GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS IN CUMIN [*Cuminum cyminum* L.]

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GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS IN CUMIN [*Cuminum cyminum* L.]

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ABSTRACT

Genetic variability, correlation and path coefficient analysis were studied in a set of 30 genotypes of cumin [*Cuminum cyminum* L.] grown at Main Spices Research Station, Sardarkrushinagar Dantiwada Agricultural University, Jagudan (Gujarat). The experiment was conducted during *rabi* 2003-2004 in a Randomized Block Design with three replications. Observations on five randomly selected plants were recorded for days to germination, days to 50% flowering, days to maturity, plant height (cm), plant height up to main umbel (cm), number of branches per plant, number of umbels per plant, number of seeds per main umbel, number of umbellates per umbel, number of seeds per umbellate, grain yield per plant (g), grain yield per plot (kg), 1000-seed weight and volatile oil content.

Analysis of variance revealed significant genotypic differences for all the characters under study and a wide range of variation was apparent for all the characters. High genotypic and phenotypic variances were observed for

number of umbels per plant, number of seeds per main umbel, days to maturity and days to 50% flowering.

The genotypic coefficient of variation was highest for 1000-seed weight followed by number of umbels per plant and volatile oil content. Heritability estimates were high for volatile oil content, number of umbels per plant, 1000-seed weight and days to 50% flowering. High genetic advance as per cent of mean was recorded for 1000-seed weight and number of umbels per plant suggesting that phenotypic selection for these traits would be effective.

Correlation analysis revealed that grain yield per plot was positively and significantly correlated with days to 50% flowering, plant height, number of branches per plant, number of umbels per plant, number of seeds per main umbel, number of umbellates per umbel, number of seeds per umbellate, grain yield per plant and 1000-seed weight. These yield contributing characters also possessed positive association among themselves. Days to maturity had non-significant positive association with grain yield.

Path coefficient analysis indicated the highest positive direct effect of number of umbellates per umbel followed by number of seeds per umbellate, days to 50% flowering, plant height, number of branches per plant, number of umbels per plant, days to maturity, plant height up to main umbel and 1000-seed weight. Number of seeds per main umbel had high negative direct effect on grain yield.

Based on these findings, it was suggested that for improving yield in cumin, more emphasis should be given to umbellates per umbel, seeds per umbellate, days to 50% flowering, plant height, branches per plant, umbels per plant, days to maturity, plant height up to main umbel and 1000-seed

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CERTIFICATE

This is to certify that the thesis entitled "**GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS IN CUMIN [*Cuminum cyminum* L.]**" submitted by **PATEL PANKAJKUMAR TRIBHOVANDAS** in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (Agriculture) in the subject of PLANT BREEDING AND GENETICS of the Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title. All the help received during the course of the investigation has been duly acknowledged.

Place: Sardarkrushinagar
Date: 10-1-2005
15-7-2005

[I. D. PATEL]
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DECLARATION

This is to declare that the research work reported in this thesis in partial fulfilment of the requirements of the degree of MASTER OF SCIENCE IN AGRICULTURE in the subject of PLANT BREEDING AND GENETICS by the undersigned is the result of the investigation done by me under the direct guidance and supervision of Dr. I. D. PATEL, Retd. Research Scientist, Main Spices Research Station, Sardarkrushinagar Dantiwada Agricultural University, Jagudan and that no part of the work has been submitted for any other degree so far.

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I INTRODUCTION

Cumin *(Cuminum cyminum* L.) is an annual herb belonging to the family umbelifereae having 2n=14 chromosomes. Cumin commonly known as "Jira" is an important, highly viable seed spice and cash *rabi* crop of arid and semi-arid regions of Gujarat and Rajasthan. Cumin seeds have an aromatic fragrance due to cuminol and are used as spice to flavour various food preparations. Cumin seeds are extensively used in mixed spices for flavouring curries, soups, sausages, bread and cakes. It is an ingredient of curry powder, pickles and chutneys.

Cumin is believed to be a native of Egypt and Syria, Turkistan and the Eastern Mediterranean. The important cumin growing countries of the world are India, Turkey, Iran, Egypt, Pakistan, Syria and Italy. Turkey and Iran are major competitors for cumin seed in the world. India holds a major position in the production of cumin. It is a short duration spice crop grown in certain places in India like Rajasthan, Gujarat, and Uttar Pradesh. Cumin is an important cash crop of semi-arid regions. The area, production and productivity of cumin in India during 2000-2001 were 2.86 lakh hectares, 127980 M tones and 448 kg/ha respectively. In India, Gujarat ranks first in area (1.30 lakh hectares), production (61400 M tones) and productivity (480 kg/ha) contributing about 63.00% to the country's total production (Anonymous, 2000-01). It is most extensively grown in North Gujarat and Saurashtra region. It is extensively cultivated in Mehsana, Banaskantha, Bhavnagar, Ahmedabad and parts of Surendranagar districts.

Cumin is a self-pollinated crop. The attempt for improvement and extent of potential gain achieved in this crop has been very limited as compared to other crops. Low production of cumin is primarily due to poor productivity potentials of the present varieties. Therefore, understanding of yield and its different attributes is very much essential for improving the genetic potential of crop plants. The development of high yielding varieties with high volatile oil content is of immense importance.

Genetic variability is prime requirement in any crop improvement. Therefore, it is essential to assess the extent of genetic variation present in breeding material, knowledge of genetic parameters such as genotypic coefficient of variability, heritability and expected genetic advance are required in genetic improvement of crop yield. A dependent character is the resultant effect of a number of quantitative characters. The study of association between pairs of these characters and yield provides basis for further breeding plans. In order to have clearer picture of the direct and indirect contribution of individual character, the cause and effect relationship need to be studied through path coefficient analysis.

Therefore, present investigation was carried out to study the genetic variability, heritability, expected genetic advance, correlation coefficient and path coefficient analysis in thirty entries of cumin with the following objectives:

- To ascertain the nature and magnitude of variability present in cumin genotypes for yield and its attributes and other component traits.
- To estimate correlation coefficients between yield and its component characters for suggesting suitable selection criteria.
- To analyze path coefficient for assessing the direct and indirect effect of individual character on yield.

II REVIEW OF LITERATURE

Information regarding genetic variability present in a population, association of various yield contributing characters and direct and indirect effects of yield components on seed yield is of immense help to the breeder in selection of suitable crop improvement programme. The available literature on cumin and its related crops has been reviewed and presented in the following headings :

2.1. Genetic variability, heritability and genetic advance

2.2. Correlation studies

2.3. Path coefficient analysis

2.1 GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE

Variability refers to the presence of differences among the individuals of a population due to differences in their genetic constitution or the environment in which they are grown. Heritability can be defined as the ratio of the genotypic variance to phenotypic variance or it specifies the proportion of the total variability that is due to genetic causes. Expected genetic advance represent the shift in a population towards superior side under selection pressure after single generation of selection. In short genetic advance is the improvement in mean genotypic value of selected plant over base population.

Knowledge of genetic variability present in a population and heritability are the prerequisites for designing an effective breeding programme for improvement of any crop. The genetic variability is determined with the help of parameters such as genotypic coefficient of variation (GCV), heritability and genetic advance (GA). Heritability in broad sense is the ratio of genotypic variance to the phenotypic variance, while narrow-sense heritability refers to portion of total variation, which is due to the additive gene action.

Panse (1957) postulated the necessity for partitioning the phenotypic variability into heritable and non-heritable components. He also emphasized on heritable characters rather than non-heritable once because, highly heritable characters show the least influence of environment.

Joshi *et al.* (1967) studied 99 inbreds of coriander and reported significant amount of variability at the phenotypic as well as genotypic level for many economic traits.

Mathur *et al.* (1971) reported high phenotypic variability in cumin for plant height, number of branches per plant, yield per plant and 1,000-grain weight whereas days to flower and days to maturity showed low range of gross variation. The genetic analysis showed high genotypic coefficient of variation in all the traits studied, while high heritability was registered for days to maturity, 1,000-grain weight, days to flower, yield per plant, number of branches and plant height. The yield per plant and the 1,000-grain weight showed high genetic advance along with high heritability.

In variability study of five economic traits of coriander, Arumugam and Muthukrishnan (1978) reported significant amount of variability in all the traits except plant height. They also noticed wide range of variation for all traits. Genetic variance and genetic coefficient of variation were maximum for number of mericarp per plant and plant height.

Mehta and Patel (1980) reported significant variability for plant height, numbers of umbellates per umbel, days to flowering, umbels per plant, seeds per umbellate, 1000-seed weight and seed yield per plant. High genotypic and phenotypic variances recorded for seed yield per high for 1000-grain weight, days to flowering and maturity; whereas low for umbels per plant, umbellates per umbel and grain yield per plant in cumin.

Suthanthirapandian *et al.* (1980) observed significant varietal differences for all the traits while studying 60 genotypes of coriander. High heritability estimates were exhibited by all the traits ranging from 66.48% for number of primary branches to 84.93% for yield per plant. They also reported that despite of high heritability, the genetic advance was low for number of umbellates per umbel as compared to other traits, indicating the non-additive gene effect.

Rama Rao *et al.* (1981) observed high degree of genotypic and phenotypic coefficients of variation for number of secondary branches per plant, number of umbels per plant and number of fruits per umbel in coriander.

Baswana *et al.* (1983) studied genetic variability for yield and its five component traits using 50 diverse genotypes of cumin. They reported significant differences among genotypes suggesting wide range of variation. The genetic coefficients of variation were high for yield per plant, days to germination, number of seeds per umbel and plant height. Yield per plant exhibited the highest range, co-efficient variation, heritability and genetic advance indicating presence of additive gene effect. They advocated yield per plant should be given due importance while selection.

Mehta and Patel (1983) studied 61 genotypes of fennel and observed wide variation in characters like number of seeds per umbellate, number of umbellates per umbel and number of umbels per plant. The genetic analysis revealed high genotypic coefficient of variation, genetic variance, heritability and genetic advance for number of seeds per umbellate and number of umbels per plant, indicating dominance or additive genetic effect.

Such relationship pinpoints that these traits may serve as important selection indices in fennel.

During study of variability in 23 genotypes of coriander, Jindal *et al.* (1985) found that plant height, number of umbels per plant and number of seeds per umbel exhibited high heritability and genetic advance.

Mehta and Patel (1985) reported significant variability for seed yield per plant and its related traits in coriander. They observed high heritability for all the traits. It was the maximum for days to fifty per cant flowering followed by number of umbels per plant. They further noticed that the additive gene effect was important for number of umbels per plant and number of seeds per umbellate and suggested both these traits should be used as selection indices for crop improvement.

Jindal and Allah-Rang (1986) studied seed yield per plot and five related characters in 15 *Foeniculum vulgare* genotypes. Plant height and number of umbellules per umbel showed high heritability. Expected genetic advance was high for seed yield and umbellates number per umbel.

Reddy *et al.* (1989) studied variability for yield and its component characters in coriander. From the estimates of heritability and genetic advance, they suggested that the traits like, number of secondary branches, primary branches and number of umbels per plant should be considered important while selecting for high yielding varieties.

Sharma and Sharma (1989) reported significant variability for plant height, number of branches per plant, days to flowering and maturity, umbels and umbellates per plant, grains per umbellate, 1000-grains weight, straw and grain yield per plant. The heritability estimates were high for 1000-grain weight, days to flowering and maturity, whereas low for umbels and umbellates per plant and grain yield per plant in coriander.

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

Ramavtar *et al.* (1991) reported high heritability estimates for grain yield, days to flowering, primary branches and umbels per plant in cumin.

In a study of genetic variability among 30 genotypes of coriander, Sanker and Khader (1991a) reported that primary branches and umbels per plant exhibited the highest genotypic covariance, heritability and genetic advance.

Bhandari and Gupta (1993) recorded significant differences for all the 12 traits studied in coriander. They reported high heritability for days to flowering. 1000-grain weight, and days to maturity, moderate for plant height, straw yield, umbels, umbellates, and number of primary branches per plant and low for harvest index, effective branches, grain yield and grains per umbellate.

Ali *et al.* (1994) evaluated 12 genotypes of coriander for seed yield and its component characters and found significant differences for all the traits. They also observed that seed yield per plant and number of umbels per plant exhibited medium heritability and high genetic advance.

Agnihotri *et al.* (1997) evaluated 48 genotypes of fennel for eight yield components. They noticed significant variability for days to flowering, plant height, branches per plant, umbels per plant, umbellates per umbel, seeds per umbel, 1000-seed weight, yield per plant and yield per plot. Broad sense heritability was high for 1000-seed weight, umbels per plant and seed yield per plant, while genetic advance was high for umbels per plant, yield

Dhayal *et al.* (1999) studied variability in nine genotypes of cumin grown under normal and saline soil. They reported higher estimates of genotypic coefficient of variance, phenotypic coefficient of variance, heritability and genetic advance for plant height, number of umbels per plant, number of seeds per umbel, test weight, seed yield per 10 plants, on normal soil and number of seeds per umbel and test weight on saline soil.

Yadav (1999) evaluated a coriander germplasm collection at Raigarh, Jabalpur, Madhya Pradesh. He found wide variation in yield components, indicating the suitability of the germplasm for breeding programme.

Tripathi *et al.* (2000) evaluated 40 strains per genotypes of coriander including controls to work out phenotypic and genotypic coefficient of variations, heritability, genetic advance and correlation coefficients for 10 metric traits. They found high estimates of PCV, GCV, heritability and GA and indicated substantial genetic variability and scope for selection for days to maturity, secondary branches per plant, 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.

Singh *et al.* (2001) studied genetic variability for days to 50% flowering, plant height, branches per plant, umbels per plant, umbellates per umbel, test weight, grains per umbel, biological yield and harvest index in ten cumin genotypes grown under saline conditions at Jaipur; Rajasthan, India. Relatively high estimate of genotypic and phenotypic coefficients of variation, heritability and genetic advance were recorded for grain yield, umbels per plant, grains per umbel and harvest index. Selection based on these traits therefore would be effective for improvement of cumin yield under saline condition.

Krishnamurthy and Madalagiri (2002) conducted study to assess the range of variability and correlation coefficient for yield and its attributes in 15 genotypes of Ajwain. The study revealed wide range of variability in various growth and yield attributing characters. High heritability coupled with high genetic advance was observed for number of seeds per plant, total dry weight, essential oil content, numbers of umbels per plant, numbers of seeds per umbel and number of tertiary branches.

Rajput and Singh (2002) studied variability in 10 genotypes of cumin and reported significant differences among varieties for days to flowering, branches per plant, umbels per plant, umbellates per umbel, seeds per umbel and seed yield. Heritability in broad sense was high for days to flowering, seed yield, branches per plant and umbellates per umbel. Genetic advance was high for seed yield and branches per plant.

At the main spices research station, GAU, Jagudan, 133 germplasm entries of cumin were tested for variability. Wide range of variability was recorded for days to 50% flowering (50-62 days), days to maturity (98-118 days), plant height (28-46.3 cm), number of branches per plant (3-9), number of umbels per plant (19-62), number of umbellates per umbel (4-6), number of seed per umbellate (4-8), test weight (3-6.8 g) and yield per row of 3 metres. (45-200 g.)(Anonymous, 2002-03).

In genetic variability study of fennel, Rajput *et al.* (2004) revealed significant differences among entries for all the characters studied. The phenotypic coefficients of variation were slightly higher than corresponding genotypic coefficients of variation for all the characters except soluble sugar content in seeds, which indicate that environment has little influence on the characters expression. The coefficients of variation were high for total soluble sugar content followed by umbels per plant, harvest index, crude

50% flowering. Maximum heritability was observed for umbels per plant followed by seed yield per plant, harvest index, crude fiber content in seeds and biological yield per plant. Low heritability was observed for total soluble sugar content followed by days to 50% flowering. The estimate of genetic gain was maximum for umbels per plant followed by harvest index, seed yield per plant, crude fiber content in seeds.

Sharma *et al.* (2004) while studying genetic variability in coriander reported significant variability among the accessions for all the characters except seed yield per plant. The phenotypic coefficients of variation were higher then corresponding genotypic coefficients of variation for all the characters indicating influence of environment. Genotypic and phenotypic coefficients of variation were moderate (21-50%) for umbels per umbels per plant and seeds per umbel and low (up to 20%) for days to 50% flowering, plant height, branches per plant, umbellets per umbel and 1000-seed weight. High heritability coupled with high genetic advance (>50%) was observed only for seeds per umbel. Days to 50% flowering, plant height, umbels per plant and 1000-seeds weight showed high heritability and moderate genetic advance as %age of mean (21-50%), indicating the importance of these traits in yield improvement programme.

In genetic variability and character association study by using 10 varieties of cumin, Singh *et al.* (2004) reported significant differences among varieties for all the characters except test weight indicating wide range of variability. The genotypic coefficients of variation were almost equal to phenotypic coefficients of variation indicating least influence of environment on expression of these characters. Heritability in broad sense ranged from 46.90% (test weight) to 94.10% (days to flowering). It was 92.90% for seed yield per plant. Genetic advance as percentage of mean was the highest for seed yield per plant (87.68%) followed by umbels per plant (48.37%) and seeds per umbel (33.10%).

2.2 CORRELATION COFFICIENT ANALYSIS

Correlation coefficient is a statistical measure, which is used to find out the degree and direction of relationship between two or more variables. In plant breeding, correlation measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement of yield.

The concept of correlation was first put forward by Galton (1889) and later elaborated by Fisher (1918). It is an index of proportion of causes common in the genesis of two variables to the total and not to causes themselves (Bowley, 1920). The study of correlation is very useful to plant breeder for selecting suitable plant type. Correlation studies provide better understanding of yield components, which helps the plant breeder during selection (Robinson *et al.*, 1951; Johnson *et al.*, 1955).

Arumugam and Muthukrishnan (1978) studied association of characters in coriander and reported that plant height, number of mericarps per plant and umbellates per umbel exhibited significant and positive correlation with seed yield per plant.

Rama Rao *et al.* (1981) observed significant and positive correlation between plant height and number of umbels per plant in 42 varieties of coriander.

Shinde *et al.* (1985) reported that grain yield per plant had positive significant correlation with plant height, number of branches, number of umbels and dry matter accumulation per plant in coriander.

Jindal and Allah-Rang (1986) revealed that plant height, umbels umbellate and seed yield were positively correlated with each other in fennel.

Sharma and Sharma (1989) studied correlation between different characters in coriander and found that grain yield per plant had significant and positive correlation with plant height, number of branches, number of umbels, umbellates per plant, grains per umbellate and straw yield per plant.

Vedamuthu *et al.* (1989) collected data on seed yield and its components in 40 accessions of coriander and subjected to correlation and path coefficient analysis. Seed yield had positive correlation with number of umbels per plant and plant height. Number of umbels was the main trait contributing to yield, while height influenced yield through other traits.

In characters association study, Ramavtar *et al.* (1991) indicated that yield was positively associated with plant height, branches per plant, umbellates per umbel and therefore emphasis to be given these characters in crop improvement programme.

Sanker and Khader (1991b) estimated correlation coefficients between yield and other component traits in coriander. They indicated that the yield had positive correlation with number of secondary branches only in coriander.

Bhandari and Gupta (1993) carried out correlation study in coriander and reported moderate correlation of yield with umbellates per plant, umbels per plant, number of effective branches per plant, straw yield per plant, number of primary branches per plant and plant height.

During evaluation of 25 genotypes of fennel for correlation, Mehta *et al.* (1993) found that seed yield exhibited significant positive relationship with number of primary branches and number of umbels per plant.

Ali *et al.* (1994) evaluated 12 genotypes of coriander for correlation study and reported that yield had significant and positive association with number of branches and umbels per plant.

In correlation study with 29 genotypes of fennel, Patel (1995) found that seed yield exhibited significant positive correlation with plant height, number of branches per plant, total number of umbels per plant, number of seeds per umbellate, number of seeds per umbel and 1000 seed weight.

Agnihotri *et al.* (1997) reported significant and positive correlation between seed yield per plot and yield per plant in fennel.

Gurbuz (1998) conducted an experiment at Ankara, Turkey to study correlation and path analysis among yield components of 25 winter resistant lines of coriander. The highest correlation was found between single plant yield and single plant weight, branches number and number of branches with seeds.

Tripathi *et al.*(2000) in their correlation studies reported that plant height, number of secondary branches, days to flowering, days to maturity and number of umbels per plant were the major yield components whereas number of primary branches, number of umbellates per umbel and number of seeds per umbel were negatively correlated with yield and less important.

Positive correlation of seed yield per ha with days to flowering, days to harvest, number of umbels per plant and essential oil content in seeds of Ajwain reported by Krishnamurthy and Madalagiri (2002).

In correlation and path analysis study on coriander, Jain *et al.* (2003) reported positive and significant correlation of seed yield 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 umbelletes per

Singh *et al.* (2003) studied phenotypic and genotypic correlation coefficients and genotypic path coefficient in 34 genotypes of fennel. They reported that seed yield per plant was positively and significantly associated with plant height, number of primary branches per plant, number of secondary branches per plant, number of umbels per plant, umbel diameter, test weight and seeds per umbel suggesting that the phenotypic selection could be made on the basis of the said characters.

During correlation study in fennel, Rajput *et al.* (2004) reported that seed yield per plant showed significant and positive genotypic correlation with plant height, branches per plant, umbels per plant, test weight, biological yield and harvest index. The days to 50% flowering had negative correlation with seed yield.

While character association study in coriander, Sharma and Meena (2004) reported that the seed yield per plant had positive and significant correlation with plant height, branches per plant, umbel's per plant, umbelletes per umbel and seeds per umbel. Among the inter relationship, the association of plant height, with all other traits was significant and positive, but with 1000-seed weight it was negative. Similarly, umbels per plant had significant positive association with plant height and branches per plant. The umbellates per umbel exhibited significant and positive association with seed yield per umbel and negative association with 1000-seed weight.

During character association study of cumin, Singh *et al.* (2004) indicated that seed yield per plant showed significant and positive genotypic association with days to flowering, plant height and umbels per plant. The seed yield per plant also had positive but non-significant association with seeds per umbel.

2.3 PATH COEFFICIENT ANALYSIS

Wright (1921) originally developed the concept of path analysis, but Dewey and Lu (1959) first used the technique for plant selection. Path coefficient analysis is simply standardize partial regression coefficient which splits the correlation coefficient into direct and indirect effects on a dependent character. It measures the direct and indirect contribution of independent variable on dependent variable and thus helps breeder in determining the yield components. Path analysis has been widely applied to several crop species like crested wheat grass (Dewey and Lu, 1959); cereals and legumes (Singh and Singh, 1959; Dixit and Singh, 1975). The information obtained by this technique helps in indirect selection for genetic improvement of yield.

In selection criteria, there must be perfect knowledge about the direct effect of characters to increase the yield because yield being the most important and polygenic complex character. Interrelationship among direct and indirect influence of component characters on yield is important in predicting the correlated response to directional selection and in the detection of trait as useful marker.

In their study of path coefficient in coriander, Rama Rao *et al.* (1981) observed that plant height, number of umbels and seed weight had direct effect on yield, and hence these traits were contributing maximum to the seed yield.

Path coefficient analysis by Jindal *et al.* (1985) revealed that days to flowering, plant height and number of umbellates per plant were important for improving seed yield in coriander.

In path coefficient analysis with 200 lines of coriander, Sharma and Sharma (1989) reported that number of branches per plant, umbellates per selecting high yielding genotypes, as they had direct positive effect on grain yield.

Sanker and Khader (1991b) reported that secondary umbels per plant had largest direct effect on yield, but the negative indirect effect through primary branches, secondary branches and primary umbels had nullified this effect, resulting to non-significant genotypic correlation in coriander.

Bhandari and Gupta (1993) reported maximum direct contribution to grain yield per plant through umbellates per plant, followed by straw yield per plant, umbels per plant and grains per umbellate in coriander. Umbellates per plant made considerable indirect effect via straw yield per plant and vice-versa.

Agnihotri *et al.* (1997) reported that branches per plant showed a high positive, direct effect on yield per plot, followed by seeds per umbel and plant height in fennel.

Gurbuz (1998) reported the highest direct and positive effect of single plant weight on single plant yield, but plant height had the highest negative effect on single plant yield in coriander.

Srivastava *et al.* (2000) studied path analysis in coriander and reported that the most of the characters had positive direct effect on seed yield. Days to flowering had the highest direct effect on seed yield followed by days to maturity and number of umbels per plant. However, plant height, number of primary branches and number of seeds per umbel had weak direct effect on seed yield.

Jain *et al.* (2003) reported 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% flowering had a significant negative correlation with seed yield. The results suggest that

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.

In genotypic path coefficient study with 34 genotypes of fennel, Singh *et al.* (2003) reported that 100-seed weight had maximum direct contribution towards yield followed by number of umbels per plant and seeds per umbel.

Rajput *et al.* (2004) reported that harvest index had the highest direct effect with seed yield per plant followed by biological yield, umbels per plant and seeds per umbel in fennel.

Singh *et al.* (2004) while studying path coefficient analysis in cumin indicated that the plant height had the highest direct effect on seed yield per plant followed by days to flowering and umbels per plant.

III MATERIALS AND METHODS

3.1 LOCATION AND CLIMATIC CONDITIONS :

The present investigation was conducted at The Main Spices Research Station, Sardar Krushinagar Dantiwada Agricultural University, Jagudan during *rabi* 2003-2004. The soil of the experimental plot was sandy loam. Geographically, Jagudan is situated at 23° 52' N latitude and 72° 13' E longitudes with an altitude of 70.00 meters above Mean Sea Level. It has typical semi-arid climate with moderate rainfall during June to October. The meteorological data for the cropping season are presented in Appendix-I.

3.2 EXPERIMENTAL MATERIAL :

The experimental material for the present investigation consisted of 30 genotypes of diverse geographic and genetic origin of cumin (*Cuminum cyminum* L.) obtained from the germplasm maintained at the Main Spices Research Station, Sardar Krushinagar Dantiwada Agricultural University, Jagudan, Dist. Mehsana (N.G.). The details of genotypes used are listed in Table 3.1.

3.3 EXPERIMENTAL DETAILS :

The experiment was laid out in a Randomized Block Design with three replications. Each plot consisted of two rows of 4.5 meter length. The distances between rows and within rows were 30 cm and 10 cm, respectively. The experiment was sown on 17th November, 2003. The recommended agronomic practices and plant protection measures were followed timely to raise healthy crop.

3.4 CHARACTERS STUDIED :

In each plot five competitive plants were randomly selected from the two rows to record observations on various plant characters. Detailed procedures adopted for taking observations were as under:

3.4.1 Days to germination:

The number of days taken from the date of sowing to the date of appearance of 50% germinated plants in plot was recorded.

3.4.2 Days to 50% flowering :

The number of days from the date of sowing to the date of appearance of flowers on 50% plants was recorded.

3.4.3 Days to maturity :

The number of days from the date of sowing to the date on which more than 50% the plants maturity, confirmed by hardiness of seeds.

3.4.4 Plant height :

Plant height was recorded in centimeters from the base of the plant to the tip of the plant at maturity.

3.4.5 Plant height up to main umbel:

Plant height was recorded in centimeters from the base of the plant to the tip of the main umbel at maturity.

3.4.6 Number of branches per plant :

The total number of branches arising on main stem was counted at maturity.

3.4.7 Number of umbels per plant :

Total number of umbels on plant were counted and recorded at maturity.

3.4.8 Number of seeds per main umbel :

Total number of seeds per main umbel of the selected plants were counted and recorded at maturity.

3.4.9 Number of umbellates per umbels:

Total number of umbellates on main umbel of the selected plants were counted and recorded at maturity.

3.4.10 Number of seeds per umbellate:

Primary umbellate selected randomly from main umbel of the selected plants and their total number of seeds were counted and recorded at maturity.

3.4.11 Grain yield per plant (g) :

The total quantity of seeds obtained from the selected five plants of each plot were dried and weighed in grams and the mean was worked out.

3.4.12 Yield per plot (kg):

The total quantity of seeds obtained from the two rows of net three meters (Net plot of 3m x 0.6m) were dried and weighed in kilograms and recorded.

3.4.13 1000-seed weight (g) :

One thousand seeds were randomly collected from the randomly selected five plants and weighed in gram.

3.4.14 Volatile Oil (%):

The Volatile Oil content of each seed sample was estimated by steam distillation method and recorded.

3.5 STATISTICAL ANALYSIS

Replication wise mean values of individual characters were subjected to statistical analysis with the help of computer software viz., Indostat and Basic. The procedures used are as under:

3.5.1 Analysis of variance (ANOVA) :

The analysis of variance to test the variation among genotypes for each character was carried out using randomized complete block design, which is based on following statistical model (Panse and Sukhatme, 1978).

$$Y_{ij} = \mu + r_i + g_j + e_{ij}$$

Where,

Y_{ij} = Yield of j^{th} genotype in i^{th} replication.

μ = General mean.

r_i = Effect of i^{th} replication.

g_j = Effect of j^{th} genotype.

e_{ij} = Uncontrolled variation associated with i^{th} replication and j^{th} genotype.

Analysis of Variance table:

Source	Df	Mean squares	Expected MS
Replication (r)	(r-1)	M_r	$\sigma^2_e + g\sigma^2_r$
Genotypes (g)	(g-1)	M_g	$\sigma^2_e + r\sigma^2_g$
Error (e)	(r-1)(g-1)	M_e	σ^2_e

Where,

g = number of genotypes,

r = number of replications.

σ^2_e, σ^2_r, σ^2_g = variance due to error, replications and genotypes, respectively.

M_r, M_g, M_e = Mean squares for replication, genotypes and error, respectively.

3.6 ANALYSIS OF VARIANCE COMPONENTS

The genotypic, phenotypic and environmental variances were calculated as follows:

3.6.1 Genotypic variance (σ^2_g)

It is the variance contributed by genetic causes or the occurrence of differences among individuals due to differences in their genetic make-up. It was calculated as per formula given by Panse and Sukhatme (1978) for randomized block design:

$$\sigma^2_g = \frac{Mg - Me}{r}$$

Where,

σ^2_g = genotypic variance,

Mg = genotypic mean square of the character,

Me = error mean square of the character,

r = number of replications.

3.6.2 Error variance (σ^2_e)

Defined as error mean square due to environmental variances.

$$\sigma^2_e = M_e$$

Where,

σ^2_e = Environmental variance

M_e = Error mean sum of square

3.6.3 Phenotypic variance (σ^2_p)

It is sum of the variance contributed by genetic causes and environmental factors. It was calculated as under:

$$\sigma^2_p = \sigma^2_g + \sigma^2_e$$

Where,

σ^2_p = Phenotypic variance

σ^2_g = Genotypic variance

σ^2_e = Error variance

3.7 VARIABILITY PARAMETERS

3.7.1 Range

It is the difference between the highest and the lowest value for each character.

3.7.2 Mean

The mean value of each character was worked out with the help of following formula.

$$\overline{X} = \frac{\Sigma X_{ij}}{n}$$

Where,

$\overline{X}$ = general mean,

X_{ij} = observed value in j^{th} genotype in i^{th} replication,

n = number of observations,

Σ = summation.

3.7.3 Standard error of mean (S.Em.)

Standard error of mean was calculated with the help of error mean square from the analysis of variance table.

$$S.Em. = \sqrt{\frac{\sigma_e^2}{r}}$$

Where,

S.Em. = Standard error of mean,

σ_e^2 = error mean square,

r = number of replications.

3.7.4 Critical difference (C.D.)

Critical differences for all the characters were calculated to compare the treatment means as per the following formula.

C.D. at 5% = Std. Error of mean x $\sqrt{2}$ x table $t_{0.05}$ at error df

3.7.5 Coefficient of variation (C.V.%)

The coefficient of phenotypic and genotypic variation was calculated by using the formula suggested by Burton (1952).

(a) Phenotypic coefficient of variation (P.C.V.%)

$$P.C.V.(\%) = \frac{\sqrt{\sigma_p^2}}{\overline{X}} x100$$

(b) Genotypic coefficient of variation (G.C.V.%)

$$G.C.V.(\%) = \frac{\sqrt{\sigma_g^2}}{\overline{X}} x100$$

Where, σ_p^2 = phenotypic variance,

σ_g^2 = genotypic variance,

$\overline{X}$ = general mean.

3.7.6 Heritability (Broad sense)

It is the proportion of phenotypic variability that is due to genetic reasons.

In broad sense, it is calculated by using the formula proposed by

$$h^2\% = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where, h^2 = heritability (broad sense),

σ^2_g = genotypic variance,

σ^2_p = phenotypic variance.

3.7.7 Expected Genetic Advance (GA) :

Expected genetic advance represents the shift in a population towards superior side under some selection pressure after single generation of selection.

It can be calculated by using methodology suggested by Allard (1960) at 5% selection intensity using the constant K as 2.06.

$$G.A. = h^2 \times K \times \sigma_p$$

Where, G.A. = genetic advance,

h^2 = heritability (Broad sense)

K = Selection intensity at 5% = 2.06

σ_p = phenotypic standard deviation.

3.7.8 Genetic advance expressed as percentage of mean (Genetic gain)

The expected genetic advance as expressed in percent of mean was calculated by method suggested by Johnson *et al.* (1955).

$$\text{Genetic gain} = \frac{G.A.}{\overline{X}} \times 100$$

Where, G.A. = Expected genetic advance,

$\overline{X}$ = General mean of the character under study.

3.8 CORRELATION COEFFICIENT ANALYSIS

The phenotypic, genotypic and environmental correlation coefficients for all the characters were worked out for grain yield. The data were subjected to covariance analysis from which different components at mean sum of product were estimated.

Analysis of Co-Variance

Source	Df	M.S.P.	Expected MSP
Replications (r)	(r-1)	-	-
Genotypes (g)	(g-1)	MSP_1	$Co\sigma^2 + rCo\sigma^2_{g1.2}$
Error	(r-1)(g-1)	MSP_2	$\sigma^2_{e1.2}$

Where,

MSP_1 = mean sum of products due to genotypes between character first and character second.

MSP_2 = mean sum of products due to error between character first and character second.

r = number of replications.

The genotypic, phenotypic and error variances and covariances were used for calculating the genotypic, phenotypic and environmental correlation coefficient, respectively.

(a) Genotypic correlation coefficient ($r_{g1.2}$)

$$r_{g1.2} = \frac{CoV_{g1.2}}{\sqrt{\sigma^2_{g1} \times \sigma^2_{g2}}}$$

(b) Phenotypic correlation coefficient ($r_{p1.2}$)

$$r_{p1.2} = \frac{CoV_{p1.2}}{\sqrt{\sigma^2_{p1} \times \sigma^2_{p2}}}$$

(c) Environmental correlation coefficient ($r_{e1.2}$)

$$r_{e1.2} = \frac{CoV_{e1.2}}{}$$

Where,

$CoV_{g1.2}$ = genotypic covariance for a pair of trait first and second,

$CoV_{p1.2}$ = phenotypic covariance for a pair of trait first and second,

$CoV_{e1.2}$ = environmental covariance for a pair of trait first and second

σ^2_{g1}, σ^2_{p1} = genotypic and phenotypic variance for trait first,

σ^2_{g2}, σ^2_{p2} = genotypic and phenotypic variance for trait second,

σ^2_{e1}, σ^2_{e2} = error variance for trait first and second, respectively

Test of significance :

The significance of correlation coefficient was tested using the following formula :

$$t = \frac{r}{\sqrt{(1-r^2)}} \times \sqrt{(n-2)}$$

Where,

r = correlation coefficient

n = number of pairs of observation

3.9 PATH COEFFICIENT ANALYSIS

The estimation of direct and indirect contribution of thirteen characters, showing high genotypic correlation coefficient with seed yield in individual analysis, was carried out through path analysis as suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

The direct effects designated as 'p' were calculated by inversing the following correlation matrix as per do-little method given by Steel and Torrie (1960). The following equations express the base relationship.

$r_{1y} = p_{1y} + r_{12y}p_{2y} + r_{23y}p_{3y} + \ldots\ldots\ldots\ldots\ldots\ldots r_{1i}p_{iy} + \ldots\ldots\ldots + r_{2n}p_{ny}$

$r_{2y} = p_{2y} + r_{21y}p_{1y} + r_{23}p_{3y} + \ldots\ldots\ldots\ldots\ldots\ldots r_{2i}p_{iy} + \ldots\ldots\ldots + r_{2n}p_{ny}$

$\vdots \qquad \vdots$

$$\begin{array}{llllll} : & : & : & : & : & : \\ r_{iy} = p_{iy} & + r_{i1y}p_{1y} & + r_{i3}p_{3y} & + \ldots\ldots\ldots\ldots & r_{i(i-1)}p_{iy} & + \ldots\ldots\ldots r_{in}p_{ny} \\ : & : & : & : & : & : \\ : & : & : & : & : & : \\ r_{ny} = p_{ny} & + r_{n1}p_{2n} & + r_{n3}p_{3n} & + \ldots\ldots\ldots\ldots & r_{n(n-1)}p_{ny} & + \ldots\ldots\ldots r_{nn}p_{ny} \end{array}$$

Where,

r_{1y} to r_{iy} = Genotypic correlation coefficient between causal characters, 1 to n and dependent character yield (y),

r_{i3} to $r_{i(i-1)}$ = Genotypic correlation coefficient among causal characters (independent variable),

P_{iy} to P_{ny} = Direct effect of causal characters, 1 to n on character 'y' (Path coefficient).

The above equations written in a matrix form are as under :

Matrix – A Matrix – C Matrix – B

$$\begin{bmatrix} r_{1y} \\ r_{2y} \\ r_{3y} \\ : \\ : \\ r_{iy} \\ : \\ : \\ : \\ r_{ny} \end{bmatrix} = \begin{bmatrix} 1 & r_{12} & r_{13} \ldots\ldots\ldots r_{1i} & & \\ r_{21} & 1 & r_{23} \ldots\ldots\ldots r_{2i} & & \\ r_{31} & r_{32} & 1 \ \ldots\ldots\ldots r_{3i} & & \\ : & : & : & & : \\ : & : & : & & : \\ r_{i1} & r_{i2} & r_{i3} & r_{ii} & r_{in} \\ : & : & : & & : \\ : & : & : & & : \\ : & : & : & & : \\ r_{n1} & r_{n2} & r_{n3} & r_{ni} & r_{nn} \end{bmatrix} \times \begin{bmatrix} P_{1y} \\ P_{2y} \\ P_{3y} \\ : \\ : \\ P_{iy} \\ : \\ : \\ : \\ P_{ny} \end{bmatrix}$$

With the help of matrix inversion (Gaulden, 1962) the following inverted 'C' matrix was obtained.

$$B = C^{-1}A$$

Where,

$$C^{-1} = \begin{bmatrix} C_{11} & C_{12} & C_{13}\ldots & C_{1i}\ldots & C_{1n} \\ C_{21} & C_{22} & C_{23}\ldots & C_{2i}\ldots & C_{2n} \\ C_{31} & C_{32} & C_{33}\ldots & C_{3i}\ldots & C_{3n} \\ C_{i1} & C_{i2} & C_{i3}\ldots & C_{ii}\ldots & C_{in} \\ C_{n1} & C_{n2} & C_{n3}\ldots & C_{ni}\ldots & C_{nn} \end{bmatrix}$$

The direct effect was calculated as under:

$$\begin{array}{lcccc} P_{1y} & = & \sum_{i=1}^{n} C_{1i} & * & r_{1y} \\ P_{2y} & = & \sum_{i=1}^{n} C_{2i} & * & r_{2y} \\ P_{3y} & = & \sum_{i=1}^{n} C_{3i} & * & r_{3y} \\ \vdots & & \vdots & & \vdots \\ P_{iy} & = & \sum_{i=1}^{n} C_{ii} & * & r_{iy} \\ \vdots & & \vdots & & \vdots \\ P_{ny} & = & \sum_{i=1}^{n} C_{ni} & * & r_{ny} \end{array}$$

The indirect effects were calculated by taking the products of genotypic correlation coefficients between corresponding two characters and the path coefficient (direct effect) connecting the causal effect with yield. The residual effect measures the contribution of the characters which are not considered in the causal scheme and was calculated as under:

$$R = \sqrt{\{1-(p_{iy}.r_{iy})\}}$$

Where,

$$p_{iy}\, r_{iy} = p_{1y}\, r_{1y} + p_{2y}\, r_{2y} + \ldots + p_{ny}\, r_{ny}$$

IV EXPERIMENTAL RESULTS

The results of the present investigation are presented under the following heads:-

4.1 Variability

4.2 Heritability and genetic advance

4.3 Correlation coefficient analysis

4.4 Path coefficient analysis

4.1 VARIABILITY

The analysis of variance for experimental design was carried out for all the characters under study and is given in table 4.1. The results showed the mean sum of squares due to entries were highly significant for all the traits, indicating considerable amount of variability among the entries for various characters.

The range, mean, phenotypic, genotypic and environmental variances for fourteen characters are presented in table 4.2 whereas the genotypic and phenotypic coefficient of variation, heritability (broad sense) and expected genetic advance and genetic gain (genetic advance expressed as percentage of mean) for all the characters under study are presented in table 4.3.

4.1.1 Days to germination

The range for number of days to germination varied from 7 (JC-95-7) to 11.7 (JC-2000-22 and JC-2000-27) with mid value of 8.81 days. The estimates of genotypic variance and phenotypic variance were 1.90 and 2.48, respectively and the genotypic and phenotypic coefficients of variation were 15.66% and 17.88%, respectively.

Table 4.1: Analysis of variance of various characters in cumin

Characters	Replication M.S. (2 df)	Genotypic M.S. (29 df)	Error M.S. (58 df)	S.Em.	C.D. at 5%	C.V.%
Days to germination	0.88	6.29**	0.58	0.44	1.24	8.64
Days to 50% flowering	5.41	30.21 **	1.78	0.77	2.18	2.24
Days to maturity	10.03	45.36**	4.39	1.21	3.42	2.04
Plant height (cm)	2.09	23.93 **	4.49	1.22	3.46	6.52
Plant height up to main umbel (cm)	5.25	15.59**	2.16	0.85	2.40	5.33
No. of Branches per plant	0.23	1.53**	0.11	0.19	0.53	6.76
No. of Umbels per plant	0.11	73.60**	2.10	0.84	2.37	5.16
No. of Seeds per main umbel	5.81	44.58**	2.98	1.00	2.82	5.72
No. of umbellates per Umbel	0.13	0.52**	0.05	0.13	0.38	4.73
No. of Seeds per Umbellate	0.92	0.83**	0.33	0.33	0.93	9.19
Grain yield per plant (g)	0.06	0.17**	0.03	0.09	0.26	7.00
Grain yield per plot (kg)	0.0001	0.0007**	0.0001	0.01	0.02	8.28
1000-seed weight (g)	0.03	3.35**	0.12	0.20	0.57	6.29
Volatile Oil (%)	0.02	1.25**	0.01	0.06	0.18	2.77

* significant at P=0.05 and ** significant at P = 0.01

Table 4.2: Mean, range, genotypic, phenotypic and environmental variance for various characters in cumin

Characters	Mean	Range	Genotypic variance	Phenotypic variance	Environment variance
Days to germination	8.81	7.0-11.7	1.90	2.48	0.58
Days to 50% flowering	59.44	52.7-66.0	9.48	11.26	1.78
Days to maturity	102.77	94.3-111.0	13.66	18.05	4.39
Plant height (cm)	32.49	27.3-38.1	6.48	10.97	4.49
Plant height up to main umbel (cm)	27.60	24.0-32.4	4.48	6.64	2.16
No. of Branches per plant	4.81	3.3-6.1	0.48	0.58	0.10
No. of Umbels per plant	28.07	19.7-38.9	23.83	25.93	2.10
No. of Seeds per main Umbel	30.22	23.3-38.7	13.87	16.85	2.98
No. of umbellates per Umbel	4.86	4.3-6.5	0.16	0.21	0.05
No. of Seeds per Umbellate	6.22	5.2-7.5	0.17	0.50	0.33
Grain yield per plant (g)	2.259	1.4-2.7	0.05	0.08	0.03
Grain yield per plot (kg)	0.135	0.089-0.159	0.0002	0.0003	0.0001
1000-seed weight (g)	5.50	4.0-7.5	1.08	1.20	0.12
Volatile Oil (%)	3.99	2.7-5.1	0.41	0.42	0.01

Table 4.3: Estimates of Genotypic (GCV) and Phenotypic (PCV) coefficient of variation, Heritability (h^2) and Genetic advance for various characters in cumin

Characters	GCV (%)	PCV (%)	h^2 (broadsense) (%)	Genetic advance	GA as% of general mean
Days to germination	15.66	17.88	76.69	2.49	28.25
Days to 50% flowering	5.18	5.64	84.20	5.82	9.79
Days to maturity	3.60	4.13	75.70	6.62	6.44
Plant height (cm)	7.84	10.19	59.10	4.03	12.41
Plant height up to main umbel (cm)	7.67	9.34	67.43	3.58	12.97
No. of Branches per plant	14.31	15.83	81.70	1.28	26.65
No. of Umbels per plant	17.39	18.14	91.90	9.64	34.34
No. of Seeds per main Umbel	12.32	13.58	82.30	6.95	23.03
No. of umbellates per Umbel	8.10	9.38	74.60	0.70	14.42
No. of Seeds per Umbellate	6.61	11.32	34.11	0.49	7.95
Grain yield per plant (g)	9.86	12.10	66.50	0.37	16.57
Grain yield per plot (kg)	10.18	13.13	60.20	0.02	16.26
1000-seed weight (g)	18.84	19.86	90.00	2.03	36.83
Volatile Oil (%)	16.08	16.32	97.10	1.30	32.64

4.1.2 Days to 50% flowering

The earliest genotype JC-94-262 flowered after 52.70 days from sowing whereas latest genotype JC-2000-60 flowered after 66.00 days. An average flowering duration was 59.44 days. The values for genotypic and phenotypic variance were 9.48 and 11.26, respectively. The genotypic coefficient of variation (5.18%) was close to phenotypic coefficient of variation (5.64%) for the trait.

4.1.3 Days to maturity

The trait showed phenotypic variation ranging from 94.30 days (JC-94-262) to 111.00 days (JC-2000-21) with a general mean of 102.77 days. Phenotypic and genotypic variances were 18.05 and 13.66, respectively. Phenotypic coefficient of variation (4.13%) was near to genotypic variation of coefficient (3.60%).

4.1.4 Plant height

The plant height ranged from 27.30 cm (JC-2000-54) to 38.1 cm (JC-96-47) with a general mean of 32.49 cm. Phenotypic as well as genotypic variances were 10.97 and 6.48, respectively and Phenotypic and genotypic coefficients of variation were 10.19% and 7.84%, respectively.

4.1.5 Plant height up to main umbel

The plant height up to main umbel varied from 24.00 cm (JC-2000-11) to 32.4 cm (JC-96-47) with an average of 27.60 cm. Phenotypic and genotypic variances were 6.64 and 4.48, respectively while Phenotypic and genotypic coefficients of variation were 9.34% and 7.67%, respectively.

4.1.6 Number of branches per plant

The phenotypic variation for this trait ranged from 3.30 (JC-95-93) to 6.10 (GC-2) with a general mean of 4.81. The genotypic variance and phenotypic variance were 0.48 and 0.58, respectively. Phenotypic coefficient of variation (15.83%) was very close to the genotypic coefficient of variation (14.31%).

4.1.7 Number of umbels per plant

The genotypes GC-3 had the highest (38.90) number of umbels per plant, while JC-94-262 had the lowest (19.70) number of umbels per plant. The general mean was 28.07. The variance observed for phenotypes was 25.93 and 23.83 for genotypes. The phenotypic (18.14%) and genotypic coefficients of variation (17.39%) showed almost same values.

4.1.8 Number of seeds per main umbel

The phenotypic variation for this trait ranged from 23.30 (JC-94-262, JC-2000-54) to 38.70 (GC-4) with a general mean of 30.22. The genotypic variance and phenotypic variance were 13.87 and 16.85, respectively. Phenotypic coefficient of variation (13.58%) was very close to the genotypic coefficient of variation (12.32%).

4.1.9 Number of umbellates per umbel

The phenotypic variation for this trait varied from 4.30 (JC-94-276, JC-2000-22) to 6.50 (GC-4) with mean value of 4.86. The phenotypic and genotypic variances were 0.21 and 0.16 respectively. The phenotypic and genotypic coefficients of variation were 9.38% and 8.10%, respectively.

4.1.10 Number of seeds per umbellate

The phenotypic variation for this trait spread from 5.20 (JC-2000-54) to 7.50 (JC-95-7) with a general mean of 6.22. Phenotypic and genotypic variances were 0.50 and 0.17 respectively, whereas, the environment variance was 0.33. The phenotypic coefficient of variation (11.32%) was much higher than the genotypic coefficient of variation (6.61%).

4.1.11 Grain yield per plant (g)

The variation for grain yield per plant was ranged from 1.40 g (JC-94-

phenotypic and environmental variances for this trait were 0.05, 0.08 and 0.03 respectively. The estimates of phenotypic and genotypic coefficients of variation were 12.10% and 9.86%, respectively.

4.1.12 Grain yield per plot (kg)

The grain yield per plot was ranged from 0.089 kg (JC-94-276) to 0.159 kg (GC-4) with a general mean of 0.135 kg per plot. The genotypic, phenotypic and environmental variances for this trait were 0.0002, 0.0003 and 0.0001, respectively. The estimates of phenotypic and genotypic coefficients of variation were 13.12% and 10.18%, respectively.

4.1.13 1000-seed weight

The variation for test weight was ranged from 4.00 g (JC-99-22) to 7.50 g (GC-4) with a general mean of 5.50 g. Phenotypic (1.20) and genotypic variance (1.08) did not show wide difference. The phenotypic coefficient of variation was 19.86% and genotypic coefficient of variation was 18.84%, which were close to each other.

4.1.14 Volatile Oil (%)

This trait exhibited the phenotypic variation ranging from 2.7% (JC-2000-3) to 5.1% (JC-2000-11) with a general mean of 3.99%. The phenotypic, genotypic and environment variances were 0.42, 0.41 and 0.01 respectively. The genotypic and phenotypic coefficients of variation were 16.08% and 16.32%, respectively and showed close correspondence with each other.

4.2 HERITABILITY AND GENETIC ADVANCE

The estimates of heritability in broad sense, genetic advance and expected genetic advance as % of mean for the characters under study are presented in Table-4.3.

4.2.1 High heritability with moderate genetic advance

In the present investigation three characters viz., volatile oil content [h^2 (b) = 97.10% and GA = 32.64%], number of umbels per plant [h^2 (b) = 91.90% and GA = 34.34%] and 1000-seed weight [h^2 (b) = 90.00% and GA = 36.83%] exhibited high heritability and moderate genetic advance.

4.2.2 High heritability with low genetic advance

In the present investigation nine characters viz., days to 50% flowering [h^2 (b) = 84.20% and GA = 9.79%], number of seeds per main umbel [h^2 (b) = 82.30% and GA = 23.03%], number of branches per plant [h^2 (b) = 81.70% and GA = 26.65%], days to germination [h^2 (b) = 76.69% and GA = 28.25%], days to maturity [h^2 (b) = 75.70% and GA = 6.44%], number of umbellates per umbel [h^2 (b) = 74.60% and GA = 14.42%], plant height up to main umbel [h^2 (b) = 67.43% and GA = 12.97%], yield per plant [h^2 (b) = 66.50% and GA = 16.57%] and yield per plot [h^2 (b) = 60.20% and GA = 16.26%] exhibited high heritability with low genetic advance.

4.2.3 Moderate heritability with low genetic advance

The characters viz., plant height and number of seeds per umbellate exhibited moderate heritability [h^2 (b) = 59.10% and h^2 (b) = 34.11%, respectively] and low genetic advance [GA = 12.41% and GA = 7.95%, respectively].

4.3 CORRELATION COEFFICIENT ANALYSIS

The seed yield is a complex and polygenic character dependent on number of component characters. Therefore, the study of relationship among yield contributing characters and their association with seed yield is of immense importance to provide information for exercising selection

The correlation coefficients between grain yield and its components and among the component characters were estimated at phenotypic and genotypic levels. The phenotypic (P) and genotypic (G) correlation coefficients of twelve characters studied are presented in table 4.4.

The data showed that correlation at genotypic and phenotypic levels had the same trend and all significant values were positive except correlation between plant height and days to 50% flowering and days to maturity and between plant height up to main umbel and days to maturity. In majority of the cases, the value of genotypic correlations was higher than the corresponding values of phenotypic correlations.

4.3.1 Relationship of grain yield per plot with component characters

The results indicated that the character grain yield per plot was significantly correlated at 1% level with grain yield per plant (r_g = 0.984 and r_p = 0.700), days to 50% flowering (r_g = 0.329 and r_p = 0.237), plant height (r_g = 0.623 and r_p = 0.376), plant height up to main umbel (r_g = 0.479 and r_p = 0.262), number of branches per plant (r_g = 0.851 and r_p = 0.626), number of umbels per plant (r_g = 0.839 and r_p = 0.617), number of seeds per main umbel (r_g = 0.693 and r_p = 0.491), number of umbellates per umbel (r_g = 0.721 and r_p = 0.535) and 1000-seed weight (r_g = 0.962 and r_p = 0.757) both at genotypic and phenotypic levels, while number of seeds per umbellate (r_g = 0.436 and r_p = 0.194) was highly and significantly correlated at genotypic level, but r value was non-significant at phenotypic level. It had showed positive but non-significant correlation (r_g = 0.199 and r_p = 0.130) with days to maturity. It is interesting to note that the value of genotypic correlation coefficient was higher than the corresponding phenotypic correlation coefficient for all the characters.

Table 4.4 : Genotypic (G) and Phenotypic (P) correlation coefficients among twelve traits in cumin

Characters		Yield per plant	Days to 50% flowering	Days to maturity	Plant height (cm)	Plant height up to main umbel (cm)	Branches per plant	Umbels per plant	Seeds per main umbel	Umbellates per umbel	Seeds per umbellate	1000-seed weight
Yield per plot (kg)	G	0.984**	0.329**	0.198	0.623**	0.479**	0.851**	0.839**	0.693**	0.721**	0.436**	0.962**
	P	0.700**	0.237*	0.130	0.376**	0.262*	0.626**	0.617**	0.491**	0.535**	0.194	0.757**
Yield per plant (g)	G		0.548**	0.275**	0.476**	0.513**	0.732**	0.751**	0.521**	0.484**	0.356**	0.812**
	P		0.357**	0.193	0.295**	0.185	0.538**	0.614**	0.437**	0.395**	0.213*	0.648**
Days to 50% flowering	G			0.734**	-0.284**	-0.039	0.297**	0.448**	0.343**	0.123	0.431**	0.323**
	P			0.601**	-0.162	0.001	0.246*	0.432**	0.272**	0.102	0.203	0.277**
Days to maturity	G				-0.429**	-0.209*	0.040	0.233*	0.358**	0.106	0.363**	0.119
	P				-0.305**	-0.156	0.051	0.227*	0.281**	0.060	0.193	0.118
Plant height (cm)	G					0.935**	0.477**	0.356**	0.390**	0.331**	0.458**	0.594**
	P					0.653**	0.312**	0.274**	0.258*	0.257*	0.267*	0.393**
Plant height up to main umbel (cm)	G						0.314**	0.297**	0.221*	0.298**	0.203	0.406**
	P						0.244*	0.235*	0.101	0.184	0.153	0.254*
Branches per plant	G							0.937**	0.486**	0.526**	0.229*	0.923**
	P							0.782**	0.446**	0.442**	0.097	0.787**
Umbels per plant	G								0.595**	0.584**	0.306**	0.871**
	P								0.514**	0.469**	0.173	0.790**
Seeds per main umbel	G									0.655**	0.859**	0.685**
	P									0.549**	0.648**	0.610**
Umbellates per umbel	G										0.107	0.704**
	P										0.026	0.583**
Seeds per umbellate	G											0.475**
	P											0.247*

* and ** significant at 5% and 1% levels, respectively.

4.3.2 Relationship of grain yield per plant with component characters

The results from experiment clearly indicated that the character grain yield per plant was highly and significantly correlated with days to 50% flowering (r_g = 0.548 and r_p = 0.357), plant height (r_g = 0.477 and r_p = 0.295), number of branches per plant (r_g = 0.732 and r_p = 0.538), number of umbels per plant (r_g = 0.751 and r_p = 0.614), number of seeds per main umbel (r_g = 0.521 and r_p = 0.437), number of umbellates per umbel (r_g = 0.484 and r_p = 0.395), number of seeds per umbellate (r_g = 0.356 and r_p = 0.213) and 1000-seed weight (r_g = 0.812 and r_p = 0.684) both at genotypic and phenotypic levels, while days to maturity (r_g = 0.275 and r_p = 0.193) and plant height up to main umbel (r_g = 0.513 and r_p = 0.185) is highly significantly correlated at genotypic level only. Moreover, the values of genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients for all the characters.

4.3.3 Days to 50% flowering

The positive and highly significant genotypic and phenotypic association for days to 50% flowering with days to maturity (r_g = 0.734 and r_p = 0.601), number of branches per plant (r_g = 0.297 and r_p = 0.246), number of umbels per plant (r_g = 0.448 and r_p = 0.432), number of seeds per main umbel (r_g = 0.343 and r_p = 0.272), and 1000-seed weight (r_g = 0.323 and r_p = 0.277), while correlation (r_g = 0.431) with number of seeds per umbellate was highly significant only at genotypic level. It showed negative significant correlation with plant height (r_g = -0.284 and r_p = -0.162) at genotypic level. The trait, number of umbellates per umbel (r_g = 0.123 and r_p = 0.102) showed positive but non-significant association with days to 50% flowering.

4.3.4 Days to maturity

The trait had positive and significant genotypic and phenotypic correlations with number of umbels per plant ($r_g = 0.233$ and $r_p = 0.227$) and number of seeds per main umbel ($r_g = 0.358$ and $r_p = 0.281$), while number of seeds per umbellate ($r_g = 0.363$ and $r_p = 0.193$) showed highly significant correlation at genotypic level only. The traits, 1000-seed weight ($r_g = 0.119$ and $r_p = 0.118$), number of umbellates per umbel ($r_g = 0.106$ and $r_p = 0.060$), number of branches per plant ($r_g = 0.040$ and $r_p = 0.051$) showed positive but non-significant association with days to maturity. This character showed negative and significant correlation with plant height ($r_g = -0.429$ and $r_p = -0.305$) and plant height up to main umbel ($r_g = -0.209$ and $r_p = -0.156$).

4.3.5 Plant height

The plant height showed positive and highly significant association at genotypic and phenotypic levels with plant height up to main umbel ($r_g = 0.935$ and $r_p = 0.653$), number of branches per plant ($r_g = 0.477$ and $r_p = 0.312$), number of umbels per plant ($r_g = 0.356$ and $r_p = 0.274$), number of seeds per main umbel($r_g = 0.390$ and $r_p = 0.258$), number of umbellates per umbel ($r_g = 0.331$ and $r_p = 0.257$), number of seeds per umbellate ($r_g = 0.458$ and $r_p = 0.267$) and 1000-seed weight ($r_g = 0.594$ and $r_p = 0.393$).

4.3.6 Plant height up to main umbel

This character had reflected positive and highly significant correlation at genotypic level and significant correlation at phenotypic level with number of branches per plant ($r_g = 0.314$ and $r_p = 0.244$), number of umbels per plant ($r_g = 0.297$ and $r_p = 0.235$) and 1000-seed weight ($r_g = 0.406$ and $r_p = 0.254$). Whereas, number of seeds per main umbel ($r_g = 0.211$ and $r_p = 0.101$), number of umbellates per umbel ($r_g = 0.298$ and $r_p = 0.184$) showed positive and significant correlation only at genotypic level only. The number of seeds per umbellate (r_g = 0.203 and r_p = 0.153) had non-significant correlation at both the level.

4.3.7 Number of branches per plant

The number of branches per plant had highly significant positive correlation at both phenotypic and genotypic levels with number of umbels per plant (r_g = 0.937 and r_p = 0.782), number of seeds per main umbel (r_g = 0.486 and r_p = 0.446), number of umbellates per umbel (r_g = 0.526 and r_p = 0.442) and 1000-seed weight (r_g = 0.923 and r_p = 0.787). Whereas, number seeds per umbellate (r_g = 0.229 and r_p = 0.097), showed positive and significant correlation only at genotypic level, but non-significant correlation at phenotypic level.

4.3.8 Number of umbels per plant

The number of umbels per plant showed positive significant correlation with number of seeds per main umbel (r_g = 0.595 and r_p = 0.514), number of umbellates per umbel (r_g = 0.584 and r_p = 0.469) and 1000-seed weight (r_g = 0.871 and r_p = 0.790) at both the level. Whereas, number seeds per umbellate (r_g = 0.306 and r_p = 0.173) showed positive significant correlation only at genotypic level, but phenotypic correlation failed to reach at significance level.

4.3.9 Number of seeds per main umbel

This trait showed positive significant genotypic and phenotypic correlation with number of umbellates per umbel (r_g = 0.655 and r_p = 0.549), number of seeds per umbellate (r_g = 0.859 and r_p = 0.648) and 1000-seed weight (r_g = 0.685 and r_p = 0.610).

4.3.10 Number of umbellate per umbel

This trait showed positive significant genotypic and phenotypic correlation with 1000-seed weight (r_g = 0.704 and r_p = 0.583). Whereas, number seeds per umbellate (r_g = 0.107 and r_p = 0.026) had poor positive correlation with this trait at both the level.

4.3.11 Number of seeds per umbellate

The number of seeds per umbellate showed positively significant correlation with 1000-seed weight (r_g = 0.475 and r_p = 0.247) at both the levels.

4.4 PATH COEFFICIENT ANALYSIS

Grain yield per plant is the result of direct and indirect effects of several yield-contributing characters. To know the contribution of various characters towards grain yield, the genotypic correlations of different traits with grain yield were partitioned into their direct and indirect effects. This will provide more precise information for the selection of important traits, which may contribute more towards grain yield per plant. The estimates of direct and indirect effects of various traits on grain yield per plant are presented in table 4.5.

4.4.1 Days to 50% flowering

The positive genotypic correlation was observed for days to 50% flowering (0.548) with grain yield per plant. The direct effect of this trait on grain yield was positive and high (0.355). The indirect effect via days to maturity (0.105) and number of seeds per umbellate (0.187)were moderate and positive, while via number of branches per plant (0.079), number of umbels per plant (0.069), number of umbellates per umbel (0.069) and 1000-seed weight (0.023), it was positive and low. Its indirect effect via number of seeds per main umbel (-0.245) was negative and high, While it was low with plant height (-0.078) and plant height up to main umbel (-0.003).

Table 4.5: Path coefficient analysis showing direct (bold letter) and indirect effect of ten traits on grain yield per plant in cumin

Characters	Days to 50% flowering	Days to maturity	Plant height (cm)	Plant height up to main umbel (cm)	Branches per plant	Umbels per plant	Seeds per main umbel	Umbellates per umbel	Seeds per umbellate	1000-seed weight	Correlation with yield per plant
Days to 50% flowering	**0.355**	0.105	-0.078	-0.003	0.079	0.069	-0.245	0.056	0.187	0.023	0.548**
Days to maturity	0.261	**0.144**	-0.118	-0.016	0.011	0.036	-0.256	0.048	0.157	0.008	0.275**
Plant height (cm)	-0.101	-0.062	**0.275**	0.070	0.127	0.055	-0.279	0.150	0.199	0.042	0.476**
Plant height up to main umbel (cm)	-0.014	-0.030	0.258	**0.075**	0.083	0.046	-0.158	0.135	0.088	0.029	0.513**
Branches per plant	0.105	0.006	0.131	0.024	**0.265**	0.145	-0.348	0.239	0.099	0.066	0.732**
Umbels per plant	0.159	0.034	0.098	0.022	0.249	**0.155**	-0.425	0.265	0.132	0.062	0.751**
Seeds per main umbel	0.122	0.051	0.107	0.017	0.129	0.092	**-0.715**	0.297	0.372	0.049	0.521**
Umbellates per umbel	0.044	0.015	0.091	0.022	0.140	0.090	-0.469	**0.454**	0.046	0.050	0.484**
Seeds per umbellate	0.153	0.052	0.126	0.015	0.061	0.047	-0.614	0.048	**0.433**	0.034	0.356**
1000-seed weight	0.115	0.017	0.164	0.030	0.245	0.135	-0.490	0.319	0.206	**0.071**	0.812**

Residual effect= 0.4760, R square = 0.7734

* significant at P=0.05 and ** significant at P = 0.01

4.4.2 Days to maturity

The positive and significant genotypic correlation was observed between days to maturity (0.275) and grain yield. Its direct effect on grain yield was positive and moderate (0.144). Its indirect effect was positive moderate via days to 50% flowering (0.261) and number of seeds per umbellate (0.157).While it was positive and low through number of branches per plant (0.011), number of umbellates per umbel (0.048), number of umbels per plant (0.036), and 1000-seed weight (0.008). Its indirect effect via plant height (-0.118) and number of seeds per main umbel (-0.256) was negative and high. Whereas, it was low and negative (-0.016) with plant height up to main umbel. .

4.4.3 Plant height

This trait exhibited high and positive significant correlation (0.476) with grain yield. Its direct effect on yield per plant was positive and high (0.275). Its indirect effect via number of branches per plant (0.127), number of umbellates per umbel (0.150) and number of seeds per umbellate (0.199) was positive and high, but it was positive and low via plant height up to main umbel (0.070) and number of umbels per plant (0.055) and 1000-seed weight (0.042). Its indirect effect via days to 50% flowering (-0.101), number of seeds per main umbel (-0.279) was negative and high. Whereas it was low with days to maturity (-0.062).

4.4.4 Plant height up to main umbel

High and positive significant genotypic correlation was observed for plant height up to main umbel (0.513) with grain yield. The direct effect of this trait on grain yield was positive (0.075). Its indirect effect positive and high via plant height (0.258) and number of umbellates per umbel (0.135), but it was positive and low via number of branches per plant (0.083), and 1000-seed weight (0.029). Its indirect effect via number of seeds per main umbel (-0.158) was negative and high. Whereas it was low with days to maturity (-0.030) and days to 50% flowering (-0.014).

4.4.5 Number of branches per plant

The genetic correlation between number of branches per plant and grain yield per plant was high, significant and positive (0.732). Its direct effect on grain yield was high and positive (0.265). Its indirect effect via days to 50% flowering (0.105), plant height (0.131), number of umbels per plant (0.145) and number of umbellates per umbel (0.239) were positive and high, but they were positive and low via days to maturity (0.006), plant height up to main umbel (0.024), number of seeds per umbellate (0.099) and 1000-seed weight (0.066). Its indirect effect via number of seeds per main umbel was negative and high (-0.348).

4.4.6 Number of umbels per plant

This trait showed high positive significant correlation (0.751) with grain yield. Its direct effect was low and positive (0.155). Its indirect effects were high and positive via days to 50% flowering (0.159), number of branches per plant (0.249), number of umbellates per umbel (0.265) and number of seeds per umbellate (0.132), but were positive and low via plant height (0.098), plant height up to main umbel (0.022) and days to maturity (0.034) 1000-seed weight (0.062). Its indirect effect via and number of seeds per main umbel was negative and high (-0.425).

4.4.7 Number of seeds per main umbel

This trait showed high and negative (-0.715) direct effect with grain yield per plant. But the genotypic correlation between number of seeds per main umbel with grain yield per plant was positive and high (0.521). This positive correlation may due to its high and positive indirect effects via per plant (0.129), number of umbellates per umbel (0.297) and number of seeds per umbellate (0.372) and positive and low via days to maturity (0.051), plant height up to main umbel (0.017), number of umbels per plant (0.092) and 1000-seed weight (0.049).

4.4.8 Number of umbellates per umbel

This character had positive and highly significant correlation with grain yield per plot (0.484). Its direct effect on grain yield was high and positive (0.454). Its indirect effects were high and positive via number of branches per plant (0.140), but were positive and low via days to 50% flowering (0.044), days to maturity (0.015), plant height (0.091), plant height up to main umbel (0.022), number of umbels per plant (0.090), number of seeds per umbellate (0.046) and 1000-seed weight (0.050). Its indirect effect via number of seeds per main umbel was negative and high (-0.469).

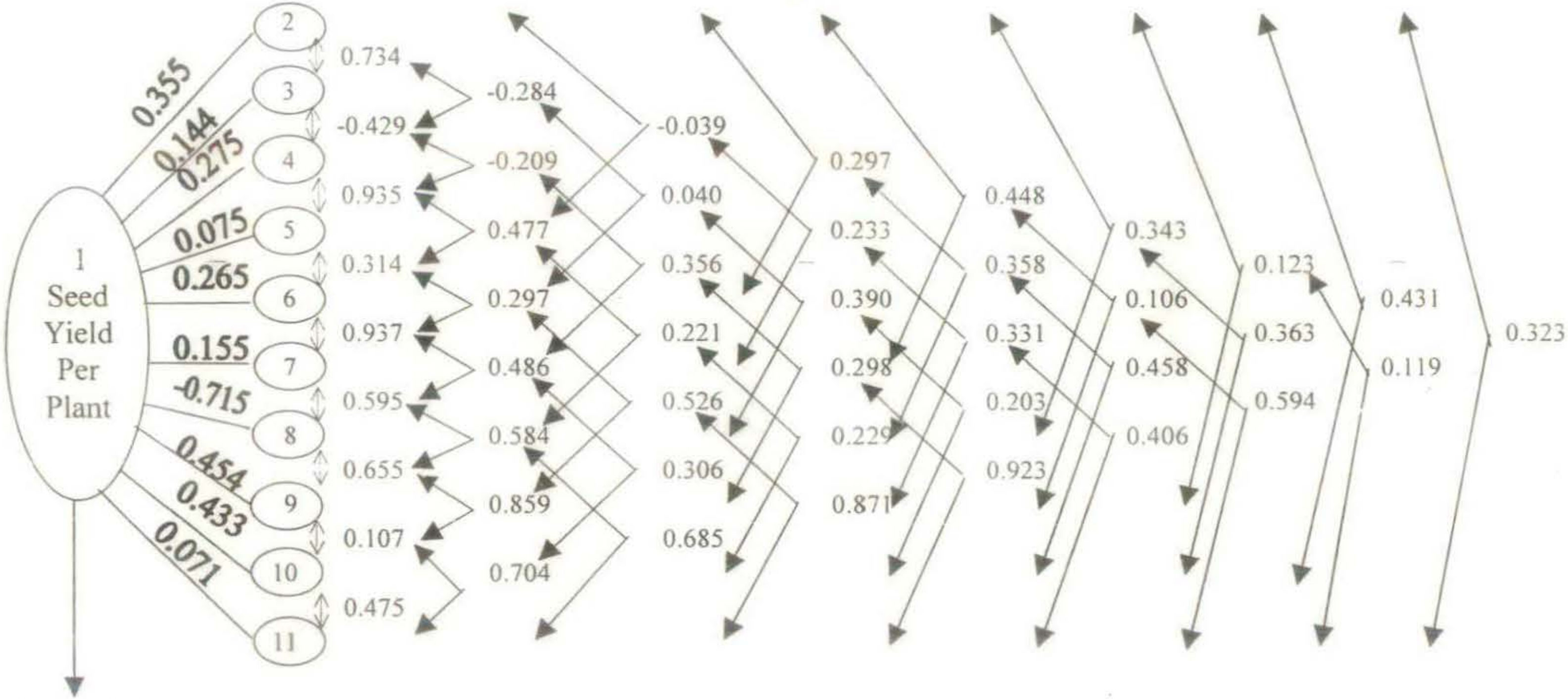
4.4.9 Number of seeds per umbellate

High and positive significant genotypic correlation was observed for number of seeds per umbellate (0.356) with grain yield. The direct effect of this trait on grain yield was high and positive (0.433). Its indirect effects were high and positive via days to 50% flowering (0.153), but were positive and low via days to maturity (0.052), plant height up to main umbel (0.015), number of branches per plant (0.061), number of umbels per plant (0.047), number of umbellates per umbel (0.048) and 1000-seed weight (0.034). Its indirect effect via plant height (-0.126) and number of seeds per main umbel and was negative and high (-0.614).

4.4.10 1000-seed weight (g)

The genetic correlation between 1000-seed weight and grain yield per plant was very strong, highly significant and positive (0.812). Its direct high via days to 50% flowering (0.115), plant height (0.164), number of branches per plant (0.245), number of umbels per plant (0.135), number of umbellates per umbel (0.319) and number of seeds per umbellate (0.206), but it was positive and low via days to maturity (0.017) and plant height up to main umbel (0.030). Its indirect effect via number of seeds per main umbel was negative and high (-0.490).

Figure 1. Genotypic path diagram for grain yield per plant in 30 genotypes of cumin



Residual effect 0.4760

1 = Grain yield per plant, 2 = Days to flowering, 3 = Days to maturity, 4 = Plant height, 5 = Plant height up to main umbel, 6 = Branches per plant, 7 = Umbels per plant, 8 = Seeds per main umbel, 9 = Umbellates per umbel, 10 = seeds per umbellate, 11 = 1000-seed weight

V DISCUSSION

Cumin is an important *rabi* foreign exchange earning seed spice crop of arid and semi-arid regions of Gujarat and Rajasthan. The crop is indigenous and grown all over the country. Research is on way only at three institutes (Jagudan, Ajmer and Jobner) for developing high yielding varieties resistant to pests, diseases, adverse soils and weather. Very few achievements have been obtained in cumin crop due to limited infrastructure and manpower. Available information says that cumin is self pollinated plant, grown in one agroclimatic zone in limited area has not any wild relatives or sub species. All these features are responsible for limited variability in this crop. Therefore, attempt has been made to study genetic variability by using some diverse lines collected from cumin growing areas of Rajasthan and Gujarat and selected from exotic collection.

The aim of the present investigation was to study the range of variation, heritability, genetic advance, correlation and path analysis in cumin for fourteen different traits. Twenty-seven new genotypes and three released varieties were included in the experiment. The results obtained on these aspects have been presented in the previous chapter and is discussed giving both supporting and contradictory reference along with probable reasoning under the following heads.

5.1. Variability, heritability (broad sense) and genetic advance

5.2. Correlation coefficient analysis

5.3. Path coefficient analysis

5.1 VARIABILITY, HERITABILITY AND GENETIC ADVANCE

5.1.1 Genetic variability

The analysis of variance (Table 4.1) revealed highly significant differences among genotypes for all the characters under investigation indicated presence of considerable amount of variability in the material. A wide range of variability for different characters has been observed by Mathur *et al.* (1971), Mehta and Patel (1980), Baswana *et al.* (1983), Dhayal *et al.* (1999), Singh *et al.* (2001), Rajput and Singh (2002), Anonymous (2002-03), Singh *et al.* (2004) in cumin; Mehta and Patel (1983), Agnihotri *et al.* (1997), Rajput *et al.* (2004) in fennel; Joshi *et al.* (1967), Arumugam and Muthukrishnan (1978), Suthanthirapandian *et al.* (1980), Rama Rao *et al.* (1981), Mehta and Patel (1985), Reddy *et al.* (1989), Sharma and Sharma (1989), Shridar *et al.* (1990), Bhandari and Gupta (1993), Ali *et al.* (1994), Yadav (1999), Tripathi *et al.* (2000), Sharma *et al.* (2004) in coriander and Krishnamurthy and Madalagiri (2002) in Ajwain. Among the character under study, number of branches per plant, number of umbels per plant, grain yield per plant and plot and volatile oil content in seeds showed wide range of variability (more than 80%). The results suggested great scope for improvement of yield in cumin by selection as it is self pollinated crop.

The phenotypic variation is not a precise parameter to judge heritable variability present in the population. The other genetic parameters such as variance components, genotypic coefficient of variation, heritability and genetic advance are important to judge the extent of genetic variability more precisely. The phenotypic variance was partitioned into genetic and environmental components to know the magnitude of genetic variability for each character.

5.1.2 Components of variance

The genotypic and phenotypic variances showed the same trend. However, genotypic variances were greater than environmental variances for all the characters except number of seeds per umbellate (Table 4.2). Almost same results were observed for genotypic and phenotypic coefficients of variation (Table 4.3). This implied that phenotypic variability or *per se* performance may be considered as a reliable measure of genotypic variability. In order to compare the different quantitative characters in respect of phenotypic and genotypic variability, the phenotypic coefficients of variation (PCV) and genotypic coefficients of variation (GCV) were worked out (Table 4.3). The results revealed that the magnitudes of genetic variability were very close to that of phenotypic one for all the traits except number of seeds per umbellate, indicating that phenotypic variability was largely due to the genetic differences. Under such genetic behavior, selection is effective for improvement of yield and its attributing traits.

5.1.3 Coefficient of variation

Burton (1952) suggested that the genetic coefficient of variation is more reliable index for measuring genetic variation.

The highest genotypic and phenotypic coefficient of variation was observed for 1000-seed weight followed by number of umbels per plant, volatile oil content, days to germination and number of branches per plant. Majority of the traits viz., number of seeds per main umbel, seed yield per plot, seed yield per plant, number of umbellates per umbel, plant height, plant height up to main umbel exhibited moderate to high values of genotypic and phenotypic coefficients of variation, whereas number of seeds per umbellate, days to 50% flowering and days to maturity had lower values of genotypic ahd phenotypic coefficients of variation. High per plant, yield per plant, 1000-seed weight, days to flower and days to maturity reported by Mathur *et al.* (1971), for yield per plant, days to germination, number of seeds per umbel and plant height reported by Baswana *et al.* (1983), for plant height, number of umbels per plant, number of seeds per umbel, test weight, seed yield per 10 plants reported by Dhayal *et al.* (1999), for genotypic and phenotypic coefficient of variations for seed yield, umbels per plant, seeds per umbel and harvest index reported by Singh *et al.* (2001) in cumin; for number of seeds per umbellate and number of umbels per plant reported by Mehta and Patel (1983), for umbels per plant and seed yield per plant reported by Rajput *et al.* (2004) in fennel; for plant height reported by Arumugam and Muthukrishnan (1978), plant height, number of umbellate per main umbel, number of umbels per plant, number of seeds per main umbel and seed yield per plant reported by Suthanthirapandian *et al.* (1980), for number of umbels per plant reported by Rama Rao *et al.* (1981), for plant height, number of umbels per plant, number of seeds per main umbel and seed yield per plant reported by Sharma and Sharma (1989), for number of umbels per plant reported by Reddy *et al.* (1989) and Sanker and Khader (1991a), for days to maturity, secondary branches, days to flowering, and 1000-seed weight reported by Tripathi *et al.* (2000), for number of umbels per plant and number of seeds per umbel reported by Sharma *et al.* (2004) in coriander.

The results indicated that characters showing high value of genotypic and phenotypic coefficients of variation may easily improved by careful selection of desired genotypes from population.

5.1.4 Heritability (Broad sense) and genetic advance

It is not possible to determine the exact amount of heritable variability with the help of genetic coefficient of variation alone. Burton (1952) would give a better idea about the amount of genetic advance to be expected from selection.

The magnitude of variability present in a crop species is of at most importance as it is the base for the effective selection. In crop improvement, only the genetic components of variation are important because only these components are transmitted to the next generation. Heritability indicates the effectiveness with which selection of genotypes could be based on phenotypic performance. This could be achieved through the estimates of heritability and genetic gain.

The heritability estimates were quiet high for days to germination, days to 50% flowering, days to maturity, plant height, plant height up to main umbel, branches per plant, umbels per plant, seeds per main umbel, umbellates per umbel, seed yield per plant, test weight, volatile oil content in seeds and seed yield per plant. These findings are in agreement with the results obtained by Mathur *et al.* (1971) for days to maturity, 1000-seed weight, days to flower, yield per plant, number of branches and plant height; Mehta and Patel (1980) for 1000-seed weight, days to flowering and maturity; Baswana *et al.* (1983) for yield per plant; Ramavtar *et al.* (1991a) for seed yield, days to flowering, primary branches and umbels per plant; Dhayal *et al.* (1999) for plant height, number of umbels per plant, number of seeds per umbel, test weight, seed yield per 10 plants; Singh *et al.* (2001) for seed yield, umbels per plant, seeds per umbel and harvest index; Rajput and Singh (2002) for days to flowering, seed yield, branches per plant and umbellates per umbel; Singh *et al.* (2004) for test weight, days to flowering and seed yield per plant in cumin. The high heritability estimates in fennel for number of seeds per umbellate, number of umbels per plant, plant height, number of umbellets per umbel, 1000-seed weight, seed yield per plant

Rajput *et al.*, 2004). In coriander for plant height, number of umbels per plant and number of umbellates per main umbel were noted by Arumugan and Muthukrishnan, 1978; Rama Rao *et al.*, 1981; Jindal *et al.*, 1985; Reddy *et al.*, 1989; Sharma and Sharma, 1989; Bhandari and Gupta, 1993 and Sankar and Khader, 1991a. Similarly for days to flowering, 1000-seed weight; and days to maturity (Bhandari and Gupta, 1993), seed yield per plant and number of umbels per plant (Ali *et al.*, 1994), days to maturity, days to flowering, and 1000-seed weight (Tripathi *et al.*, 2000), seed per umbel, days to 50% flowering, plant height, umbels per plant and 1000-seeds weight (Sharma *et al.,* 2004). Krishnamurthy and Madalagiri (2002) reported high heritability for number of seeds per plant, essential oil content, numbers of umbels per plant, and numbers of seeds per umbel in Ajwain.

Moderate value of heritability was obtained for number of seeds per umbellate which indicated that this character was influenced by environment.

The higher estimates of heritability indicate that these characters were comparatively less affected by environment. The traits viz., 1000-seed weight, number of umbels per plant, volatile oil content, days to germination and number of branches per plant displayed high heritability estimates along with high GCV indicating their reliability for selection of desired genotypes.

Shift in gene frequency towards superior side under selection pressure is termed as genetic advance and is generally expressed as %age of mean (Genetic gain). Johnson *et al.* (1955) suggested that heritability together with genetic advance is more useful parameters in choice of the best genotype by selection.

In the present investigation, high heritability coupled with moderate plant and volatile oil content. Mathur *et al.* (1971) reported a higher value of genetic advance along with high heritability values in yield per plant and the 1000-seed weight; Mehta and Patel (1980) reported heritability estimates were high for 1000-seed weight, days to flowering and maturity; Baswana *et al.* (1983) reported high heritability and genetic advance for yield per plant; Dhayal *et al.* (1999) reported higher estimates of heritability and genetic advance for plant height, number of umbels per plant, number of seeds per umbel, test weight, seed yield per 10 plants; Singh *et al.* (2001) reported higher estimates of heritability and genetic advance for green yield, umbels per plant and seeds per umbel; Rajput and Singh (2002) reported high heritability and genetic advance for seed yield and branches per plant; Singh *et al.* (2004) reported high heritability and genetic advance for seed yield per plant in cumin. Mehta and Patel (1983) reported high heritability with moderate to high genetic advance for majority of the traits except 1000-seed weight; Jindal and Allah-Rang (1986) high heritability with high genetic advance for number of umbellates per umbel; Agnihotri *et al.* (1997) high heritability with high genetic advance for umbels per plant, yield per plant and yield per plot; Rajput *et al.* (2004) high heritability with high genetic advance for umbels per plant, seed yield per plant in fennel. Similarly in coriander, moderate to high genetic advance was observed for plant height and number of umbels per plant by Arumugan and Muthukrishnan (1978); for number of seeds per main umbel and seed yield by Rama Rao *et al.* (1981); for plant height, number of umbels per plant and number of seeds per main umbel by Jindal *et al.* (1985); for plant height, days to flowering, number of umbels per plant and seed yield by Sharma and Sharma (1989); for number of umbels per plant and seed yield by Ali *et al.* (1994) and for days to 50% flowering, plant height, umbels per plant and 1000-seed weight

High heritability with low genetic advance was observed for days to 50% flowering, number of seeds per main umbel, number of branches per plant, days to germination, days to maturity, number of umbellates per umbel, plant height up to main umbel, yield per plant, and yield per plot, whereas, moderate heritability with low genetic advance was recorded for the characters viz., plant height and number of seeds per umbellate. This finding is in agreement with the results obtained by Rajput and Singh (2002) for 1000-seed weight and Tripathi *et al.* (2000) for number of umbellates per umbel, primary branches per plant and plant height.

High genotypic coefficient of variation with high heritability and moderate genetic advance was observed for 1000-seed weight, number of umbels per plant and volatile oil content in seeds. Moderate coefficient of variation with high heritability and moderate genetic advance was observed for days to germination, number of branches per plant and number of seeds per main umbel.

Based on all variability parameters, it is revealed that the characters viz., number of umbels per plant, test weight, volatile oil content in seeds, number of branches per plant, days to germination, number of seeds per main umbel, seed yield per plant and seed yield showed substantial to high genetic variability. Further, the above mentioned characters also exhibited moderate genetic gain. Therefore, selection practiced on these characters would be helpful in improvement of cumin yield. Further, such highly heritable characters can be easily transferred to cultivated varieties for improvement of specific character.

5.2 CORRELATION COEFFICIENT ANALYSIS

In breeding crops for higher yield, it is imperative to obtain information regarding the interrelationship of different plant characters with yield and among themselves, since it facilitates the quicker assessment of high yielding genotypes in selection programme. Estimation of only phenotypic correlation coefficient is not sufficient to understand complete association between characters as it is the result of interaction between the genotype and environment. The real association could be known only through genotypic correlation which eliminates the environmental effects. Hence, in the present investigation the genotypic and phenotypic correlation coefficients were worked out between seed yield per plot and other component characters.

In general, present results indicated that the values of genotypic correlation were higher than their phenotypic correlation (Table 4.4). This indicated that though there was a high degree of association between two variables at genotypic level, but its phenotypic expression was deflated by environment.

Seed yield per plot showed positive and highly significant correlation with all the characters studied except days to maturity and seeds per umbellate (at phenotypic level) at both genotypic and phenotypic levels. A number of workers also reported similar genotypic and phenotypic association for different characters with seed yield like plant height, branches per plant, and umbellates per umbel (Ramavtar *et al.*, 1991) in cumin; number of primary branches and number of umbels per plant (Mehta *et al.*, 1993), yield per plant (Agnihotri *et al.*, 1997) in fennel; plant height and umber of umbels per plant (Rama Rao *et al.*, 1981), number of umbels per plant and plant height (Vedamuthu *et al.*, 1989), number of secondary umbels per plant, number of effective branches, number of primary branches per plant and plant height (Bhandari and gupta, 1993), number of branches and umbels per plant (Ali *et al.*, 1994), plant height, number of secondary branches, days to flowering, days to maturity and number of umbels (Tripathi *et al.*, 2000) in coriander.

Seed yield per plant was highly and significantly correlated with days to 50% flowering, plant height, plant height up to main umbel, number of branches per plant, number of umbels per plant, number of seeds per main umbel, number of umbellates per umbel, number of seeds per umbellate and 1000-seed weight at genotypic and phenotypic levels, while days to maturity was significantly correlated at genotypic level only. Moreover, the values of genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients for all characters. A number of workers also reported similar genotypic and phenotypic association for different characters with seed yield per plant viz. days to flowering, plant height and umbels per plant (Singh *et al.*, 2004) in cumin; plant height, umbels number per plant, umbellates number per umbel and seeds number per umbellate (Jindal and Allah-Rang, 1986); plant height, number of branches per plant, total number of umbels per plant, number of seeds per umbellate, number of seeds per umbel and 1000-seed weight (Patel, 1995); plant height, number of primary branches per plant, number of umbels per plant, 100-seed weight and seeds per umbel (Singh *et al.*, 1999); plant height, branches per plant, umbels per plant and test weight (Rajput *et al.*, 2004) in fennel; plant height, number of mericarps per plant and umbellates per umbel (Arumugam and Muthukrishnan, 1978); plant height and number of umbels per plant (Rama Rao *et al.*, 1981); plant height, number of branches and number of umbels (Shinde *et al.*, 1985); plant height, number of branches, number of umbels, and Sharma, 1989); single plant weight and number of branches (Gurbuz, 1998); plant height, branches per plant, umbels per plant, umbelletes per umbel and seeds per umbel (Sharma and Meena, 2004) in coriander.

Days to 50% flowering showed positive and highly significant genotypic and phenotypic association with days to maturity, number of branches per plant, number of umbels per plant, number of seeds per main umbel, and 1000-seed weight, while number of seeds per umbellate was significantly correlated at genotypic level only. It showed negative significant correlation with plant height and non-significant correlation with plant height up to main umbel at genotypic level. This finding is supported by Singh *et al.* (2004) for seed yield per plant in cumin and Tripathi *et al.* (2000) for seed yield per plot in coriander.

Days to maturity showed highly significant and positive correlation with number of umbels per plant and number of seeds per main umbel, while number of seeds per umbellate was significantly correlated at genotypic level. The traits, test weight, number of umbellates per umbel, number of branches per plant showed positive non-significant association with days to maturity. Negative and significant association of days to maturity with plant height and plant height up to main umbel was observed. Similar result obtained for seed yield per plot by Tripathi *et al.* (2000) in coriander.

Plant height was positively and significantly correlated with plant height up to main umbel, number of branches per plant, number of umbels per plant, number of seeds per main umbel, number of umbellates per umbel, number of seeds per umbellate and 1000-seed weight. Similar association of plant height found with number of umbels per plant, height up to the base of the main umbel, number of branches per plant, number of umbellets per umbel, number of seeds per umbel, and 1000-seed weight (Jain *et al.*, 2003), seed yield per plant, branches per plant, umbels per plant, umbellates per umbel and seeds per umbel (Sharma and Meena, 2004).

Plant height up to main umbel reflected positive and highly significant correlation at genotypic and phenotypic levels with number of branches per plant, number of umbels per plant, number of seeds per main umbel, number of seeds per umbellate and 1000-seed weight. This trait showed positive and significant correlation only at genotypic level with number of umbellates per umbel. Similar association of height up to the base of the main umbel obtained with plant height, number of umbels per plant, number of branches per plant, number of umbellates per umbel, number of seeds per umbel, and 1000-seed weight (Jain *et al.*, 2003)

Number of branches per plant exhibited positive and significant correlation at both phenotypic and genotypic levels with number of umbels per plant, number of seeds per main umbel, number of umbellates per umbel and 1000-seed weight. Number seeds per umbellate showed positive and significant correlation only at genotypic level. These results are in conformity with the findings of Sharma and Meena (2004).

Number of umbels per plant was significantly correlated in desired direction with number of seeds per main umbel, number of umbellates per umbel and 1000-seed weight at both the level. Whereas, this character showed positive and significant correlation with number of seeds per umbellate only at genotypic level.

Number of seeds per main umbel showed positive significant genotypic and phenotypic correlation with number of umbellates per umbel, number of seeds per umbellate and 1000-seed weight at both the level.

Number of umbellates per umbel showed positive significant level. Whereas, this trait had poor positive correlation with number seeds per umbellate at both the level. Sharma and Meena (2004) observed significant and positive correlation of plant umbelletes per umbel with seed per umbel.

Positive significant correlation observed between number of seeds per umbellate and 1000-seed weight at both the level.

In the present investigation from the inter relationship, it can be presumed that for improving seed yield per plot in cumin an ideal plant type would be tall and moderate in flowering with maximum umbels per plant, branches per plant, seeds per main umbel, umbellates per umbel, seeds per umbellate, test weight and yield per plant. Hence, these characters could be utilized as selection criteria for improving seed yield in cumin crop.

5.3 PATH COEFFICIENT ANALYSIS

The correlation programme can serve the purpose when few variables are considered in study. But, with increase in variables the situation becomes complex. For overcoming this complexity, path analysis is a valuable technique. It is possible to judge relative contribution of various component characters to seed yield in terms of direct and indirect effects. The analysis of correlation coefficient together with path analysis helps considerably in identification of suitable characters for proper weightage during selection.

To achieve a clear cut picture of interrelationship of various component characters with yield, direct and indirect effects were calculated using path coefficient analysis at genotypic level.

In the present investigation, high and positive direct effect on seed yield per plant was recorded with number of umbellates per umbel height, number of branches per plant, number of umbels per plant, days to maturity, plant height up to main umbel and 1000-seed weight. Similar result have been reported by Singh *et al.* (2004) for plant height and days to flowering and umbels per plant in cumin; Agnihotri *et al.* (1997) for branches per plant, seeds per umbel and plant height; Singh *et al.* (1999) for 100-seed weight, number of umbels per plant and seeds per umbel; Rajput *et al.* (2004) for umbels per plant and seeds per umbel in fennel; Rama Rao *et al.* (1981) for plant height, number of umbels and seed weight; Jindal *et al.* (1985) for days to flowering, plant height and number of umbellates per plant; Sharma and Sharma (1989) for number of branches per plant, umbellates per plant and 1000-grain weight; Sanker and Khader (1991b) for secondary umbels per plant; Bhandari and Gupta (1993) for umbellates per plant, umbels per plant and grains per umbellate; Gurbuz (1998) for single plant weight on single plant yield and plant height; Srivastava *et al.* (2000) for days to flowering, days to maturity and number of umbels per plant; Jain *et al.* (2003) for total plant height, number of umbels per plant and 1000-seed weight; Sharma and Meena (2004) for umbels per plant, plant height, seeds per umbel, 1000-seed weight and branches per plant in coriander. The negative direct effect of number of seeds per main umbel was high. Such negative direct effects were also reported by Jain *et al.* (2003) for number of days to 50% flowering in coriander.

Days to 50% flowering showed positive correlation with seed yield due to its positive and high direct effect on seed yield per plant. Its indirect effects via days to maturity and number of seeds per umbellate were high and positive, while via number of branches per plant, number of umbels per plant, number of umbellates per umbel and 1000-seed weight, it was positive and low. Its indirect effect via and number of seeds per main
... and high. While it was low via plant height and plant

height up to main umbel. Singh *et al.* (2004) in cumin and Jindal *et al* (1985) and Srivastava *et al.* (2000) in coriander reported positive direct effect of days to flowering on seed yield.

Low and positive significant genotypic correlation was observed between days to maturity and seed yield per plant. Its direct effect on seed yield per plant was positive and moderate. Its indirect effects were positive and high via days to 50% flowering and number of seeds per umbellate. While it was positive and low via number of branches per plant, number of umbellates per umbel, number of umbels per plant, and 1000-seed weight. Its indirect effect via plant height and number of seeds per main umbel was negative and high. Whereas, it was negative and low with plant height up to main umbel. Positive direct of days to maturity on seed yield per plant was reported by Srivastava *et al.* (2000) in coriander.

Plant height exhibited high and positive significant correlation with seed yield per plant due to its positive and high direct effect on yield per plant. Its indirect effects via number of branches per plant, number of umbellates per umbel and number of seeds per umbellate were positive and high, but it was positive and low via plant height up to main umbel and number of umbels per plant and 1000-seed weight. Its indirect effect via days to 50% flowering, number of seeds per main umbel was negative and high. Whereas it was low with days to maturity. Singh *et al.* (2004) in cumin; Agnihotri *et al.* (1997) in fennel; Rama Rao *et al.* (1981), Jindal *et al.* (1985), Gurbuz (1998), Jain *et al.* (2003) and Sharma and Meena (2004) in coriander reported positive direct effect of plant height on seed yield.

High, positive and significant genotypic correlation was observed for plant height up to main umbel with seed yield per plant. The direct effect of this trait on seed yield was low and positive. Its indirect effect was positive and high via plant height and number of umbellates per umbel, but it was positive and low via number of branches per plant, number of umbels per plant, number of seeds per umbellate and 1000-seed weight. Its indirect effect via number of seeds per main umbel was negative and high. Whereas it was low with days to maturity and days to 50% flowering.

The genetic correlation of number of branches per plant and seed yield per plant was highly, significant and positive due to its high direct effect on seed yield. It gave positive and high indirect effects via days to 50% flowering, plant height, number of umbels per plant and number of umbellates per umbel. But its indirect effect was positive and low via days to maturity, plant height up to main umbel, number of seeds per umbellate and 1000-seed weight. Its indirect effect via number of seeds per main umbel was negative and high. Agnihotri *et al.* (1997) in fennel and Sharma and Sharma (1989) and Sharma and Meena (2004) reported positive direct effect of branches per plant on seed yield in coriander.

Number of umbels per plant showed high positive significant correlation with seed yield per plant due to its high and positive direct effect. Its indirect effect was high and positive via days to 50% flowering, number of branches per plant, number of umbellates per umbel and number of seeds per umbellate. Its indirect effect was positive but low via plant height, plant height up to main umbel, days to maturity and 1000-seed weight. Its indirect effect via and number of seeds per main umbel was negative and high. Singh *et al.* (1999) and Rajput *et al.* (2004) in fennel and Rao *et al.* (1981), Bhandari and Gupta (1993), Srivastava *et al.* (2000), Jain *et al.* (2003) and Sharma and Meena (2004) in coriander reported positive direct effect of number of umbels per plant on seed yield.

Numbers of seeds per main umbel showed high and negative direct character was positive and high due to its high and positive indirect effects via days to 50% flowering, plant height, number of branches per plant, number of umbellates per umbel and number of seeds per umbellate and positive and low indirect effect via days to maturity, plant height up to main umbel, number of umbels per plant and 1000-seed weight. Such negative direct effects were also reported by Jain *et al.* (2003) for number of days to 50% flowering in coriander.

Number of umbellates per umbel had positive, high and significant correlation with seed yield per plant. Its direct effect on seed yield was high and positive. Its indirect effect was high and positive via number of branches per plant, but it was positive and low via days to 50% flowering, days to maturity, plant height and plant height up to main umbel, number of umbels per plant, number of seeds per umbellate and 1000-seed weight. Its indirect effect via number of seeds per main umbel was negative and high. Positive direct of number of umbellates per plant on seed yield per plant was reported by Jindal *et al.* (1985), Sharma and Sharma (1989) and Bhandari and Gupta (1993) in coriander.

High and positive significant genotypic correlation was observed for number of seeds per umbellate with seed yield per plant due to its high and positive direct effect and indirect effect via days to 50% flowering. But its indirect effect was positive and low via days to maturity, plant height up to main umbel, number of branches per plant, number of umbels per plant and number of umbellates per umbel and 1000-seed weight. Its indirect effect via plant height and number of seeds per main umbel was negative and high. Bhandari and Gupta (1993) reported that grains per umbellate had high direct effect on seed yield per plant in coriander.

The genetic correlation between 1000-seed weight and seed yield per plot was very strong, significant and positive on the account its high indirect positive effects via days to 50% flowering, plant height, number of branches per plant, number of umbels per plant, number of umbellates per umbel and number of seeds per umbellate. But its direct effect was very low and positive. Its indirect effect was positive and low via days to maturity and plant height up to main umbel. Its indirect effect via number of seeds per main umbel was negative and high. Singh *et al.* (1999) in fennel; Sharma and Sharma (1989), Jain *et al.* (2003) and Sharma and Meena (2004) reported positive direct effect of 1000-seed weight on seed yield in coriander.

An important consideration for formulating the path diagram is that all the important causal factors affecting the seed yield per plant are included. Seed yield is a very complex character affected by several factors. It was not feasible to include all the characters in the present study. Under such circumstances, provision is made for a residual path which will take care of all such non-considered factors. In the study the residual effect at genotypic level was 0.4760 which suggested that there might be a few more component traits responsible for the seed yield per plant. In the present study overall picture of path analysis revealed that while selection for improving seed yield in cumin, weightage should be given to tall and moderately maturing plant with maximum umbellates per umbel, seeds per umbellate, branches per plant, umbels per plant and 1000-seed weight.

VI SUMMARY AND CONCLUSIONS

The investigation was carried out on variability, heritability, genetic advance, correlation and path coefficient in thirty genotypes of cumin [*Cuminum cyminum* L.]. The genotypes were selected from the germplasm maintained at the Main Spices Research Station, Sardarkrushinagar Dantiwada Agricultural University, Jagudan. Fourteen characters viz., days to germination, days to 50% flowering, days to maturity, plant height, plant height up to main umbel, number of branches per plant, number of umbels per plant, number of seeds per main umbel, number of umbellates per umbels, number of seeds per umbellate, grain yield per plant, grain yield per plot, 1000-seed weight, and volatile oil content were considered for the study. The experiment was conducted in a Randomized Block Design with three replications.

The salient findings are summarized below:

1. The analysis of variance for all the characters showed highly significant differences among the genotypes, indicating sufficient amount of variability present in the material.
2. The genotypic and phenotypic variances were higher for number of umbels per plant, number of seeds per main umbel and days to germination.
3. The highest genotypic coefficient of variation was observed for 1000-seed weight followed by number of umbels per plant, volatile oil content, days to germination and number of branches per plant.
4. High heritability estimates (broad sense) were found for 1000-seed weight, number of umbels per plant, volatile oil content, days to germination and number of branches per plant indicating that these

characters were less influenced by the environment and direct selection for these traits would be effective for further improvement.

5. High heritability estimates coupled with moderate genetic advance as percent of mean was recorded for 1000-seed weight, number of umbels per plant and volatile oil content indicating the predominance of additive gene action for this trait.
6. Estimates of correlation coefficients revealed that in general genotypic correlations were higher than their phenotypic counterpart. Highly significant and positive correlations were observed for grain yield per plot with days to germination, days to 50% flowering, plant height, plant height up to main umbel, number of branches per plant, number of umbels per plant, number of seeds per main umbel, number of umbellates per umbels, grain yield per plant, 1000-seed weight, and volatile oil content. Considering above relationships an ideal plant type in cumin can be tall, moderate in flowering with high individual plant yield coupled with maximum number of umbels per plant, branches per plant, seeds per main umbel, umbellates per umbel, seeds per umbellate and 1000-seed weight.
7. Path coefficient analysis revealed the highest positive direct effect of number of umbellates per umbel followed by number of seeds per umbellate, days to 50% flowering, plant height, number of branches per plant, number of umbels per plant, days to maturity, plant height up to main umbel and 1000-seed weight on seed yield per plant.
8. Based on these findings, it could be concluded that in breeding programme aiming to improve grain yield in cumin, more weightage should be given to plant height, number of branches per plant, number of umbels per plant, number of umbellates per umbel, grain yield per single plant and 1000-seed weight.

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APPENDIX – I

Meteorological data during the period of investigation

Main Spices Research station, SDAU, Jagudan (Gujarat)

Month	Standard Week		Temperature °C		Humidity	Rainfall (mm)
	No.	Date	Min.	Max.	(%)	
1	2	3	4	5	6	7
Nov 2003	44	29-4	20.9	33.3	51.57	-
	45	5-11	21.6	34.1	72.71	-
	46	12-18	18.9	75.4	58.43	-
	47	19-25	18.3	31.4	50.00	-
	48	26-2 Dec	16.1	30.6	46.86	-
Dec 2003	49	3-9	13.4	30.5	44.57	-
	50	10-16	13.2	31.0	41.43	-
	51	17-23	12.4	29.5	39.14	-
	52	24-31	12.1	23.8	41.63	-
Jan 2004	1	1-7	11.5	22.2	38.14	-
	2	8-14	13.1	24.6	43.71	-
	3	15-21	12.5	28.3	58.43	-
	4	22-28	10.3	23.9	42.00	-
Feb 2004	5	29-4	10.4	23.7	46.57	-
	6	5-11	11.1	26.4	50.29	-
	7	12-18	12.6	30.0	48.14	-
	8	19-25	13.4	30.1	35.43	-
Mar 2004	9	26-4	14.5	34.4	41.25	-
	10	5-11	15.1	35.0	39.71	-
	11	12-18	17.2	35.8	37.29	-
	12	19-25	20.1	38.8	39.14	-
	13	26-1 Apr	18.8	36.2	37.14	-
					Total...	-

APPENDIX - II

Mean performance of 30 genotypes

Sr. No.	Genotypes	Days to germination	Days to 50% flowering	Days to maturity	Plant height (cm)	Plant height up to main umbel	Branches per plant	Umbels per plant	Seeds per main umbel	Umbellates per umbel	Seeds per umbellate	1000-seed weight (g)	Volatile Oil (%)	Yield/ plant (g)	Yield/ plot (kg)
1.	HAIRY - CUMIN	9.33	55.67	99.00	31.03	25.50	4.47	26.60	32.00	5.07	6.20	5.53	3.30	2.167	0.138
2.	SEL.81-1	7.67	61.33	102.67	33.60	28.10	3.60	21.13	31.00	4.60	6.87	4.47	2.90	2.000	0.122
3.	JC-94-70	8.00	57.33	101.33	34.13	28.60	4.67	25.27	26.33	4.40	5.60	5.27	3.80	2.300	0.138
4.	JC-94-262	8.33	52.67	94.33	32.27	27.10	4.40	19.67	23.33	4.67	5.33	5.07	3.10	2.100	0.127
5.	JC-94-276	7.67	55.00	97.00	29.53	25.40	4.47	23.40	25.33	4.33	5.73	4.13	4.17	1.400	0.089
6.	JC-95-1	7.67	58.67	99.33	35.53	29.70	5.53	32.60	30.33	5.20	6.13	6.87	3.37	2.600	0.158
7.	JC-95-7	7.00	60.33	101.67	35.73	30.40	5.00	32.40	38.67	5.13	7.47	6.90	3.80	2.400	0.147
8.	JC-95-10	7.67	56.67	97.67	33.20	27.00	4.47	23.20	33.00	4.93	6.60	4.47	3.80	2.200	0.133
9.	JC-95-90	7.33	58.33	100.33	34.00	28.70	4.13	25.20	28.33	5.20	5.60	5.10	3.80	2.133	0.132
10.	JC-95-93	7.33	54.67	100.00	32.87	27.30	3.33	21.07	26.67	4.93	6.00	4.13	3.70	2.033	0.122
11.	JC-95-127	7.67	56.00	100.33	32.87	27.90	5.27	28.40	28.67	5.00	5.80	5.87	3.90	2.433	0.142
12.	JC-96-10	7.67	58.00	103.33	35.33	30.60	5.27	34.60	31.33	5.20	6.07	5.97	4.00	2.367	0.144
13.	JC-96-11	8.33	61.33	105.67	37.27	32.40	5.73	32.60	36.33	5.00	7.27	7.10	3.17	2.500	0.151
14.	JC-96-47	7.67	58.67	102.67	38.07	32.30	5.20	29.60	31.67	5.00	6.33	5.93	4.43	2.333	0.141
15.	JC-99-22	8.00	59.00	104.33	32.00	27.30	4.20	24.00	28.67	4.40	6.60	4.00	3.57	2.133	0.127

Sr. No.	Genotypes	Days to germination	Days to 50% flowering	Days to maturity	Plant height (cm)	Plant height up to main umbel	Branches per plant	Umbels per plant	Seeds per main umbel	Umbellates per umbel	Seeds per umbellate	1000-seed weight (g)	Volatile Oil (%)	Yield/ plant (g)	Yield/ plot (kg)
16.	JC-99-24	7.67	55.67	100.67	33.27	28.00	4.27	26.40	27.33	4.73	5.93	4.37	4.20	2.033	0.110
17.	JC-99-40	7.33	57.33	102.00	33.27	28.20	4.80	22.00	28.33	4.47	6.07	4.73	3.50	2.133	0.128
18.	JC-99-42	11.00	61.00	102.33	35.73	30.80	5.53	31.80	33.33	5.07	7.07	7.33	3.80	2.533	0.150
19.	JC-2000-3	9.00	60.67	106.33	32.93	27.10	4.93	29.40	26.67	4.80	5.93	5.53	2.67	2.300	0.139
20.	JC-2000-11	9.00	60.00	107.33	28.73	25.20	4.00	25.33	32.33	4.40	6.40	4.53	5.10	2.333	0.117
21.	JC-2000-20	9.00	64.00	105.33	27.53	24.00	4.33	25.53	26.33	4.53	6.00	4.63	4.97	2.100	0.118
22.	JC-2000-21	11.33	63.00	111.00	29.27	24.50	4.40	25.73	31.33	4.93	6.33	5.57	4.83	2.233	0.134
23.	JC-2000-22	11.67	62.33	110.33	28.67	24.80	4.33	26.07	30.67	4.27	6.93	4.93	4.60	2.167	0.132
24.	JC-2000-27	11.67	60.33	107.33	30.13	25.70	5.47	33.40	32.33	5.00	6.13	6.37	4.40	2.400	0.144
25.	JC-2000-54	9.33	62.67	105.33	27.27	25.20	4.53	27.87	23.33	4.60	5.20	4.53	4.57	2.200	0.127
26.	JC-2000-60	9.00	66.00	99.67	34.33	29.90	5.67	34.67	28.00	4.60	6.20	6.33	5.00	2.733	0.142
27.	JC-2000-71	9.33	63.67	104.67	28.27	24.70	4.40	26.13	30.67	4.93	6.07	4.63	4.53	2.300	0.125
28.	GC-2	9.67	59.33	100.33	33.47	27.30	6.07	33.67	31.67	5.00	6.40	6.63	3.80	2.300	0.146
29.	GC-3	11.00	60.33	102.33	32.80	27.60	6.00	38.93	34.00	5.00	6.20	6.67	4.23	2.400	0.154
30.	GC-4	11.00	63.33	108.33	31.67	26.70	5.93	35.47	38.67	6.47	6.07	7.47	4.80	2.500	0.159
	C.V.	8.64	2.24	2.04	6.52	5.33	6.76	5.16	5.72	4.73	9.19	6.29	2.77	7.00	8.29
	S.Em ±	0.439	0.770	1.210	1.223	0.849	0.188	0.837	0.997	0.133	0.330	0.200	0.064	0.091	0.006
	C.D. 5%	1.244	2.180	3.424	3.462	2.404	0.532	2.370	2.823	0.376	0.934	0.566	0.181	0.259	0.018

CERTIFICATE

This is to certify that I have no objection for supplying to any scientist a copy of any part of this thesis, if necessary for rendering reference service in a library or documentation center.

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[P. T. PATEL]