel, number of fruits per umbellate , seed yield per plot(g), seed yield per plant (g), seed yield kg per ha and 1000-seed weight (g). Character association indicate seed yield (kg per hectare) have significant and positive correlation with plant height upto main umbel (0.325), plant height including main umbels (0.331), number of fruits per umbel

(0.290), seed yield per plot (0.743) and seed yield per plant (0.361). The path coefficient analysis revealed that the highest direct effect was shown by seed yield per plot (0.6975), toward on seed yield (kg per hectare) followed by number of fruits per umbels (0.2716), seed yield per plant (0.1143), 1000-seed weight (0.060), days to 50 per cent flowering (0.0281), number of primary branches per plant (0.0734) and plant height upto main umbels.

Harishchand *et al* (2017) evaluated during Rabi season of the year 2010-2011 at Main Experiment Station (Vegetable Research Farm), Narendra Deva University of Agriculture and Technology, (Narendra Nagar) Kumarganj, Faizabad (U.P.) India. 110 lines of coriander germplasm maintained in All India Co-ordinated research project on spices under Department of Vegetable Science NDUAT, Kumarganj, Faizabad were taken for this investigation. This study revealed that the seed yield per plot showed highly and positive significant correlation with test weight (0.6008) followed by seed yield per plant (0.5995). The highest positive direct effect on seed yield per plant (g) was exhibited by test weight (0.3225) followed by secondary branches per plant (0.2292) and umbellates per umbel (0.1087). The perusal of path coefficient analysis shown that the highest positive direct effect on seed yield per plant (g) was exhibited by test weight (0.3225) followed by secondary branches per plant (0.2292) and umbellates per umbel (0.1087). Therefore, greater emphasis should be given on these characters while selecting for higher yield and related traits.

CHAPTER-3
MATERIALS AND METHODS

The present investigation entitled "**Germplasm Evaluation, Correlation and Path Analysis in Coriander (*Coriandrum sativum* L.) in High Hills of Uttarakhand**" was carried out during *Kharif* season of 2016-17. The detail of materials, techniques, and methods used for studies, experimental design adopted and statistical procedures followed are presented in this chapter.

3.1 Experimental site

The investigations entitled "**Germplasm Evaluation, Correlation and Path Analysis in Coriander (*Coriandrum sativum* L.) in High Hills of Uttarakhand**" was conducted at Medicinal and Aromatic Block, Department of Spices, Plantation, Medicinal and Aromatic Plants, College of Horticulture, Bharsar, VCSG Uttarakhand University of Horticulture and Forestry, Bharsar. The soil of research field was of medium sandy loam with pH of 6.5.

3.2 Location and climate

Pauri Garhwal is one of the 13 districts of Uttarakhand, and is located between 29^0 20'-29^0 75' N Latitude and 78^0 10'-78^0 80' E Longitude. Bharsar is situated about 57 km from the district head quarter Pauri of Pauri Garhwal of the East-South direction at Pauri-Thalisain-Ram Nagar National Highway 121/41 at an altitude of 1950 MSL.

In general, the climate of the Bharsar represents the mild summer, higher precipitation and colder or severe cold prolonged winter. The climate factors *i.e.* precipitation, temperature, relative humidity and wind, in association with proximity to Great Himalaya, slope aspects, drainage, vegetation etc. are responsible for the unique micro-climate of this area. A major form of precipitation is rainfall, besides occasional occurrence of dew, hailstorm, fog, frost, snowfall etc. The South-East monsoon commences towards the end of June while the North-East monsoon causes occasional winter showers from November to February. During winter, snowfall is common in this region. During summer months, the valley has hot climate prevailing for few hours in a day. The maximum temperature during May-June is recorded between 30°C-35°C however, nights are cool. December and January are the coldest months;

the minimum temperature reaches to 1°C to -4°C. Relative humidity is normally highest during rainy season (July - August), often recorded near to saturation point (92-97%) and it gradually decreases towards December.(Annonymous 2016)

The details of the experiment are as under:

- **Experimental design** : Randomized Complete Block Design (RCBD)
- **Total number of genotypes of coriander** : 24
- **Replication** : 3
- **Spacing** : 15 cm x 30 cm
- **Plot size** : 1.20 m x 1.50 m
- **Number of plants per plot** : 40
- **Total number of plots** : 72
- **Sowing season and year** **:** Spring season (16/02/2016)
- **Harvesting season and year** **:** Rainy season (15/06//2016)

3.3 Experimental material

The experimental material that is 24 genotypes of coriander for present investigation were collected from four different states of India namely, Uttar Pradesh, Andhra Pradesh, Rajasthan and Uttarakhand. (Table 3.1.)

3.4 Experimental layout

Seeds were sown directly in the field in the month of February 16 2016 at a spacing of (15×30) cm in a plot of (1.2×1.5) m^2 size. There were five rows in each plot. Forty plants per plot were raised after thining out operation. Each genotype was sown in a Randomized Block Design (RBD) with three replications. The standard cultural practices recommended in the 'Package of Practices for Seed Spices Crops' by Thamburaj were followed to exploit the maximum genetic potential of the genotypes.

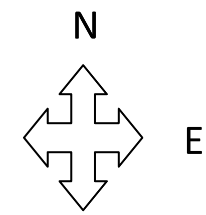
Table 3.1: List of coriander genotypes studied along with their sources

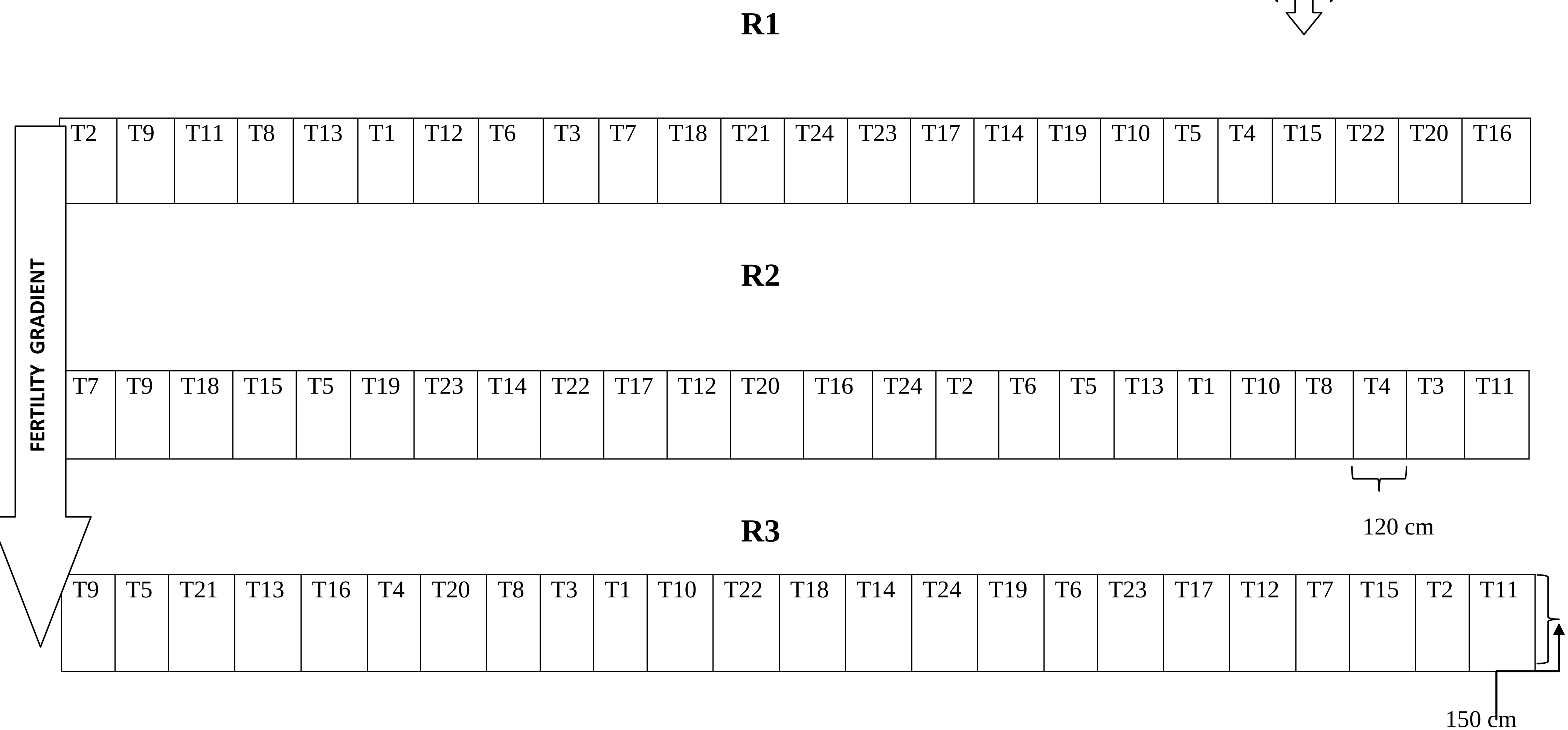
S. No.	Genotype	Source/Place of Collection	Treatment
1	Pant LC	Pantnagar (Uttarakhand)	T1
2	Pali	Pabau (Uttarakhand)	T2
3	KP Local	Pabau (Uttarakhand)	T3
4	Bareilly Local	Bareilly (U.P.)	T4
5	PLC	Pantnagar (Uttarakhand)	T5
6	Pant Haritma	G.B.P.U.A.&T., (Uttarakhand)	T6
7	PD-21	G.B.P.U.A.&T., (Uttarakhand)	T7
8	R-CO-75	Dholpur (Rajasthan)	T8
9	ALC	Sikandrabad (A.P)	T9
10	RL-13	Rudrapur (Uttarakhand)	T10
11	Siku-LC	Pauri (Uttarakhand)	T11
12	Kota	Pabau (Uttarakhand)	T12
13	LS-800	Saharanpur (U.P.)	T13
14	Dhulet Local	Bharsar (Uttarakhand)	T14
15	CO-4	Bharsar (Uttarakhand)	T15
16	HL-Normal+	Bharsar (Uttarakhand)	T16
17	HL-Thick	Bharsar (Uttarakhand)	T17
18	HL-Big	Bharsar (Uttarakhand)	T18
19	Thailisain LC	Thalisain (Uttarakhand)	T19
20	Raltham LC	Pauri (Uttarakhand)	T20
21	Hanumangarh Rajasthan	Hanumangarh (Rajasthan)	T21
22	Jaunpur Local	Jaunpur (U.P.)	T22
23	Small CO	Sultanpur (Uttarakhand)	T23
24	Lakhimpur	Lakhimpur (U.P.)	T24

+Check Cultivar (Nearest village to Bharsar campus)

Fig. 3.1 Layout of the experimental block

Allotment of treatments in experimental field under RCBD





3.5 Method of seed sowing

Nursery beds of convenient size (1.5 m length, 1.2 m width and 15 cm height) were prepared by adding well rotten farmyard manure at five-kilogram per m^2. The seeds were sown on 17th February 2016 in rows continuously covered with thin layer of well rotten fine compost to ensure germination. The beds were watered every evening with water cane and necessary precautions were taken against insect-pests and diseases.

3.6 Preparation of the field

The experimental site was ploughed well to bring the soil to fine tilth by cultivator. Removal of weeds and stubbles were done several times by using hand hoe. The plots were prepared measuring 1.55 m in length and 1.25m in width.

3.7 Manure and fertilizers

The basal dose of well rotten farmyard manure (FYM) was incorporated @ 5 kg/m^2 into the soil at the time of field preparation to improve the fertility of the field. In addition 10 g/m^2 Nitrogen, Phosphorous and Potash each were also applied. Half the quantity of Nitrogen and full dose of Phosphorus and Potash were applied at the time of sowing, while the remaining dose of Nitrogen was applied one month after germination. Nitrogen was applied in the form of CAN, Phosphorous in the form of Diammonium Phosphate (DAP), and Potassium in the form of Murate of Potash (MOP).

3.8 Cultural operations

3.8.1 Irrigation

The experimental plots were irrigated at an interval of one to two days at initial stages and 3-4 days at later stages to maintain optimum moisture throughout the experimentation.

3.8.2 Thining

The plots were thinned out to maintain specified spacing *i.e*. 30 cm row to row and 15 cm within plants in a row.

3.8.3 Weeding

Weeds compete with crop plants for nutrients, moisture, space and light, therefore, for better growth and development of crop plants, the experimental field was kept weed-free by hand weeding and hoeing at regular intervals.

3.8.4 Stacking

As the plant reached to height of 50-60cm each plant was supported by 75-80 cm long bamboo stick to keep the plants erect. The plant with bamboo stick was fastened loosely using a jute string to avoid lodging.

3.8.5 Plant protection

The prophylactic measures were adopted timely and uniformly as and when required to protect the crop against insect-pests and diseases.

3.9 Plant tagging

Five plants were selected randomly in each treatment plot and tagged for the purpose of recording data on various parameters.

3.10 Observations recorded

The following observations were recorded on the tagged plants at different stages of plant growth, flowering and yield characters.

3.10.1 Plant height (cm)

The height of the five randomly selected individual plants from each plot was recorded, from ground level to main umbel of the plant with the help of a meter scale and averaged, at the time of harvesting.

3.10.2 Number of primary branches per plant

At the time of harvesting, the number of primary branches originating from the main stem of randomly selected five individual plants was recorded and averaged.

3.10.3 Number of secondary branches per plant

At the time of harvesting, the number of secondary branches originating from the first primary branch of randomly selected five individual plants was recorded and averaged.

3.10.4 Umbel Diameter (mm)

At the time of harvesting, the umbels were measured with the help of vernier calipers

3.9.1.5 Number of umbels per plant

At the time of harvesting, number of umbels originating from all the branches were counted in five randomly tagged plants and averaged.

3.9.1.6 Number of umbellates per umbel

At the time of harvesting, number of umbellate present in all umbels of a plant were counted in five tagged plants and averaged.

3.9.1.7 Number of fruits per umbel

At the time of harvesting number of fruits in an umbel will be counted in five randomly tagged plant for average.

3.9.1.8 Number of fruits per umbellate

At the time of harvesting number of fruits in a umbellate will be counted in five randomly tagged plant for average.

3.9.1.9 Days to first umbel unfolding

Days required from sowing to anthesis of the main umbel in 100% of the plants in a plot will be counted to represent days to first flowering.

3.9.1.10 Days to 50 per cent flowering

It will be recorded from the days of sowing till the days in which 50 per cent of the plants in the plot show flowering.

3.9.1.11 Maturity duration

Days required by the crop to complete its life cycle to attain maturity.

3.9.1.12 Seed yield per plot (g)

Weight of all plant seed in a plot to obtain seed yield per plot (g).

3.9.1.13 Seed per plant (g)

At the time of harvesting seeds weight will be counted in five randomly tagged plants for average.

3.9.1.14 Test weight (g)

1000 seeds from each accession were counted and weight was taken in grams.

3.10 Statistical analysis

The statistical analysis was carried out for each observed character under the study using MS-Excel, OPSTAT and SPAR 1.0 packages. The mean values of data were subjected to analysis of variance as described by Gomez and Gomez (1983) for Randomized Complete Block Design (RCBD). For estimation of different statistical parameters, following procedures and formulae were adopted.

Table 3.2Analysis of variance

Source of variance	Degree of freedom	Sum of squares	Mean sum of squares	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-value was compared with tabulated F-value. When F-test was found significant, critical difference was calculated to find out the superiority of one entry over the others.

The standard error and critical differences were calculated as follows:

SE (m) ± = $\sqrt{Me/r}$

SE (d) ± = $\sqrt{2\,Me/r}$

$CD_{0.05}$ = S.E. (d) x $t_{(0.05)}$ (r-1) (g-1) df

Where,

SE (m) ± = Standard error of mean

SE (d) ± = Standard error of difference

$CD_{0.05}$ = Critical difference at 5 per cent level of significance

All the traits, which differed significantly, were utilized further for estimation of following genetic parameters:

3.10.1 Mean performance and genetic variation

3.10.2 Heritability (in broad sense)

3.10.3 Genetic advance (GA)

3.10.4 Genetic gain (GG)

3.10.5 Correlation coefficients

3.10.6 Path analysis

3.10.7 Genetic divergence (D^2 analysis)

3.10.1 Mean performance and genetic variation

The Genotypic and Phenotypic Coefficients of Variation were calculated as per formulae given by Burton and De-Vane (1953).

A) Genotypic Coefficient of variation (GCV)

$$GCV\ (\%) = \frac{\sqrt{\text{Genotypic variance (Vg)}}}{\text{General mean of population }(\bar{x})} \times 100$$

B) Phenotypic Coefficient of variation (PCV)

$$PCV\ (\%) = \frac{\sqrt{\text{Phenotypic variance (Vp)}}}{\text{General mean of population }(\bar{x})} \times 100$$

3.10.2 Heritability (in broad sense)

Heritability in broad sense was calculated by the formula as suggested by Allard (1960).

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

Where,

Vg = Genotypic variance [Vg = (Mg - Me) / r]

Vp = Phenotypic variance [Vg + Ve]

3.10.3 Genetic advance (GA)

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

Genetic advance = H x σ p x K

Where,

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

σ p = Phenotypic standard deviation

H = Heritability in broad sense

3.10.4 Genetic gain (GG)

Genetic gain expressed as per cent ratio of genetic advance and population mean was calculated by the method given by Johnson *et al.* (1955).

$$\text{Genetic gain (\%)} = \frac{\text{Genetic advance}}{\text{General mean of population } (\bar{x})} \times 100$$

For categorizing the magnitude of different parameters, Sharma (1994) suggested the following limits:

- PCV and GCV
  > 30% - High

  15-30% - Moderate

  <15% - Low
- Heritability (H)
  >80% - High

  50-80% - Moderate

  < 50% - Low
- Genetic gain (GG)
  >50% - High

  25-50% - Moderate

  < 25% - Low

3.10.5 Correlations

The genotypic and phenotypic correlations were calculated as per Al-Jibouri *et al.* (1958) by using analysis of variance and covariance matrix in which total variation has splited into replications, genotypes and errors. All the components of variance were estimated from the analysis of covariance as given below:

Source of variance	Degree of freedom	Mean sum of squares		Mean sum of products	F-Value
		X	Y		
Replications (r)	r-1				
Genotypes (g)	g-1	Mg X	Mg Y	Mg XY = MP_1	MP_1/MP_2
Error (e)	(r-1) (g-1)	Me X	Me Y	Me XY = MP_2	

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

Ve XY = MP_2

Vg XY = $(MP_1-MP_2)/ r$

Vp XY = Vg XY + Ve XY

Where,

Ve XY = Environmental covariance between X and Y

Vg XY = Genetic covariance between X and Y

Vp XY = Phenotypic covariance between X and Y

3.10.5.1 Coefficients of correlation

a) Genotypic correlation coefficient between X and Y

$$r_g = \frac{\text{Vg XY}}{\sqrt{\text{Vg X x Vg Y}}}$$

Where,

Vg XY = Genotypic covariance between X and Y

Vg X = Genotypic variance of X

Vg Y = Genotypic variance of Y

b) Phenotypic correlation coefficient between X and Y

$$r_p = \frac{Vp\ XY}{\sqrt{Vp\ X \times Vp\ Y}}$$

Where,

Vp XY	=	Phenotypic covariance between X and Y
Vp X	=	Phenotypic variance of X
Vp Y	=	Phenotypic variance of Y

Genotypic variance (Vg) = (Mg-Me) / r

Phenotypic variance (Vp) = (Vg+Ve)

The calculated correlation coefficients (r) values were compared with 'r' tabulated values as given by Fisher and Yates (1963) at (n-2) degrees of freedom to test their significance, where 'n' denotes number of genotypes. If calculated 'r' value at 5 per cent level of significance was greater than tabulated value of 'r', the correlation was said to be significant.

3.10.6 Path coefficient analysis

The genotypic and phenotypic correlation coefficients were used in finding out their direct and indirect contribution towards yield per plot.

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

$r_{14:}\ P_{14} + P_{24}\, r_{12} + P_{34}\, r_{13}$

$r_{24:}\ P_{14}\, r_{21} + P_{24} + P_{34}\, r_{23}$

$r_{34:}\ P_{14}\, r_{31} + P_{24}\, r_{32} + P_{34}$

Where,

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

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

$P_{14} = C_{11}\, r_{14} + C_{12}\, r_{24} + C_{13}\, r_{34}$

$P_{24} = C_{21}\, r_{14} + C_{22}\, r_{24} + C_{23}\, r_{34}$

$P_{34} = C_{31}\, r_{14} + C_{32}\, r_{24} + C_{33}\, r_{34}$

Where,

C_{11}, C_{22}, C_{23} and C_{33} are constants derived by using abbreviated Doulittle's technique as explained by Goulden (1954).

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

Residual effect

The variation in the dependent variable which remained undetermined by including all the variables was assumed to be due to variable (s) not included in the present investigation. The degree of determination of such variable (s) on dependent variable was calculated as follows:

$1 = P^2x_4 + P_{14}^2 + P_{24}^2 + P_{34}^2 + 2P_{14}\, r_{12}\, P_{24} + 2P_{14}\, r_{13}\, P_{34} + 2P_{24}\, r_{23}\, P_{34}$

3.10.7 Diversity analysis

3.10.7.1 Estimation of genetic divergence

The genetic divergence in 24 coriander genotypes was estimated by Mahalanobis D^2 statistics (Generalized distance as suggested by Rao 1952). Transformation of original means of various characters to uncorrelated varieties as carried out by pivotal condensation method as the common dispersion matrix by using computer. This made D^2 value as simple sum of squares of differences in transformed values for various characters. The D^2 values which determine the statistical distance among various genotypes reflecting their genetic diversity was estimated for each pair of genotypes under study. The calculation of D^2 values involved following steps (Murty and Arunachalam, 1966).

- A set of uncorrelated linear combination (Y,s) was obtained by pivotal condensation of the common dispersion matrix (Rao 1952) of a set of correlated variables (X,s; the common dispersion matrix was arranged with the help of error mean of squares and sum of products).

- Using the relationship between Y,s and X,s the mean values of different characters (X1 to Xn) were transformed into the mean values of a set of uncorrelated linear combination (Y1 to Yn).
- The D^2 values between ith and jth lines for kth character is calculated as under:

$$D^2ij = \Sigma kt=1 \ (Yit - Yjt)$$

- ✓ The 'K' component and D^2 for each combination were ranked in

descending order of magnitude.

- ✓ D-square values over all combinations were obtained.

3.10.7.2Clustering/Group Constellation

Based on D^2 values (Mahalanobis, 1936) lines were grouped into a number of clusters. D^2 being treated as the square of generalized distance, according to the method described by non-hierarchical Euclidean cluster analysis. Criterion used in clustering by this method is that any line belonging to the same cluster showed, at least on an average, a smaller D^2 value than those belonging to two different clusters. The first step of grouping their genotypes into distinct clusters was to arrange them in order of their relative distance from each other. Two populations having the smallest distance from each other were considered first, to which a third population was added having a smallest average D^2 value but higher than the previous two. Similarly, the next population was added and the process continued till at average D^2 value increased considerably with the next addition. At certain stage, when it was felt that after adding a particular population, if there was an abrupt increase in their average value this population was not added in that cluster. Similarly, a second cluster was formed. D^2 values of all possible combination of genotypes in one cluster with those in other was computed and its square root was useed to represent the statistical distance between two cluster. The cluster mean for each of the characters was calculated by averaging the total mean values of each member belonging to that cluster and inter and intra cluster distances values were also calculated as under:

Average intra-cluster distances (D=√D²)

$$D^2 = \frac{\sum D_i^2}{n}$$

Where,

$\sum D_i^2$= Sum of distances between all possible combinations of the populations included in a cluster

n = Number of populations in a cluster

Average inter-cluster distances (D=√D²)

$$D^2 = \frac{\sum D_{ij}^2}{n_i x n_j}$$

Where,

$\sum D_{ij}^2$= Sum of distances between all possible combinations of the two cluster

n_i = Number of populations in i^{th} cluster

n_j = Number of populations in j^{th} cluster

CHAPTER-4

EXPERIMENTAL RESULTS

The present investigation entitled "**Germplasm Evaluation, Correlation and Path Analysis in Coriander (*Coriandrum sativum* L.) in High Hills of Uttarakhand**" was carried out on 24 genotypes of coriander including one check variety to generate information on various horticultural traits, variability studies, correlation, path analysis and genetic divergence. The experimental results obtained are presented under the following heads:

4.1 Variability Studies

4.1.1 Mean performance of genotypes

4.1.2 Parameters of variability

4.2 Correlation Studies

4.2.1 Phenotypic correlations

4.2.2 Genotypic correlations

4.3 Path Coefficient Analysis

4.3.1 Direct and indirect effects

4.4 Genetic Divergence

4.1 Variability Studies

4.1.1 Mean performances of genotypes

The analysis of variance showed highly significant differences among the genotypes for all the traits studied in *Kharif,* 2016 which revealed the existence of good amount of variability in the germplasm. The mean performance of all the genotypes for various traits under study is given below:

4.1.1.1 Plant height (cm)

In *Kharif*, 2016, the mean performance of the genotypes ranged from 23.10-67.64 centimetres (Table 4.1). General mean for the character was 45.14.Ten genotypes including check cultivar have plant height more than population mean. Maximum length of whole plant was recorded in Pant Haritma (67.64) and it was statistically at par with three genotypes *viz*, PD-21 (65.77), Pant LC (64.55) and KPL (61.54), while minimum length of whole plant was observed in CO-4 (23.10).

4.1.1.2 Number of primary branches per plant

Mean performance of genotypes ranged from 1.57- 4.37 (Table 4.1). General mean for the character was 2.51. Nine genotypes produced higher number of primary branches than population mean. Maximum number of primary branches was recorded in KPL (4.37) and it was found statistically at par with Jaunpur Local (4.00). While minimum number of primary branches was observed in PLI-100 (1.57).

4.1.1.3 Number of secondary branches per plant

Number of secondary branches per plant ranged from 2.37-8.20 (Table 4.1). General mean for the character was 5.17. Ten genotypes produced higher number of secondary branches per plant than population mean. Maximum number of secondary branches per plant was recorded in Hanumangarh Rajasthan (8.20) and it was found statistically at par with Kota (8.03). While minimum number of secondary branches per plant was observed in ALC (2.37). Thirteen genotypes were found having maximum number of secondary branches per plant than check cultivar HL-Normal (4.80) for number of secondary branches per plant.

4.1.1.4 Number of umbels per plant

Number of umbels per plant ranged from 4.24-18.57 (Table 4.2). General mean for the character was 9.64. Eleven genotypes including check cultivar produced higher number of umbels per plant than population mean. Maximum number of umbels per plant was recorded in Pant Haritma (18.57), while minimum number of umbels per plant was observed in CO-4 (4.24). Four genotypes were found to have more values than check cultivar HL-Normal (12.3) for number of umbels per plant.

Table: 4.1 Mean performances of coriander genotypes for days to plant height, primary branches and secondary branches (*Kharif* 2016)

Sr.No.	Genotype	Plant height	Primary branches	Secondary branches
1	Pant LC	64.54* ± 2.64	1.73 ± 0.29	3.66 ± 0.27
2	PLI-100	55.52 ± 2.53	1.57 ± 0.23	3.90 ± 0.26
3	KPL	61.54 * ± 2.66	4.37 ± 0.26	6.73 ± 0.29
4	Bareilly Local	33.58 ± 3.51	2.73 ± 0.29	4.73 ± 0.29
5	PLC	47.98 ± 3.15	2.16 ± 0.26	4.36 ± 0.26
6	Pant Haritma	67.64 ± 2.74	2.67 ± 0.27	6.00 ± 0.30
7	PD-21	65.77 * ± 3.07	2.37 ± 0.26	4.93 ± 0.29
8	R-CO-75	25.39 ± 2.54	2.20 ± 0.30	2.86 ± 0.29
9	ALC	36.34 ± 3.13	2.10 ± 0.26	2.36 ± 0.26
10	RL-13	36.58 ± 2.84	2.67 ± 0.27	5.00 ± 0.30
11	Siku-LC	38.66 ± 2.72	2.20 ± 0.30	6.50 ± 0.28
12	Kota	38.92 ± 2.66	3.23 ± 0.27	8.03* ± 0.27
13	LS-800	30.28 ± 2.66	2.4 0 ± 0.30	5.20 ± 0.23
14	Dhulet Local	55.11 ± 2.79	2.63 ± 0.29	5.43 ± 0.23
15	CO-4	23.10 ± 2.62	2.23 ± 0.27	5.00 ± 0.30
16	HL-Normal+	53.38 ± 2.68	2.33 ± 0.29	4.80 ± 0.30
17	HL-Thick	48.89 ± 0.98	2.23 ± 0.27	3.93 ± 0.29
18	HL-Big	48.35 ± 2.25	1.97 ± 0.26	4.60 ± 0.30
19	TLC	43.85 ± 2.45	1.97 ± 0.26	4.13 ± 0.29
20	RS Local	39.57 ± 2.77	1.93 ± 0.29	4.50 ± 0.28
21	Hanumangarh Rajasthan	42.76 ± 2.53	3.43 ± 0.28	8.20 ± 0.30
22	Jaunpur Local	41.56 ± 2.78	4.00 * ± 0.30	6.93 ± 0.29
23	Small CO	43.88 ± 2.75	2.03 ± 0.27	5.20 ± 0.30
24	Lakhimpur	40.22 ± 2.63	3.17 ± 0.26	6.93 ± 0.37
	Mean	**45.14**	**2.51**	**5.16**
	SE(d)	**3.72**	**0.39**	**0.41**
	$CD_{(0.05)}$	**7.49**	**0.59**	**0.82**

+Check cultivar, *(Significant at 5% level of significance compared with maximum value)

4.1.1.5 Number of umbellates per umbel

Number of umbellates per umbel ranged from 2.83-6.20 (Table 4.2). General mean for the character was 3.91. Fifteen genotypes produced higher number of umbellates per umbel than population mean. Maximum number of umbellates per umbel was recorded in Pant Haritma (6.20). While minimum number of umbellates per umbel was observed in CO-4 (2.83). Twenty two genotypes were found to have more values than check cultivar HL-Normal (2.93) for number of umbellates per umbel.

4.1.1.6 Fruits per umbel.

The number of fruits per umbel in the germplasm ranged from 8.40-27.13 (Table 4.2). General mean for the character was 16.50. Twelve genotypes produced more fruits per umbel than population mean. Maximum fruits per umbel were recorded in Pant Haritma (27.13). While minimum fruits per umbel were observed in CO-4 (8.40). Seventeen genotypes were found to be better performer over check cultivar HL-Normal (13.06) for fruits per umbel.

4.1.1.7 Fruits per umbellates

Fruits per umbellates for all the genotypes studied ranged from 2.27-4.87 (Table 4.7). General mean for the character was 3.96. Sixteen genotypes including check cultivar produced more fruits per umbellates than population mean. Maximum fruits per umbellates were recorded in Pant Haritma (4.87) and it was statistically at par with twelve genotypes, while minimum fruits per umbellates were observed in CO-4 (2.27). Pant Haritma (4.87) was found better than check cultivar HL-Normal (4.73) for fruits per umbellates.

4.1.1.8 Umbel diameter (mm)

Umbel diameter (mm) in all the genotypes studied, ranged from 15.03-41.18 mm (Table 4.3). General mean for the character was 26.81 mm. Twelve genotypes produced umbel diameter larger than population mean. Maximum umbel diameter was recorded in Pant Haritma (41.18) and it was statistically at par with LS-800 (39.14), R-CO-75 (38.57), Small CO (34.71) and Lakhimpur (33.64). While minimum umbel diameter was observed in Siku-LC (15.03). Twenty genotypes were found to have more umbel diameter than check cultivar HL-Normal (20.57).

Table: 4.2 Mean performances of coriander genotypes for umbel/plant, umbellates/umbel and fruits/umbel (*Kharif* 2016)

Sr.No.	Genotype	Umbel/plant	Umbellates /umbel	Fruits/umbel
1	Pant LC	13.53 ± 1.47	4.13 ± 0.40	20.46 ± 1.15
2	PLI-100	11.86 ± 0.98	4.00 ± 0.30	18.93 ± 0.59
3	KPL	12.10 ± 1.05	4.40 ± 0.30	20.30 ± 2.96
4	Bareilly Local	6.19 ± 0.20	3.80 ± 0.30	12.45 ± 0.10
5	PLC	13.06 ± 0.35	4.07 ± 0.29	15.33 ± 2.88
6	Pant Haritma	18.57 ± 0.37	6.20 ± 0.30	27.13 ± 2.81
7	PD-21	16.00 ± 2.30	4.07 ± 0.29	20.29 ± 1.91
8	R-CO-75	4.93 ± 0.37	3.20 ± 0.44	8.73 ± 0.34
9	ALC	6.85 ± 0.37	4.07 ± 0.29	13.76 ± 0.28
10	RL-13	7.00 ± 0.30	3.93 ± 0.37	17.86 ± 3.16
11	Siku-LC	7.23 ± 0.27	4.13 ± 0.29	21.20 ± 2.77
12	Kota	7.40 ± 0.30	4.40 ± 0.30	17.26 ± 2.65
13	LS-800	5.80 ± 0.30	3.50 ± 0.29	12.80 ± 1.20
14	Dhulet Local	11.8 ± 0.94	4.27 ± 0.29	21.33 ± 1.66
15	CO-4	4.24 ± 0.15	2.83 ± 0.30	8.40 ± 0.21
16	HL-Normal+	12.3 ± 0.40	2.93 ± 0.29	13.06 ± 1.69
17	HL-Thick	11.6 ± 0.41	3.40 ± 0.30	12.86 ± 2.54
18	HL-Big	10.86 ± 0.46	4.20 ± 0.30	14.73 ± 2.85
19	TLC	10.06 ± 0.29	3.93 ± 0.29	15.00 ± 2.60
20	RS Local	9.50 ± 0.32	3.20 ± 0.30	11.73 ± 2.03
21	Hanumangarh Rajasthan	7.73 ± 0.96	3.93 ± 0.29	20.00 ± 0.50
22	Jaunpur Local	8.20 ± 0.69	3.27 ± 0.29	15.40 ± 2.41
23	Small CO	6.13 ± 0.40	4.20 ± 0.30	16.80 ± 0.91
24	Lakhimpur	8.46 ± 0.35	3.73 ± 0.29	20.13 ± 1.09
	Mean	**9.64**	**3.91**	**16.50**
	SE(d)	**1.07**	**0.45**	**2.76**
	$CD_{(0.05)}$	**2.16**	**0.90**	**5.55**

+Check cultivar, *(Significant at 5% level of significance compared with maximum value)

4.1.1.9 Seed yield per plant (g)

All the genotypes studied for seed yield per plant ranged from 0.06-8.03 (Table 4.5). General mean for the character was 2.12. Seven genotypes produced higher seed yield per plant than population mean. Maximum seed yield per plant was recorded in Pant Haritma (8.03) while minimum seed yield per plant was observed in CO-4 (0.06). Six genotypes were found to have more values than check cultivar HL-Normal (1.96) for seed yield per plant.

4.1.1.10 Seed yield per plot (g)

All the genotypes studied for seed yield per plot ranged from 2.33-307.80 (Table 4.3). General mean for the character was 79.87. Seven genotypes produced higher seed yield per plot than population mean. Maximum seed yield per plot was recorded in Pant Haritma (307.80) and it was found statistically at par with PD-21, while minimum seed yield per plot was observed in CO-4 (2.33). Seven genotypes were found to have more values than check cultivar HL-Normal (73.28) for seed yield per plot.

4.1.1.11 Test weight (g)

All the genotypes studied for test weight ranged from 1.61-23.48 g (Table 4.4). General mean for the character was 8.95 g. Ten genotypes *viz,* TLC (10.93), HL-Thick (10.85), HL-Normal (12.39), Dhulet Local (12.91), PD-21 (23.48), Pant Haritma (21.57), PLC (14.29), KPL (17.04), PLI-100 (16.87) and Pant LC (19.10) including check cultivar produced higher test weight than population mean. Maximum test weight was recorded in PD-21 (23.48) and it was statistically at par with genotype Pant Haritma (21.57). While minimum test weight was observed in CO-4 (1.61). Seven genotypes *viz,* Pant LC (19.10), PLI-100 (16.87), KPL (17.04), PLC (14.29), Pant Haritma (21.57), PD-21 (23.48) and Dhulet Local (12.91) were found better than check cultivar HL-Normal (12.39) for test weight.

4.1.1.12 Days to First Umbel unfolding (Number of days)

All the genotypes studied for days to first umbel unfolding ranged from 21.57-47.80 days (Table 4.4). General mean for the character was 36.88 days. Thirteen genotypes *viz*, PLI-100 (37.00), R-CO-75 (42.25), ALC (40.13), Kota (40.07), LS-800 (47.80), CO-4 (38.60), HL-Normal (42.13), HL-Thick (37.97), HL-Big (39.40), TLC (39.27), Jaunpur Local (40.2), Small CO (37.67) and Lakhimpur (45.93) including check cultivar has taken higher days to first umbel unfolding than population mean. Maximum days to first umbel unfolding was recorded in LS-800 (47.80). While minimum days to first umbel unfolding was observed in Pant Haritma (21.57). Twenty genotypes were found minimum *viz*, Pant LC (30.60), PLI-100 (37.00), KPL (31.27), Bareilly Local (26.53), PLC (32.00), Pant Haritma (21.57), PD-21 (29.93), ALC (40.13), RL-13 (31.53), Siku-LC (31.58), Kota (40.07), Dhulet Local (34.20), CO-4 (38.60), HL-Thick (37.97), HL-Big (39.40), TLC (39.27), RS Local (30.53), Hanumangarh Rajasthan (31.73), Jaunpur Local (40.2) and Small CO (37.67) than check cultivar (HL-Normal) (42.13) for days to first umbel unfolding.

4.1.1.13 Days to 50% flowering (Number of days)

All the genotypes studied for days to 50% flowering ranged from 36.60-57.20 days (Table 4.4). General mean for the character was 45.96 days. Fifteen genotypes including check cultivar has taken higher days to 50% flowering than population mean. Maximum days to 50% flowering was recorded in LS-800 (57.20) and was statistically at par with Lakhimpur (55.20). While minimum days to 50% flowering was observed in Bareilly Local (36.60). Nineteen genotypes were found earlier than check cultivar HL-Normal (48.93) for days to 50% flowering.

4.1.1.14 Days to maturity

In *Kharif*, 2016 all the genotypes studied for days to maturity ranged from 70.60-118 days (Table 4.5). General mean for the character was 97.44 days. Sixteen genotypes including check cultivar has taken higher days to maturity than population mean. Maximum days to maturity were recorded in Pant Haritma (118) and it was statistically at par with two genotype *viz*, PD-21 (112.73) and Pant LC (107.87). While minimum days to maturity was observed in ALC (70.60). Eighteen genotypes were found earlier than check cultivar HL-Normal (103.67) for days to maturity.

Table: 4.3 Mean performances of coriander genotypes for Fruits/umbellate and Umbel diameter and Seed yield/plot (*Kharif* 2016).

Sr.No.	Genotype	Fruits/umbellate	Umbel diameter (mm)	Seed yield/plot (g)
1	Pant LC	4.2* ± 0.34	21.05 ± 3.05	211.24 ± 2.96
2	PLI-100	4.13* ± 0.29	19.18 ± 2.88	153.48 ± 1.29
3	KPL	4.37* ± 0.29	32.10 ± 2.84	247.37± 2.54
4	Bareilly Local	3.47 ± 0.29	23.91 ± 3.04	6.67 ± 1.45
5	PLC	3.50 ± 0.29	22.97 ± 3.02	113.63 ± 2.08
6	Pant Haritma	4.87 ± 0.35	41.18 ± 3.00	307.80 ± 2.43
7	PD-21	4.10* ± 0.36	23.93 ± 3.11	288.85* ± 2.45
8	R-CO-75	2.80 ± 0.50	38.57* ± 2.83	3.09 ± 0.05
9	ALC	3.80 ± 0.53	21.95 ± 2.83	10.01± 1.28
10	RL-13	4.00 ± 0.30	30.05 ± 2.72	15.68 ± 1.03
11	Siku-LC	4.07 ± 0.29	15.03 ± 2.76	19.19 ± 2.04
12	Kota	4.13* ± 0.29	27.17 ± 2.88	16.62 ± 0.67
13	LS-800	3.40 ± 0.30	39.14* ± 2.49	6.41 ± 0.48
14	Dhulet Local	4.40* ± 0.30	23.20 ± 2.81	129.14 ± 2.08
15	CO-4	2.27 ± 0.30	23.88 ± 2.77	2.33 ± 0.63
16	HL-Normal+	4.73* ± 0.07	20.57 ± 2.70	73.28 ± 2.47
17	HL-Thick	4.20* ± 0.34	29.02 ± 3.18	61.38 ± 1.65
18	HL-Big	4.00 ± 0.30	26.99 ± 3.05	54.52 ± 1.06
19	TLC	4.20* ± 0.30	21.39 ± 2.47	63.34 ± 1.50
20	RS Local	3.83 ± 2.03	16.22 ± 2.60	18.40 ± 0.47
21	Hanumangarh Rajasthan	4.20* ± 0.50	28.37 ± 3.02	33.87 ± 0.49
22	Jaunpur Local	4.27* ± 2.41	29.26 ± 3.24	25.06 ± 1.48
23	Small CO	3.80 ± 0.92	34.71* ± 3.01	22.20 ± 1.52
24	Lakhimpur	4.26* ± 1.09	33.64* ± 2.61	33.31 ± 0.65
	Mean	**3.96**	**26.81**	**79.87**
	SE(d)	**0.39**	**4.14**	**20.94**
	$CD_{(0.05)}$	**0.78**	**8.34**	**42.15**

+Check cultivar, *(Significant at 5% level of significance compared with maximum value)

Table: 4.4 Mean performances of coriander genotypes for Test weight, Umbel unfolding and Days to 50% flowering (*Kharif* 2016).

Sr.No.	Genotype	Test weight (g)	I[st] Umbel unfolding (days)	Days to 50 % flowering
1	Pant LC	19.10 ± 1.02	30.60 ± 2.48	46.07 ± 2.54
2	PLI-100	16.87 ± 1.14	37.00 ± 2.66	46.80 ± 2.61
3	KPL	17.04 ± 1.27	31.27 ± 2.77	39.07 ± 2.75
4	Bareilly Local	2.36 ± 0.18	26.53 ± 1.94	36.60 ± 2.00
5	PLC	14.29 ± 0.74	32.00 ± 2.37	39.97 ± 2.65
6	Pant Haritma	21.57* ± 22.32	21.57 ± 2.54	38.00 ± 2.71
7	PD-21	23.48 ± 1.44	29.93 ± 2.60	40.67 ± 2.48
8	R-CO-75	1.97 ± 0.06	42.25 ± 2.84	48.67 ± 2.84
9	ALC	2.44 ± 0.28	40.13 ± 2.72	47.77 ± 2.53
10	RL-13	3.16 ± 0.29	31.53 ± 2.48	39.87 ± 2.62
11	Siku-LC	3.53 ± 0.08	31.58 ± 2.37	47.73 ± 2.26
12	Kota	3.48 ± 0.47	40.07 ± 2.48	50.00 ± 2.23
13	LS-800	2.20 ± 0.02	47.80 ± 2.61	57.20 ± 2.76
14	Dhulet Local	12.91 ± 1.19	34.20 ± 2.31	42.47 ± 2.43
15	CO-4	1.61 ± 0.21	38.60 ± 2.66	48.80 ± 2.34
16	HL –Normal[+]	12.39 ± 1.20	42.13 ± 2.45	48.93 ± 2.51
17	HL-Thick	10.85 ± 1.36	37.97 ± 2.67	47.10 ± 2.38
18	HL-Big	8.45 ± 1.22	39.40 ± 2.14	46.53 ± 3.00
19	TLC	10.93 ± 0.65	39.27 ± 2.71	48.33 ± 2.20
20	RS Local	4.48 ± 0.09	30.53 ± 2.75	39.40 ± 2.42
21	Hanumangarh Rajasthan	5.74 ± 0.39	31.73 ± 2.71	41.53 ± 2.30
22	Jaunpur Local	5.15 ± 0.36	40.2 ± 2.54	49.13 ± 2.55
23	Small CO	5.97 ± 0.46	37.67 ± 2.58	47.20 ± 2.31
24	Lakhimpur	5.13 ± 0.42	45.93 ± 2.49	55.2* ± 2.32
	Mean	**8.95**	**36.88**	**45.54**
	SE(d)	**1.28**	**2.90**	**3.42**
	$CD_{(0.05)}$	**2.58**	**1.77**	**6.88**

[+]Check cultivar, *(Significant at 5% level of significance compared with maximum value)

Table: 4.5 Mean performances of coriander genotypes for maturity duration and seed yield per plant (*Kharif* 2016)

Sr. No.	Genotype	Maturity duration (days)	Seed yield per plant (g)
1	Pant LC	107.87* ± 2.81	5.62 ± 0.12
2	PLI-100	103.87 ± 3.05	4.15 ± 0.13
3	KPL	105.13 ± 2.81	6.51 ± 0.16
4	Bareilly Local	83.07 ± 2.87	0.24 ± 0.17
5	PLC	103 ± 3.01	3.02 ± 0.10
6	Pant Haritma	118 ± 2.98	8.03 ± 0.13
7	PD-21	112.73* ± 2.90	7.53 ± 0.12
8	R-CO-75	76.47 ± 2.86	0.07 ± 0.10
9	ALC	70.60 ± 17.85	0.28 ± 0.11
10	RL-13	89.27 ± 2.79	0.42 ± 0.13
11	Siku-LC	90.87 ± 3.04	0.53 ± 0.15
12	Kota	92.60 ± 2.89	0.43 ± 0.17
13	LS-800	82.93 ± 2.68	0.17 ± 0.13
14	Dhulet Local	102.33 ± 2.95	3.56 ± 0..12
15	CO-4	81.07 ± 2.90	0.06 ± 0.11
16	HL –Normal+	103.67 ± 2.43	1.96 ± 0.10
17	HL-Thick	103.27 ± 2.85	1.64 ± 0.13
18	HL-Big	100.53 ± 3.00	1.46 ± 0.11
19	TLC	103.53 ± 2.53	1.63 ± 0.13
20	RS Local	99.40 ± 2.96	0.47 ± 0.10
21	Hanumangarh Rajasthan	101.13 ± 3.13	0.88 ± 0.11
22	Jaunpur Local	102.93 ± 3.03	0.66 ± 0.10
23	Small CO	101.9 ± 2.15	0.59 ± 0.13
24	Lakhimpur	102.4 ± 3.03	0.91 ± 0.13
	Mean	**97.44**	**1.99**
	SE(d)	**5.89**	**0.05**
	$CD_{(0.05)}$	**11.86**	**0.10**

+Check cultivar, *(Significant at 5% level of significance compared with maximum value)

4.1.2 Parameters of variability

Genetic variability in *Kharif* season of year 2016 has been considered as an important factor which is also essential prerequisite for crop improvement programmes. The assessment of existence of genetic variability *viz*, coefficients of variation (phenotypic and genotypic), heritability (in broad sense) and genetic advance as per cent of mean (genetic gain) were worked out to generate an idea and scope for response of selection to various characters. The results are presented in Table 4.6.

The present investigation reported significant variations in the characters among all the genotypes due to effect of genotype and environment both. Phenotypic and genotypic coefficient of variations provides information about the magnitude of genotypic and phenotypic variability. A perusal of data for all the characters studied indicated that phenotypic and genotypic coefficients of variation have difference but very less for most of characters. The magnitude of coefficients of variation varied from character to character from moderate to high which indicates about varying amount of variability present for different traits. According to Sharma (1994) PCV and GCV values greater than 30% are higher while values falling between 15-30% are moderate and values less than 15% are low. The phenotypic coefficients of variation (PCV) were recorded highest for seed yield per plot (121.07%), test weight (76.89%), umbel per plant (38.96%), fruits per umbel (31.74%), primary branches per plant (31.42%) and umbel diameter (30.51%). While moderate for secondary branches per plant (29.64%), plant height (28.26%), umbellates per umbel (20.50%) and days to first umbel unfolding (16.62%). whereas low phenotypic coefficient of variation was observed in maturity duration (13.38%) and days to 50% flowering (13.73%). Similarly, the genotypic coefficients of variation (GCV) were recorded highest for seed yield per plot (116.73%), test weight (74.86%), umbel per plant (36.50%). While moderate for secondary branches per plant (28.01%), plant height (26.39%), primary branches per plant (25.18%), umbel diameter (23.94), fruits per umbel (24.26%) and umbellate per umbel (15.03%). Whereas, low genotypic coefficient of variation was observed for days to first umbel unfolding (13.53%), fruits per umbellate (12.47%), maturity duration (11.14%) and days to 50% flowering (10.27%).

Table 4.6: Range, Mean, PCV, GCV, Heritability and Genetic gain for different traits for coriander germplasm in (*Kharif* 2016).

Sr. No.	Characters	Range	Mean	Coefficients of Variability (%)		Heritability (%)	Genetic Gain (%)	Genetic Advance
				Phenotypic	Genotypic			
1.	Days to 50% flowering	36.60-57.20	45.96	13.73	10.27	56.00	15.84	7.28
2.	Days to first umbel unfolding(days)	26.53-47.80	36.88	16.62	13.53	66.34	22.72	8.38
3.	Maturity duration	70.60-118.00	97.44	13.38	11.14	69.38	19.12	18.63
4.	Plant height.	23.10-67.64	45.14	28.26	26.39	87.22	50.78	22.92
5.	Primary branches/plant	1.57-4.37	2.51	31.42	25.18	64.24	41.83	1.05
6.	Secondary branches / plant	2.37-8.20	5.17	29.64	28.01	89.33	54.55	2.82
7.	Umbel/plant	4.24-18.57	9.64	38.96	36.50	87.75	70.43	6.79
8.	Umbellates / umbel	2.83-6.20	3.91	20.50	15.03	53.72	22.76	0.89
9.	Umbel diameter	15.03-41.18	26.81	30.51	23.94	61.55	38.68	10.37
10.	Fruits/ umbel	8.40-27.13	16.50	31.74	24.26	58.39	38.18	6.30
11.	Fruits / umbellate	2.27-4.87	3.96	17.33	12.47	51.78	18.43	0.73
12.	Test weight (g)	1.61-23.48	8.95	76.89	74.86	94.77	150.06	13.43
13	Seed yield/ plant	0.06-8.03	2.12	118.50	116.33	96.37	234.90	4.98
14.	Seed yield/plot	2.33-307.80	79.87	121.07	116.73	92.96	231.81	185.15

4.1.2.1 Heritability

In the present investigation, estimates of heritability (broad sense) were also worked-out which varied from 51.78% to 96.37% for different characters under study (Table 4.6). The classification of heritability value was done as per Sharma, values greater than 80% shows highest heritability, while values ranging between 50-80% are moderate and values less than 50% shows less heritability. Highest heritability was recorded for seed per plant (96.37), test weight (94.77%), seed yield per plot (92.96%), secondary branches per plant (89.33%), umbel per plant (87.75%), plant height (87.22%), whereas moderate heritability was recorded for maturity duration (69.38%), days to first umbel unfolding (66.34%), primary branches per plant (64.24%), umbel diameter (61.55%), fruits per umbel (58.39), days to 50% flowering (56.00%), umbellates per umbel (53.72%) and fruits per umbellate (51.78).

4.1.2.2 Genetic advance and genetic gain

Genetic advance was measured as genetic gain under selection of per cent of population mean was low to high for various characters studied in the present experiment. The classification of values of genetic gain and genetic advance was done as per Sharma, 1994. As shown in table 4.6 the range for genetic advance was from 0.73 to 185.15 where highest genetic advance was recorded highest in seed yield per plot (185.15) while medium was recorded in plant height (22.92), maturity duration (18.63), test weight (13.43), and umbel diameter (10.37). While lowest genetic advance was observed in days to first umbel unfolding (8.38), days to 50% flowering (7.28), umbel per plant (6.79), fruits per umbel (6.30), secondary branches per plant (2.82), primary branches per plant (1.05), umbellates per umbel (0.89) and fruits per umbellate (0.73). Highest genetic gain was recorded for seed per plant (234.90), seed yield per plot (231.81%), test weight (150.06%), umbel per plant (70.43%), secondary branches per plant (54.55%) and plant height (50.78%). However, primary branches per plant (41.83%), umbel diameter (38.68%) and fruits per umbel (38.18%) are moderate. Umbellates per umbel (22.76%), days to first umbel unfolding (22.72%), maturity duration (19.12%), fruits per umbellate (18.43%) and days to 50% flowering (15.84%) gave low estimates of genetic gain.

4.2 Correlation studies

The correlation coefficients studies in *Kharif* season of 2016 among the different traits were worked out at phenotypic and genotypic levels and presented in Table 4.7 and 4.8. In general, the genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients. The information on nature and magnitude of correlation coefficients helps breeders to determine the selection criteria for concurrent progress of various characters along with economic yield.

4.2.1 Phenotypic correlations

In *Kharif* season, phenotypic correlation coefficients (Table 4.8) showed that seed yield per plant had positively strong significant association with test weight (0.9455), umbel per plant (0.8501), plant height (0.8600) while moderately positive and significant with, number of fruits per umbel (0.5888) fruits per umbellate (0.4583) and number of umbellates per umbel (0.4446).

Seed yield per plant showed negative and significant correlation between maturity duration (-0.5336), days to first umbel unfolding (-0.2248) and number of days for 50% flowering (-0.2297).

4.2.2 Genotypic correlations

The genotypic correlation for different characters and their interrelation between each other is presented in the table 4.7.

Seed yield per plant showed positive correlation at genotypic level with test weight (0.9678), umbels per plant (0.9391) and plant height (0.9231) while moderately favourable correlation with fruits per umbel (0.6282) number of umbellates per umbel (0.5794) and fruits per umbellate (0.5146).

Seed yield per plant showed negative and significant correlation between maturity duration (-0.4536), number of days to first umbel unfolding (-0.3301) and number of days to 50% flowering (-0.3064).

4.3 Path Coefficient Analysis

Simple correlation coefficient indicates association between any two characters but does not give a complete picture of complex relationship. Therefore, it is essential to have path coefficient analysis in order to get clear picture of association among characters, as it splits the correlation coefficient into the measure of direct and indirect effects of a set of independent variables (characters) on the dependant variable through other component traits.

The direct and indirect effects of various characters along with their genotypic and phenotypic correlation coefficients with seed yield per plant at genotypic and phenotypic both levels have been presented in Table 4.9 and 4.10. In the present study, path coefficients were worked out using seed yield per plant as dependant and remaining thirteen characters *viz*, plant height, number of primary branches per plant, number of secondary branches per plant, number of umbel per plant, number of umbellates per umbel, fruits per umbel, fruits per umbellate, umbel diameter, seed yield per plot, test weight and days taken to first umbel unfolding, days to 50% flowering as independent variables (Lenka and Mishra.1973).

4.3.1 Direct effects and Indirect effects

Table 4.9 and 4.10 revealed that very highly direct positive effect on the seed yield/ plant was contributed by fruits per umbel (0.5003,0.1422) followed by umbel/plant (0.9883,0.0861), days to 50% flowering (0.2342,0.0721) days to first umbel unfolding (0.2071,0.0257), test weight (0.1447,0.8251) and primary branches (0.3948,0.1010) at both genotypic and phenotypic levels, respectively.

The fruits per umbellate shows highest negative and direct (-0.4338, -0.1325) effect on seed yield per plant at both genotypic and phenotypic levels, respectively.

Regarding indirect effects, it was observed that the plant height had the highest positive indirect effect via number of umbels per plant (0.9662), number of fruits per umbel (0.3703) and test weight (0.1405,0.7387). While for umbellate per umbel had highest positive indirect effect via fruits per umbel (0.4608) and number of umbel per plant (0.4286). While for fruits per umbel had highest positive indirect effect via umbel per plant (0.5177). Similarly fruits per umbellate had the highest positive indirect effect via number of umbels per plant and number of fruits per umbel respectively (0.6863) and (0.3480) it was observed at genotypic level while at phenotypic level the values were showing negligible effect. While test weight had the positive indirect effect via number of umbels per plant (0.9481) at genotypic level only. Maturity duration had the positive indirect effect via number of umbels per plant (1.0379) at genotypic level only while they were showing negligible effect at phenotypic level.

Table- 4.7: Genotypic coefficients of correlation among different traits in coriander (*Kharif* 2016)

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13
1	**1.0000**	0.0393	0.0773	0.9777	0.6091	0.7400	0.7919	-0.1021	0.9706	-0.2989	-0.2831	1.0609	0.9339**
2		**1.0000**	0.7782	-0.0497	0.4570	0.4713	0.2709	0.4304	-0.0789	-0.0529	-0.1424	-0.1225	-0.0772
3			**1.0000**	-0.0321	0.3554	0.5210	0.4231	0.2181	-0.0873	0.0334	0.0116	-0.0291	0.0099
4				**1.0000**	0.4337	0.5238	0.6944	-0.0789	0.9593	-0.2977	-0.3358	1.0502	0.9171**
5					**1.0000**	0.9210	0.4555	0.1005	0.4771	-0.4552	-0.4197	0.5280	0.6212**
6						**1.0000**	0.6955	-0.0026	0.5734	-0.2668	-0.2631	0.5233	0.6555**
7							**1.0000**	-0.1298	0.5661	-0.1760	-0.1749	0.8425	0.5146**
8								**1.0000**	-0.0715	0.2744	0.1802	-0.2679	-0.0743*
9									**1.0000**	-0.2587	-0.2432	0.9950	0.9564**
10										**1.0000**	1.1353	-0.4888	-0.3301
11											**1.0000**	-0.5251	-0.3064
12												**1.0000**	-0.4356**
13													**1.0000**

1. Plant height (cm)
2. Number of primary branches/plant
3. Number of secondary branches/plant
4. Umbel/plant
5. Umbellate / umbel
6. Fruits /umbel
7. Fruits /umbellate
8. Umbel diameter
9. Test weight
10. Days to first umbel unfolding
11. Days to 50% flowering
12. Maturity duration
13. Seed Yield / plant

C –Correlation
* =Significant at 5 % level
**=Significant at 1 % level

Table- 4.8: Phenotypic coefficients of correlation among different traits in coriander (*Kharif* 2016)

Characters	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1	1.0000	0.0317	0.0583	0.8464**	0.4139**	0.5875**	0.6617**	0.0755	0.8992**	0.2448	-0.2445	0.6201**	0.8600**
2		1.0000	0.6907**	0.0733	0.3197**	0.3504**	0.2562*	0.2892	-0.0670	-0.0894	-0.1106	0.0333	-0.0598
3			1.0000	-0.0395	0.2810	0.4747**	0.3607**	0.1761	-0.0687	-0.0160	-0.0247	0.0904	0.0073
4				1.0000	0.2297	0.4407**	0.5772**	-0.0371	0.9020**	0.1894	-0.2102	0.5480**	0.8501**
5					1.0000	0.6617**	0.3425	0.0482	0.3633**	-0.2223	-0.2893	0.2058	0.4446**
6						1.0000	0.6139**	0.0164	0.5224**	-0.1833	-0.1452	0.3180**	0.5888**
7							1.0000	-0.1415	0.5015**	-0.0475	-0.1278	0.3999**	-0.4583**
8								1.0000	-0.0560	0.0599	0.0872	-0.0679	0.0564
9									1.0000	-0.1803	-0.1731	0.6008**	0.9455**
10										1.0000	0.7572**	-0.2645	-0.2248
11											1.0000	-0.2634	-0.2297
12												1.0000	0.5336**
13													**1.0000**

1. Plant height (cm)
2. Number of primary branches/plant
3. Number of secondary branches/plant
4. Umbel/plant
5. Umbellate / umbel
6. Fruits /umbel
7. Fruits /umbellate
8. Umbel diameter
9. Test weight
10. Days to first umbel unfolding
11. Days to 50% flowering
12. Maturity duration
13. Seed Yield / plant

C –Correlation
* =Significant at 5 % level
**=Significant at 1 % level

Table: 4.9. Genotypic path estimates of direct and indirect effects of different traits on seed yield per plant in coriander (*Kharif* 2016)

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13
1	-0.0190	-0.0007	-0.0015	-0.0185	-0.0116	-0.0140	-0.0150	0.0019	-0.0184	0.0057	0.0054	-0.0201	0.9339**
2	-0.0010	-0.0248	-0.0193	0.0012	-0.0113	-0.0117	-0.0067	-0.0107	0.0020	0.0013	0.0035	0.0030	0.0722
3	-0.0005	-0.0051	-0.0066	0.0002	-0.0023	-0.0034	-0.0028	-0.0014	0.0006	-0.0002	-0.0001	0.0002	0.0099
4	0.9662	-0.0491	-0.0317	0.9883	0.4286	0.5177	0.6863	-0.0779	0.9481	-0.2942	-0.3319	1.0379	0.9171**
5	-0.0334	-0.0250	-0.0195	-0.0238	-0.0548	-0.0505	-0.0250	-0.0055	-0.0261	0.0249	0.0230	-0.0289	0.6212**
6	0.3703	0.2358	0.2607	0.2621	0.4608	0.5003	0.3480	-0.0013	0.2869	-0.1335	-0.1317	0.2618	0.6555**
7	-0.3435	-0.1175	-0.1836	-0.3012	-0.1976	-0.3017	-0.4338	0.0563	-0.2456	0.0763	0.0759	-0.3655	-0.5146**
8	-0.0074	0.0313	0.0158	-0.0057	0.0073	-0.0002	-0.0094	0.0726	-0.0052	0.0199	0.0131	-0.0195	-0.0743*
9	0.1405	-0.0114	-0.0126	0.1388	0.0691	0.0830	0.0819	-0.0103	0.1447	-0.0374	-0.0352	0.1440	0.9564**
10	-0.0619	-0.0109	0.0069	-0.0617	-0.0943	-0.0553	-0.0365	0.0568	-0.0536	0.2071	0.2352	-0.1013	-0.3301
11	0.0663	0.0334	-0.0027	0.0786	0.0983	0.0616	0.0410	-0.0422	0.0570	-0.2659	-0.2342	0.1230	-0.3064
12	-0.1427	0.0165	0.0039	-0.1413	-0.0710	-0.0704	-0.1133	0.0360	-0.1339	0.0658	0.0707	-0.1345	-0.4356**

GENOTYPIC RESIDUAL EFFECT = 0.1280

1. Plant height (cm)
2. Number of primary branches/plant
3. Number of secondary branches/plant
4. Umbel/plant
5. Umbellate / umbel
6. Fruits /umbel
7. Fruits /umbellate
8. Umbel diameter
9. Test weight
10. Days to first umbel unfolding
11. Days to 50% flowering
12. Maturity duration
13. Seed Yield / plant

C –Correlation
* =Significant at 5 % level
**=Significant at 1 % level

Table: 4.10. Phenotypic path estimates of direct and indirect effects of different traits on seed yield per plant in coriander (*Kharif* 2016)

Characters	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.0713	0.0023	0.0042	0.0604	0.0295	0.0419	0.0472	-0.0054	0.0641	-0.0175	-0.0174	0.0442	0.8600**
2	0.0032	0.1010	0.0698	-0.0074	0.0323	0.0354	0.0259	0.0292	-0.0068	-0.0090	-0.0112	0.0034	-0.0598
3	-0.0024	-0.0280	-0.0405	0.0016	-0.0114	-0.0192	-0.0146	-0.0071	0.0028	0.0006	0.0010	-0.0037	0.0073
4	0.0729	-0.0063	-0.0034	0.0861	0.0198	0.0379	0.0497	-0.0032	0.0777	-0.0163	-0.0181	0.0472	0.8501**
5	0.0083	0.0064	0.0057	0.0046	0.0202	0.0133	0.0069	0.0010	0.0073	-0.0045	-0.0058	0.0042	0.4446**
6	0.0835	0.0498	0.0675	0.0627	0.0941	0.1422	0.0873	0.0023	0.0743	-0.0261	-0.0206	0.0452	0.5888**
7	-0.0877	-0.0339	-0.0478	-0.0765	-0.0454	-0.0813	-0.1325	0.0187	-0.0664	0.0063	0.0169	-0.0530	-0.4583**
8	-0.0051	0.0196	0.0120	-0.0025	0.0033	0.0011	-0.0096	0.0679	-0.0038	0.0041	0.0059	-0.0046	0.0564
9	0.7387	-0.0550	-0.0564	0.7410	0.2984	0.4292	0.4120	-0.0460	0.8215	-0.1481	-0.1422	0.4935	0.9455**
10	-0.0063	-0.0023	-0.0004	-0.0049	-0.0057	-0.0047	-0.0012	0.0015	-0.0046	0.0257	0.0195	-0.0068	-0.2248
11	0.0176	0.0080	0.0018	0.0151	0.0208	0.0105	0.0092	-0.0063	0.0125	-0.0546	0.0721	0.0190	-0.2297
12	-0.0341	-0.0018	-0.0050	-0.0302	-0.0113	-0.0175	-0.0220	0.0037	-0.0331	0.0146	0.0145	-0.0550	0.5336**

PHENOTYPIC RESIDUAL EFFECT = 0.2565

1. Plant height (cm)
2. Number of primary branches/plant
3. Number of secondary branches/plant
4. Umbel/plant
5. Umbellate / umbel
6. Fruits /umbel
7. Fruits /umbellate
8. Umbel diameter
9. Test weight
10. Days to first umbel unfolding
11. Days to 50% flowering
12. Maturity duration
13. Seed Yield / plant

C –Correlation
* =Significant at 5 % level
**=Significant at 1 % level

-4.4 Genetic divergence studies

The clustering pattern of twenty four diverse genotypes of coriander was made on the basis of Mahalanobis D^2 analysis of various traits under study (Fig.4.2).During any hybridization programme, the selection of parents using D^2 statistic provides the required potential parents, which are under study with respect to an array of characters. With the selection of genotypes, based on their genetic distance and yield potential, a breeder can formulate an appropriate crossing programme for the desired crop improvement.

The significant values of mean sum of squares due to genotypes from the analysis of variance revealed the presence of significant variation among the genotypes for all the characters investigated but such analysis is unable to tell anything about extent of genetic diversity present among the genotypes taken for the investigation. To overcome this problem and simultaneously to quantify genetic divergence between any two genotypes or group of genotypes, Mahalanobis D^2 statistics (1936) as described by Rao (1952) was used and the grouping of genotypes into different clusters was done by following Tocher's method (Rao, 1952).

All the genotypes grouped into 5 clusters, have been represented in the table 4.11. Where, maximum numbers of genotypes were accommodated in the cluster-IV (9) and minimum in cluster III.

4.4.1 Intra and inter-cluster average D^2 values

The intra and inter cluster D^2 values among 24 genotypes of coriander presented in Table 4.12, revealed that the maximum intra cluster distance was recorded in Cluster III (159.22**)** followed by Cluster I (139.54) and the lowest intra cluster distance is found in cluster II (31.78**).** The inter-cluster distance was maximum (2271.66) between the cluster III and IV indicating that genotypes belonging to these groups were genetically most divergent. Next, higher inter cluster distance (1774.36) was found between the cluster III and V, indicating that genotypes clustered in this groups also have high diversity. Minimum inter cluster distance was observed between the cluster IV and V (166.37).

In Table 4.13, the highest cluster mean value for the plant height was found in cluster III (64.98) followed by cluster I (55.79) and the lowest cluster mean value for plant height was found in cluster IV (34.15). Highest cluster mean for number of primary branches per plant was found in cluster V (3.45) and lowest in the cluster I (2.02). Highest cluster mean was found in cluster V (7.52) incase of number of secondary branches per plant and the lowest in cluster I (4.34). Incase of number of umbel per plant, the highest cluster mean was found in cluster III (15.55) and the lowest in IV (6.43). The cluster mean of umbellates per umbel was found lowest in cluster II (3.61) while highest was observed in cluster III (4.88). Cluster mean incase of fruits per umbel was highest in cluster III (22.57) and lowest incase of IV (13.75). Cluster mean incase of number of fruits per umbellate was highest in cluster III (4.44) and lowest incase of cluster IV (3.49). The cluster mean incase of umbel diameter was highest in case of cluster III (32.40) and lowest incase of cluster I (21.59). Incase of seed yield per plot the highest cluster mean was found in cluster III (281.33) and the lowest in cluster IV (11.45). Incase of seed yield per plant the highest cluster mean was found in cluster III (7.36) and the lowest in cluster IV (0.31).The cluster means incase of test weight was highest in the cluster III (20.56) and lowest in cluster IV (3.08). Cluster mean incase of days to first umbel unfolding was highest in cluster II (39.69) and lowest in cluster I (33.45).The cluster mean incase of days to 50% flowering was highest in cluster V (48.96) and lowest in cluster III (42.57). Cluster mean incase of number of days to maturity duration was highest in cluster III (111.95) and lowest incase of cluster IV (80.02).

Table 4.11 Clustering pattern of twenty four genotypes of coriander on the basis of genetic divergence.

Clusters	Number of genotypes	Genotypes along with their sources
I	**4**	Pant LC, PLI-100, PLC and Dhulet Local
II	**4**	HL-Thick, HL-Normal, , HL-Big and TLC
III	**3**	Pant Haritma, PD-21 and KPL
IV	**9**	R-CO-75, Bareilly Local, RL-13, RS, ALC, Siku-LC, Small CO, LS-800 and CO-4
V	**4**	Kota, Hanumangarh Rajasthan, Jaunpur Local and Lakhimpur

Table 4.12 Average intra and inter cluster distance (D^2).

Clusters	I	II	III	IV	V
I	<u>**139.54**</u>				
II	308.24	<u>**31.78**</u>			
III	556.77	1324.49	<u>**159.22**</u>		
IV	862.26	248.61	2271.66	<u>**99.6**</u>	
V	692.21	216.09	1774.36	166.37	<u>**33.88**</u>

(Note):- Bold and <u>underlined</u> numbers show intra cluster distance while others are inter cluster

Fig. 4.13 Dendrogram using average linkage (between groups)

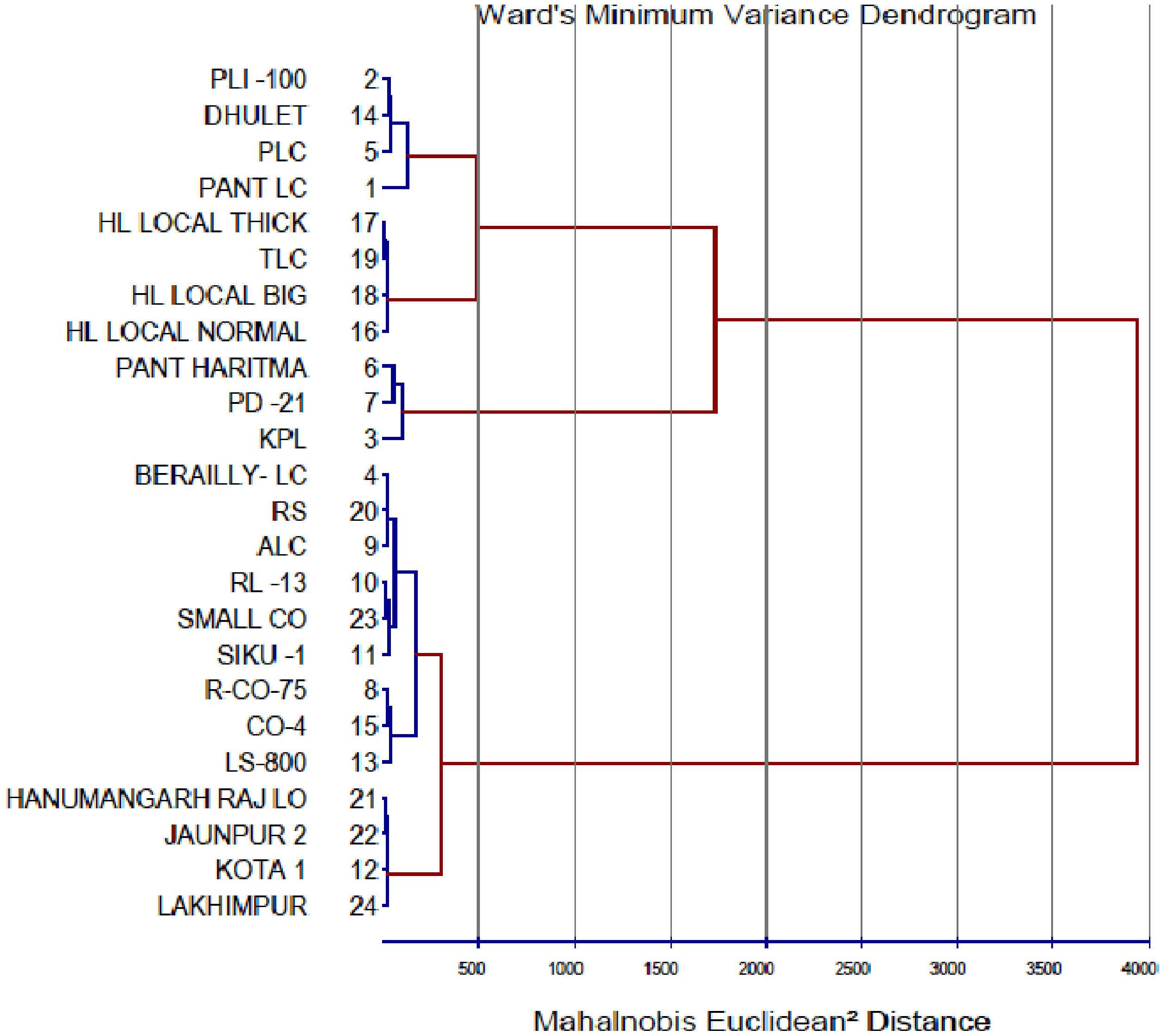
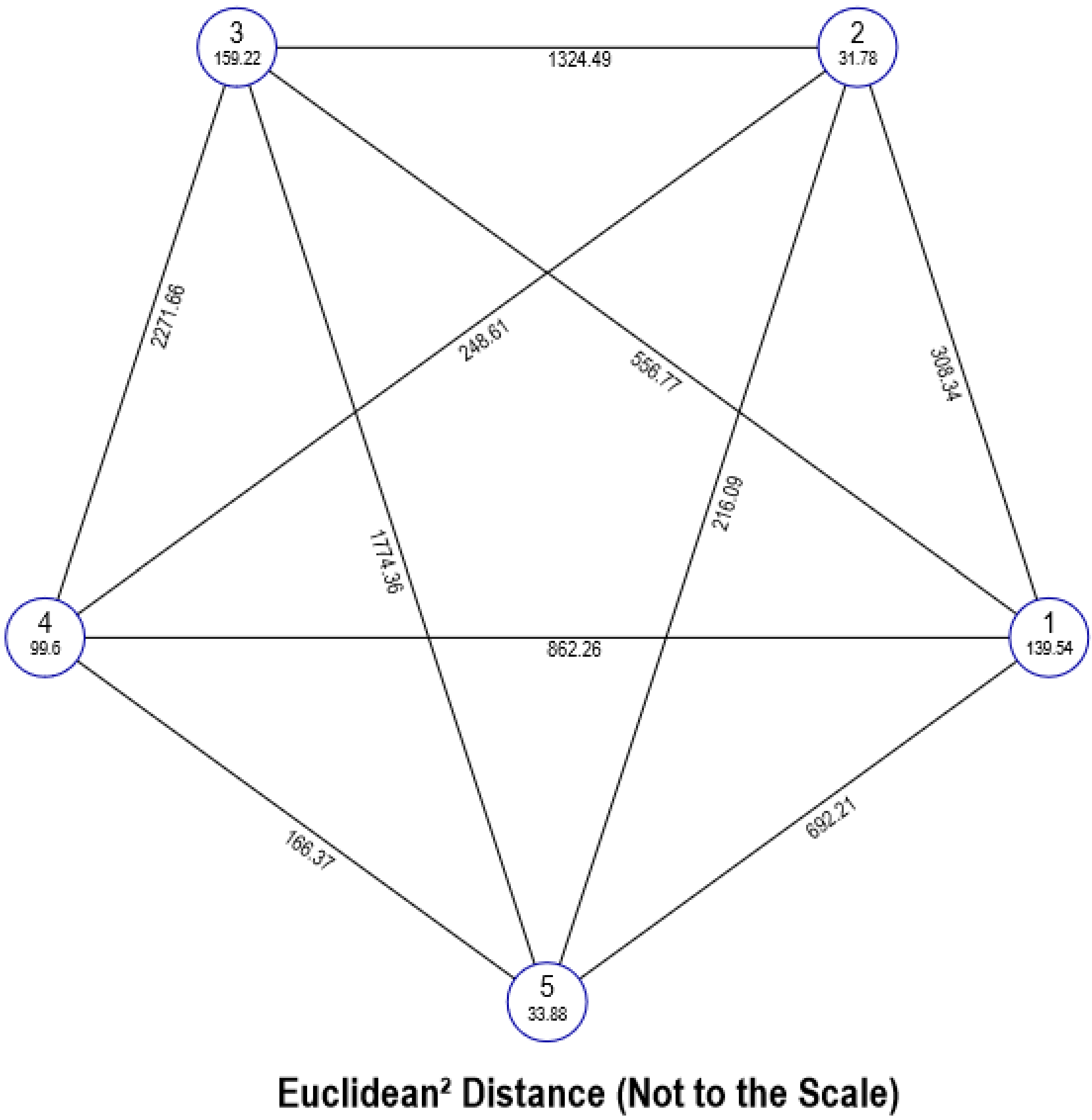


Table 4.14 Cluster means for different trait in twenty four genotypes of coriander.

Sr.	Traits	Cluster				
		I	**II**	**III**	**IV**	**V**
1.	**Days to 50 % flowering**	43.82	47.72	42.57	45.47	48.96
2.	**Days to first umbel unfolding**	33.45	39.69	34.48	36.80	39.48
3.	**Maturity duration**	104.26	102.75	111.95	88.02	90.91
4.	**Plant height**	55.79	48.61	64.98	34.15	40.86
5.	**Primary branches**	2.02	2.12	3.13	2.27	3.45
6.	**Secondary branches**	4.34	4.36	5.88	4.59	7.52
7.	**Umbel /plant**	12.56	11.20	15.55	6.43	7.95
8.	**Umbellates /umbel**	4.11	3.61	4.88	3.65	3.83
9.	**Umbel diameter**	21.59	24.49	32.40	27.05	29.61
10.	**Fruits /umbel**	19.01	13.91	22.57	13.75	18.20
11.	**Fruits /umbellate**	4.05	4.28	4.44	3.49	4.21
12.	**Test weight**	15.79	10.65	20.56	3.08	4.87
13.	**Seed yield /plant**	4.08	1.67	7.36	0.31	0.71
14.	**Seed yield/ plot**	151.85	63.13	281.33	11.55	27.21

Fig 4.2: Cluster diagram showing average intra and inter-cluster D^2 values of genotypes



A coriander full plant view

EXPERIMENTAL PLOT VIEW

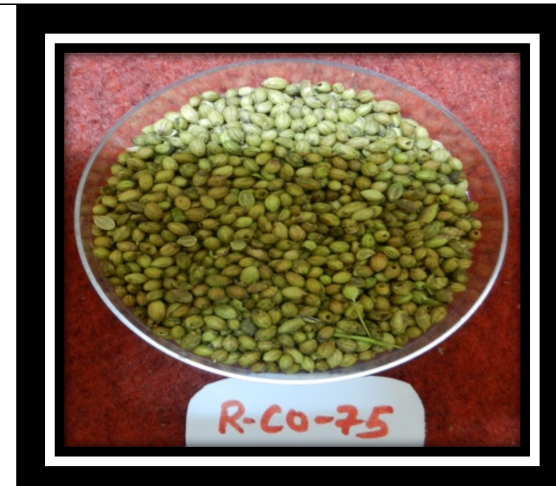
Germination in a plot **Researcher irrigating his field**

A 25 days old plant

Same plot showing 100% flowering at 55 days

Partial Fruits developing in a plot

List of Coriander Germplasm



List of Coriander Germplasm

CHAPTER-5

DISCUSSION

Coriander (*Coriandrum sativum* L.) is one of the most popular winter season seed spice crop grown throughout the world because of its wider adaptability, high yielding potential and suitability for use even in dried form. Realizing this, there is a need for continuous crop improvement in coriander which can be achieved by isolating superior breeding lines / varieties having desirable horticultural traits.

Large amount of variation in the germplasm provide better chance of selecting desired genotypes. Hence, knowledge of the magnitude and kind of variability existing in the germplasm for yield and its attributing traits is an essential pre-requisite to carry out any crop improvement programme. Heritability examines the extent of heritable portion of variability, while study of genetic advance predicts the possible yield through selection. The yield in coriander is a complex character and is dependent on number of yield components. To incorporate desirable yield and quality traits in a variety / hybrid, there is a need to know the inter-relationship of different characters. Moreover, knowledge of inter character relationship helps in the identification of important attributes which, in other words, is used to design suitable plant type with improved characters and for multiple trait selection. Path coefficient analysis on the other hand, partitioned the correlation coefficients into direct and indirect effects and the information so generated could be utilized in restructuring desirable plant type. Further, grouping of genotypes based on D^2 analysis is useful in choosing suitable parental lines for heterosis breeding. Such studies are also useful in selection of parents for hybridization to recover superior transgressive segregants, which can be released as improved open pollinated varieties for commercial cultivation.

Therefore, the present investigation was carried out on 24 diverse genotypes of coriander in *Kharif*, 2016 to study genetic variability, correlation, path analysis and genetic divergence for different horticultural and quality traits. These traits have been discussed hereunder in the light of available literature,

5.1 Variability Studies

The analysis of variance was carried out for all the characters in Randomized Block Design in the year 2016. The main objective of the present investigation was to study the diversity present in twenty four genotypes of coriander. The analysis of variance indicated highly significant differences among the genotypes for all the traits studied which indicates the presence of genetic diversity in the existing germplasm *viz*, plant height (cm), primary branches per plant, secondary branches, umbel per plant, umbellates per umbel, fruits per umbel, fruits per umbellate, umbel diameter (mm), seed yield per plant (g), seed yield per plot (g), test weight (g), days to first umbel unfolding (days), days to 50% flowering and maturity duration (days).These results were in agreement with Sharma and Sharma (1989**)**, Megeji and Karla (2002), Karla *et al* (2003), Shah *et al* (2003) and Rajput and Singh (2003).

Yield is a complex polygenic character and is resultant of interactions of several genetic and environmental factors. According to Grafius (1959) and Whitehouse *et al* (1958) there may not be genes for yield but for their components, the multiplicative interactions result in ultimate yield. It would be therefore, desirable to have information on component characters and their relationship with yield and among the components.

5.1.1 Mean performance of genotypes

The analysis of variance indicated highly significant differences among the genotypes for all the traits studied *i.e.* the mean performance of the genotypes revealed a wide range of variability for all the traits. The variation was highest for days to maturity (70.60-118) followed by days to 50% flowering (36.60-57.20), plant height (23.10-67.64), days to first umbel unfolding (26.53-47.80), umbel diameter (15.03-41.18), number of fruits per umbel (8.40- 27.13), number of umbels per plant (4.24-18.57), umbellates per umbel (2.83-6.20), seed per plant (0.06-8.03), seed yield per plot (2.33-307.80), number of secondary branches per plant (2.37-8.20), test weight (1.61-23.48) and number of primary branches per plant (1.57-4.37). The variation for plant height was also observed by Srivastava *et al* (2000), Rajput and Singh (2003), Singh *et al* (2005), Singh and Prasad (2006), Bertini *et al* (2010) and Abou El-Nasr *et al* (2013).

The maximum numbers of primary and secondary branches per plant were recorded for the genotypes KPL and Hanumangarh Rajasthan, respectively, while the genotype PLI-100 exhibited minimum number of primary branches per plant and genotype ALC recorded minimum number of secondary branches per plant. Probable reasons for enhanced number of primary and secondary branches per plant might be due to apical dominance and endogenous hormonal level. This finding is also in agreement with the findings of Srivastava *et al* (2000), Rajput and Singh (2003), Singh *et al* (2005), Singh *et al* (2011) and Dyulgerov and Dyulgerova (2013).

The earliest umbel unfolding and 50% flowering were recorded for the genotypes Pant Haritma (21.57, 38.00) and Bareilly Local (26.53, 36.60), respectively. However, the genotype LS-800 was found to be latest with respect of days taken to first umbel unfolding and 50% flowering *i.e.* 47.80 and 57.20 respectively. These genotypes can introduce diversity in crop improvement programme because the early and late type can easily fetch the market demands and give better economic returns. The result have been reported by Srivastava *et al* (2000), Singh *et al* (2005), Singh and Prasad (2006), Patel and Agalodiya (2007), Bertini *et al* (2010) and Meena *et al* (2014).

The maximum numbers of umbels per plant was recorded in the genotype Pant Haritma (18.57). However, the genotype CO-4 was recorded with minimum umbels per plant (4.24). The level in variability for the traits also reflected in the findings of Srivastava *et al* (2000), Jain *et al* (2002), Rajput and Singh (2003), Singh *et al* (2006), Singh and Prasad (2006) and Meena *et al* (2014).

Genotype Pant Haritma exhibited maximum umbellates per umbel (6.20), while lowest umbellates per umbel was noted in CO-4 (2.83). The same extent of variability for the trait was also seen in the reportings of Srivastava *et al* (2000), Tripathi *et al* (2000), Rajput and Singh (2003), Singh *et al* (2005), Singh *et al* (2006) and Bertini *et al* (2010).

The maximum fruits per umbel were recorded in genotype Pant Haritma (27.13) while it was lowest in CO-4 (8.40). Variation observed in these factors may be due to genetic makeup of the genotype. These result are in agreement with the finding of

Srivastava *et al* (2000), Choudhary and Ramakrishna (2003), Rajput and Singh (2003), Singh *et al* (2006) and Singh and Prasad (2006).

Maximum seed yield per plant was noted in Pant Haritma (8.03). While lowest was observed in CO-4 (0.06).

Maximum seed yield per plot was noted in Pant Haritma (307.80) which was at par with PD-21 (288.85). While lowest was observed in CO-4 (2.33). The findings are in close conformity with Srivastava *et al* (2000), Jain *et al* (2002), Rajput and Singh (2003), Vijayalatha and Chezhiyan (2005) and Singh and Prasad (2006).

The similar range of values was also reported by Megeji and Karla (2002), Karla *et al* (2003), Shah *et al* (2003), Singh *et al* (2003), Singh *et al* (2003), Selvarajan *et al* (2008), Bhandari and Gupta (1991) in coriander genotypes.

5.1.2 Parameters of variability

5.1.2.1 Phenotypic and Genotypic Coefficient of Variations

In the present findings, phenotypic coefficient of variation were observed to be higher than the corresponding genotypic coefficient of variation for all the characters studied and differences were considerable for the character due to environmental variations The finding of Tripathi *et al* (2000), Megeji and Karla (2002) and Rajput and Singh (2003) were similar to that of the present findings. The selection for the characters like plant height, seed yield per plot, test weight, umbel per plant, secondary branches per plant and seed yield per plant can be performed to achieve improvement.

High genotypic coefficient of variation as well as phenotypic coefficient of variation was noted for seed yield per plot, seed yield per plant and test weight.The findings are in close harmony with the result of Megeji and Korla (2002), Rajput and Singh (2003) and Beemnet *et al* (2010) for seed yield.

5.1.2.2 Heritability, Genetic Advance and Genetic Gain

The genotypic coefficient of variation does not offer full scope to estimate the variation that are heritable and therefore, estimation of heritability becomes necessary. Sharma (1994) has suggested that genetic coefficient of variability along with heritability estimates would give a reliable indication of expected amount of improvement through selection.

The estimates of heritability (broad sense) varied from 51.78% to 96.37% for different characters under study. The classification of heritability value was done as per Sharma, values greater than 80% shows highest heritability, while values ranging between 50-80% are moderate and values less than 50% shows less heritability. Highest heritability was recorded for seed per plant (96.37), test weight (94.77%), seed yield per plot (92.96%), secondary branches per plant (89.33%), umbel per plant (87.75%), plant height (87.22%), whereas moderate heritability was recorded for maturity duration (69.38%), days to first umbel unfolding (66.34%), primary branches per plant (64.24%), umbel diameter (61.55%), fruits per umbel (58.39), days to 50% flowering (56.00%), umbellates per umbel (53.72%) and fruits per umbellate (51.78). Heritability for above studied traits was also reported earlier by Bhandari and Gupta (1991).

The classification of values of genetic gain and genetic advance was done as per Sharma, 1994. The range for genetic advance was from 0.73 to 185.15 where high genetic advance was recorded in seed yield per plot (185.15) while medium was recorded in plant height (22.92), maturity duration (18.63), test weight (13.43) and umbel diameter (10.37). while low genetic advance was observed for days to first umbel unfolding (8.38), days to 50% flowering (7.28), umbel per plant (6.79), fruits per umbel (6.30), secondary branches per plant (2.82), primary branches per plant (1.05), umbellates per umbel (0.89) and fruits per umbellate (0.73). While genetic gain (expressed as per cent of population mean) was low to high in nature and ranged from 15.84-234.90% for different characters under study. It was found high for the characters *viz,* seed per plant (234.90), seed yield per plot (231.81%), test weight (150.06%), umbel per plant (70.43%), secondary branches per plant (54.55%) and plant height (50.78%). However, primary branches per plant (41.83%), umbel diameter (38.68%) and fruits per umbel (38.18%) are moderate. Umbellates per umbel (22.76%), days to first umbel unfolding (22.72%), maturity duration (19.12%), fruits per umbellate (18.43%) and days to 50% flowering (15.84%) gave low estimates of genetic gain. These results of present findings are in agreement with Tripathi *et al* (2000), and Bhandari and Gupta (1991).

5.2 Correlation Studies

The correlation coefficients among the different characters were worked out at phenotypic and genotypic levels. In general, the genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients. The phenotypic and genotypic correlation coefficients among different characters showed that seed yield per plant had positive and significant association with test weight, plant height, umbel per plant, number of umbellates per umbel and number of fruits per umbel. The similar result was reported by Garg *et al* (2003), Jain, *et al* (2003), Beemnet *et al* (2011), Singh, *et al* (2008), Dutta (2006) and Bhandari and Gupta (1991). They reported that yield per plant were highly significant and positively correlated with number of grain per umbel, number of primary branches and plant height. The present study too suggested that plant height, number of fruits per umbel, seed yield per plot and seed yield per plant may be selected for seed yield improvement of the coriander.

5.3 Path Analysis

Although correlation studies are helpful in determining the components of yield but it does not provide a clear picture of nature and extent of contributions made by number of independent traits. Path-coefficient analysis gives ideas about contribution of each independent character on dependent character *i.e.* yield. Since the mutual relationship of component characters might vary both in magnitude and direction, it is necessary to partition the association of yield with yield attributes into direct and indirect effects of each other.

5.3.1 Path Coefficient Analysis

Path coefficient analysis devised by Dewey and Lu (1959) helps in showing the direct and indirect effects of characters over seed yield per plant.

Path coefficient analysis was carried out by taking seed yield per plant as dependent variable to partition correlation coefficients into direct and indirect effects in order to determine the contribution of different characters towards the seed yield per plant. Direct and indirect effects of various characters on seed yield per plant indicated that there is an agreement between direction and magnitude of direct effect of various character and correlation with seed yield per plant. Thus, a significant improvement in seed yield per plant can be expected through selection in the component traits with high positive direct effects. This may contribute to account for the residual effect.

5.3.2 Direct effects and indirect effects

Highly direct positive effect on the seed yield/ plant was contributed by plant height, umbel per plant, umbellate per umbel, fruits per umbel and test weight at both genotypic and phenotypic levels. This indicates that these are major yield contributing trait for enhancing yield of coriander. The fruits per umbellates show highest negative and direct effect on seed yield per plant at both genotypic and phenotypic levels respectively.

Regarding indirect effects, it was observed that the plant height had the highest positive indirect effect via number of umbels per plant, number of fruits per umbel and test weight. The similar result reported by Jain *et al* (2003). While, the umbellates per umbel had highest positive indirect effect *via* number of fruits per umbel and number of umbels per plant. Similarly fruits per umbellate had the highest positive indirect effect *via* number of umbels per plant and number of fruits per umbel, respectively. It was observed at genotypic level while at phenotypic level the values were showing negligible effect. On the basis of the present study, it may be concluded that the characters like umbels per plant and number of fruits per umbel are important characters affecting seed yield since they had high positive direct effect.

Similarly number of fruits per umbel had the highest positive indirect effect *via* umbel per plant at genotypic level while showing negligible effect at phenotypic level. The similar finding have also reported by Arumugam and Muthurkrishnan (1979), Suthanthirapandian *et al* (1980), Rao *et al* (1981), Bhandari and Gupta (1991) , Srivastava *et al* (2000), Tripathi *et al* (2000), Gurbuz (2001), Choudhary and Ramkrishna (2003), Davila *et al* (2004), Singh *et al* (2008), Dutta (2006), Singh *et al* (2006) and Singh *et al* (2011).

5.4 Genetic Divergence Studies

Creation of variability and selection within, leading to diverse genotypes is the common protocol that a conventional plant breeder follows. Genetic relationship among genotypes thus generated can be measured by similarity or dissimilarity of any number of quantitative characters, assuming that the differences between the characters of genotypes ultimately reflect on the divergence of the genotypes. In heterosis breeding programme, the diversity of parents is always emphasized upon. More diverse the parents within a reasonable range, better is the chances of improving economic traits under consideration in the resulting offspring. However, it is a difficult task for the breeder to select the most suitable and genetically divergent parents, unless one is provided with necessary information about genetic variability and genetic diversity present in the available germplasm.

Generally, geographical diversity is considered and taken as a measure of genetic diversity when no scientific tool is available. However, inferential criterion may not be used for discrimination among the populations occupying ecologically marginal habits. The multivariate analysis, using Mahalanobis D^2 statistic, provides a useful statistical tool for measuring the genetic diversity in a given population with respect to the characters considered together. Further, the problem of selecting diverse parents for the hybridization programme can be narrowed, if one can identify the characters, responsible for the discrimination between populations.

In the present study the clustering based on D^2 statistics grouped the genotypes into 5 different clusters. Maximum numbers of genotypes are present in cluster IV that includes 9 coriander varieties, namely R-CO-75, Siku-LC, Bareilly Local, RL-13, RS, ALC, LS-800, Small CO and CO-4. Lowest numbers of genotypes were present in Cluster III, that include only three coriander genotypes; Pant Haritma, KPL and PD-21. Cluster I, II and V each includes 4 coriander genotypes *i.e.* Pant LC, PLI-100, PLC and Dhulet Local in cluster I, HL-Thick, HL-Normal, HL-Big and TLC in cluster II, and Hanumangarh Rajasthan, Jaunpur Local, Lakhimpur and Kota in cluster V. The grouping pattern indicates the relationship between genetic divergence and geographical diversity. In cluster I, II and III all the genotypes are from the state Uttarakhand, which indicates the role of geographical diversity in genetic diversity. While pattern of distribution of genotypes in rest of the cluster where different geographical regions clustered into a cluster with different was at random supporting that geographical diversity is not related to genetic diversity. The main forces other than geographical origin responsible for this genetic diversity may be natural or artificial selection, exchange of breeding materials, genetic drift and environmental variation. The intra and inter cluster D^2 values revealed that the maximum intra cluster distance was recorded in Cluster III (159.22**)** followed by Cluster I (139.54) and the lowest intra cluster distance was found in cluster II (31.78). It means genotypes included in the cluster III are very diverse, and it may be due to both natural and artificial selection forces among the genotypes. The inter-cluster distance was maximum between the cluster III and IV indicating that genotypes belonging to these groups were genetically most divergent and the genotypes included in these clusters can be used as a parent in the hybridization programme to get higher heterotic hybrids. Srivastava *et al* (2000). Next, higher inter cluster distance found between the cluster III and V, indicating that genotypes clustered in this group also have high variability and genotypes from there clusters can be used as a parent in hybridization programme. Minimum cluster distance was observed between the cluster IV and V. The inter-cluster distances were much higher than those of intra-cluster distances, suggesting homogeneous and heterogeneous nature of the germplasm lines within and between the clusters (Rai *et al.,* 2007).

The cluster mean in case of days to 50% flowering was highest in cluster V and lowest in cluster III. While for days to first umbel unfolding was highest in cluster II and lowest in cluster I. Cluster mean in case of number of days to maturity duration was highest in cluster III and lowest in case of cluster IV. The highest cluster mean value for the plant height was found in cluster III followed by cluster I and the lowest cluster mean value for plant height was found in the cluster IV. The cluster means in case of number of primary branches per plant was highest in the cluster V and lowest in cluster I and number of umbel per plant was highest in cluster III and lowest in cluster IV. The cluster mean in case of umbel diameter was highest in case of cluster III and lowest in case of cluster I. The cluster mean in case of number of fruits per umbel was highest in cluster III and lowest in cluster IV. The cluster means in case of test weight was highest in the cluster III and lowest in cluster IV. For seed yield per plant cluster III has the highest values that means genotypes of this cluster must invariabily be used for the improvement of yield while designing crossing plans as per their performance usually transferred to advance breeding generations if they are coming from additive gene effect. Similar variation in cluster mean also reported by Beemet *et al* (2011) and Ravi *et al* (2009) and Singh *et al* 2005).

CHAPTER- 6

SUMMARY AND CONCLUSION

The present investigation "Germplasm Evaluation, Correlation and Path Analysis in coriander (*Coriandrum sativum* L.) in High Hills of Uttarakhand" was undertaken with the objectives to estimate extent of genetic variability, character association among agronomic characters, path coefficient analysis, principal component analysis and non-hierarchical Euclidean cluster analysis. The experiment was conducted during *Kharif,*2016 with 24 genotypes in Randomized Block Design including check (HL-Normal) at Medicinal Aromatic Plant Block, V.C.S.G Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal, Uttarakhand.

Observations were recorded on thirteen growth and yield characters namely days to 50 per cent flowering, days to first umbel unfolding, plant height, number of primary branches per plant, number of secondary branches per plant, umbels per plant, umbellates per umbel, umbel diameter, number of fruits per umbel, number of fruits per umbellate, seed yield per plant (g), seed yield per plot (g) and test weight (g). The data were subjected to statistically analysis the results obtained and summarized as follows:

Analysis of variance revealed highly significant for all the characters, number of primary branches per plant, number of secondary branches per plant, number of umbellates per umbel, umbels per plant, umbel diameter, seed yield per plot (g), test weight of seed, plant height. Indicating sufficient amount of variation for those characters.

6.1 Variability Studies

6.1.1 Mean performance

Among all the genotypes, Bareilly Local was found earliest in days to 50% flowering (36.60 days) followed by Pant Haritma (38.00), KPL (39.07) and PLC (39.97). Besides this, fifteen genotypes 50% flowered earlier than check cultivar HL-Normal (48.93).

Among all the genotypes, Pant Haritma was found earliest days to first umbel unfolding (21.57 days). Besides this, nine genotypes matured earlier than check cultivar HL-Normal (42.13).

Among all the genotype, ALC was found earliest in maturity (70.60 days). While eighteen genotypes matured earlier than check cultivar HL-Normal (103.67).

Significantly highest plant height (cm) was recorded in Pant Haritma (67.64), followed by PD-21 (65.77) besides this, six genotypes had more plant height than check cultivar HL-Normal (53.38).

Number of primary branches were recorded significantly maximum in the genotype KP Local (4.37). Besides this, eleven genotypes found more primary branches than check cultivar HL-Normal (2.33).

Number of secondary branches was recorded significantly maximum in the genotype Hanumangarh Rajasthan (8.20). Besides this, thirteen genotypes had more secondary branches than check cultivar HL-Normal (4.80).

Number of umbels per plant was recorded significantly maximum in the genotype Pant Haritma (18.57). Besides this, four genotypes had more umbels per plant than check cultivar HL- Normal (12.3).

Number of umbellate per umbel was recorded significantly maximum in the genotype Pant Haritma (6.20). Besides this, twenty two genotypes had more number of umbellates per umbel than check cultivar HL-Normal (2.93).

Number of fruits per umbellate was recorded significantly maximum in the genotype Pant Haritma (4.87) and only Pant Haritma had more number of fruits per umbellate than check cultivar HL-Normal (4.73).

Number of umbel diameter was recorded significantly maximum in the genotype Pant Haritma (41.18). Besides this, twenty genotypes had more number of umbel diameter than check cultivar HL-Normal (20.57).

Seed yield per plot was recorded significantly maximum in the genotype Pant Haritma (307.80). Besides this, seven genotypes had more seed yield per plot than check cultivar HL-Normal (73.28).

6.1.2 Coefficients of variability

For all the characters studied, phenotypic coefficients of variation were higher in magnitude than genotypic coefficients of variation, though difference was very less in majority of cases. The phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) were recorded high for seed yield per plot, seed yield per plant and test weight. The estimates of heritability (broad sense) were found high for seed yield per plant, seed yield per plot, test weight, secondary branches per plant, umbels per plant and plant height thereby suggesting that straight selection for these traits may bring worthwhile improvement in identifying superior genotypes in coriander. Besides this, high heritability estimates coupled with high genetic gain were observed in seed yield per plant, seed yield per plot, test weight and number of umbel per plant which indicated that these characters are under additive gene effects and these characters are more reliable for effective selection.

6.2 Correlation studies

The phenotypic and genotypic correlation coefficients among different characters showed that seed yield per plant had positive and significant association with test weight, plant height, number of umbel per plant, number of umbellates per umbel, number of umbellates per umbel and number of fruits per umbel. Hence, there is ample scope for yield improvement in coriander through selection of these traits.

6.3 Path coefficient analysis

The path coefficient analysis revealed that maximum positive direct effect towards seed yield per plant was contributed by number of umbels per plant followed by number of fruits per umbel, number of primary branches per plant, test weight, days taken to first umbel unfolding, days taken to fifty percent flowering. Indicating direct selection for these traits as a criteria for improvement in coriander. In the mean while, maximum positive indirect effects of plant height via umbel per plant, fruits per umbel and test weight. Fruit per umbel via umbel per plant**,** fruits per umbellate via number of umbels per plant and fruits per umbel, test weight via umbel per plant, maturity duration via umbel per plant and fruits per umbel. There by indicating the importance of yield contributing traits for yield improvement in coriander through indirect selection.

6.4 Genetic divergence studies

For those traits, where selection is not responsive and non-additive gene effects are playing major role in the expressions, hybridization between diverse parents on the basis of their mean performance to get superior hybrids or transgressive segregants or partitioning of additive genetic variation and non-additive genetic variation in segregating generations will be useful. Studies on genetic divergence will be helpful in identification of better parents. Here in this case, genetic divergence studies grouped twenty four genotypes into five clusters. The hybridization between genotypes of cluster III and cluster IV can be utilized for getting superior recombinants or transgressive segregants in segregating population because these clusters were found most divergent.

Conclusion

1. The performance of genotypes were evaluated on the basis of there performance with respect to check for that character. Three genotypes viz. Pant Haritma, PD-21, Pant LC, PLI-100 and KPL showed best performance in 2016. Genotypes showed best performance with reference to seed yield based on the average performance was best genotype.

2. The range of variation was maximum for maturity duration, plant height, days to 50% flowering, number of fruits per umbellate, umbel diameter (mm), seed yield per plot (g), test weight (g).

3. Character association analysis indicate that seed yield per plant exhibited significant and positive correlation with plant height, number of umbel per plant, number of fruits per umbel, number of fruits per umbellate, test weight, number of umbellates per umbel.

4. The path coefficient analysis revealed that the highest direct effect was shown by seed yield per plant (g), toward on number of fruits per umbel, followed by umbel per plant, days to 50% flowering, and test weight at both genotypic and phenotypic levels, respectively.

5. Twenty four genotypes were classified into five non-over lapping clusters on the basis of non-hierarchical Euclidean cluster analysis for yield and growth traits. The maximum (159.22) intra cluster distance was seen in cluster III and minimum (31.78) was observed in II. The maximum inter cluster distance (2271.66) was found in between clusters III and IV, followed by (1774.36) between clusters III and V. Whereas, minimum inter cluster distance (166.37) was observed between clusters IV and V. Cluster IV have the maximum number of genotypes nine. The minimum numbers of genotypes are only three in cluster III, while cluster I, II and V only have four genotypes in each cluster. The grouping of genotypes in clusters reflects the relative divergence of clusters and allows a convenient selection group of genotypes with their overall phenotypic similarity for hybridization programme facilitating better exploitation of germplasm. Thus it may be suggested that crosses between accessions of clusters III and IV may result in substantial segregates and further selection for overall improvement of species may be possible.

CHAPTER-7

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ABSTRACT

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Thesis Title: **"Germplasm Evaluation, Correlation and Path Analysis in Coriander (*Coriandrum sativum* L.) in High Hills of Uttarakhand"**

The present investigation entitled "**Germplasm Evaluation, Correlation and Path Analysis in Coriander (*Coriandrum sativum* L.) in High Hills of Uttarakhand**" was carried out at the "Medicinal and Aromatic Block", College of Horticulture, VCSG UUHF, Bharsar, during *Kharif*, 2016 to evaluate diverse germplasm of coriander. The experiment was laid out in a RCBD with three replications. In this study, twenty four genotypes were evaluated for different horticultural traits Pali LC, KP Local, Pant Haritma, PD-21, Dhulet Local and Pant LC recorded highest seed yield per plot and also performed better for other horticultural traits. Pant Haritma, Dhulet Local, Siku-LC and Pant LC recorded highest fruits per umbel and also performed better for other horticultural traits than check cultivar. Genetic analysis indicated that phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) in all of the attributes studied.The phenotypic and genotypic coefficients of variation were found high for almost all the traits except maturity duration, days to 50% flowering and days to first umbel unfolding High heritability estimates coupled with high genetic gain were observed for almost all the traits studied except fruits per umbellate, umbellates per umbel, days to 50% flowering and fruits per umbel which indicated that these traits are under additive gene effects and are more reliable for effective selection. Linear correlation analysis showed that seed yield per plant had positive and significant correlation with test weight, umbel per plant, plant height were significantly and positively associated with yield both at genotypic and phenotypic leveHence, these traits should be taken into consideration, while making the selection for yield improvement in coriander. Path coefficient analysis revealed that direct positive effect on the seed yield per plant was contributed by fruits per umbel followed by umbels per plant, days to 50% flowering, days to first umbel unfolding, test weight and number of primary branches per plant and plant height. Further, on the basis of D^2 analysis these genotypes were grouped into five divergent clusters and divergence between cluster III and IV is found to be maximum, therefore superior cross combinations are expected to be obtained in future breeding programmes by crossing between the genotypes of these clusters. Environment and its interaction with the genotypes were observed to be significant for all the traits in the present study. Therefore, environments have significant impact over the performance of the genotype.

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षट्मास एवं प्रवेश वर्षः प्रथम, 2014

महाविद्यालयः औद्यानिकी महाविद्यालय

गौण विषयः आनुवंशिकी एवं पादप प्रजनन

उपाधिः स्नातकोत्तर औद्यानिकी (मसाले, पौध रोपण, औषधीय एवं सुगंधित पादप)

विभागः मसाले, पौध रोपण, औषधीय एवं सगंध पादप

शोध विषयः "धनिया (कोरिएन्डरम सेटाइवम एल.) जीन प्रारूपो का सह–संबंध एवं पाथ विशलेषण मूल्यांकन उत्तराखण्ड के उच्च पर्वतीय क्षेत्र में"

वर्तमान शोध "धनिया (कोरिएन्डरम सेटाइवम एल.) जीन प्रारूपो का सह–संबंध एवं पाथ विशलेषण मूल्यांकन उत्तराखण्ड के उच्च पर्वतीय क्षेत्र में" शीर्षक अंर्तगत औषधीय एवं सगंध पादप प्रदर्शन प्रखण्ड, औद्यानिकी महाविद्यालय, वी.चं. स. ग. उत्तराखण्ड औद्यानिकी उवं वानिकी विश्वविद्यालय. भरसार, में वर्ष 2016 की खरीफ ऋतु में मूल्यांकन हेतू संचालित किया गया था। प्रयोग आर.सी.बी.डी. में तीन प्रतिकृतियों के साथ रखा गया था। इस अध्ययन में चौबीस जीन प्रारूपों का विभिन्न बागवानी गुणों के लिए मुल्यांकन किया गया, जिनमें पंत हरितमा, पी.डी.–21, के.पी.एल. एवं पंत एल.सी में सबसे अधिक बीज दर प्रति भूखण्ड या क्यारी मे दर्ज की गई थी, एवं साथ ही अन्य बागवानी गुणों में भी बेहतर प्रदर्शन दर्ज किया था। पंत हरितमा, धुलैत लोकल, सीकू एल.सी एवं पंत एल.सी. जीन प्रारूपों ने अधिकतम प्रति अम्बेल या गूच्छा फल संख्या को दर्ज किया तथा साथ ही साथ तुलनात्मक किस्म या जॉच किस्म की तुलना में अन्य बागवानी लक्षणों के लिए बेहतर प्रदर्शन किया था। आनुवांशिक विश्लेषण संकेत करता है कि प्ररूपी या आकारिकी विविधता का गुणांक अध्ययनित सभी गुणों में जननिक या जीन प्रारूपिक गुणांक की विविधता से अधिक थे। जीनप्रारूपिक तथा प्ररूपी या आकारिकी विविधता गुणांक पौधे के परिपक्वता की अवधि, 50 प्रतिशत पुष्पन की अवधि, प्रथम अम्बेल के खुलने के दिन की संख्या, के साथ–साथ सभी लक्षण अधिकतम पाये गये थे। इनके अतिरिक्त प्रति अमब्लेट फल, प्रति अमब्ल अमब्लेट्स 50 प्रतिशत पुष्पन की अवधि, फल प्रति अमब्ल के साथ साथ अध्ययनित लगभग सभी लक्षणों के लिए उच्च आनुवंशिक लाभों के साथ उच्च आनुवंशिकता का अनुमान लगाया गया था। जिसमें संकेत प्राप्त हुए कि ये लक्षण गुणात्मक जीन प्रभाव के अंतर्गत हैं तथा प्रभावी चयन के लिए अधिक विश्वसनीय हैं। रेखीय सह–संबंध विशलेषण दर्शाता है कि बीज दर प्रति क्यारी या भूखण्ड के साथ सकारात्मक एवं महत्वपूर्ण था, परीक्षण भार, अम्बेल प्रति पौधा एवं पौधे की ऊँचाई के साथ उपज में जीन प्रारूपिक एवं प्ररूपी या आकारिकी स्तर पर, इसलिए धनिया में उपज सुधार के लिए चयन करते समय इन लक्षणों को ध्यान में रखा जाना चाहिए। पाथ गुणांक विशलेषण में दर्ज हुआ कि सीधा सकारात्मक प्रभाव बीज दर प्रति क्यारी में फल प्रति अम्बल के साथ अम्बल प्रति पौधा, 50 प्रतिशत पुष्पन की दिन, अम्बल के खुलने के दिन परिक्षण भार, प्राथमिक शाखाओं की संख्या प्रति पौधा उवं पौधे की ऊँचाई के साथ संयोजित था। इसके अतिरिक्त डी^{2} विशलेषण के आधार पर जीन प्रारूप को पाँच विभिन्न समूहों में बांटा गया तथा विचलन और क्लस्टर पाँच एवं द्वितीय के मध्य अन्तर अधिकतम पाया जाता है इसलिए भविष्य में इन जीन प्रारूपों के मध्य प्रजनन कार्यक्रमों में बेहतर संकरण संयोग प्राप्त होना अनुमानित है। वर्तमान अध्ययन में सभी गुणों के लिए पर्यावरण एवं जीन प्रारूपों के मध्य पारस्परिक संबंध महत्वपूर्ण दर्ज किया गया था।

अतः जीन प्रारूप के प्रदर्शन पर पर्यावरण का महत्वपूर्ण प्रभाव पड़ता है।

(प्रो. बी.पी. नौटियाल)
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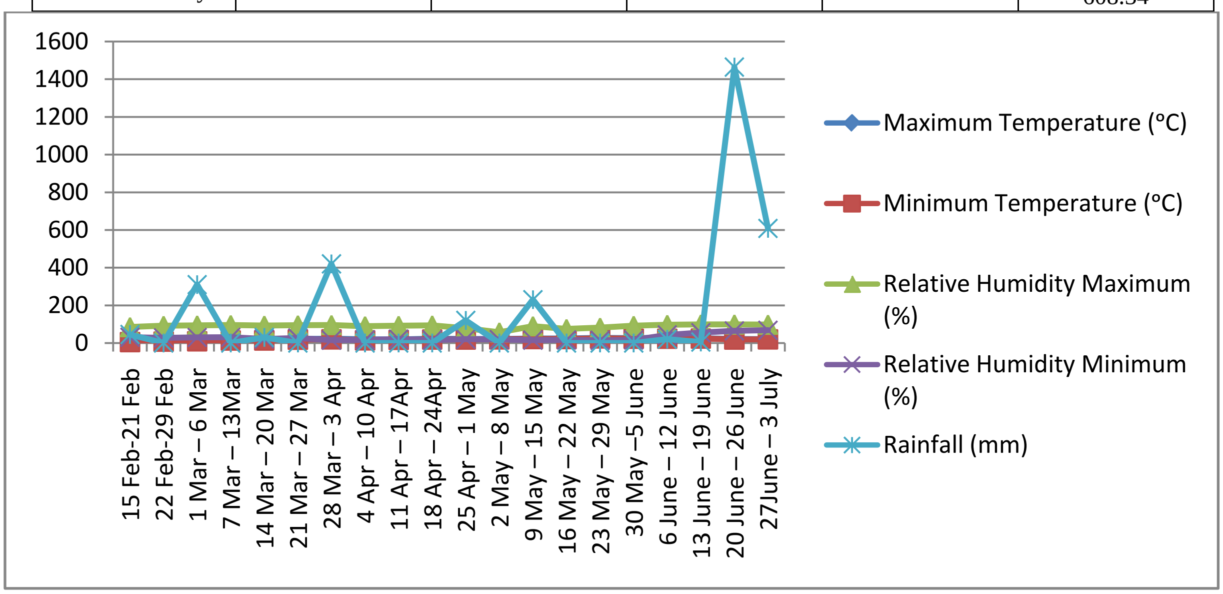
(डॉ. अजय पालीवाल)
सलाहकार

(जयदेव चौहान)
लेखक

Appendix- I

Mean monthly meteorological data of Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry for the year 2016 (Feb to July)

Month	Maximum Temperature (^{0}C)	Minimum Temperature (^{0}C)	Relative Humidity Maximum (%)	Relative Humidity Minimum (%)	Rainfall (mm)
15 Feb-21 Feb	9.42	5.13	85	31	45.00
22 Feb-29 Feb	10.52	7.85	92	28	0.00
1 Mar – 6 Mar	12.25	9.25	94	30.00	310.00
7 Mar – 13Mar	16.60	13.30	96	31	0.00
14 Mar – 20 Mar	16.75	14.08	93	22	30.00
21 Mar – 27 Mar	21.75	18.33	95	27	0.00
28 Mar – 3 Apr	22.87	19.50	96	16	420.00
4 Apr – 10 Apr	19.75	14.75	90	17	0.00
11 Apr – 17Apr	19.10	16.70	92	21	0.00
18 Apr – 24Apr	22.75	18.88	94	16	0.00
25 Apr – 1 May	21.00	18.50	78	21	120.00
2 May – 8 May	21.55	19.75	57	19	0.00
9 May – 15 May	23.75	21.67	90	16	230.00
16 May – 22 May	23.58	21.25	75	17	0.00
23 May – 29 May	27.42	24.67	82	15	0.00
30 May –5 June	25.50	22.67	92	17	0.00
6 June – 12 June	28.16	22.69	97	43	20.00
13 June – 19 June	26.00	23.75	99	45	5.40
20 June – 26 June	21.75	19.08	99	53	1464.78
27June – 3 July	20.25	19.33	98	64	608.34



Appendix II

Table : Analysis of variance for different characters of coriander genotypes

S. NO	Characters	Mean Sum of square		
		Replication	Genotype	Error
Degree of Freedom		2	23	46
1.	Days to 50% flowering	47.09	84.36**	17.51
2.	Days to first umbel unfolding	175.49	405.79**	12.64
3.	Maturity duration (days)	325.22	405.79**	52.03
4.	Plant height(cm)	47.33	446.52**	20.79
5.	Number of primary branches per plant	0.44	1.43**	0.22
6.	Number of secondary branches per plant	0.28	6.53**	0.25
7.	Number of umbels per plant	1.85	38.90**	1.73
8.	Number of umbellates per umbel	0.24	1.33*	0.30
9.	Umbel diameter	4.21	149.34**	25.74
10.	Fruits per umbel	25.86	59.47**	11.41
11.	Number of fruits per umbellate	1.98	33.62**	0.35
12.	Test weight	2.33	136.99**	2.47
13.	Seed yield per plant	0.06	18.44**	0.23
14.	Seed yield per plot	67.27	26733.13**	657.74

* Significant at 5% level

** Significant at 1% level

CURRICULUM VITAE

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Sex	**:**	Male
Marital Status	**:**	Unmarried
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Certificate/ degree	Class/ grade	Board/ University	Year
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B.Sc.(Life Science)	First	H.N.B. Garhwal University, BGR,Pauri	2014

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(Jaidev Chauhan)