GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS IN FENNEL
(*Foeniculum vulgare* Miller)

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BY

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ABSTRACT

GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS IN FENNEL
(*Foeniculum vulgare* Miller)

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ABSTRACT

Genetic variability, correlation and path coefficient analysis were studied in a set of 36 genotypes of fennel (*Foeniculum vulgare* Miller) grown at Main Spices Research Station, Sardarkrushinagar Dantiwada Agricultural University, Jagudan. The experiment was conducted during *kharif* 2003-2004 in a Randomized Block Design with three replications. Observations on five randomly selected plants were recorded for days to 50 per cent flowering, days to maturity, plant height up to main umbel, plant height, primary branches per plant, total branches per plant, number of effective umbels per plant, diameter of main umbel, number of umbellates per umbel, number of seeds per umbellate, number of seeds per main umbel, length of internode, 1000-seed weight and volatile oil content in seed.

Analysis of variance revealed highly significant differences for all the characters under study. Thus, wide range of variation was apparent for all the characters. High genotypic and phenotypic variances were observed for days to 50 per cent flowering, days to maturity, plant height, plant height up to main umbel, total branches per plant, number of seeds per main umbel and seed yield per plant.

The genotypic coefficient of variation was the highest for volatile oil content in seed followed by total branches per plant and number of seeds per main umbel. Heritability estimates were high for seed yield per plant, days to 50 per cent flowering, number of primary branches per plant, total branches per plant, test weight and volatile oil content. High genetic advance as per cent of mean was recorded for seed yield per plant, days to 50 per cent flowering, primary branches per plant, total branches per plant, effective umbels per plant, number of umbellates per umbel, number of seeds per main umbel, test weight and volatile oil content suggesting that phenotypic selection for the traits would be effective.

Correlation analysis revealed that seed yield per plant was positively and significantly correlated with plant height, primary branches per plant, total branches per plant and effective umbels per plant. These yield contributing characters also showed positive association among themselves.

Path coefficient analysis revealed the highest positive direct effect of number of effective umbels per plant followed by number of seeds umbellate, total branches per plant and number of umbellates per umbel. Plant height up to main umbel and primary branches per plant had indirect effects via total branches per plant and number of effective umbels per plant was high and positive.

Based on these findings it is clear that sufficient variability for seed yield and different yield attributing traits of fennel. Which can be utilized for further improvement of this crop. It is also suggested that for improving yield in fennel, more emphasis should be given on plant height, primary branches per plant, total branches per plant and effective umbels per plant. The culture, JF-521 had given the highest seed yield, which was significantly higher than all the improved varieties. Further higher yield of this culture was supported by high values of attributing traits. This culture may be further evaluated for yield.

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CERTIFICATE

This is to certify that the thesis entitled **"GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS IN FENNEL (*Foeniculum vulgare* Miller)"** submitted by **PATEL DINESHKUMAR GANGARAM** in partial fulfilment of the requirements to award the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **PLANT BREEDING AND GENETICS** by the Sardarkrushinagar Dantiwada Agricultural University is a record of bonafide research work carried out by him under my personal guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

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DECLARATION

This is to declare that the whole of the research work reported in the thesis in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **PLANT BREEDING AND GENETICS** is the result of investigations done by me under the direct guidance and supervision of **Dr. I. D. PATEL**, Research Scientist (Rtd.), Main Spices Research Station, Sardarkrushinagar Dantiwada Agricultural University, Jagudan and no part of the work has been submitted for any other degree so far.

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(D. G. PATEL)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

I. INTRODUCTION

Fennel (*Foeniculum vulgare* Miller) belongs to family umbelliferae, having 2n = 22 chromosomes and native of Mediterranean region. Every part of this plant is aromatic. The seeds have a fragrant smell and pleasant aromatic taste. The seeds of fennel are widely used in various food preparations, such as soups, sauces, pastries, confectionery, pickles, liquors *etc.* The seeds are aromatic, stimulant and carminative and therefore have pharmaceutical value.

Fennel is an annual, dollar earning seed spice grown both as *kharif* and *rabi* crop in the country. The main fennel growing countries are India, Lebanon, Egypt, China, Russia, Rumania, Hungary, Germany, France, Italy, Malaya, Japan, Ceylon, Argentina and U.S.A. (Mc Millan, 1925 and Sankarikutty *et al.,* 1978). The area, production and productivity of fennel in India during 2002-2003 were 24090 hectares, 30430 tonnes and 1262 kg/ha, respectively. Gujarat ranks first in area (17950 hectares), production (25090 tonnes) and productivity (1398 kg/ha) contributing about 67.00 per cent to the country's total production (Anonymous, 2002-2003). In Gujarat this crop is mainly grown in Mehsana, Patan, Banaskantha, Sabarkantha, Ahmedabad and Anand districts.

The collection, maintenance and evaluation of germplasm are most crucial and primary steps in any crop improvement programme. For formulating a successful breeding programme, better understanding of the nature and magnitude of genetic variability present in the breeding material is important. Yield is a complex character governed by several other yield attributing characters. Since, most of the yield attributing characters are quantitatively inherited and highly affected by environment, it is difficult to judge whether the observed variability is heritable or not. The primary parameters, *viz.*, genotypic and phenotypic variances, genetic advance, genetic gain and heritability are useful in understanding the nature of inheritance of different traits.

The study of various traits and their associations with each other is an important strategy designated to break genetic barriers of yield. Correlation studies are helpful in determining the components of a complex trait like yield. However, they do not provide an exact magnitude of direct and indirect effects towards the yield. In this context, path coefficient analysis is an important tool to partition the correlation coefficients into direct and indirect effects. This information is useful to breeder in selecting high yielding genotypes, important yield attributing characters and suitable breeding programme for improvement of crop.

Fennel is an important cash crop of North Gujarat and adjoining part of Rajasthan but very few scientific efforts have been made to improve this crop through genetic manipulations and therefore, the present study was undertaken to elicit information on the following aspects of fennel.

- To ascertain the nature and magnitude of variability present in fennel crop for yield and its attributes.
- 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 effects of individual character on yield.

REVIEW OF LITERATURE

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 fennel 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 the 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 genetic parameters such as genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), 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 because, highly heritable characters show the least influence of environment.

Jcshi *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 1000-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, high heritability was registered for days to maturity, 1000-grain weight, days to flower and yield per plant, number of branches and plant height. The yield per plant and the 1000-grain weight showed high genetic advance along with high heritability.

Arumugam and Muthukrishnan (1978) studied the extent of variability for five economic traits of coriander and reported significant amount of variability in all the traits except plant height. They also noticed wide range of variation for all the traits. Genetic variances and genetic coefficients 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 plant followed by days to 50 per cent flowering. The heritability estimates were 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 per cent for number of primary branches to 84.93 per cent for yield per plant. They also reported that despite high heritability, the genetic advance was low for number of umbellates per umbel as compared to other traits, indicating non-additive gene effect.

Rama Rao *et al.* (1981) observed high degree of genotypic and phenotypic coefficients of variation for total effective 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 estimates of coefficient of variation revealed that yield per plant, days to germination, number of seeds per umbel and plant height had high degree of genotypic coefficient of variation. Yield per plant exhibited the highest range, coefficient variation, heritability and genetic advance indicating presence of additive gene effect and advocated that 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.

Jindal *et al.* (1985) studied variability in 23 genotypes of coriander and 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 50 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 advocated that both these traits should be used as selection indices for crop improvement.

Jindal *et al.* (1986) estimated variability and other genetic parameters for seed yield of fennel and five related characters by using 15 genotypes. Plant height and number of umbellates per umbel showed high heritability. Expected genetic advance was high for seed yield and umbellates 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, numbers of branches per plant, days to flowering and maturity, umbels and umbellates per plant, seeds per umbellate, 1000-grains weight, straw and grain yield per plant in coriander. 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.

Agnihotri (1990) observed wide variability for different traits among 49 fennel accessions. He also observed higher estimates of heritability in broad sense and genetic advance for umbels per plant and yield per plant and per plot. While moderate estimates were obtained for grains per umbel and umbellates per umbel.

Shridar *et al.* (1990) studied genetic variability in coriander (*Coriandrum sativum* L.) 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 per cent flowering, 1000-seed weight and seed yield per plant.

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

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

Bhandari and Gupta (1993) recorded significant differences for all the twelve 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 and low for harvest index, effective branches, grain yield and grains per umbellate.

Patel (1995) observed wide range of variability in 29 genotype of fennel. Genotypic and phenotypic coefficients of variation were high for seed yield per plant, plant height, umbels per plant, effective umbels per plant, umbellates per umbel, seeds per umbellate and volatile oil. She reported high heritability for seed yield per plant, days to 50 per cent flowering, days to maturity, umbellates per main umbel, volatile oil and length of seed.

Agnihotri *et al.* (1997) evaluated forty-eight genotypes of fennel at the SKN College of Agriculture, Jobner, 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 per plant and yield per plot.

Dhayal *et al.* (1999) studied variability in nine genotypes of cumin grown under normal and saline soil. They reported higher estimates for genotypic coefficients of variance, phenotypic coefficients 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 coriander germplasm collection at Raigarh, Jabalpur, Madhya Pradesh. They found wide variation in yield components, indicating the suitability of the germplasm for breeding programme.

Tripathi *et al.* (2000) evaluated forty strains per genotypes of coriander including controls to work out phenotypic and genotypic coefficients of variation, 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 per cent 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). Relatively high estimates 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 *et al.* (2002) conducted study at Dharwad, Karnataka, India during the 1998 *kharif* season 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 couple 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 per plant.

Rajput and Singh (2002) studied variability in ten 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.

Singh *et al.* (2004) studied genetic variability and character association in ten varieties of cumin. They 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 per cent (test weight) to 94.10 per cent (days to flowering). It was 92.90 per cent 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 %).

Sharma *et al.* (2004) studied genetic variability in coriander and 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 to 50 %) for umbels per umbels per plant and seeds per umbel and low (up to 20 %) for days to 50 per cent flowering, plant height, branches per plant, umbellates per umbel and 1000-seed weight. High heritability coupled with high genetic advance (>50 %) was observed only for seeds per umbel. Days to 50 per cent flowering, plant height, umbels per plant and 1000-seed weight showed high heritability and moderate genetic advance as percentage of mean (21-50 %), indicating the importance of these traits in yield improvement programme.

Rajput *et al.* (2004) studied genetic variability in fennel and revealed significant differences among entries for all the characters studied including seed yield per plant. The phenotypic coefficients of variation were slightly higher than corresponding genotypic coefficients of variation for all the characters except soluble sugar content, suggested little environment influence on the characters expression. The coefficients of variation were high for total soluble sugar content, followed by umbels per plant, harvest index, crude fiber content and seed yield per plant while it was the lowest for days to 50 per cent flowering. The study showed high heritability values for most of the characters. Maximum heritability was observed for umbels per plant followed by seed yield per plant, harvest index, crude fiber content and biological yield per plant. Low heritability was observed for total soluble sugar content followed by days to 50 per cent flowering. The estimates of genetic gain were maximum for umbels per plant followed by harvest index, seed yield per plant, crude fiber content.

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). Correlation studies provide better understanding of yield components, which is helpful to the plant breeder for selecting suitable plant type (Robinson *et al.*, 1951 and 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 umbels 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 umbel per plant in 42 varieties of coriander.

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

Jindal *et al.* (1986) revealed that plant height, umbels per plant, umbellates per umbel, seeds per umbellate and seed yield were positively correlated with each another.

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, grain per umbellate and straw yield per plant.

Vedamuthu *et al.* (1989) collected data on seed yield and its components in 40 accessions in 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 per plant was the main trait contributing to yield, while plant height influenced yield through other traits.

In characters association study, Ramavtar *et al.* (1991b) 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 for cumin.

Sanker and Khader (1991b) studied correlation between yield and other component traits. They indicated that the yield had positive correlation with number of secondary branches only. Other traits had no bearing on yield.

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.

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

Patel (1995) found that seed yield showed significant positive correlation with plant height, number of branches per plant, number of effective umbels per plant, number of seeds per umbellate, number of seeds per umbel and 1000 seed weight in fennel.

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

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

Tripathi *et al.* (2000) estimated correlation between yield and it's components in coriander and reported that plant height, number of secondary branches, days to flowering, days to maturity and number of umbels per plant was the major yield components. However, number of primary branches, number of umbellates per umbel and number of seeds per umbel was negatively correlated with yield.

Yadav and Khurana (2001) studied the correlation between yield and its components (19 traits) in fennel. They observed that seed yield of fennel cv. HF-33 had inconsistent relationship with plant height, biological yield and number of primary branches. The relationship of number of primary, secondary and tertiary umbels and number of umbellates in main and primary umbels was not always positive and significant. The relationship of seed yield with number of seeds in main and primary umbels and test weight of different order umbels was positive and significant.

Positive correlation of seed yield per hectare with days to flowering, days to harvest, umbels per plant and essential oil content in seed was reported by Krishnamurthy *et al.* (2002) in Ajwain.

Jain *et al.* (2003) reported positive and significant correlation of seed yield with all the traits except number of days to 50 per cent flowering in coriander. Total plant height was positively associated with number of umbels per plant, height up to the base of the main umbel, number of branches per plant, number of umbellates per umbel, number of seeds per umbel and 1000-seed weight.

Singh *et al.* (2003) evaluated on 34 genotypes of fennel. Correlation analysis revealed 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 1000-seed weight and seeds per umbel suggesting thereby that the phenotypic selection could be made on the basis of per se performance.

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 in cumin. The seed yield per plant also had positive but non-significant association with seeds per umbel.

Sharma and Meena (2004) reported that the seed yield per plant had positive and significant correlation with plant height, branches per plant, umbels per plant, umbellates per umbel and seeds per umbel in coriander. 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.

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 in fennel. The days to 50 per cent flowering had negative correlation with seed yield.

2.3 PATH COEFFICIENT ANALYSIS :

Yield is the complex character, controlled by several characters and therefore prominent direct effect of any character on yield is most crucial while selection. Inter-relationship 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.

Wright (1921) originally developed the concept of path analysis and Dewey and Lu (1959) first used the technique for plant selection. Path coefficient analysis splits the correlation coefficient into direct and indirect effects. It measures the direct and indirect contribution of independent variable on dependent variable and thus helps to breeder in determining the important yield components.

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 in coriander.

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.

Sharma and Sharma (1989) studied path coefficient analysis with 200 lines of coriander and reported that number of branches per plant, umbellates per plant and 1000-grain weight were the most important characters for selecting high yielding genotypes, as they had direct positive effects on grain yield.

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.

Patel (1995) reported that number of umbellate per main umbel had the highest direct effect on seed yield followed by number of effective umbels per plant and number of seeds per main umbel in fennel.

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

Gurbuz *et al.* (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 per cent flowering had a significant negative correlation with seed yield. The results suggest that selection for greater total plant height, number of umbels per plant and 1000-seed weight, earliness, and less height up to the base of the main umbel will be effective for the improvement of the seed yield of coriander.

Singh *et al.* (2003) studied path analysis in thirty-four genotypes of fennel and revealed that 100 seed weight had maximum direct contribution towards yield followed by number of umbels per plant and seeds per umbel.

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

Rajput *et al.* (2004) made path coefficient study in fennel and 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.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The present investigation on fennel (*Foeniculum vulgare* Miller) was under taken to study variability, correlation and path coefficient analysis using 36 genotypes. The experiment was conducted at the Main Spices Research Station, Sardarkrushinagar Dantiwada Agricultural University, Jagudan during *kharif* 2003-2004.

3.1 GEOGRAPHIC AND ADAPHIC DETAILS :

Geographically, Jagudan is located on 23° 52' North latitude and 72° 43' East longitudes at an altitude of 70 meters. The soil type of Jagudan is sandy loam. The weather data for *kharif – rabi* 2003-04 are given in Appendix-I.

3.2 EXPERIMENTAL MATERIALS :

The present study consisted of thirty six diverse genotypes collected from germplasm materials maintained at the Main Spices Research Station, Sardarkrushinagar Dantiwada Agricultural University, Jagudan. The entries were selected on the basis of their per se performance for various traits.

The detail information of genotypes and their source is given in Table 3.1.

3.3 EXPERIMENTAL DETAILS :

The experimental was laid out in Randomized Block Design replicated thrice during *kharif* 2003. Each entry was grown in a single row of 9 meter length. The distance between two rows was 90 cm, while between two plants it was 60 cm. The recommended dose of fertilizers, other agronomic practices and plant protection measures were adopted for raising the crop.

Table 3.1 : Particulars of genotypes of fennel (*Foeniculum vulgare* Miller)

Sr. No.	Name of genotype	Source
1.	JF-275	Jagudan, Dist. Mehsana (Gujarat)
2.	JF-303	Jagudan, Dist. Mehsana (Gujarat)
3.	JF-351-1-2	Satlasana, Dist. Mehsana (Gujarat)
4.	JF-351-5	Satlasana, Dist. Patan (Gujarat)
5.	JF-376-5	Jagudan, Dist. Mehsana (Gujarat)
6.	JF-376-6	Jagudan, Dist. Mehsana (Gujarat)
7.	JF-420-1-1	Chandalaj, Dist. Patan (Gujarat)
8.	JF-427-1-1	Varvada, Dist. Patan (Gujarat)
9.	JF-460	Pratapgadh, Dist. Sabarkantha (Gujarat)
10.	JF-464-1	Pratapgadh, Dist. Sabarkantha (Gujarat)
11.	JF-471-2	Jagudan, Dist. Mehsana (Gujarat)
12.	JF-472-2-3	Jagudan, Dist. Mehsana (Gujarat)
13.	JF-490	Rupalkampa, Dist. Sabarkantha (Gujarat)
14.	JF-500-2	Jagudan, Dist. Mehsana (Gujarat)
15.	JF-501	Ganeshpurakampa, Dist. Sabarkantha (Gujarat)
16.	JF-512-2	Tintoi, Dist. Sabarkantha (Gujarat)
17.	JF-517-2	Ramsikampa, Dist. Sabarkantha (Gujarat)
18.	JF-518-2	Ramsikampa, Dist. Sabarkantha (Gujarat)
19.	JF-521	Ramsikampa, Dist. Sabarkantha (Gujarat)
20.	JF-525	Ramsikampa, Dist. Sabarkantha (Gujarat)
21.	JF-526	Sivapurakampa, Dist. Sabarkantha (Gujarat)
22.	JF-531-1	Shahpurakampa, Dist. Sabarkantha (Gujarat)
23.	JF-535-1	Shahpurakampa, Dist. Sabarkantha (Gujarat)
24.	JF-537	Shahpurakampa, Dist. Sabarkantha (Gujarat)
25.	JF-543	Jagudan, Dist. Mehsana (Gujarat)
26.	JF-568	Vadadal Dist. Kheda (Gujarat)
27.	JF-572	Jagudan, Dist. Mehsana (Gujarat)
28.	JF-573	Jagudan, Dist. Mehsana (Gujarat)
29.	JF-575	Jagudan, Dist. Mehsana (Gujarat)
30.	JF-578	Jagudan, Dist. Mehsana (Gujarat)
31.	JF-582	Jagudan, Dist. Mehsana (Gujarat)
32.	JF-592	Vadadal Dist. Kheda (Gujarat)
33.	EC-386375	Exotic culture (Germany)
34.	Guj.Fennel-1	Old variety
35.	Guj.Fennel-2	Popular variety
36.	Guj.Fennel-11	Newly released variety

3.4 CHARACTERS STUDIED :

The observations were recorded on five randomly selected plants from each replication for each genotype for all the characters, except days to 50 per cent flowering, days to 50 per cent maturity and amount of volatile oil content in seeds. Detail about individual character is as under.

3.4.1 Seed yield per plant (g)

The seeds from all effective umbels of a plant were weighed in grams.

3.4.2 Days to 50 per cent flowering

The number of days taken from the date of transplanting to the date of flowering of main umbel on fifty per cent plants were recorded as days to 50 per cent flowering.

3.4.3 Days to 50 per cent maturity

The number of days taken from the date of transplanting to the date of physiological maturity of main umbel on fifty per cent plants was recorded as day to 50 per cent maturity.

3.4.4 Plant height up to main umbel (cm)

The height of plant was measured in centimeter and from the base of plant to the top portion of main umbel at maturity.

3.4.5 Total plant height (cm)

The height of plant was measured in centimeter and from the base of plant to the topper portion of the plant at maturity.

3.4.6 Number of primary branches per plant

Total number of primary branches on each plant were counted at time of maturity and recorded. The primary branches are that branches which arise from main stem.

3.4.7 Total branches per plant

Total number of branches (umbel bearing branches) on each plant were counted at the time of maturity and recorded.

3.4.8 Number of effective umbels per plant

At the time of maturity effective umbels (seed bearing umbels) were recorded from each plant.

3.4.9 Diameter of main umbel (cm)

The diameter of main umbel measured in centimeter and recorded.

3.4.10 Number of umbellates per umbel

The number of effective umbellates on main umbel was counted.

3.4.11 Number of seeds per umbellate

The number of seeds on randomly selected five umbellates from main umbel were counted and recorded.

3.4.12 Number of seeds per main umbel

Total number of seeds on main umbel were counted and recorded.

3.4.13 Length of internode (cm)

At the time of maturity length of second last internode was measured in centimeter and recorded.

3.4.14 Test weight (g)

One thousand seeds were counted at random from the bulk produce of selected plants and were weighted in grams.

3.4.15 Volatile oil content of seeds

The oil content was estimated by water distillation method. For distillation a sample of seeds was taken from the bulk produce of each genotype from each replication.

3.5 STATISTICAL ANALYSIS :

Replication wise mean values of individual character were subjected to statistical analysis with the help of computer software. 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

Source	d.f.	Mean Squares	Expected MS
Replication (r)	(r-1)	M_r	$s^2_e + gs^2_r$
Genotypes (g)	(g-1)	M_g	$s^2_e + rs^2_g$
Error (e)	(r-1) (g-1)	M_e	s^2_e

Where,

g : Number of genotypes

r : Number of replications

s^2_e, s^2_r, s^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 using following formulae :

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 :

$$s^2_g = \frac{M_g - M_e}{r}$$

Where,

s^2_g	:	Genotypic variance
M_g	:	Genotypic mean square of the character
M_e	:	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.

$$s^2_e = M_e$$

Where,

s^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 :

$$s^2_p = s^2_g + s^2_e$$

Where,

s^2_p	:	Phenotypic variance
s^2_g	:	Genotypic variance
s^2_e	:	Environmental 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.

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

Where,

$\bar{X}$: General mean

X_{ij} : Observed value in j^{th} genotype in i^{th} replication

S : 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.

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

Where,

S.Em. : Standard error of mean

s^2_e : 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 % =S.Em. x $\sqrt{2}$ x table $t_{0.05}$ at error d.f.

Where,

S.Em. =Standard error of mean

3.7.5 Co-efficient 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. %)

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

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

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

Where,

σ_p^2 : Phenotypic variance

σ_g^2 : Genotypic variance

$\bar{X}$: 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 was calculated by using the formula proposed by Allard (1960).

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

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 per cent. 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 per cent =2.06
σ^2_p	:	Phenotypic standard deviation

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

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

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

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 coefficient for all the characters was 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	d.f.	M.S.P.	Expected MSP
Replications (r)	(r-1)	-	-
Genotypes (g)	(g-1)	MSP_1	$Cos^2 + rCos^2_{g1.2}$
Error	(r-1) (g-1)	MSP_2	$s^2_{e1.2}$

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 co-variances 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 ($r_{e1.2}$)**

$$r_{e1.2} = \frac{CoV_{e1.2}}{\sqrt{\sigma^2_{e1} \times \sigma^2_{e2}}}$$

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
s^2_{g1}, s^2_{p1}	:	Genotypic and phenotypic variance for trait first
s^2_{g2}, s^2_{p2}	:	Genotypic and phenotypic variance for trait second
s^2_{e1}, s^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.

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

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

$$|\quad\quad|\quad\quad|\quad\quad|\quad\quad\quad\quad\quad\quad|\quad\quad\quad\quad|$$

$$r_{iy} = p_{iy} + r_{i1y}p_{1y} + r_{i3}p_{3y} + \ldots\ldots\ldots\ldots\ldots r_{i(i-1)}p_{iy} + \ldots\ldots\ldots r_{in}p_{ny}$$

$$|\quad\quad|\quad\quad|\quad\quad|\quad\quad\quad\quad\quad\quad|\quad\quad\quad\quad|$$

$$r_{ny} = p_{ny} + r_{n1}p_{2n} + r_{n3}p_{3n} + \ldots\ldots\ldots\ldots\ldots r_{n(n-1)}p_{ny} + \ldots\ldots\ldots r_{nn}p_{ny}$$

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 :

$$\underset{\text{Matrix-A}}{\begin{pmatrix} r_{1y} \\ r_{2y} \\ r_{3y} \\ \vdots \\ r_{iy} \\ \vdots \\ r_{ny} \end{pmatrix}} = \underset{\text{Matrix-C}}{\begin{pmatrix} 1 & r_{12} & r_{13} & \cdots & r_{1i} \\ r_{21} & r_{1} & r_{23} & \cdots & r_{2i} \\ r_{31} & r_{32} & 1 & \cdots & r_{3i} \\ & \vdots & & & \\ r_{i1} & r_{i2} & r_{i3}.r_{ii} & \cdots & r_{in} \\ & \vdots & & & \\ r_{n1} & r_{n2} & r_{n3}.r_{ni} & \cdots & r_{nn} \end{pmatrix}} \times \underset{\text{Matrix-B}}{\begin{pmatrix} p_{1y} \\ p_{2y} \\ p_{3y} \\ \vdots \\ p_{iy} \\ \vdots \\ p_{ny} \end{pmatrix}}$$

With the help of matrix inversion (Goulden, 1962) the following form of inverted "C" matrix was obtained.

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

Where,

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

The direct effect was calculated as under :

$$P_{1y} = \sum_{i=1}^{n} C_{1i} * r_{1y}$$

$$P_{2y} = \sum_{i=1}^{n} C_{2i} * r_{2y}$$

$$P_{3y} = \sum_{i=1}^{n} C_{3i} * r_{3y}$$

$$\vdots \qquad \vdots \qquad \vdots$$

$$P_{iy} = \sum_{i=1}^{n} C_{ii} * r_{iy}$$

$$\vdots \qquad \vdots \qquad \vdots$$

$$P_{ny} = \sum_{i=1}^{n} C_{ni} * r_{ny}$$

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,

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

$$= R^2$$

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results obtained in the present investigation are presented under the following heads :

4.1 Analysis of variance

4.2 Mean performance and phenotypic variability

4.3 Variance components

4.4 Genotypic and phenotypic coefficients of variation

4.5 Heritability

4.6 Genetic advance

4.7 Correlation coefficients

4.8 Path coefficient analysis

4.1 ANALYSIS OF VARIANCE :

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 genetic variability among genotypes for all the traits under study.

4.2 MEAN PERFORMANCE AND PHENOTYPIC VARIABILITY :

The data on mean performance of 36 genotypes of fennel evaluated in respect of different traits are given in Appendix-II and range of phenotypic variability is presented in Table 4.2. The variety Gujarat Fennel-11 was release for general cultivation in Gujarat during 2002. The performance of genotypes

Table 4.1 : Analysis of variance of various characters in fennel

Characters	Repli. M.S. (2 df)	Treat. M.S. (35 df)	Error M.S. (70 df)	S.Em.	C.D. at 5 %	C.V. %
Grain yield per plant (g)	424.06**	2023.26**	139.50	9.64	27.21	9.10
Days to 50 per cent flowering	389.59**	351.35**	6.06	1.42	4.01	2.33
Days to maturity	345.34**	941.03**	300.24	10.00	28.23	8.74
Plant height up to main umbel (cm)	26.78**	585.18**	162.39	7.36	20.76	10.71
Plant height (cm)	136.15**	965.86**	133.36	6.67	18.81	7.13
Number of primary branches per plant	2.00	10.34	0.63	0.46	1.29	7.95
Total branches per plant	5.64**	310.17**	19.34	3.59	10.15	10.58
Number of effective umbels per plant	96.35**	165.54**	33.94	3.36	9.49	17.65
Diameter of main umbel (cm)	5.75**	11.51**	2.68	0.95	2.67	9.77
Number of Umbellate per Umbel	3.05**	142.57**	17.05	2.38	6.73	8.83
Number of Seeds per Umbellate	2.98**	77.96**	17.06	2.38	6.72	10.43
Number of Seeds per main umbel	112.00**	479353**	39199	144.31	322.51	10.74
Length of internode (cm)	2.50**	14.98**	4.17	1.18	3.33	9.76
1000-seed weight (g)	0.59	3.39	0.12	0.20	0.55	4.00
Volatile Oil (%)	0.0195	0.445	0.0106	0.06	0.17	6.53

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

Characters	Mean	Range	Genotypic variance	Phenotypic variance	Environment variance
Grain yield per plant (g)	149.0	105-214	627.92	767.42	139.50
Days to 50 per cent flowering	105.6	79.0–129.3	115.10	121.16	6.06
Days to maturity	198.3	138.3–230.3	213.60	513.83	300.24
Plant height up to main umbel (cm)	119.0	92–144	140.93	303.32	162.39
Plant height (cm)	161.9	111.7–200.3	277.60	410.96	133.36
Number of primary branches per plant	9.9	6.4–13.5	3.24	3.86	0.62
Total branches per plant	42.39	23.7–69.7	96.94	116.28	19.34
Number of effective umbels per plant	33.0	17.3–50.8	43.87	77.81	33.94
Diameter of main umbel (cm)	16.7	11.7–19.8	2.94	5.62	2.68
Number of Umbellate per Umbel	46.7	31.3–62.6	41.84	58.89	17.05
Number of Seeds per Umbellate	39.6	29.8–50.2	20.3	37.36	17.06
Number of Seeds per main umbel	1843.1	1074–2650	146718	185917	39199
Length of internode (cm)	20.9	15.9–24.3	3.61	7.78	4.17
1000-seed weight (g)	8.5	5.9–10.2	1.09	1.21	0.12
Volatile Oil (%)	1.6	1.2–3.0	0.14	0.16	0.02

therefore, was compared with the best variety, Gujarat Fennel-11. The range of phenotypic variability is described in subsequent paragraphs.

4.2.1 Seed yield per plant

The range of phenotypic variability for seed yield per plant was varied from 105.0 g (JF-537) to 214.0 g (JF-521) with general mean of 149.0 g. Seven genotypes, JF-521 (214.0 g), JF-512-2 (182.0 g), JF-568 (172.0 g), JF-525 (170.0 g), Jf-490 (165.0 g), JF-518-2 (165.0 g) and JF-275 (164.0 g) out yielded the best variety Gujarat Fennel-11. But only one genotype, JF-521 (214.0 g) had significantly higher seed yield per plant.

4.2.2 Days to 50 per cent flowering

The range of phenotypic variability for this trait was varied from 79.0 days (JF-543) to 129.3 days (JF-490) with general mean being 105.6 days. Fourteen genotypes, JF-543 (79.0 days), JF-376-6 (84.3 days), JF-568 (84.7 days), JF-376-5 (91.7 days), JF-512-2 (91.7 days), JF-572 (95.0 days), JF-573 (98.3 days), JF-582 (99.3 days), JF-521 (99.7 days), JF-472-2-3 (100.0 days), JF-351-5 (101.7 days), JF-275 (102.3 days), JF-525 (102.3 days) and JF-592 (103.7 days) were significantly early in flowering than the best check variety. While six genotypes, JF-490 (129.3 days), Gujarat Fennel-1 (124.7 days), JF-420-1-1 (119.7 days), JF-464-1 (119.0 days), JF-460 (114.0 days) and EC-386375 (113.7 days) were significantly late than the best check.

4.2.3 Day to 50 per cent maturity

The phenotypic variability for days to 50 per cent maturity was varied from 138.3 days (JF-526) to 230.7days (JF-490) with general mean of 198.3 days. Only one genotype, JF-526 (138.3 days) was significantly early than the best variety Gujarat Fennel-11.

4.2.4 Plant height up to main umbel

The range of phenotypic variability for plant height up to main umbel varied from 91.7 cm (JF-537) to 144.0 cm (JF-501) with general mean being 119.0 cm. The genotype JF-537 (91.7 cm), JF-535-1 (92.0 cm), JF-472-2-3 (96.7 cm), JF-543 (98.0 cm) and JF-531-1 (99.0 cm) were significantly dwarf than Gujarat Fennel-11 (124.0 cm).

4.2.5 Total Plant height

The range of phenotype variability for total plant height varied from 111.7 cm (JF-537) to 200.3 cm (JF-501) with general mean of 161.9 cm. The genotype JF-537 (111.7 cm), JF-575 (123.0 cm), JF-543 (135.0 cm), JF-471-2 (135.4 cm) and JF-460 (146.7 cm) were significantly dwarf than Gujarat Fennel-11 (166.0 cm). While genotypes JF-501 (200.3 cm) and JF-521 (188.7 cm) were significantly tall than the check variety.

4.2.6 Number of primary branches per plant

The range of phenotypic variation in case of primary branches per plant was spreaded from 6.4 (JF-537) to 13.5 (JF-275) having general mean of 9.9. Genotypes, JF-275 and JF-303 were significantly superior for primary branches per plant as compared to the control variety.

4.2.7 Total branches per plant

The range of phenotypic variability for total branches per plant varied from 23.7 (JF-537) to 69.7 (JF-512-2) with general mean of 41.6. Two genotypes JF-512-2 (69.7) and JF-521 (68.9) significantly debarred the best variety for this trait.

4.2.8 Number of effective umbels per plant

The phenotypic variation in case of number of effective umbels per plant was ranging from 17.3 (JF-537) to 50.8 (JF-512-2) with general mean being 33.0. Genotype JF-512-2 (50.8) had significantly more number of effective umbels per plant.

4.2.9 Diameter of main umbel

The range of phenotypic variability for main umbel diameter was varied from 11.7 cm (JF-512-2) to 19.8 cm (Gujarat Fennel-1) being general mean of 16.7 cm. None of the genotype significantly debarred the best variety for this trait. However, Gujarat Fennel-1 (19.8 cm), JF-501 (19.2 cm), JF-420-1-1 (18.5 cm), JF-464-1 (19.4 cm), JF-472-2-3 (19.4 cm), JF-490 (19.4 cm), JF-568 (19.2 cm), JF-572 (18.7 cm), JF-582 (19.6 cm) and Gujarat Fennel-2 (18.5 cm) had more diameter of main umbel than the best check variety.

4.2.10 Number of umbellates per main umbel

The range of phenotypic variability for this trait was varied from 31.3 (JF-303) to 62.6 (JF-568) with general mean of 46.7. Five genotypes JF-568 (62.6), JF-464-1 (57.7), JF-518-2 (55.7), JF-573 (55.3) and JF-521 (54.4) had more number of umbellates per main umbel than the best check variety. Out of which genotype JF-568 (62.6) had significantly higher number of umbellates per main umbel.

4.2.11 Number of seeds per umbellate

The range of phenotypic variation for number of seeds per umbellate varied from 29.8 (JF-303) to 50.2 (JF-582, JF-592) with general mean being 39.6. Twenty genotypes showed significantly more number of seeds per umbellate than the best check variety. The best five genotypes were JF-592 (50.2), JF-582 (50.2), JF-578 (48.1), JF-464-1 (46.3) and JF-521 (45.3).

4.2.12 Number of seeds per main umbel

The wide range of phenotypic variability was recorded for this trait (1074 to 2650) with general mean of 1843.1. Fifteen genotypes, JF-427-1-1, JF-460, JF-464-1, JF-471-2, JF-490, JF-517-2, JF-518-2, JF-521, JF-525, JF-526, JF-535-1, JF-568, JF-573, JF-582 and JF-592 gave significantly more number of seeds per main umbel than the best check variety. Among these five top genotypes were JF-464-1 (2650.7), JF-582 (2564.3), JF-521 (2443.3), JF-518-2 (2401.7) and JF-592 (2340.3).

4.2.13 Length of internode

The range of phenotypic variability for this trait varied from 15.9 cm (JF-537) to 24.3 cm (Gujarat Fennel-11) having general mean of 20.9 cm. Fifteen genotypes JF-351-5, JF-376-5, JF-420-1-1, JF-471-2, JF-501, JF-512-2, JF-517-2, JF-518-2, JF-526, JF-535-1, JF-537, JF-568, JF-578, JF-592 and Gujarat Fennel-2 gave significantly less length of internode. The best three genotypes were JF-537 (15.9 cm), JF-535-1 (17.5 cm) and JF-471-1 (17.7 cm).

4.2.14 Test weight

The range for test weight varied from 5.9 g to 10.2 g with general mean of 8.5 g. Six genotypes, JF-568, JF-573, Gujarat Fennel-1, JF-525, JF-575 and JF-471-2 had significantly more test weight than the best check variety. The maximum test weight observed for JF-568 (10.2 g) followed by JF-537 (9.9 g) and Gujarat Fennel-1 (9.6 g).

4.2.15 Volatile oil content in seed

Volatile oil content varied from 1.2 to 3.0 per cent with general mean of 1.6 per cent. Two genotypes EC-386375 (3.0 %) and JF-531-1 (2.7 %) were significantly superior for volatile oil content in seed than the best check variety.

4.3 VARIANCE COMPONENTS :

Genotypic and phenotypic variances were near to each other for days to 50 per cent flowering, number of primary branches per plant, total branches per plant, test weight and volatile oil content in seeds with minimum values of environmental variation. The values of environmental variance were more than genotypic variance for days to 50 per cent maturity, plant height up to main umbel and length of internode. The magnitude of genotypic and environmental variances were all most same for total number of effective umbels per plant and diameter of main umbel. The results suggested that the former traits were less affected by environment while latter were sensitive to environment.

4.4 GENOTYPIC AND PHENOTYPIC COEFFICIENTS OF VARIATION :

The genotypic and phenotypic coefficients of variation for all the characters are presented in Table 4.3.

4.4.1 Genotypic Coefficients of Variation (GCV)

The genotypic coefficients of variation for various traits varied from 7.37 per cent (days to 50 per cent maturity) to 26.82 per cent (total branches per plant). Moderate to high genotypic coefficients of variation were observed for total branches per plant (26.82 %), volatile oil content in seed (24.13 %), number of seeds per main umbel (20.78 %), number of effective umbels per plant (20.07 %), number of primary branches per plant (18.07 %), grain yield per plant (14.17 %) and number of umbellates per main umbel (13.84 %). The rest of the characters had low values of genotypic coefficients of variation.

4.4.2 Phenotypic Coefficient of Variation (PCV)

The estimates of phenotypic coefficients of variation revealed that it was the highest for total branches per plant (28.75 %) followed by number of effective umbels per plant (26.73 %), volatile oil per cent in seeds (25.00 %), number of seeds per main umbel (23.39 %). Moderate values were recorded for number of primary branches per plant (19.76 %), number of umbellates per main umbel (16.42 %), grain yield per plant (14.68 %), plant height up to main umbel (14.64 %) and diameter of main umbel (14.16 %). Length of internode (13.32 %), total plant height (12.52 %), test weight (12.29 %), days to 50

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

Characters	GCV (%)	PCV (%)	h^2 (Broad sense) (%)	Genetic advance	GA as % of general mean
Grain yield per plant (g)	14.17	14.68	93.10	41.97	28.16
Days to 50 per cent flowering	10.15	10.42	95.00	21.54	20.39
Days to maturity	7.37	11.43	41.60	19.41	9.79
Plant height up to main umbel (cm)	9.99	14.64	46.46	16.67	14.01
Plant height (cm)	10.29	12.52	67.54	28.20	17.42
Number of primary branches per plant	18.07	19.76	83.81	3.39	34.12
Total branches per plant	26.82	28.75	87.00	21.84	51.52
Number of effective umbels per plant	20.07	26.73	56.38	10.24	31.04
Diameter of main umbel (cm)	10.24	14.16	52.33	2.56	15.26
Number of Umbellate per Umbel	13.84	16.42	71.04	11.23	24.03
Number of Seeds per Umbellate	11.39	15.43	54.33	6.84	17.27
Number of Seeds per main umbel	20.78	23.39	78.92	700.96	38.03
Length of internode (cm)	9.07	13.32	46.33	2.66	12.71
1000-seed weight (g)	12.29	12.92	90.42	2.05	24.06
Volatile Oil (%)	24.13	25.00	93.17	0.76	47.99

per cent maturity (11.43 %) and days to 50 per cent flowering (10.42 %) had low phenotypic coefficient of variation.

4.5 HERITABILITY :

The estimates of heritability in broad sense for all the 15 traits studied and are presented in table 4.3. In general the estimates were high for all the traits. The range of heritability varied from 41.60 per cent (days to 50 % maturity) to 95.00 per cent (days to 50 % flowering). High heritability values were recorded for days to 50 per cent flowering (95.00 %), volatile oil content in seed (93.17 %), grain yield per plant (93.10 %), test weight (90.42 %), total branches per plant (87.00 %) and number of primary branches per plant (83.81 %). Moderate values were observed for number of seeds per main umbel (78.92 %), number of umbellates per main umbel (71.04 %), total plant height (67.54 %), number of effective umbels per plant (56.38 %), number of seeds per umbellate (54.33 %) and diameter of main umbel (52.33 %). Plant height up to main umbel (46.46 %), length of internode (46.33 %) and day to 50 per cent maturity (41.57 %) had low heritability.

4.6 GENETIC ADVANCE :

The expected values of genetic advance for the characters at 5 per cent selection intensity were calculated. Since these values are not comparable, they were expressed as expected genetic advance in percentage of mean and given in Table 4.3. The high values genetic advance was observed for total branches per plant (51.52 %), volatile oil content in seed (47.99 %) and number of seeds per main umbel (38.03 %). Moderate values were recorded for number of primary branches per plant (34.12 %), number of effective umbels per plant (31.04 %), grain yield per plant (28.16 %), test weight (24.06 %), number of umbellates per main umbel (24.03 %) and day to 50 per cent flowering (20.39 %). Low genetic advance was observed for total plant height (17.42 %), number of seeds per umbellate (17.27 %), diameter of main umbel (15.26 %), plant height up to main umbel (14.01 %), length of internode (12.71 %) and day to 50 per cent maturity (9.79 %).

4.7 CORRELATION COEFFICIENTS :

The correlation coefficients between seed yield per plant and fourteen traits and among them selves were estimated at phenotypic and genotypic levels (Table 4.4). It was revealed that magnitude of genotypic correlations were higher than their corresponding phenotypic correlations. Secondly, all the correlation coefficients values were similar in sign or direction at both the levels. The results of correlation between different paired characters are described below.

4.7.1 Seed yield per plant

Seed yield per plant was positively and significantly correlated with number of effective umbels per plant (r_p =0.686, r_g =0.930), total branches per plant (r_p =0.808, r_g =0.863), number of primary branches per plant (r_p =0.688, r_g =0.775), total plant height (r_p =0.540, r_g =0.662), number of umbellates per umbel (r_p =0.341, r_g =0.356) and number of seeds per main umbel (r_p =0.325, r_g =0.384) at both the levels.

Table 4.4 : Genotype (G) and Phenotypic (P) correlation coefficients in fennel

Character	r	Days to 50 per cent flowering	Days to maturity	Plant height up to main umbel (cm)	Plant height (cm)	Number of primary branches per plant	Total branches per plant	Number of effective umbels per plant	Diameter of main umbel (cm)	Number of Umbellate per Umbel	Number of Seeds per Umbellate	Number of Seeds per main umbel	Length of internode (cm)	1000-seed weight (g)	Volatile Oil (%)
Seed yield per plant	P	-0.013	-0.030	0.269	0.540**	0.688**	0.808**	0.686**	0.140	0.341*	0.216	0.325*	0.107	-0.120	0.079
	G	-0.014	-0.096	0.382*	0.662**	0.775**	0.863**	0.930**	0.180	0.356*	0.213	0.384*	0.158	-0.151	0.092
Days to 50 per cent flowering	P	1.000	0.459**	0.203	0.133	0.147	-0.072	-0.040	0.242	0.113	0.102	0.142	-0.028	0.010	0.176
	G		0.781**	0.324	0.168	0.141	-0.095	-0.019	0.392*	0.107	0.099	0.194	-0.009	-0.007	0.187
Days to maturity	P		1.000	0.145	-0.001	0.076	-0.073	-0.118	0.167	0.091	0.117	0.125	0.031	-0.107	-0.103
	G			0.358*	0.061	0.134	-0.155	-0.222	0.369*	0.107	0.162	0.252	0.050	0.149	-0.126
Plant height up to main umbel (cm)	P			1.000	0.703**	0.359*	0.250	0.179	0.290	-0.085	0.082	0.063	0.495**	0.184	0.002
	G				0.917**	0.557**	0.433**	0.339*	0.462**	-0.079	0.261	0.098	0.538**	-0.226	0.013
Plant height (cm)	P				1.000	0.554**	0.494**	0.510**	0.301	0.069	0.221	0.179	0.274	-0.265	0.139
	G					0.663**	0.603**	0.621**	0.454**	0.035	0.273	0.230	0.386*	-0.352*	0.200
Number of primary branches per plant	P					1.000	0.748**	0.636**	0.257	0.064	0.003	0.036	0.088	-0.199	0.064
	G						0.843**	0.845**	0.420**	0.025	-0.080	-0.002	0.179	-0.249	0.075
Total branches per plant	P						1.000	0.781**	0.009	0.052	-0.001	-0.137	-0.009	-0.144	0.106
	G							0.961**	0.031	-0.175	-0.344*	-0.171	0.119	-0.188	0.119
Number of effective umbels per plant	P							1.000	0.036	-0.007	-0.099	-0.088	-0.034	-0.149	0.155
	G								0.009	-0.089	-0.291	-0.178	-0.045	-0.233	0.255
Diameter of main umbel (cm)	P								1.000	0.155	0.212	0.244	0.257	0.100	-0.120
	G									0.278	0.433**	0.357*	0.373*	0.168	-0.179
Number of Umbellate per Umbel	P									1.000	0.477**	0.668**	0.008	0.193	-0.119
	G										0.182	0.897**	0.138	0.193	-0.142
Number of Seeds per Umbellate	P										1.000	0.604**	0.130	0.039	0.064
	G											0.930**	0.477**	-0.014	0.097
Number of Seeds per main umbel	P											1.000	0.136	0.072	-0.029
	G												0.330*	0.111	-0.053
Length of internode (cm)	P												1.000	-0.218	0.137
	G													-0.331*	0.234
1000-seed weight (g)	P													1.000	-0.463**
	G														-0.503**

* and ** significant at 5 and 1 per cent levels, respectively.

4.7.2 Days to 50 per cent flowering

This character was significantly and positively correlated with days to 50 per cent maturity (r_p =0.459, r_g =0.781) at phenotypic and genotypic levels. It was significantly correlated with diameter of main umbel (r_g = 0.392) at genotypic level only.

4.7.3 Days to 50 per cent maturity

Days to 50 per cent maturity had positive and significant correlation with plant height up to main umbel (r_g =0.358) and diameter of main umbel (r_g =0.369) at genotypic level.

4.7.4 Plant height up to main umbel

This character was highly significant and positively correlated with total plant height (r_p = 0.703, r_g = 0.917), number of primary branches per plant (r_p = 0.359, r_g = 0.557) and length of internode (r_p = 0.495, r_g = 0.538) at genotypic and phenotypic levels. Plant height up to main umbel had positive and significant correlation with number of effective umbels per plant (r_g = 0.339), total branches per plant (r_g =0.466) and diameter of main umbel (r_g =0.462) at genotypic level only.

4.7.5 Total plant height

Total plant height had positive and significant correlation with number of primary branches per plant (r_p =0.554, r_g =0.663), total branches per plant (r_p =0.494, r_g =0.603) and number of effective umbels per plant (r_p =0.510, r_g = 0.621) at both the levels. But it had positive and significant correlation with length of internode (r_g =0.386) and diameter of main umbel (r_g =0.454) at genotypic level only. Whereas, it was significantly but negatively associated with test weight (r_g =-0.352) at genotypic level only.

4.7.6 Primary branches per plant

Number of primary branches per plant had positive and highly significant correlation with total branches per plant (r_p =0.748, r_g =0.843) and number of effective umbels per plant (r_p =0.636, r_g =0.845) at both the levels. But it had positive and significant correlation with diameter of main umbel (r_g =0.420) at genotypic level only.

4.7.7 Total branches per plant

Total branches per plant had positive and highly significant association with number of effective umbels per plant (r_p =0.781, r_g =0.961) at both the levels. It had negative and significant correlation with number of seeds per umbellate (r_g =-0.344) at genotypic level only.

4.7.8 Number of effective umbels per plant

None of the character significantly correlated with this character. However, it had positive correlation with volatile oil content (r_p = 0.155, r_g =0.255) at both the levels and negative correlation with number of seeds per umbellate (r_g = -0.291) and test weight (r_g =-0.233) at genotypic level only.

4.7.9 Diameter of main umbel

Diameter of main umbel had positive and significant association with number of seeds per umbellate (r_g =0.433), number of seeds per main umbel (r_g =0.357) and length of internode (r_g =0.373) at genotypic level only.

4.7.10 Number of umbellates per main umbel

Number of umbellates per main umbel had positive and significant correlation with number of seeds per main umbel (r_p =0.668, r_g =0.897) at both the levels but it had positive and significant correlation with number of seeds per umbellate (r_p =0.477) at phenotypic level only.

4.7.11 Number of seeds per umbellate

This character had positive and highly significant correlation with number of seeds per main umbel (r_p =0.604, r_g =0.930) at both the levels but with length of internode (r_g =0.477) at genotypic level.

4.7.12 Number of seeds per main umbel

Number of seeds per main umbel showed positive and significant correlation with length of internode (r_g =0.330) at genotypic level only.

4.7.13 Length of internode

Length of internode had negative and significant correlation with test weight (r_g = -0.331) at genotypic level.

4.7.14 Test weight

It has negative and highly significant correlation with volatile oil (r_p =-0.463, r_g = - 0.503) at both the levels.

4.7.15 Volatile oil content in seed

It has negative and highly significant correlation with test weight (r_p =-0.463, r_g = -0.503) at both levels.

4.8 PATH COEFFICIENT ANALYSIS :

In present study, seven characters *viz.,* plant height up to main umbel, number of primary branches per plant, total branches per plant, number of effective umbels per plant, diameter of main umbel, number of umbellates per main umbel and number of seeds per umbellate were selected for partitioning their genotypic correlation coefficients with seed yield into direct and indirect effects. The seed yield per plant is considered as the resultant variable while the above mentioned seven component traits as the causal variables. The direct and indirect effects of these causal variables on seed yield per plant are presented in Table 4.5.

4.8.1 Plant height up to main umbel vs. seed yield

The genotypic correlation between plant height up to main umbel and seed yield per plant was positive and highly significant (r_g =0.382). However, the direct effect of this character on seed yield per plant was negative and very low (-0.069). The indirect effects of this trait via total branches per plant (0.248), number of effective umbels per plant (0.251) and number of seeds per umbellate (0.154) were positive and high.

4.8.2 Number of primary branches per plant vs. seed yield

Number of primary branches per plant showed highly significant and positive correlation with seed yield (r_g =0.775). But direct effect of this trait on seed yield was negative (-0.218). Its indirect effects through number of effective umbels per plant (0.627) and total branches per plant (0.482) were

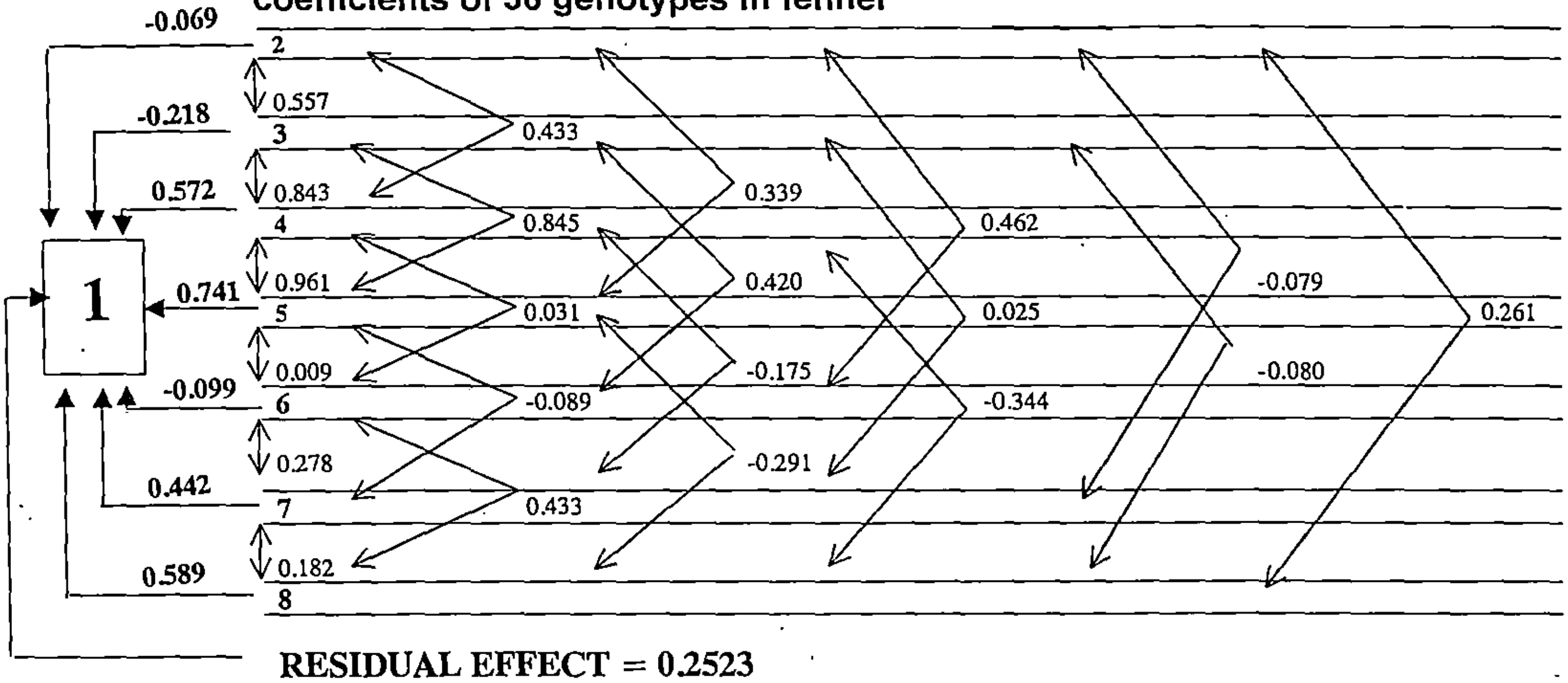
Table 4.5 : Path coefficient analysis showing direct (Bold letter) and indirect effect of seven traits on grain yield per plant in fennel

Characters	Plant height up to main umbel (cm)	Number of primary branches per plant	Total branches per plant	Number of effective umbels per plant	Diameter of main umbel (cm)	Number of umbellates per main umbel	Number of seeds umbellates	Genotypic correlation with seed yield per plant
Plant height up to main umbel (cm)	**-0.069**	-0.121	0.248	0.251	-0.046	-0.035	0.154	0.382*
Number of primary branches per plant	-0.038	**-0.218**	0.482	0.627	-0.042	0.011	-0.047	0.775**
Total branches per plant	-0.030	-0.183	**0.572**	0.786	-0.004	-0.077	-0.203	0.863**
Number of effective umbels per plant	-0.023	-0.184	0.607	**0.741**	-0.001	-0.039	-0.171	0.930**
Diameter of main umbel (cm)	-0.032	-0.092	0.018	0.007	**-0.099**	0.123	0.255	0.180
Number of umbellates per main umbel	0.005	-0.005	-0.100	-0.066	-0.028	**0.442**	0.108	0.356*
Number of seeds umbellates	-0.018	0.017	-0.197	-0.216	-0.043	0.081	**0.589**	0.213

Residual effect =0.2523

* and ** significant at 5 and 1 per cent levels, respectively.

Fig 1 : Path diagram indicating direct effect of components of yield and their correlation coefficients of 36 genotypes in fennel



<-> Correlation coefficient, ← Direct effect

Diagrammatic representation of factors influencing seed yield per plant.

1 Seed yield per plant
2 Plant height up to main umbel
3 Number of primary branches per plant
4 Total branches per plant
5 Number of effective umbel per plant
6 Diameter of main umbel
7 Number of umbellates per main umbel
8 Number of seeds per umbellate

positive and high. These indirect values may be responsible to give positive correlation of this trait with yield.

4.8.3 Total branches per plant vs. seed yield

Highly significant and positive genotypic correlation was observed between total branches per plant (r_g =0.863) and seed yield. The direct effect of total branches per plant on seed yield was positive and very high (0.572). The positive and high influence was registered indirectly via number of effective umbels per plant (0.786). Its contribution via primary branches per plant (-0.183), number of seeds per umbellate (-0.203), number of umbellates per umbel (-0.077) and plant height up to main umbel (-0.030) was negative.

4.8.4 Number of effective umbels per plant vs. seed yield

The genotypic correlation between number of effective umbels per plant and seed yield was positive and highly significant (r_g =0.930). The direct effect of this trait on seed yield was positive and very high (0.741). The positive and high indirect effects via total branches per plant. (0.607) was observed. Its indirect effects through number of primary branches per plant (-0.184), number of seeds per umbellate (-0.171), number of umbellates per umbel (-0.039) and plant height up to main umbel (-0.023) were negative.

4.8.5 Diameter of main umbel vs. seed yield

The genotypic correlation between diameter of main umbel and seed yield was positive (r_g = 0.180). The direct effect of this trait was negative (-0.099). The positive influence was registered indirectly by number of seeds per umbellate (0.255), number of umbellate per umbel (0.123), total branches per plant (0.018) and number of effective umbels per plant (0.007) while its indirect effects via number of primary branches per plant (-0.092) and plant height up to main umbel (-0.032) were negative.

4.8.6 Number of umbellates per main umbel vs. seed yield

Number of umbellates per main umbel showed positive and significant correlation with seed yield ($r_g = 0.356$). The direct effect of this trait on seed yield was positive and high (0.442). It had positive indirect effects via number of seeds per umbellate (0.108) and plant height up to main umbel (0.005) while negative influence was observed via rest of the traits.

4.8.7 Number of seeds per umbellate vs. seed yield

Number of seeds per umbellate exhibited positive genotypic correlation ($r_g = 0.213$). The direct effect of this trait was positive and high (0.589). The indirect effects via number of umbellates per umbel (0.081) and number of primary branches per plant (0.017) while negative influence was observed via rest of the traits.

DISCUSSION

V. DISCUSSION

The aim of the present investigation was to assess genetic variability for various traits and identify superior genotypes from germplasm to be included in future breeding programmes. A total of 36 genotypes of fennel were evaluated for their yield potential, extent of variability at phenotypic and genotypic levels, heritability, genetic advance, character associations and path analysis. These are the basic parameters in framing better breeding programmes for improvement of any crop.

The presence of adequate genetic variability in the base material is a prerequisite for any breeding programme. In addition, the nature and magnitude of variability for various yield attributing traits and extent of environmental influence on these characters, forms the basis on which a breeder can predict the extent of dependence on phenotypic selection for improvement of a character. Further, knowledge of the interrelationship of quantitative traits of economic importance with seed yield and among themselves is essential for improvement of a complex character like yield through selection. Correlation studies are helpful to the breeder; however, they do not take into consideration the cause and effect relationship which restrict their practical utility in selection programme. The technique of path coefficient analysis devised by Wright (1921) is an efficient method for disintegrating total correlation between two variables in to direct and indirect effects. This technique could be used to understand value and degree to which various components of yield determine variation present in the yield. The results obtained on these aspects have been presented in the previous chapter and are discussed with supporting and contradictory references 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 knowledge of nature and magnitude of variation present in base population is of great importance for effective selection of superior genotypes.

The analysis of variance (Table 4.1) revealed highly significant differences among genotypes with wide range of variability 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 Mehta and Patel (1983), Agnihotri (1990), Madhu (1995), Agnihotri *et al.* (1997), Rajput *et al.* (2004) in fennel; 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; 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), Yadav (1999), Tripathi *et al.* (2000), Sharma *et al.* (2004) in coriander. Among the character under study, grain yield per plant, number of primary branches per plant, number of effective branches per plant, number of effective umbels per plant, number of umbellates per main umbel, number of seeds per main umbel, test weight and volatile oil content in seed showed wide range of variability (more than 80 %). The results suggested great scope for improvement of yield in fennel.

The genotype JF-521 gave maximum and significantly higher yield over the three commercially cultivated varieties. This genotype was early in flowering and had very good number of effective umbels per plant, total branches per plant, umbels per plant, umbellates per umbel and seeds per umbel. Therefore, this genotype may be evaluated further for yield under field trials.

The phenotypic variation is not a precise parameter to judge heritable variability present in the population. The 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. Therefore, 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 days to 50 per cent maturity, plant height up to main umbel and length of internode (Table 4.2).

The results revealed that the magnitudes of genetic variability were very close to that of phenotypic one for all the traits except days to 50 per cent maturity, plant height up to main umbel and length of internode, indicating that phenotypic variability was largely due to the genetic differences. Under such genetic behaviour, selection is effective for improvement yield and its attributing traits. This implied that phenotypic variability or *per se* performance may be considered as a reliable measure for genetic variability.

5.1.3 .Coefficient of variation

Burton (1952) suggested that the genetic coefficient of variation is more reliable index for measuring genetic variation. 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 highest genotypic and phenotypic coefficient of variation was observed for total branches per plant followed by volatile oil content in seed, number of seeds per main. umbel, number of effective umbels per plant and number of primary branches per plant. The traits *viz*., seed yield per plant, days to 50 per cent flowering, total plant height, diameter of main umbel, number umbellates per main umbel, number of seeds per umbellate, test weight exhibited moderate values of genotypic and phenotypic coefficients of variation, whereas days to 50 per cent maturity, plant height up to main umbel, length of internode showed low values of genotypic and phenotypic coefficients of variation. High genotypic and phenotypic coefficients of variation for umbels per plant and seed yield per plant reported by Rajput *et al.* (2004) in fennel; for number of branches 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 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 suggested 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) suggested that genetic coefficient of variation together with heritability 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 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 fifty per cent flowering, number of primary branches per plant, number of total branches per plant, number of seeds per main umbel, 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/ plant, seeds/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 umbellates/umbel, 1000-seed weight, seed yield per plant (Mehta and Patel, 1983; Jindal and Allah-Rang, 1986; Agnihotri *et al.*, 1997; 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 fifty per cent 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/plant, essential oil content, numbers of umbels/plant, and numbers of seeds/umbel in Ajwain.

Moderate values of heritability were obtained for number of seeds per main umbel, number of umbellates per umbel, plant height, numbers of effective umbels per plant, number of seeds per umbellate and diameter of main umbel, which indicated that this characters were influenced by environment.

The higher estimates of heritability indicate that these characters were comparatively less affected by environment. The traits *viz.,* number of primary branches per plant, total branches per plant, seed yield per plant and volatile oil content in seeds displayed high heritability estimates along with high GCV.

Shift in gene frequency towards superior side under selection pressure is termed as genetic advance and is generally expressed as percentage 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 genetic advance was recorded for volatile oil content in seeds, number of primary branches per plant, seed yield per plant, test weight, days to 50 per cent flowering and total effective branches per plant. Mathur *et al.* (1971) reported a higher value of genetic advance along with high heritability values in yield per plant and the 1,000-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 ten 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 fifty per cent flowering, plant height, umbels per plant and 1000-seeds weight by Sharma *et al.* (2004).

Moderate heritability with low genetic advance as per cent of mean was recorded for the characters *viz.*, total plant height, diameter of main umbel and number of seeds per umbellate. This finding is in agreement with the results obtained by Rajput and Singh (2002) for total plant height and Tripathi *et al.* (2000) for number of seeds per umbellate, diameter of main umbel and plant height.

High genotypic coefficient of variation with high heritability and genetic advance was observed for total branches per plant, seed yield per plant, volatile oil content in seeds and number of primary branches per plant. Moderate coefficient of variation with moderate heritability and moderate genetic advance as per cent of mean was observed for plant height, diameter of main umbel and number of seeds per umbellate.

Based on all variability parameters, it is revealed that the characters *viz.*, number of effective umbels per plant, test weight, volatile oil content in seeds, number of primary branches per plant, number of seeds per main umbel, seed yield per plant, total branches per plant, seed yield per plant 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 fennel yield. Further, such highly heritable characters can be easy transferred to cultivate varieties for improvement of specific character.

5.2 CORRELATION COEFFICIENT ANALYSIS :

Searle (1965) has suggested that average merit of a character in a population can be changed by means of selection programme based on phenotype. However, such improvement would be more reliable if indirect selection based on the other traits correlated with it. Thus, for rational improvement of yield and its components, the understanding of correlation between each other is very useful.

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 plant showed positive highly significant correlated with number of effective umbels per plant, total plant height, number of primary branches per plant, total branches per plant, number of umbellates per umbel and number of seeds per main umbel at genotypic and phenotypic levels. Moreover, the values of genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients for almost all the characters. A number of workers also reported similar genotypic and phenotypic association for different characters with seed yield per plant *viz.,* days to 50 per cent 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 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, umbellates per plant, seeds per umbellate and straw yield per plant (Sharma and Sharma, 1989); plant height, branches per plant, umbels per plant, umbellates per umbel and seeds per umbel (Sharma and Meena, 2004) in coriander.

Days to 50 per cent flowering showed positive and highly significant genotypic and phenotypic association with days to maturity, while diameter of main umbel was significantly correlated at genotypic level only. 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 50 per cent maturity was positive and significantly correlated with plant height up to main umbel, at both levels. Diameter of main umbel at genotypic level only.

Plant height up to main umbel reflected positive and highly significant correlation at genotypic and phenotypic levels with number of primary branches per plant, total plant height and length of internode. This trait showed positive and significant correlation only at genotypic level with total branches per plant, diameter of main umbel and number of effective umbels per plant. 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).

Total plant height showed significant and positive correlations with number of primary branches per plant, total branches per plant and number of effective umbels per plant at both the levels, while diameter of main umbel, length of internode and 1000-seed weight were significantly correlated at genotypic level only. It is suggest that taller plant should be selected, while breeding for higher yield.

Number of primary branches per plant exhibited positive and significant correlation at both phenotypic and genotypic levels with total branches per plant and number of effective umbels per plant. Diameter of main umbel showed positive and significant correlation at genotypic level only. These results are in conformity with the findings of Sharma and Meena (2004).

Total branches per plant had positive and significant correlation at both phenotypic and genotypic levels with number of effective umbels per plant. This indicated that selection for more total effective branches per plant may be useful in increasing the number of effective, umbels per plant. Which are important yield attributing characters.

Diameter of main umbel exhibited positive and significant correlation at genotypic level only with number of seeds per umbellate, number of seeds per main umbel, length of internode.

This suggested that selection for more diameters per main umbel though increase number of seeds per umbellate, number of seeds per main umbel and length of internode.

Number of umbellates per main umbel was significantly and positively associated with number of seeds per main umbel at phenotypic as well as genotypic levels. This indicated that selection for more number of umbellates per main umbel would increase number of seeds per main umbel.

Number of seeds per umbellate were found to be significantly and positively correlated with number of seeds per main umbel at both levels. Length of internode showed positive and significant correlation at genotypic level only, suggesting that selection of this character may increase the number of seeds per main umbel.

Number of seeds per main umbel was positive and significant correlation with length of internode at genotypic level only, suggesting that selection for this trait may increase the length of internode.

Length of internode was found to be negative but significant correlations with 1000-seed weight at genotypic level only, indicating that with increase the1000-seed weight and decrease the length of internode.

In the present study, 1000-seed weight had negatively and significant Correlation with volatile oil content in seed, suggesting that selection of this character may decrease the volatile oil

In general, plant height, number of primary branches per plant, total branches per plant and number of effective umbels per plant exhibited positive correlations of considerable magnitude with seed yield and hence, they can be used as selection parameters for evolving high yielding varieties.

5.3 PATH COEFFICIENT ANALYSIS :

Yield is a complex character and is the multiplicative and product of several components. Some of them may be grouped as main components which directly contribute towards yield, whereas others may not contribute directly to the yield but may influence the yield by changing the behaviour and growth of different components. The simple correlation, may not give a clear picture of system operating on the material selected for study. In order to achieve the clear-cut picture of interrelationship of various component characters with yield, direct and indirect effects were calculated by using path co-efficient analysis at genotypic level.

The highest positive direct effect on yield was with number of effective umbels per plant followed by number of seeds per umbellate, total branches per plant and number of umbellates per umbel. These characters had positive and significant correlation with seed yield per plant. Similar results have been reported by Agnihotri *et al.* (1997) for branches per plant and seeds per umbel; Singh *et al.* (2003) for seeds per umbel; Rajput *et al.* (2004) for seeds per umbel in fennel; Sharma and Sharma (1989) for number of branches per plant; Sharma and Meena (2004) for seeds per umbel and branches per plant in coriander.

Plant height up to main umbel showed negative direct effect on seed yield per plant, but the genotypic correlation between these two characters was positive due to its positive indirect effects via total branches per plant, number of effective umbels per plant and number of seeds per umbellate. Such direct effect was also reported by Jain *et al.* (2003) for days to 50 % flowering in coriander.

Number of primary branches showed negative direct effect on seed yield per plant, but correlation with seed yield was positive due to its positive and high indirect effects through total branches per plant and number of effective umbels per plant. Such direct effect was reported by Jain *et al.* (2003) for days to 50 % flowering in coriander.

Total branches per plant exhibited high and positive significant correlation and high direct effect on seed yield per plant. Its indirect effect via number of effective umbels per plant was high and positive. 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 effective umbels per plant showed high positive significant correlation and high direct effect on yield per plant. Its indirect effect was high and positive via total branches per plant. Its indirect effect via rest of characters were negative and low. Singh *et al.* (2003) and Rajput *et al.* (2004) in fennel; Rama Rao *et al.* (1981), Bhandari and Gupta (1993), Jain *et al.* (2003) and Sharma and Meena (2004) in coriander reported positive direct effect of number of seeds per main umbel on seed yield.

Number of umbellates per umbel had positive and significant correlation with seed yield per plant. Its direct effect on seed yield was high and positive. Its indirect effect was positive via number of seeds per umbellate and plant height up to main umbel. Positive direct effect 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.

Positive genotypic correlation was observed for number of seeds per umbellate and positive direct effect on seed yield. Its indirect effect via number of umbellates per umbel and number of primary branches per plant were positive and low. Bhandari and Gupta (1993) reported that grains per umbellate had high direct effect on seed yield per plant 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 not considered factors. In the study the residual effect at genotypic level was 0.2523, which suggested that there might be 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 of fennel, weightage should be given to moderate height up to main umbel with maximum total branches, number of effective umbels per plant, number of umbellates per main umbel, number of seeds per umbellate and number of primary branches.

SUMMARY & CONCLUSIONS

VI. SUMMARY AND CONCLUSIONS

The investigation was carried out on variability, heritability, genetic advance, correlation and path analysis coefficient in thirty-six genotypes of fennel. The genotypes were selected from the germplasm maintained at the Main Spices Research Station, Sardarkrushinagar Dantiwada Agricultural University, Jagudan, Gujarat State. Fifteen characters *viz.,* grain yield per plant, days to 50 per cent flowering, days to maturity, plant height up to main umbel, plant height, number of primary branches per plant, total branches per plant, number of effective umbels per plant, diameter of main umbel, number of umbellates per main umbel, number of seeds per umbellate, number of seeds per main umbel, length of internode, 1000-seed weight and volatile oil content in seed 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 presence of sufficient amount of variability in the material.

[2] The genotypic and phenotypic variances were higher for grain yield per plant, days to 50 per cent flowering, days to maturity, plant height up to main umbel, plant height, total branches per plant, number of effective umbels per plant, number of umbellates per main umbel, number of seeds per umbellate, number of seeds per main umbel.

[3] The highest genotypic coefficient of variation was observed for total branches per plant followed by volatile oil content in seed, number of effective umbels per plant and number of seeds per main umbel.

[4] High heritability estimates (Broad sense) were found for days to 50 per cent flowering, volatile oil content in seed, 1000-seed weight, number of primary branches per plant, total branches per plant and seed yield 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 per cent of mean was recorded for volatile oil content in seeds, number of primary branches per plant, seed yield per plant, test weight, days to 50 per cent flowering and total branches per plant 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 plant with plant height, plant height up to main umbel, number of primary branches per plant, total branches per plant, number of effective umbels per plant, number of umbellates per umbel and number of seeds per main umbel. Considering above relationships an ideal plant type in fennel can be moderate height up to main umbel with high individual plant yield coupled with maximum number of primary branches per

plant, total effective branches per plant, number of effective umbels per plant, number of umbellates per umbel and number of seeds per main umbel.

[7] Path coefficient analysis revealed the highest positive direct effect of number of seeds per main umbel followed by total branches per plant. Total branches per plant had indirect effects via number of umbellate per umbel and numbers of seeds per main umbel were high and positive. Number of seeds per main umbel had indirect effects via number of effective umbels per plant and numbers of primary branches per plant were positive.

[8] Based on these findings, it could be concluded that in breeding programme aiming to improve grain yield in fennel, more weightage should be given to total branches, number of seeds per main umbel and number of primary branches.

[9] The culture JF-521 was the best yielder and had high values of major yield attributing characters. This culture may be further evaluated under field trials to confirm it's superiority for the yield.

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APPENDICES

Appendix–I : Meteorological data during the period of investigation

Months	Std. Week	Date	Temperature °C		Relative Humidity (%)	Rainfall (mm)	Rainy Days
			Min.	Max.			
June-2003	23	4-10	28.4	41.4	80.14	-	-
	24	11-17	28.6	39.6	87.29	3	-
	25	18-24	26.7	31.4	85.71	38	2
	26	25-1 July	29.2	36.8	78.57	-	-
July-2003	27	2-8	33.9	33.9	88.57	29	2
	28	9-15	31.8	31.8	93.71	63	3
	29	16-22	31.6	31.6	92.71	77	3
	30	23-29	29.1	29.1	96.00	218	6
August-2003	31	30-5	26.0	29.6	96.57	29	2
	32	6-12	26.1	31.4	92.00	-	-
	33	13-19	27.0	32.2	81.00	1	-
	34	20-26	26.6	31.7	85.86	135	2
	35	27-2 Sept.	25.0	29.3	92.00	20	2
September-2003	36	3-9	25.6	31.1	87.57	5	1
	37	10-16	25.3	32.3	80.00	-	-
	38	17-23	26.1	31.9	84.71	35	2
	39	24-30	25.2	32.6	83.71	-	-
October-2003	40	1-7	24.7	34.1	76.86	-	-
	41	8-14	22.2	34.7	69.29	-	-
	42	15-21	19.9	33.9	64.71	-	-
	43	22-28	19.4	33.9	65.57	-	-
November-2003	44	29-4	20.9	33.3	51.57	-	-
	45	5-11	21.6	34.1	72.71	-	-
	46	12-18	18.9	35.4	58.43	-	-
	47	19-25	18.3	31.4	50.00	-	-
	48	26-2 Dec.	16.1	30.6	46.86	-	-

Appendix-I Contd...

Appendix-I Contd...

Months	Std. Week	Date	Temperature °C		Relative Humidity (%)	Rainfall (mm)	Rainy Days
			Min.	Max.			
December-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	-	-
January-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	-	-
February-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	-	-
March-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 April	18.8	36.2	37.14	-	-
April-2004	14	2-8	21.9	37.3	40.43	-	-
	15	9-15	22.6	39.7	43.71	-	-
	16	16-22	23.2	40.4	54.86	-	-
	17	23-29	26.5	41.6	56.14	-	-
					Total :-	**653.0**	**25**

Source : Main Spices Research station, Sardarkrushinagar Dantiwada Agricultural University, Jagudan (Gujarat).

Appendix-II : Mean performance of 36 genotypes

Sr. No.	Genotypes	Grain yield per plant (g)	Days to 50 per cent flowering	Days to maturity	Plant height up to main umbel (cm)	Plant height (cm)	No. of primary branches per plant	Total branches per plant	No. of effective umbels per plant	Diameter of main umbel (cm)	No. of umbellate per umbel	No. of seeds per umbellate	No. of seeds per main umbel	Length of internode (cm)	1000-seed weight (g)	Volatile oil (%)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.	JF-275	164	102.3	206.0	133.0	173.3	13.5	57.3	37.8	16.5	36.1	40.2	1433.3	23.5	5.9	1.7
2.	JF-303	155	109.7	213.3	140.0	182.3	13.5	62.7	42.9	16.2	31.3	29.8	1074.3	21.2	6.9	1.7
3.	JF 351-1-2	130	110.0	210.3	105.0	149.0	10.1	34.6	29.2	17.2	49.9	34.6	1727.7	22.2	8.0	1.6
4.	JF 351-5	161	101.7	208.7	112.7	157.7	11.4	48.4	40.1	15.9	47.9	32.4	1483.3	19.4	7.3	1.5
5.	JF 376-5	150	91.7	179.3	114.3	157.7	8.1	46.2	38.7	14.3	43.4	34.7	1485.7	19.2	8.1	1.3
6.	JF 376-6	130	84.3	177.0	138.3	179.3	7.1	34.2	27.3	14.8	43.0	38.6	1651.3	24.1	8.4	1.4
7.	JF 420-1-1	148	119.7	222.0	140.3	173.7	11.1	41.0	30.8	18.5	51.9	35.1	1754.7	18.2	9.0	1.3
8.	JF 427-1-1	133	111.7	196.7	114.7	161.3	8.2	31.7	24.1	14.3	51.0	39.4	2026.7	21.7	6.1	2.2
9.	JF-460	141	114.0	202.0	119.7	146.7	7.8	32.4	25.1	14.5	50.0	43.4	2139.0	23.3	8.8	1.7
10.	JF 464-1	161	119.0	222.7	124.0	167.3	9.7	37.4	33.9	19.4	57.7	46.3	2650.7	23.0	8.5	1.6
11.	JF 471-2	148	111.0	198.0	96.7	135.3	9.9	36.5	30.0	15.8	52.0	40.6	2158.3	17.7	9.8	1.3
12.	JF 472-2-3	162	100.0	186.3	136.3	174.3	12.0	49.8	36.4	19.4	41.0	41.5	1721.3	24.6	8.4	1.4
13.	JF-490	165	129.3	230.7	136.7	174.3	11.4	44.2	34.2	19.4	51.4	45.1	2335.3	24.2	8.6	1.8
14.	JF 500-2	128	111.0	207.7	128.0	151.0	8.9	35.5	26.1	15.8	46.4	36.0	1650.3	21.4	8.7	1.5
15.	JF-501	153	117.3	197.7	144.0	200.3	10.8	42.7	35.2	19.2	45.9	42.3	1890.7	19.5	8.4	1.5
16.	JF 512-2	182	91.7	169.0	110.3	160.0	11.3	69.7	50.8	11.7	40.4	35.6	1390.3	18.5	8.7	1.8
17.	JF 517-2	143	107.7	204.3	115.3	162.7	9.1	34.3	29.7	16.0	49.9	43.7	2150.0	19.8	7.8	1.5
18.	JF 518-2	165	109.0	219.7	129.0	174.3	10.7	43.2	34.7	14.3	55.7	41.4	2401.7	19.4	9.0	1.3
19.	JF-521	214	99.7	197.3	130.3	188.7	11.0	68.9	44.9	16.9	54.5	45.3	2443.3	23.2	8.6	1.5
20.	JF-525	170	102.3	204.7	125.0	167.7	12.8	56.6	38.8	17.8	46.9	41.8	1948.0	22.1	9.8	1.2
21.	JF-526	162	106.0	138.3	117.3	173.7	11.2	43.0	36.6	16.9	49.5	41.0	2022.0	19.9	7.5	1.6
22.	JF 531-1	155	104.7	184.3	99.0	157.3	9.4	41.4	37.3	16.6	46.1	42.0	1890.0	21.1	5.9	2.7
23.	JF 535-1	145	106.3	204.7	92.0	140.7	8.7	37.0	31.9	15.0	51.9	35.2	1931.0	17.5	9.0	1.3
24.	JF-537	105	107.7	211.0	91.7	111.7	6.4	23.7	17.3	15.2	41.8	36.6	1465.7	15.9	9.9	1.2
25.	JF-543	107	79.0	173.3	98.0	135.0	6.6	26.5	22.0	14.7	35.5	36.4	1308.3	20.3	9.0	1.4
26.	JF-568	172	84.7	181.7	103.7	155.7	11.6	48.6	35.5	19.2	62.6	37.4	2160.3	19.8	10.2	1.2
27.	JF-572	122	95.0	199.7	126.0	160.0	9.0	29.2	24.0	18.7	43.3	42.1	1799.3	23.4	8.7	1.5
28.	JF-573	142	98.3	190.3	116.0	157.0	9.0	34.2	28.5	16.6	55.3	41.9	2227.0	22.6	8.5	1.5
29.	JF-575	111	112.0	204.0	106.7	123.0	6.8	26.2	20.8	16.7	39.6	35.8	1370.7	21.4	9.5	1.2
30.	JF-578	147	107.0	209.7	114.7	157.3	9.7	39.6	33.4	17.8	38.7	48.1	1811.0	19.7	9.2	1.5
31.	JF-582	145	99.3	197.0	120.0	160.0	8.6	30.2	23.7	19.6	52.1	50.2	2564.3	22.6	8.5	1.5
32.	JF-592	162	103.7	211.3	121.0	183.7	11.5	45.9	33.9	17.0	47.4	50.2	2340.3	19.3	8.5	1.8
33.	EC-386375	135	113.7	193.3	118.7	163.0	9.2	40.1	35.3	15.2	39.5	37.4	1431.3	20.3	9.2	3.0
34.	Guj.F.-1	134	124.7	216.3	126.7	178.3	9.2	37.9	32.1	19.8	41.6	40.2	1711.0	21.4	9.6	1.3
35.	Guj.F.-2	154	110.3	190.3	115.0	170.3	11.0	56.7	44.8	18.5	36.4	31.1	1200.0	17.3	8.8	1.5
36.	Guj.F.-11	162	108.0	189.0	124.0	166.0	11.9	58.7	41.4	18.2	52.2	32.4	1593.0	24.3	8.9	1.7
	C.V. %	9.10	2.33	8.74	10.71	7.13	7.95	10.37	17.65	9.77	8.83	10.43	10.74	9.76	4.00	6.53
	S.Em.±	9.64	1.42	10.00	7.36	6.67	0.46	3.59	3.36	0.95	2.38	2.38	114.31	1.18	0.20	0.06
	C.D. at 5%	27.21	4.05	28.23	20.76	18.81	1.29	10.15	9.49	2.67	6.72	6.73	322.51	3.33	0.55	0.17

CERTIFICATE

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