

**EVALUATION OF FENNEL (*Foeniculum vulgare*  
Mill.) VARIETIES UNDER EASTERN DRY ZONE  
OF KARNATAKA**

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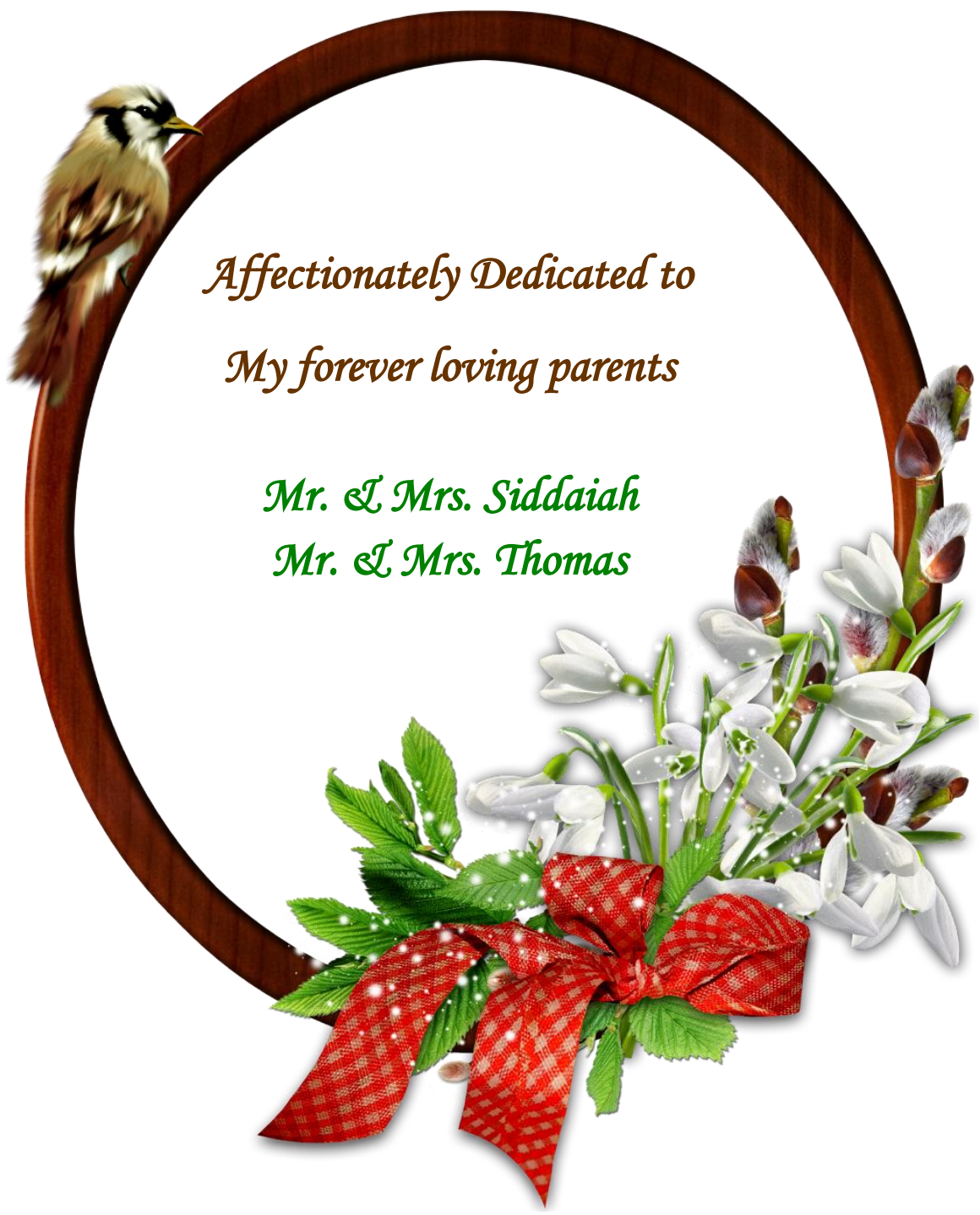
**EVALUATION OF FENNEL (*Foeniculum vulgare*  
Mill.) VARIETIES UNDER EASTERN DRY ZONE  
OF KARNATAKA**

*Thesis submitted to the  
University of Horticultural Sciences, Bagalkot  
In partial fulfilment of the requirements for the  
Degree of*

**MASTER OF SCIENCE (Horticulture)**  
**in**  
**PLANTATION, SPICES, MEDICINAL AND  
AROMATIC CROPS**

*By*  
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COLLEGE OF HORTICULTURE, BENGALURU  
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BAGALKOT  
JUNE, 2017**



*Affectionately Dedicated to*  
*My forever loving parents*

*Mr. & Mrs. Siddaiah*  
*Mr. & Mrs. Thomas*

**DEPARTMENT OF PLANTATION, SPICES, MEDICINAL  
AND AROMATIC CROPS  
COLLEGE OF HORTICULTURE, BENGALURU  
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**CERTIFICATE**

This is to certify that the thesis entitled “**EVALUATION OF FENNEL (*Foeniculum vulgare* Mill.) VARIETIES UNDER EASTERN DRY ZONE OF KARNATAKA**” submitted by **Mr. SHIVAPRASAD, S., ID No. UHS15PGM671**, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (Horticulture)** in **PLANTATION, SPICES, MEDICINAL AND AROMATIC CROPS** to the University of Horticultural Sciences, Bagalkot, is a *bona-fide* record of research work carried out by him during the period of his study in this university under my guidance and supervision and that no part of the thesis has been submitted for the award of any degree, diploma, associateship, fellowship or other similar titles.

Place: Bengaluru

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**(G. K. RAMEGOWDA)**

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*Bengaluru*

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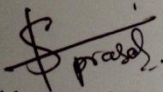
***Shivaprasad, S.***

**“EVALUATION OF FENNEL (*Foeniculum vulgare* Mill.) VARIETIES  
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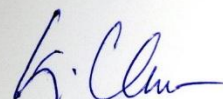
**ABSTRACT**

An investigation was carried out at College of Horticulture, UHS campus, G.K.V.K, Bengaluru during *rabi* season of 2016-17 to evaluate fennel varieties for growth, yield, and quality under Eastern Dry Zone of Karnataka. The experiment was laid out in RCBD with 3 replications for evaluating 12 varieties. Analysis of variance revealed existence of wide range of variation among varieties for all the characters except days to first flowering. Higher magnitude of GCV and PCV have been noticed for characters *viz.*, number of umbels per plant, seed yield per plant, seed yield per hectare and oil yield. High heritability coupled with high genetic advance as per cent mean was observed for plant height, number of branches, days to maturity, number of umbellets per umbel, fresh and dry weight of plant, seed yield per plant and seed yield per hectare.

In correlation studies, seed yield per plant exhibited positive and significant correlation with plant height, number of branches, days to first flowering, days to maturity, number of umbels per plant, number of umbellets per umbel, number of seeds per umbellet and dry weight of umbel. Path analysis revealed positive direct effect through number of branches, number of umbels per plant, number of umbellets per umbel and dry weight of umbel. Some of the desirable varieties *viz.*, RF 145, GF 12, RF 143 and RF 205 recorded higher seed yield but GF 2 and RF 145 gave higher oil yield and they may be recommended for commercial cultivation in Eastern Dry Zone of Karnataka.

  
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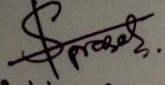
ಕರ್ನಾಟಕದ ಪೂರ್ವ ವಲಯದಲ್ಲಿ ವಿವಿಧ ಸೋಂಪು (ಫೋನಿಕ್ಯುಲಮ್

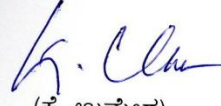
ವಲ್ಲರಿ ತಳಿಗಳ ಮೌಲ್ಯಮಾಪನ

ಸಾರಾಂಶ

ತೋಟಗಾರಿಕಾ ವಿಜ್ಞಾನಗಳ ವಿಶ್ವವಿದ್ಯಾಲಯ, ಬಾಗಲಕೋಟೆ, ವ್ಯಾಪ್ತಿಯ ಕರ್ನಾಟಕದ ಪೂರ್ವ ಒಣ ವಲಯದ ಬೆಂಗಳೂರಿನ ತೋಟಗಾರಿಕೆ ಮಹಾವಿದ್ಯಾಲಯದಲ್ಲಿ ೨೦೧೬-೨೦೧೭ರ ಹಿಂಗಾರು ಋತುವಿನಲ್ಲಿ ನಡೆಸಿದ ಕ್ಷೇತ್ರ ಸಂಶೋಧನೆಯಲ್ಲಿ ಸೋಂಪು ತಳಿಗಳ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಮತ್ತು ಗುಣಮಟ್ಟದ ಮೌಲ್ಯಮಾಪನ ಮಾಡಲಾಯಿತು. ಈ ಪ್ರಯೋಗದಲ್ಲಿ ೧೨ ವೈವಿಧ್ಯಮಯ ತಳಿಗಳನ್ನು ಮೂರು ಪುನರಾವೃತ್ತಿಗಳಲ್ಲಿ ಬೆಳೆಸಿ ಆರ್.ಸಿ.ಬಿ.ಡಿ. ಮಾದರಿಯಲ್ಲಿ ಸಂಶೋಧನೆಯನ್ನು ಕೈಗೊಳ್ಳಲಾಯಿತು.

ಗಿಡದ ಗುಣಲಕ್ಷಣಗಳಾದ ಭತ್ತಿಗಳ ಸಂಖ್ಯೆ, ಪ್ರತಿ ಗಿಡ ಹಾಗೂ ಪ್ರತಿ ಹೆಕ್ಟೇರ್ ನ ಬೀಜದ ಇಳುವರಿ ಮತ್ತು ಸುಗಂಧ ತೈಲದ ಇಳುವರಿಗಳಲ್ಲಿ ಹೆಚ್ಚಿನ ವಂಶವಾಹಿ ರೂಪ ಗುಣಾಂಶ ವಿಭಿನ್ನತೆ ಕಂಡುಬಂದಿತು. ಹೆಚ್ಚಿನ ಅನುವಂಶೀಯತೆ ಮತ್ತು ಅನುವಂಶೀಯ ಸುಧಾರಣೆಯು ಗಿಡದ ಎತ್ತರ, ಕೊಂಬೆಗಳ ಸಂಖ್ಯೆ, ಬಲಿಯುವುದಕ್ಕೆ ತೆಗೆದುಕೊಂಡ ದಿನಗಳು, ಪ್ರತಿ ಭತ್ತಿಗಳ ಸಂಖ್ಯೆ, ಗಿಡದ ಹಸಿ ಮತ್ತು ಒಣ ತೂಕ, ಪ್ರತಿ ಗಿಡ ಮತ್ತು ಪ್ರತಿ ಹೆಕ್ಟೇರ್ ನ ಬೀಜದ ಇಳುವರಿ ಚಹರೆಗಳಲ್ಲಿ ಗೋಚರಿಸಿತು. ಬೀಜದ ಇಳುವರಿಯು ಕೊಂಬೆಗಳ ಸಂಖ್ಯೆ, ಭತ್ತಿಗಳ ಸಂಖ್ಯೆ, ಹೂ ಕೊಡೆಗಳ ಸಂಖ್ಯೆ ಮತ್ತು ಭತ್ತಿಯ ಒಣ ತೂಕದೊಂದಿಗೆ ನೇರ ಧನಾತ್ಮಕ ಸಂಬಂಧ ಹೊಂದಿರುತ್ತದೆ. ಈ ಅಧ್ಯಯನದಲ್ಲಿ ತಳಿಗಳಾದ ಆರ್ ಎಫ್ ೧೪೫, ಜಿಎಫ್ ೧೨, ಆರ್ ಎಫ್ ೧೪೩ ಮತ್ತು ಆರ್ ಎಫ್ ೨೦೫ ಗಳು ಪೂರ್ವ ಒಣವಲಯದಲ್ಲಿ ಅತಿ ಹೆಚ್ಚು ಇಳುವರಿ ಹಾಗೂ ಜಿಎಫ್ ೨ ಮತ್ತು ಆರ್ ಎಫ್ ೧೪೫ ಅತಿ ಹೆಚ್ಚು ಸುಗಂಧ ತೈಲ ನೀಡಿದ್ದು, ಈ ಪ್ರದೇಶದಲ್ಲಿ ವಾಣಿಜ್ಯವಾಗಿ ಬೆಳೆಯಲು ಸೂಕ್ತವಾಗಿರುತ್ತವೆ.

  
(ಶಿವಪ್ರಸಾದ್, ಎಸ್)  
ವಿದ್ಯಾರ್ಥಿ

  
(ಕೆ. ಉಮೇಶ)  
ಮುಖ್ಯ ಸಲಹೆಗಾರರು

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# I. INTRODUCTION

India is the land of spices and the glory of Indian spices is known throughout the world. Spices are varieties of dried plant products used for flavouring foods. Spices act as appetizers and increase the secretion of digestive juice. Spices were earlier considered as luxury, but today they have become an integral part of our daily diet. There are about 109 spices in use all over the world and twenty countries are actively engaged in the production and export of one or more of them. Although, India had enjoyed a monopoly in world's spice trade once upon a time, the position today is that no single country enjoys any monopoly position either in the production or export of spices.

Spices have a profound influence on the course of human civilization. They permeate our lives from birth to death. In everyday life, spices succour us, cure us, relax us and excite us. Ancient people used spices, not only to add flavour to foods and beverages but were also used in medicines, disinfectants, incenses, stimulants and even as aphrodisiac agents. The total area under spices in India is about 31.93 lakh hectares with a production of 53.5 lakh metric tonnes and productivity is 1.8 metric tonnes per hectare (Anon., 2015).

Spices are grouped according to the part of plants used such as dried flower buds of clove, fruits such as black pepper, nutmeg and vanilla, underground stems like ginger and turmeric and seeds which refer to coriander, fennel, fenugreek, ajwain, dill, black cumin and celery, etc. Among spices, seed spices are mainly used for flavouring and curative purposes. Seed spices are the most important export oriented commodities, which play a significant role in our national economy. During 2014-15, 1,86,075 tons of seed spices worth Rs. 1673 crores were exported, which accounts to around 15 per cent share in the total spices and spice products (Including seed spices) valued at Rs. 11,171 crore (Anon., 2015).

Fennel (*Foeniculum vulgare* Mill.) is an important seed spice, commonly known as Saunf or Badi saunf, belonging to the family apiaceae (umbelliferae). It is an aromatic herb that measures 150-200 cm in height and has a pungent aroma. The leaves are 2-4 segmented pinnate, the segment is very narrow and often filiform. The stem is firm, round and finely straightened greenish blue in color. It produces tiny yellow flowers emanating from flat umbrella-shaped tops. The fruits are first bluish, later become brownish grey, fruits are oblong, cylindrical, five ridged measures 6-7 mm in size.

Apart from flavoring properties, fennel seeds have immense medicinal value. Fennel seeds cure loss of appetite, gassy colic in children, dysentery, eye strain, throat pain, stomach pain, head ache and improves eye sight. Fennel is rich in vitamin A and contains a fair amount of calcium, phosphorous and potassium. In India, seeds are used for mastication and chewing alone or with betel leaves.

The principal constituent of the fennel oil is trans-anethole (50-60%), fenchone (12-33%) and methyl chavicol (estragole) (2-5%). Indian fennel oil contains over 70 per cent anethole and six per cent fenchone. The high percentage of anethole (up to 90%) and lower amount of fenchone are responsible for its delicate sweet odour and flavour. The other constituents are  $\alpha$ -pinene, camphene, p-cymene, myrcene, limonene,  $\alpha$  and  $\beta$ -phellandrene,  $\gamma$ -terpinene, terpineol and cis-ocimene  $\gamma$ -fenchone (Farooqi and Sreeramu, 2001). Fennel oil blends well with geranium, lavender, rose and sandalwood oils. Anethole present in the essential oil has diuretic, analgesic and antipyretic properties. The most frequently investigated was its antioxidant and antimicrobial properties. On account of its carminative properties, fennel is chiefly used medicinally with purgatives to allay their side effects. Fennel water has properties similar to those of anise and dill water. Mixed with sodium bicarbonate and syrup, these waters constitute the domestic 'gripe water', used to correct the flatulence of infants.

Fennel is native to the shores of the Mediterranean region and distributed in many parts of the world namely, India, England, Germany, Tyrol, China, Iran, Vietnam and South America. In India, it is mainly cultivated in Gujarat (30200 ha area and 63850 tonnes production), Rajasthan (15560 ha area and 13850 tonnes production), Uttar Pradesh (730 ha area and 710 tonnes production), Andhra Pradesh, Punjab, Madhya Pradesh and Haryana and to a small extent in Karnataka (Anon., 2015).

Estimated area and production of fennel crop in India during 2013-14 were 46,760 ha and 78,570 tones, respectively and the export was 11,650 valued of tones to the valued at Rs. 131.65 crores. In Karnataka, fennel is mainly grown in *rabi* season under rain fed situation.

The productivity of fennel in India is low because of lack of genotypes or varieties suited to a particular agro-climatic condition. Apart from selection of suitable genotypes, optimum planting season, nutritional requirement, optimum irrigation levels, plant geometry and resistance to biotic stress are important for accomplishing higher yield in fennel. Sardarkrushinagar Dantiwada Agricultural University, Jagudan released PF 35 , Guj Fennel 1, Guj fennel 2, GF 11 and JF-444-1 for cultivation under Gujrath conditions, HC & RI, Coimbatore, released CO 1 for large scale cultivation in Tamilnadu conditions, S.K.N College of Agriculture, Jobner, released, RF 101, RF 125 and RF 143 for black cotton soil, RF 205, RF 281 and RF 178 for Rajasthan conditions, Haryana Agricultural University, Hisar released Hisar Sawrup, HF 143 and HF 33 for Hissar conditions, C.S. Azad University of agriculture and technology, Kanpur released Azad Sanuf 1 for Uttarpradesh situations and NRC on seed spices,Ajmer released, AF 1 and AF 2 for Rajasthan conditions. However, very limited scientific information is available on varietal evaluation of fennel particularly under Eastern dry zone of Karnataka and it is a nontraditional area and there is no recommended variety for this zone. Local selections are made and being grown by farmers.

Evaluation of different fennel varieties and identification of suitable high yielding variety for a particular agro-ecosystem for different seasons would be very useful to growers. The major traits of interest for breeders in fennel are seed yield and its related component traits. Success of breeding programme is essentially a manifestation of efficiency of selection. Since yield depends upon several components, selection based on yield alone is not likely to be efficient. The component characters are also interrelated among themselves and also influence the yield to a great extent. For the development of effective breeding programme, the existence of variability is of primary importance. Efficiency of selection largely depends upon the magnitude of significant variability present in the plant population.

Heritability and genetic advance are important selection parameters. Heritability is a good index of transmission of characters from parents to their offspring (Falconer, 1981). Genetic advance is the measure of genetic gain under selection. Thus, genetic advance denotes the improvement in the mean genotypic value of selected population over the parental population. Heritability estimates along with genetic advance are more helpful in predicting the improvement that could be made in a crop by selecting the elite variety for various characters.

Keeping all these aspects in view, an investigation entitled "Evaluation of fennel (*Foeniculum vulgare* Mill.) varieties under Eastern dry zone of Karnataka" was carried out at Department of plantation, spices, medicinal and aromatic crops, College of Horticulture, UHS campus, G.K.V.K post, Bengaluru with the following objectives.

1. To evaluate the fennel varieties for growth, yield and quality under Eastern dry zone of Karnataka.
2. To know the genetic association of yield with morphological traits.

## II. REVIEW OF LITERATURE

In improvement of any crop, a breeder should consider both quantitative and qualitative characters of the plant. Hence, enough knowledge of genetics of various traits is very essential in breeding programme for obtaining desired results in the next generation. The desired characters required for crop improvement are present in different lines, strains, varieties or populations of the crop species, their close relatives and wild relatives, which constitute the germplasm of a crop. However, the success of breeding depends on the extent and the magnitude of variability existing in the germplasm. At the same time, improvement is possible on the basis of heritable variation. Hence, knowledge about yield traits is necessary for the improvement of fennel. Therefore, detailed review on genetic architecture of seed yield in fennel and its attributes are presented in this chapter.

As the literature pertaining to the performance of fennel varieties under different agro-climatic zones are limited, the available literature on other related crops of the Apiaceae family and other seed spices or short duration spice crops have also been reviewed for better understanding of the subject and are presented under the following major heads.

- 2.1 Performance of fennel varieties for growth and yield attributes
- 2.2 Performance of other seed spice varieties for growth and yield attributes
- 2.3 Performance of fennel varieties for quality attributes, genetic variability parameters
- 2.4 Performance of other seed spice varieties for quality attributes and genetic variability parameters

### 2.1 Performance of fennel varieties for growth and yield attributes

Considerable differences in growth and yield parameters like plant height, number of branches, fresh and dry weight of the plant and crop duration have been noticed by several scientists in fennel and other related crops and review of literature has been presented here under.

#### 2.1.1 Growth parameters

##### 2.1.1.1 Plant height

Thirty four fennel accessions were tested in Palampur conditions and the maximum plant height recorded (120.96 cm) in JF-355 where as minimum plant height (70.59 cm) was recorded in JF-422 (Singh *et al.*, 2003)

Evaluation of ten varieties of fennel (Thakral and Tehlan, 2006) in Hissar conditions for growth and yield traits revealed that maximum plant height (146.7 cm) in GF-1. However, minimum plant height (117.6 cm) was recorded in UF-143. Field evaluation of fourteen varieties of fennel (Malik *et al.*, 2009) revealed that maximum plant height (125.8 cm) was recorded in HF-125 followed by NDF-6 (120.2 cm) and HF-33 (118.3 cm) while the minimum plant height (103.8 cm) was recorded in UF-207 at Hissar situations.

A study conducted to evaluate thirteen fennel genotypes in Jabalpur condition by Senagupta *et al.* (2014) revealed that genotypes shown significant difference for plant height and maximum plant height was noticed in FNL-40 (159.33 cm) and the minimum was in FNL-39 (130.33 cm).

### **2.1.1.2 Number of branches**

Among the seventy four fennel accessions tested under Jobner conditions UF-178 (11.7) recorded the maximum number of branches per plant and it was minimum in UF-156 (5.0/plant) (Agrawal *et al.*, 2003).

Maximum number of primary branches (5.22) was recorded in EC-279039 and minimum (1.2) was recorded in JF-345, Singh *et al.* (2003) who have collected thirty four fennel accessions tested under Palampur conditions for growth and yield parameters. Field evaluation of ten varieties of fennel by Thakral and Tehlan (2006) for growth and yield traits, revealed maximum number of branches (7.4) in HF-33 and minimum branches (6.3) in JF-186.

Out of fourteen varieties tested by Malik *et al.* (2009) revealed that recorded maximum number of branches (8.1) was by HF-125 followed by HF-33 (8.0) and UF-207 (7.7) and it was minimum (6.7) in JF-421.

Among thirteen fennel genotypes evaluated under Jabalpur conditions, number of branches per plant ranged from a maximum (11.53) in FNL-40 to a minimum (7.35) branches in FNL-39 ( Senagupta *et al.*, 2014).

## **2.1.2 Yield parameters**

### **2.1.2.1 Days to fifty per cent flowering**

Study conducted to evaluate seventy four fennel accessions by Agrawal *et al.* (2003) in Jobner situations, revealed that genotypes shown significant difference for days to fifty per cent flowering ranged from a minimum (110 days) in UF-173 to maximum (116 days) in UF- 155. Similarly the range for fifty per cent flowering was from 113.33 days (FNL-44) to 102.66 days (FNL- 39) among thirteen genotypes (Senagupta *et al.*, 2014).

There was a significant variation among 23 genotypes for 50 per cent flowering with a minimum of 66 days in Tehran accessions to a maximum of 169.33 days for a Spain accession (Salami *et al.*, 2017)

### **2.1.2.2 Number of umbels per plant and seeds per umbellet**

Variation among the cultivars of fennel and other related crops with respect to number of umbels per plant, number of umbellets per umbel and number of seeds per umbellet has been well documented.

Among seventy four fennel accessions evaluated in Jobner condition, maximum number of umbels per plant was revealed in UF-178 (45.7) and minimum umbels in UF-156 (6.6/plant) was observed (Agrawal *et al.*, 2003). These accessions shown significant difference for number of umbellets per umbel and maximum number of umbellets was noticed in NS- 9 (26.8) while minimum number of umbellets was in NS-65 (11.6). Similarly the maximum seeds per umbel was recorded in UF-177 (381.5) while minimum number of seeds per umbel was noticed in UF- 156 (125.8).

In a trial involving thirty four fennel accessions which were tested under Palampur conditions, the highest umbels per plant (74.47) and maximum seeds per umbel (237.50) were recorded in EC- 279039 as against the lowest umbels per plant (11.64) in EC- 243376-1 and minimum seeds per umbel (71.52) in UF-(M)-1. (Singh *et al.*, 2003).

Among the ten varieties evaluated the maximum umbels per plant (46.8) were reported in HF-33, while the minimum umbels per plant (34.1) were noticed in JF-186 (Thakral and Tehlan, 2006). Highest umbellets per umbel (27.0) was recorded in HF-39 as against the lowest umbellets per umbel (22.5) in PF-35. Again the maximum seeds per umbel was recorded in HF-33 (315.2) while the minimum number of seeds per umbel was noticed in local check (216.1).

In a study involving fourteen fennel varieties maximum number of umbels per plant (45.4) was reported in HF-125 while minimum number of umbels (29.1) was recorded in NDF-6 (Malik *et al.*, 2009). There was a significant difference in number of umbellets per umbel and maximum number of umbellets was noticed in UF-207 (31.6), while the minimum number of umbellets was in NDF-6 (26.6) similarly maximum seeds per umbel was recorded in HF-125 (341.9) while minimum was noticed in Local check (273.1).

Performance of thirteen genotypes of fennel under Jabalpur conditions revealed that, maximum number of umbels (25.56) was reported in FNL-40, while, minimum number of umbels (17.56) was recorded in FNL-39 (Senagupta *et al.*, 2014). Genotypes showed significant differences for number of umbellets per umbel and maximum number of umbellets was noticed in FNL-42 (36.03), while minimum number of umbellets was in FNL-39 (27.30). Maximum seeds per umbel was recorded in FNL-39 (931), while minimum number of seeds per umbel was noticed in FNL-45 (546).

Evaluation of twenty three genotypes of fennel by Salami *et al.* (2017) in Iran Study reveals that, maximum number of umbels (27.69) was recorded in Spain accession, while minimum number of umbels (15.23) was recorded in Hamedan local genotype and maximum number of seeds per umbel (620) was reported in Spain accession while, minimum number of seeds per umbel (537) was recorded in Hamedan local genotype.

### **2.1.2.3 Seed yield**

The ultimate economic value of a cultivar is determined by its yield potential. Differences in the yield among the cultivars of fennel and other related spices have been observed by several workers.

Study conducted in Jobner to evaluate seventy four fennel accessions by Agrawal *et al.* (2003) showed significant difference for seed yield and maximum seed yield was obtained from UF-178, while, minimum seed yield was obtained from NS-66 maximum seed yield per plant (46.73 g) was reported in EC-279039 while, minimum seed yield per plant (5.12 g) was recorded in JF-427 (Singh *et al.*, 2003). Among ten varieties evaluated ten varieties of fennel, maximum seed yield (2194 kg/ha) was recorded in HF-33 which was significant over all other cultivars (Thakral and Tehlan, 2006).

Field evaluation of fourteen varieties of fennel in Hissar (Malik *et al.*, 2009) revealed that, higher seed yield (2149.7 kg/ha) from HF-125 followed by UF-207 (2024.0 kg/ha). However, lowest seed yield (1609.7 kg/ha) was recorded in NDF-6. In a trial involving thirteen varieties of fennel tested under Jabalpur conditions, the highest seed yield was recorded in FNL-40 followed by FNL-42 as against the lowest seed yield in FNL-39 (Senagupta *et al.*, 2014).

Fennel varieties *viz.*, RF-205, RF-125, RF-145, RF-178 and NRCSS-AF1 evaluated in 120 farmers field (Meena and Singh, 2013) under diversified agro-climatic conditions showed that, three varieties of fennel *viz.*, NRCSS-AF1, RF-205 and RF-125 were promising over local check with higher yield of 17.90, 16.50 and 13.80 q ha<sup>-1</sup> respectively.

Among the twenty three fennel genotypes, the maximum seed yield per plant was recorded in Spain accession (35 g), while minimum number of seed yield per plant was noticed in Hamedan local genotype (26.1 g) (Salami *et al.*, 2017).

#### **2.1.2.4 Days to maturity**

Minimum number of days for maturity was recorded in FNL-37 (161 days) as compared to maximum number of days in FNL-43 (170.36 days) among thirteen genotypes of fennel evaluated under Jabalpur conditions (Senagupta *et al.*, 2014)

#### **2.1.2.5 Test weight**

Among 34 fennel accessions evaluated, maximum (8.3 g) test weight was reported in UF-90. However, minimum (0.9 g) test weight was noticed in JF- 423 (Singh *et al.*, 2003). Among the twenty three genotypes evaluated maximum test weight (4.69 g) is recorded in Gonabad local genotype and minimum test weight (2.16 g) was noticed in Spain accession (Salami *et al.*, 2017).

## **2.2 Performance of other seed spice varieties for growth and yield attributes**

### **2.2.1 Growth parameters**

Datta *et al.* (2001) screened five ajwain introductions for growth and yield attributes under Mohanpur conditions of West Bengal and observed maximum plant height in RA-2 (94.13 cm) followed by RA-4 (85.95 cm), while, the lowest plant height was recorded in local genotype (81.00 cm). Maximum number of primary and secondary branches per plant (11.5 and 20.53, respectively) was recorded in RA-2. While, these parameters were minimum in RA-6 (6.85 and 12.33, respectively).

Patidar *et al.* (2004) evaluated cumin varieties under Gujarath conditions and the maximum plant height was recorded in RZ-19 (33.3 cm) and minimum in RZ-209 (17.9 cm).

Eleven coriander genotypes were screened for growth and yield parameters under Arabhavi conditions. Among them, CO-2 recorded higher dry weight of plant (8.02 g) at harvest stage and while it was lowest in Gadag Local (5.45 g) during *kharif* season. While, in *rabi* season, RCr-41 recorded maximum dry weight (8.61 g) and the lowest dry weight was noticed in Guntur Local (5.50 g) (Velayudham, 2004). Maximum number of primary (6.5) and secondary branches (12.1) per was registered in plant in coriander var. LCC-216 (Giridhar and Sarada, 2005).

The mean data of four years in Guntur conditions revealed that, all the genotypes of fenugreek varied significantly with respect to growth parameters. JF-210 (604cm<sup>2</sup>) and JF-204 (572cm<sup>2</sup>) recorded significantly higher plant spread than the check, Lam Sel-1 (426cm<sup>2</sup>) (Sarada *et al.*, 2005).

Among thirteen varieties of fenugreek evaluated under Ludhiana conditions, plant height ranged from 80.37 to 121.53 cm in the genotypes IC-397326, IC-144312, IC 398123 and IC-144300 was recorded (Singh *et al.*, 2007). The number of branches ranged from 7.37 (Metha Amber) to 21.3 (IC-397265) in the genotypes.

Palanikumar and Rajamani (2012) evaluated seventy five genotypes of coriander for fresh and dry biomass yield under Coimbatore conditions. Among them maximum fresh and dry biomass yield noticed in CS 101(13.35 g and 2.67 g, respectively) followed by UD 685 (10.45 g

and 2.09 g, respectively), while, the minimum were observed in CS 177 (3.68 g and 0.74 g, respectively).

Twenty five fenugreek genotypes evaluated for growth and yield under Bengaluru conditions, showed significant variation in number of branches per plant. Highest number of branches per plant was observed in the genotype, CO-1 (6.45) and least was in RMT 303 (2.20) with high GCV (27.37), and PCV (31.03) and high heritability (77.77 %). Significant variation in plant spread at harvest among the genotypes was also recorded with high GCV (21.81), high PCV (22.50) and high heritability (93.94 %). (Pushpa *et al.* 2012)

An experiment was conducted to evaluate hundred forty cumin germplasms at NRCSS, Ajmer (Meena *et al.*, 2015a) recorded maximum plant height in JC-02-32 (29.35 cm) while minimum was in AC-16 (13.5 cm). Where as maximum number of branches was recorded in AC-72 (8), while minimum was in ECT (4.5).

## 2.2.2 Yield parameters

Among six local cultivars of ajwain evaluated under alluvial zone of West Bengal maximum seed yield was recorded in RA-2 (503.32 kg ha<sup>-1</sup>) as against the minimum seed yield of RA-6 (273.5 kg ha<sup>-1</sup>) (Datta *et al.*, 2001). Among the 39 accessions of fenugreek studied, five genotypes *i.e.* RMT-143, HM-271, Rajendra Kranti, CO-2 and PEB were found to be significantly superior with respect to biological yield and economic yield (Verma and Korla., 2003).

Genetic variability study carried out in fenugreek at Sriniketan, West Bengal, with 22 genotypes revealed high Phenotypic and genotypic coefficients of variability for days to flowering and duration of flowering. High to moderate estimates of heritability coupled with moderate to high genetic advance were also recorded for days to flowering and duration of flowering ( Kole, 2004).

Cumin varieties evaluated for yield attributes under Gujarath conditions in which the highest number of umbels per plant (15.10) and seeds per umbel (38.2) were recorded in RZ-19 (Patidar *et al.*, 2004).

Among eleven genotypes of coriander evaluated at Arbhavi maximum number of umbels per plant (23.80 and 32.00) and umbellets per umbel (5.12 and 5.37) were recorded in RCr-41 in *kharif* and *rabi* respectively, and maximum seeds per umbel (5.13) in CO-3 as against the minimum number of umbels per plant (14.93) and seeds per umbel (4.16 and 4.40) in Guntur Local and umbellets per umbel (4.18 and 4.00) in Gadag Local during *kharif* and *rabi* seasons respectively (Velayudham, 2004).

There was a significant difference with respect to harvest index among varieties. The highest harvest index was recorded in CO-1 (57.05%) and DWD-3 (56.16%) in *kharif* and *rabi* seasons respectively, as against the lowest harvest index in Guntur Local (46.99%) and RCr-41 (43.08%) in *kharif* and *rabi* seasons respectively (Velayudham, 2004).

Significantly least days to 50 per cent flowering was recorded by genotype LCC-192 (42.1) compared to check Sadhana which recorded 46.4 days in coriander (Giridhar and Sarada, 2005). Maximum number of umbels per plant (21.5), number of umbellets per umbel (7.4) and number of seeds per umbel (25.4) were in LCC-216 and was significantly superior to check Sadhana (15.3, 5.4 and 19.7, respectively).

Coriander genotypes LCC-170 and LCC-172 took maximum number of days to mature (86.1) as compared to minimum (81.6) in LCC-192. Similarly, coriander genotype UD-118

required maximum number of days to mature (99.2), while, minimum number of days to maturity was in LCC-174 (82.2 days). Similarly, DH-205 recorded the maximum number of days for fifty per cent flowering (69.1) and minimum in check variety Sadhana (46.7 days). LCC-216 recorded maximum yield (863.2 kg/ha) followed by LCC-212 (836.1 kg/ha), which were at par with each other and significantly superior to check Sadhana (624.8 kg/ha) (Sarada and Giridhar, 2005).

In a trial involving eleven genotypes of coriander under Kumarganj conditions of Uttar Pradesh, K-selection produced maximum seed yield (21.02 q/ha) followed by RCr-41 (20.59 q/ha) and UD-743 (20.49 q/ha). Minimum number of days recorded for maturity in DH-208 (142.66 days), which was *at par* with Pant Haritma (141.4 days) (Saxena *et al.*, 2005).

Out of 24 cumin genotypes evaluated for growth and yield attributes, highest seed yield was recorded in GC-3 (333.33 kg ha<sup>-1</sup>) followed by GC-2 (291.67 kg ha<sup>-1</sup>), while the least was recorded in JC-2003 (41.66 kg ha<sup>-1</sup>) (Agarwal *et al.*, 2006).

Among 230 coriander genotypes evaluated under Coimbatore conditions, the accession UD-15 recorded the maximum number of umbels per plant (23.92) and umbellets per umbel (6.99) over other genotypes (Prabhu and Balakrishnamoorthy, 2006). There was ample variation for seed yield and higher seed yield was reported in UD-15 (573.33 kg ha<sup>-1</sup>) followed by UD-681 (560 kg ha<sup>-1</sup>).

Among 13 varieties of fenugreek which were evaluated under Ludhiana conditions (Singh *et al.*, 2007), harvest index ranged from 11.24 to 22.34% in genotypes M-17, IC-398123, IC-296791, IC-144277 and IC-144300, respectively.

Twenty five fenugreek genotypes with diverse geographical origin were evaluated for growth and yield under Bengaluru conditions. There was a significant variation in days to 50 per cent flowering with moderate GCV (14.05), high PCV (14.05) and high heritability (99.99 %) (Pushpa *et al.*, 2012).

Anubha *et al.* (2013) subjected fifty fenugreek germplasm for study along with 5 standards check varieties and reported the existence of significant variation in the days to pod maturity, number of pods per plant and number of seeds per plant.

Among 13 promising fenugreek genotypes evaluated for growth and yield parameters significant variation in number of pods per plant, number of seeds per plant, number of days for pod maturity, pod length and for yield, maximum yield was recorded in the genotype LFC-103 (584.1 kg/ha) followed by HM-348 (542.8 kg/ha) (Giridhar *et al.* 2015).

Meena *et al.* (2015a) evaluated 160 cumin germplasms under Ajmeer conditions and observed maximum number of umbel per plant in AC-1 (35.6) as against minimum in JC-02-08 (18.9) and JC-94-44 recorded maximum seed yield (7.17 q/ha), whereas minimum (4.3 q/ha) was in JC-02-08.

## **2.3 Performance of fennel varieties for quality and genetic variability parameters**

The existence of wide range of genetic variability in a population for economically important characters enables the crop improvement in the desirable direction. Thus, for effective selection and utilization of genotypes for breeding programme, a thorough knowledge on genetic variability, heritability and genetic advance is essential.

The phenotypic variability is a measure of variability due to genotype, environment and their interaction. The genetic variability is the real measure of variability concealed in a population. It indicates the relative magnitude of genetic diversity existing in the breeding population and helps to compare the genetic variability present for different characters. The determination of genetic variability and partitioning it into heritable and non-heritable components is necessary to have an insight on genetic nature of yield and yield components characters or parameters.

Heritability refers to the degree to which variability of a character is transmitted to the progeny. The heritable variation is masked by non-heritable components. Hence, it is necessary to split the overall variability into heritable and non-heritable variation using genetic parameters. The ratio of genotypic variance to the total variance in non-segregating population is known as heritability in broad sense (Hanson *et al.*, 1956). Whereas, the ratio of additive variance to the total or phenotypic variance is referred to as narrow sense heritability (Lush, 1949). Thus, heritability is the heritable proportion of phenotypic variance.

Genetic advance under selection is the improvement in the mean genotypic value of selected plants over parental population which depends upon the genetic variability present in the population, heritability of the characters and the intensity of selection. Heritability estimates may not provide clear predictability of the breeding value. Therefore, estimation of heritability accompanied with genetic advance is generally more useful than heritability alone in prediction of the resultant effect, for selecting the best individuals (Johnson *et al.*, 1955). This is due to the fact that a character having high heritability may have very less phenotypic variation, thus, leading to low genetic advance but, in the presence of additive gene effects high genetic advance can be expected (Panse, 1957).

Hence, study on components of variances and heritable components with suitable genetic parameters such as genotypic and phenotypic coefficients of variation, heritability and genetic advance are important tools for the breeders in selection of elite genotypes from diverse population.

Performance of 34 fennel accessions was tested under Ajmer conditions for volatile oil content, anethole content and fenchone content, which revealed maximum volatile oil content (2.6 %) in UF- 177 while minimum (1.4%) in UF-134, maximum anethole content in RF-101 (40.51 %) as against minimum in RF- 125 (9.3 %) and minimum fenchone content(11.8 %) in RF-125 as against maximum fenchone content (22.77 %) in UF- 178 ( Agrawal *et al.*, 2003).

Genetic diversity study as 12 varieties of fennel and their 66 F1's for eight component traits was carried out (Sharma and Meena, 2013). Extent of variability observed for each trait was considerable, but, the extent of vigor expected in F1's as compared with the parents was not too high, which shows lack of diverse alleles in the genotypes selected.

Analysis of variability in 25 diverse genotypes of fennel in Kumarganj conditions of Uttar Pradesh, revealed higher genotypic and phenotypic co- efficient of variance for seed yield, seeds per umbel, number of umbels per plant, number of branches per plant and number of umbellets per umbel. Heritability estimates were high for test weight, seed yield, seeds per umbel, number of umbels per plant and plant height (Yadav *et al.*, 2013).

Thirteen fennel genotypes evaluated for variability under Jabalpur conditions, revealed that PCV is greater than GCV for all the characters studied. High estimates of heritability was observed for number of seeds per umbel, seed yield, branches per plant, days to maturity days to 50 per cent flowering and umbellets per umbel ( Senagupta *et al.*, 2014).

Path co-efficient analysis was done (Gujarat conditions) with the use of 55 fennel genotypes and found, higher positive direct effect on seed yield by number of umbellets per umbel followed by number of branches per plant, days to 50 per cent flowering, number of umbels per plant and test weight Patel and Patel (2015).

Genetic variability was assessed in 50 fennel genotypes under NRCSS, Ajmer conditions (Sharma *et al.*, 2015) and found that PCV was greater than GCV, heritability estimates were high for seed yield, plant height, umbellet per umbel, umbel per plant, and seeds per umbellet. High genetic advance as per cent mean was recorded for seed yield, plant height, umbellet per umbel, umbel per plant and branches per plant. Similarly, PCV was higher than GCV for most of the characters. Number of primary branches (0.75), number of secondary branches (0.63), umbel per plant (0.87), umbellate per umbel (0.63), seeds per umbellate (0.70) and test weight (0.52) exhibited high genetic advance as percentage mean along with high heritability and significantly correlated with the seed yield (Kumar *et al.*, 2017) at Ajmeer conditions.

## **2.4 Performance of other seed spice varieties for quality attributes and genetic variability parameters**

Variability of 23 genotypes of coriander was estimated which revealed that PCV was greater than the GCV. All the traits registered high heritability estimates. Heritability and genetic advance were high for harvest index, number of primary and secondary branches per plant, number of umbels per plant and 1000-grain weight Singh and Singh (2005). Similarly, high variability for, number of umbels per plant (28.65%), number of seeds per umbel (21-63%) and seed yield (22.82%) and low variability for number of days to 50 per cent flowering (12.39%) and number of umbellets per umbel (13.30%). High broad sense heritability (91.94%) and genetic advance (56.55%) were obtained for number of umbels per plant and number of seeds per umbel (Singh *et al.*, 2006).

The GC-MS analysis of coriander leaf oil and seed oil has shown that, 2-decenoic acid (30.18%) and linalool (37.70%) are the major compounds in leaf and seed respectively (Bhuiyan *et al.*, 2009). Similarly, gas chromatography mass spectroscopy analysis of coriander essential oil obtained at different maturity stages revealed that, geranyl acetate (46.27%) and linalool (76.33 and 87.50%) are major compounds at immature stage, middle stage and maturity stage respectively (Pande *et al.*, 2010).

Variability of 64 fenugreek genotypes was estimated under Jagudan conditions. High heritability (82.80) estimates along with moderate to low genetic advance (16.114) as percentage of mean were recorded for plant height (Prajapati *et al.*, 2010). Similarly, coriander essential oil was analysed through GC-MS and identified 17 chemical compounds. Linalool content was the highest (73.11%) (Zoubiri and Baaliouamer, 2010).

Coriander essential oil was analysed through GC-MS and found that, linalool (69.60%) was the principle constituent followed by geranyl acetate (4.99%) (Anwar *et al.*, 2011) and studied maturational effects on yield and composition of coriander essential oil which revealed, that higher oil yield (0.32%) along with linalool (36.69 to 72.35%) and geranyl acetate (35.17%) as main compounds was at full maturity stage (Msaada *et al.*, 2011).

Telci *et al.* (2011) evaluated two types of coriander for oil content and chemical composition. *Microcarpum* variety had higher oil content and linalool content (63.50 – 71.00%) than variety *vulgare* (42.10 – 52.70%). In a three season trial Palanikumar and Rajamani (2012) observed that, coriander genotype CS 101 recorded the maximum oil content (0.54, 0.54 and 0.54%, respectively), followed by UD 685 (0.47, 0.48 and 0.47%, respectively) and CS 136 (0.44, 0.43 and 0.43%, respectively) in all the seasons.

A variability study on 25 fenugreek genotypes grown under Bengaluru conditions and demonstrated significant variation in plant height with moderate GCV (18.71), high PCV (23.74) and high heritability (62.14 %) (Pushpa *et al.*, 2012). Similarly, 43 ajwain genotypes studied at Center for Research on Seed Spices, Jagudan conditions, also showed wide variability existed among the genotypes for morphological and economic traits *viz*, days to 50 per cent flowering (87-96), plant height (70.7- 95 cm), number of branches (7-13.3), number of umbels per plant (12-22), number of umbellets per umbel (8.7-16.7), number of seeds per umbellet (14.7- 22.3) and yield (444-1630 kg) (Ravindra babu *et al.*, 2012).

Investigation on essential oil composition of coriander herb revealed higher amount of aliphatic aldehydes like decanol, E-2-dodecanol and E-2-decenol followed by linalool (Wierdak, 2012). Similarly, essential oil content under Hisar conditions also showed no significant difference. However, DH-220 produced the highest (0.39%) essential oil content (Malik and Tehlan, 2013).

Variation in coriander essential oil content was examined at different maturity stages. Maximum oil content was observed at green fruit stage (0.37%) followed by brown fruit (0.31%), full flowering (0.23%) and vegetative (0.14%) stages (Ramezani *et al.*, 2013).

Cumin germplasms (160) were subjected to evaluation under NRCSS, Ajmer conditions. Results showed that, all attributes registered high heritability estimates. The higher GCV is observed for plant height, primary branches per plant and test weight. Heritability and genetic advance were high for seed yield, plant height, days to maturity and test weight (Bairwa *et al.*, 2015).

GC-MS analysis of coriander essential oil revealed that linalool and neryl acetate as predominant compounds in methanol extracts and disulfide, methyl 2-methyl-1-(methyl thio) butyl in acetone extracts (Thangavel *et al.*, 2015).

## III. MATERIAL AND METHODS

The investigation entitled "Evaluation of fennel (*Foeniculum vulgare* Mill.) varieties under Eastern dry zone of Karnataka" was undertaken to study the behaviour of economic traits with respect to component of variances. The experiment was carried out at Department of plantation, spices, medicinal and aromatic crops, College of Horticulture, UHS campus G.K.V.K post, Bangalore, University of Horticultural Sciences, Bagalkot during November 2016 to April 2017. The details of material used and methods followed during the course of investigation are presented in this chapter.

### 3.1 Geographical location of the experimental site

The experimental field is located at an altitude of 930 m above MSL at 12°58<sup>1</sup> North latitude and 77°35<sup>1</sup> East-longitude in the Eastern Dry Zone of Karnataka. Eastern dry zone has semi arid type of climate. The mean annual rainfall for the zone is 768.4 mm. The rainfall distribution has 2 peaks, one in May and other in September. More than 50 per cent of the rains are received between June and September. The mean monthly maximum temperature ranges between 25° C to 33° C. Soils are red loamy in major areas and clay lateritic soils in remaining areas (Annexure- I).

### 3.2 Soil and climatic conditions

The experimental field was fairly leveled land with red sandy loam soil of uniform fertility status (Annexure- II).

### 3.3 Experiment details

Experiment was laid out on a RCBD comprised of 12 varieties replicated three times, each experimental plot measures 2 m × 3 m in which fennel was sown at a spacing of 50 cm rows and 20 cm within the rows on 3<sup>rd</sup> November. Before sowing FYM at 25 t/ha and fertilizers of 60: 60 kg N and P were applied and mixed well. 30 kg nitrogen applied as topdressing at 30 days after sowing and Seed rate used was 10 kg ha<sup>-1</sup>.

#### 3.3.1 Treatment details:

Twelve varieties used as treatments in the present study

**Table 1: List of fennel varieties used in evaluation for growth, yield and quality parameters**

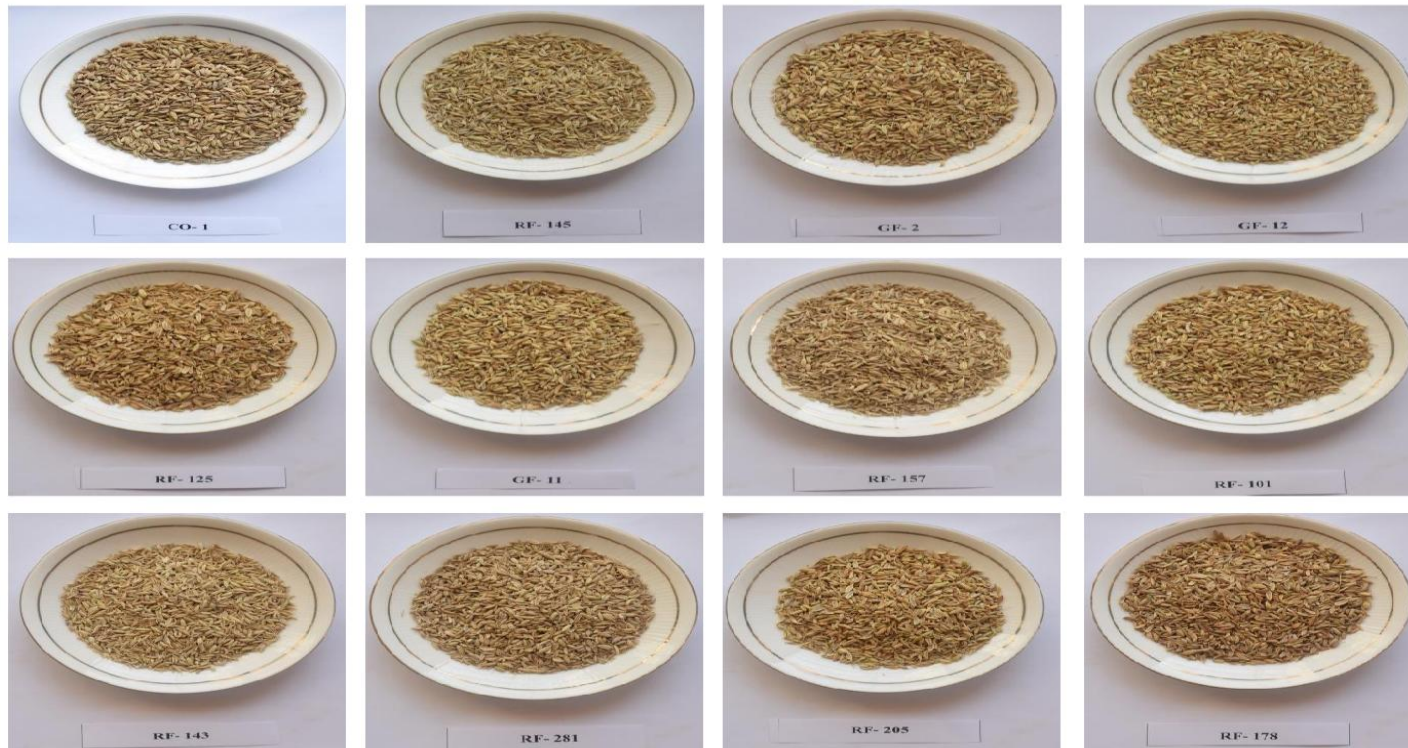
<b>Sl. No.</b>	<b>Variety</b>	<b>Source</b>
1	CO- 1	Horticulture College&Research institute, Coimbatore
2	GF- 2	Center for Research on Seed Spices, Jagudan
3	GF- 11	Center for Research on Seed Spices, Jagudan
4	GF- 12	Center for Research on Seed Spices, Jagudan
5	RF- 157	S.K.N College of Agriculture, Jobner
6	RF- 125	S.K.N College of Agriculture, Jobner
7	RF- 281	S.K.N College of Agriculture, Jobner
8	RF- 205	S.K.N College of Agriculture, Jobner
9	RF- 143	S.K.N College of Agriculture, Jobner
10	RF- 178	S.K.N College of Agriculture, Jobner
11	RF- 101	S.K.N College of Agriculture, Jobner
12	RF- 145	S.K.N College of Agriculture, Jobner

### **3.4 Cultural practices**

The details of various cultural operations carried out during the course of investigation are furnished below.

#### **3.4.1 Preparation of experimental plot**

The land was thoroughly ploughed twice and brought to fine tilth. All the weeds and stubbles were removed. Each plot was levelled.



**Plate 1. Seeds of different fennel varieties used in the experiment**

### **3.4.2 Manuring and fertilizer application**

Recommended dose of nutrients were applied to each plot through organic and inorganic sources. Recommended quantity of farm yard manure (15 kg/ plot) was incorporated one month prior to sowing and thoroughly mixed into the soil by forking. The inorganic nutrients were applied in the form of straight fertilizers. Nitrogen and phosphorus were applied in the form of urea and single super phosphate respectively. Of these, 60 kg N along with full dose of  $P_2O_5$  were broadcasted in the respective plots as basal application. The remaining 30 kg nitrogen was applied as top dressing at 30 days after sowing.

### **3.4.3 Sowing**

The seeds of different varieties of fennel procured from the various research institutes of our country and used for the experiment (Table.1) and were sown at 20 cm in lines of 50 cm apart. Three to four seeds were sown at each spot to ensure the required population. The plots were irrigated immediately after sowing through drip in order to ensure even germination and gap filling was done 15 days after sowing to maintain optimum plant population.

### **3.4.4 Irrigation**

The laterals were laid in alternate rows for uniform distribution of water through drip system. The crop was irrigated daily for two hours using inline drippers (2LPH) moulded at 30 cm apart. The irrigation was provided till the harvest of the crop.

### **3.4.5 Thinning and weeding**

Thinning was done at 15 and 30 days after sowing and two seedlings per hill were retained. The plots were kept free from weeds by regular hand weeding at 30 and 45 days after sowing.

### **3.4.6 Plant protection measures**

Pest and diseases were managed as mentioned here under.



**Plate 2a. General view of the experimental plot at 45 days after sowing**



**Plate 2b. General view of the experimental plot at 75 days after sowing**

<b>Pest/ disease</b>	<b>Pesticides used</b>	<b>Crop growth stage</b>
Collar rot	Carbandizim 50 W P (Bavistin <sup>®</sup> ) 2 g and Mancozeb 75 W P (Indizeb) 2 g per litre	47, 55 and 64 DAS
Aphids	Dimethoate 30 E C (Rogar) @ 2 ml/l	At 60 DAS

### **3.4.7 Harvesting**

The individual umbels were harvested using secateurs two times at weekly intervals when majority of umbellets or seeds were fully mature, but still green or light green before turning brown. Thereafter, the plants were cut at ground level when majority of the umbels matured and the umbels were separated. The separated umbels were dried under shade and threshed later by using wooden sticks. The seeds separated were cleaned by winnowing.

### **3.5 Observations**

The technique of random sampling was adopted for selecting plants for recording the observations on various growth and reproductive parameters of fennel. Five representative plants in each treatment and in each replication leaving the border plants were selected randomly, tagged and observations were recorded. The data recorded on five plants from each treatment was averaged and was used for statistical analysis. The details of observations recorded and techniques adopted for recording observations are described here under.

#### **3.5.1 Vegetative parameters**

##### **3.5.1.1 Plant height (cm)**

The plant height was measured from the collar region to the growing tip of the stem in five tagged plants at 30, 60, 90 and 120 days after sowing and at the time of harvest and mean values were computed and expressed in centimetre.

##### **3.5.1.2 Number of primary branches per plant**

The number of branches arising from the main stem in five tagged plants was recorded at 30, 60, 90 and 120 days after sowing and at harvest, the mean values were computed.

#### **3.5.2 Reproductive parameters**

##### **3.5.2.1 Days to first flowering**

The plants in the experimental plots were regularly observed for flower appearance. Number of days taken for the first flower appearance in each treatment in each of the replications was calculated from date of sowing.

### **3.5.2.2 Days to 50 per cent flowering**

The date on which 50 per cent of plants in the net plot area flowered in each treatment was recorded. Using this data, the number of days taken for 50 per cent flowering was computed by counting from date of sowing.

### **3.5.2.3 Days to maturity**

Number of days taken for maturity of the crop was computed by counting the days taken from the date of sowing to first harvest of umbels in each treatment.

## **3.5.3 Yield parameters**

### **3.5.3.1 Number of umbels per plant**

All the umbels in five tagged plants were counted and their average was worked out and expressed as number of umbels per plant.

### **3.5.3.2 Number of umbellets per umbel**

Five umbels were randomly selected from each of the five tagged plants for recording number of umbellets per plant. The total number of umbellets in each umbel was counted and their average was worked out and expressed as number of umbellets per umbel.



**Plate 3a. General view of the experimental plot at mass flowering stage**



**Plate 3b. Bee activity during flowering in fennel**

### **3.5.3.3 Number of seeds per umbellet**

Twenty umbellets were randomly taken from the umbels of five tagged plants and the number of seeds present in each umbellet was counted and the average was calculated and expressed as number of seeds per umbellet.

### **3.5.3.4 Fresh and dry weight of umbel (g)**

At weekly intervals and finally, all the matured umbels in the plot were harvested and their fresh weight was recorded in each treatment and in all the replications. Then, the cumulative fresh weight of umbels of all the plants, of all the harvests was computed and the average fresh weight of umbel was computed and expressed in grams. Similarly, the dry weight of umbel was computed after shade drying of harvested umbels and expressed in grams.

### **3.5.3.5 Fresh weight of the plant after harvesting (g)**

Five plants in each treatment and replication were cut at the ground after harvesting all the umbels and their fresh weight was recorded and averaged and expressed in gram per plant.

### **3.5.3.6 Dry weight of plant (g)**

After recording the fresh weight of plants, the material was kept in oven at 60° C for drying and the dry weight was recorded, averaged and expressed in gram per plant.

### **3.5.3.7 Seed yield per plant (g)**

All the matured umbels in the five tagged plants in the plot were harvested as described earlier, shade dried, threshed, cleaned and the weight of cleaned seed was recorded and expressed in gram per plant.

### **3.5.3.8 Seed yield per plot (g)**

All the matured umbels in the plot were harvested as described earlier, shade dried, threshed and cleaned and the net weight of cleaned seed was recorded. The yield yield of five randomly selected plants was also added to arrive at seed yield per plot.

### **3.5.3.9 Seed yield per hectare (kg ha<sup>-1</sup>)**

Using the data on seed yield per plot seed yield per ha was computed.

### **3.5.3.10 Harvest index (%)**

It is the ratio of economical yield to biological yield and expressed in percentage. In this case it is the ratio of seed yield to the total biological yield.

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

### **3.5.3.11 Test weight (g)**

Thousand seeds were counted and their weight was recorded in each treatment replication wise after shade drying, threshing and cleaning the seeds.

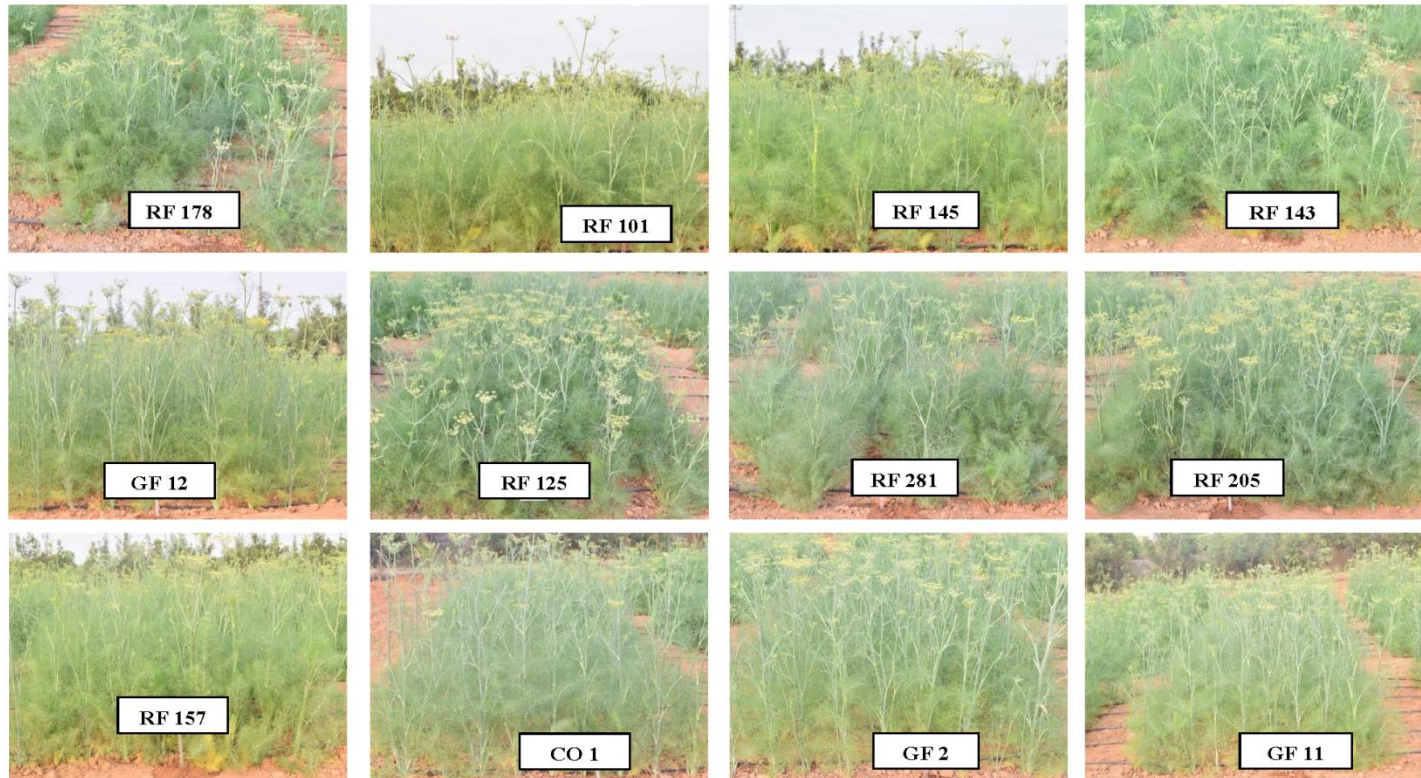
### **3.5.3.12 Oil yield (kg ha<sup>-1</sup>)**

Fennel seeds were grounded into fine powder using grinder and grounded powder was soaked in water for three hours before extraction. Oil was extracted from known quantity of grounded fennel seeds by using Clavenger's apparatus. Oil yield was estimated by using seed yield (kg ha<sup>-1</sup>) and essential oil content (%).

## **3.5.4 Quality parameters**

### **3.5.4.1 Oil content (%)**

Using Clavenger's apparatus for essential oil lighter than water oil was extracted from 300 g of freshly ground fennel seeds. The distillation time was standardized by distilling the samples for different duration. The period beyond which no increase in the volume of oil was considered as the standard time for completing a batch of samples. Taking this into consideration, the samples were distilled for a period of three hours. The volume of oil was recorded and collected and expressed as percentage (ml/100g). The oil samples were stored in the glass vials in a cool dry place away from sun light for analysing anethole content of essential oil.



**Plate 4. View of different fennel varieties studied**

### 3.5.4.2 Anethole content (%)

The oil samples were subjected to Gas Chromatography-Mass Spectroscopy (GC-MS) analysis as detailed below.

Pure anethole (99.1%) obtained from Sumana Enterprises Pvt. Ltd. Co. Bengaluru, was used as reference compound. The reference compound (10 mg) was dissolved in 5 ml of HPLC grade dichloro-methane to make a stock solution of 10000 ppm (10 mg ml<sup>-1</sup>). The components of essential oil were analyzed by GC-MS equipped with 1,000 stainless steel columns, a flame ionization detector and an integrator. Helium was used as a carrier gas. The flow rate of Helium was 0.5 ml s<sup>-1</sup>. The GC apparatus was run with the following specifications: detector temperature 250 °C; oven temperature 160 °C; injector temperature 250 °C; sample size 20 µl. The identification of the active constituents was made on the basis of retention time and their quantification was carried out comparing the experimental peaks with those obtained from the reference standards.

## 3.6 Statistical analysis

Fisher's method of analysis of variance was applied for the analysis and interpretation of the experimental data as suggested by Panse (1957). The level of significance used in 'F' and 't' test was P=0.05. The critical difference (CD) values were calculated at five per cent level, wherever 'F' test was significant.

Basic genetic analysis like mean, range, genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV), heritability, genetic advance and genetic advance as percent mean were estimated.

### 3.6.1 Study of variability parameters in fennel varieties

The variability among the genotypes for traits related to seed yield in fennel was estimated as mentioned below.

#### 3.6.1.1 Genotypic variance and phenotypic variance

Phenotypic and genotypic components of variance were estimated by using the formula given by Cochran and Cox (1957).

$$\text{Genotypic variance } (\sigma^2_g) = \frac{\text{MSS due to varieties} - \text{MSS due to error}}{R}$$

Where, 'R' is the number of replications

$$\text{Phenotypic variance} = \text{Genotypic variance } (\sigma^2_g) + \text{Error variance } (\sigma^2_e)$$

#### 3.6.1.2 Co-efficient of variability

Both phenotypic and genotypic co-efficient of variability for all characters were estimated using the formula of Burton (1952).

$$\text{Phenotypic Co-efficient of Variability (PCV\%)} = \frac{\sqrt{\text{Phenotypic variance}}}{\text{Grand mean}} \times 100$$

$$\text{Genotypic Co-efficient of Variability (GCV\%)} = \frac{\sqrt{\text{Genotypic variance}}}{\text{Grand mean}} \times 100$$

PCV and GCV were classified into three following categories as suggested by Shivasubramanian and Madhamenon (1973).

Low: Less than 10 per cent, Moderate: 10-20 per cent and High: More than 20 per cent.

### 3.6.1.3 Heritability in broad sense ( $h^2$ )

The broad sense heritability ( $h^2_{bs}$ ) was estimated for all the characters as the ratio of genotypic variance to the total of phenotypic variance as suggested by Falconer (1981).

$$h^2 = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}} \times 100$$

Heritability estimates in cultivated plants could be placed in the following categories as suggested by Robinson *et al.* (1966).

Low: 0-30 per cent;      Moderate: 30-60 per cent;      High: >60 per cent

### 3.7.1.4 Genetic advance (GA)

The expected genetic gain or advance for each character was estimated by using the following method suggested by Johnson *et al.* (1955).

$$GA = h^2_{bs} \times \sigma_p \times K$$

Where,

$h^2_{bs}$  = Heritability estimate in broad sense  
 $\sigma_p$  = Phenotypic standard deviation of the trait  
 $K$  = Selection differential (2.06) at 5 per cent selection intensity.

Genetic advance was classified as high (> 20%), moderate (10-20%) and low (<10%).

Further the Genetic advance as per cent mean was computed by using the following formula

$$\text{GA as per cent of mean} = \frac{GA}{\text{Grand mean}} \times 100$$

Genetic advance as per cent mean was categorized into following groups as suggested by Johnson *et al.* (1955).

Low: < 10 per cent, Moderate: 10-20 per cent and High: > 20 per cent

### 3.7.1.5 Analysis of variance:

Source of variation	Degrees of freedom	SS	MSS	F-ratio
Replication	r-1	RSS	$MSS_r = \frac{R_{ss}}{r-1}$	MSS <sub>t</sub> / MSS <sub>e</sub>
Treatment	t-1	TrSS	$MSS_t = \frac{Tr_{ss}}{t-1}$	
Error	(t-1)(r-1)	ESS	$MSS_e = \frac{Ess}{(t-1)(r-1)}$	
Total	tr-1	TSS		

### 3.7.1.6 Correlation analysis

To determine the degree of association of characters with yield and also among the yield components, the correlation coefficients were calculated.

Both genotypic and phenotypic coefficients of correlation between two characters were determined by using the variance and covariance components as suggested by Al-Jibouri *et al.* (1958).

$$r_g(xy) = \frac{Cov_g(xy)}{\sqrt{\sigma_g^2(x) \cdot \sigma_g^2(y)}}$$

$$r_p(xy) = \frac{Cov_p(xy)}{\sqrt{\sigma_p^2(x) \cdot \sigma_p^2(y)}}$$

Where,  $r_g(xy)$ ,  $r_p(xy)$  are the genotypic and phenotypic correlation coefficients respectively.

$Cov_g$  and  $Cov_p$  are the genotypic and phenotypic covariance of  $xy$ , respectively.  $\sigma_g^2$  and  $\sigma_p^2$  are the genotypic and phenotypic variance of  $x$  and  $y$ , respectively.

The calculated value of 'r' was compared with table 'r' value with n-2 degrees of freedom at 5 per cent and 1 per cent level of significance, where, n refers to number of pairs of observation.

Thus, the data obtained from various experimental objectives were subjected to pertinent statistical analysis to draw meaningful inference towards the genetic divergence of various fennel varieties.

### 3.7.1.7 Path coefficient analysis

Path coefficient analysis was carried out using phenotypic correlation values of yield components on yield as suggested by Wright (1921) and illustrated by Dewey and Lu (1959). Standard path coefficients which are the standardized partial regression coefficients were obtained using statistical software packages called INDOSTAT. These values were obtained by solving the following set of 'p' simultaneous equation using above package.

$$P_{01} + P_{02} r_{12} + \dots + P_{0p} r_{1p} = r_{01}$$

$$P_{01} + P_{12} r_{02} + \dots + P_{0p} r_{2p} = r_{02}$$



$P_{01} + r_{1p} + P_{02} r_{2p} + \dots + P_{0p} = r_{0p}$ . Where,  $P_{01}, P_{02}, \dots, P_{0p}$  are the direct effects of variables 1, 2, ..., p on the dependent variable 0 and  $r_{12}, r_{13}, \dots, r_{1p}, \dots, r_{p(p+1)}$  are the possible correlation coefficient between various independent variables and  $r_{01}, r_{02}, r_{03}, \dots, r_{0p}$  are the correlation between dependent and independent variables.

The indirect effects of the  $i^{\text{th}}$  variable *via*  $j^{\text{th}}$  variable is attained as  $(P_{0j} \cdot r_{ij})$ . The contribution of remaining unknown factor is measured as the residual factor, which is calculated and given below.

$$P^2_{ox} = 1 - (P^2_{01} + 2P_{01}P_{02}r_{12} + 2P_{01}P_{03}r_{13} + \dots + P^2_{02} + 2P_{02}P_{03}r_{13} + \dots + P^2_{0p})$$

Residual factor =  $v(p^2_{ox})$

Negligible: 0.00 to 0.09, Low: 0.10 to 0.19, Moderate: 0.20 to 0.29, High: 0.30 to 1.0 and Very High: > 1.0.

## IV. EXPERIMENTAL RESULTS

The objectives of the present investigation are to find out the extent of genetic variability, heritability (broad sense), genetic advance, correlation among different characters and direct and indirect effects of different characters on seed yield. The data was collected in 12 fennel varieties on 18 characters related to growth, reproductive, yield and quality parameters and subjected to biometrical analysis and the results obtained are presented here:

- 4.1 Analysis of variance
- 4.2 Genetic components of variation
- 4.3 Association among different parameters
- 4.4 Path coefficient analysis

### 4.1 Analysis of variance

Results of analysis of variance of 12 fennel varieties are presented in Table 2. The analysis of variance for 18 characters in fennel (*Foeniculum vulgare* Mill.) indicated significant differences among the varieties for all the characters except days to first flowering and test weight.

Analysis of variance for all the eighteen characters viz, plant height (cm), number of primary branches per plant, days to first flowering, days to fifty per cent flowering, days to maturity, number of umbels per plant, number of umbellets per umbel, number of seeds per umbellet, fresh weight of umbel, dry weight of umbel, fresh weight of plant, dry weight of plant, seed yield per plant (g), seed yield per plot (g), seed yield per hectare (kg), harvest index (%), test weight (g) and oil yield (kg/ha) was carried out to partition total variation due to genotype and other sources.

Co-efficient of variation for 18 characters varies from 5.15 to 14.86, this variation is observed due to because of, some parameters much affected by various environmental factors and some may not be. From the results (Table.2) found that, wide range of variation was observed for various parameters, this gives us an opportunity to select desirable variety for different characters.

**Table 2: Analysis of variance for growth, yield and quality parameters in fennel varieties**

Parameters	d.f.	Mean sum of square																	
		X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18
Treatments	11	662.66*	3.09*	12.91	29.23*	34.88*	39.59*	42.09*	16.61*	18.19*	3.17*	6256.34*	740.22*	46.44*	167255.35*	464615.69*	25.96*	1.10*	181.90*
Replication	2	1757.53	1.94	9.92	11.38	28.08	13.88	0.78	5.31	30.41	15.22	608.76	2706.03	41.40	147040.19	408404.91	1.44	0.95	56.71
Error	22	97.55	0.63	9.01	13.38	1.23	8.64	2.63	5.36	3.05	0.67	461.91	45.60	8.82	31818.68	88387.63	7.72	0.69	22.66
CV (%)	-	6.49	9.57	NS	5.23	0.80	14.04	6.02	8.00	6.80	7.68	5.81	5.15	13.68	13.69	13.69	12.89	NS	14.06

NS- Non Significant

d.f – Degrees of freedom

X1= Plant height (cm)

X2= Number of primary branches per plant

X3= Days to first flowering

X4= Days to 50 per cent flowering

X5= Days to maturity

X6= Number of umbels per plant

X7= Number of umbellets per umbel

X8= Number of seeds per umbellet

X9= Fresh weight of umbel (g)

X10= Dry weight of umbel (g)

X11= Fresh weight of plant after harvesting the umbels (g)

X12= Dry weight of plant (g)

X13= Seed yield per plant (g)

X14= Seed yield per plot (g)

X15= Seed yield per hectare (kg ha<sup>-1</sup>)

X16= Harvest index (%)

X17= Test weight (g)

X18= Oil yield (kg ha<sup>-1</sup>)

## 4.2 Genetic components of variation

Genetic improvement of any crop depends mainly on the substantial magnitude of variability in the varieties. To understand the extent to which the observed variations are due to genetic factors, genetic variability estimates including mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in broad sense ( $h^2$ ) and expected genetic advance as per cent mean (GAM) in respect of these characters were computed and are presented in Table 3, Fig.1 and 2. It is evident from the results that, large amount of variability was noticed for most of the characters under study. The character wise details of these variability parameters are presented below.

### 4.2.1 Plant height (cm)

Results pertaining to plant height of different fennel varieties recorded at 30, 60, 90 and 120 days after planting (Table 4) revealed that, significant difference among the varieties at 30 days after sowing. Plant height of different varieties ranged from 11.93 cm (RF 125) to 18.33 cm (RF 145).

At 60 days after sowing, there was a significant difference among the varieties, for plant height which ranged from 74.13 cm (RF 125) to 110.33 cm (RF 145).

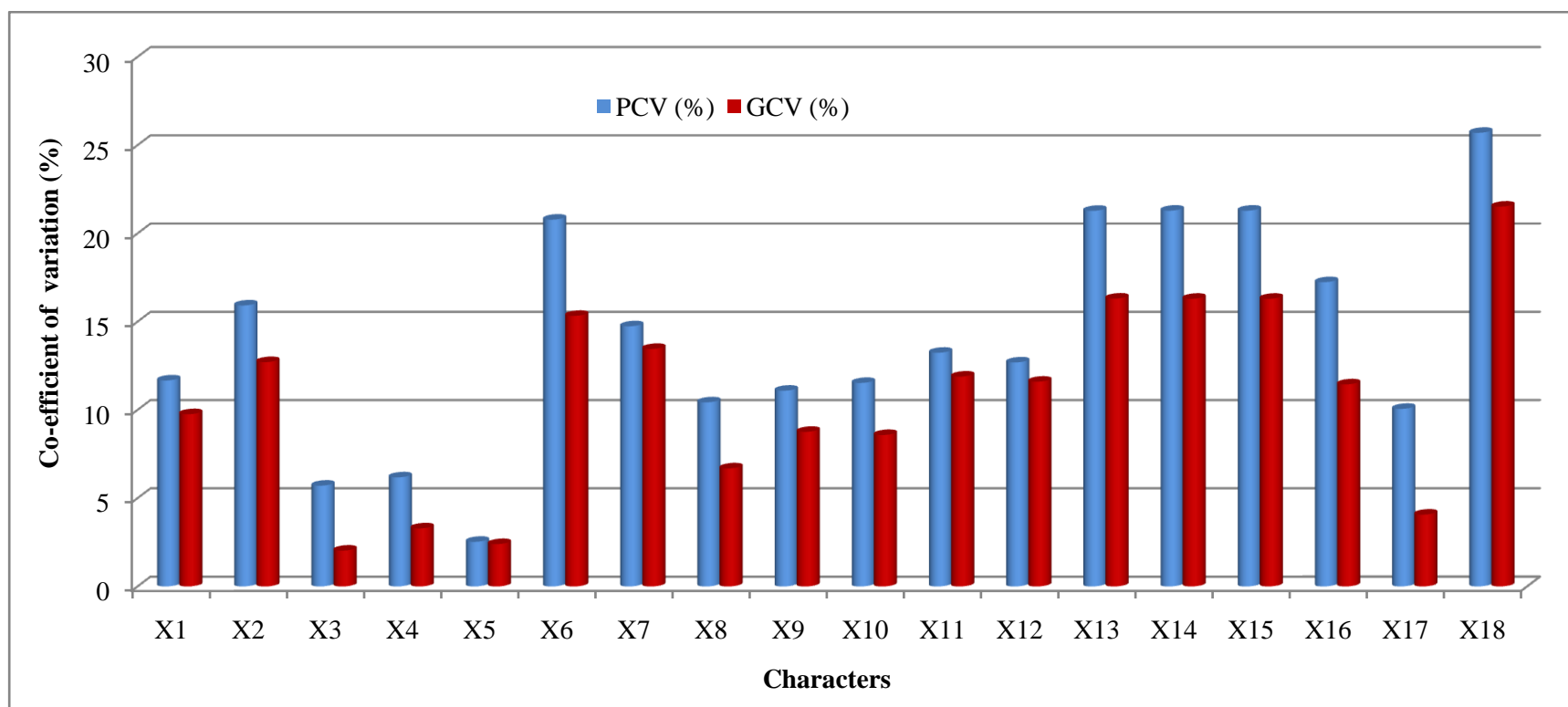
Present investigation also revealed significant difference among the varieties at 90 days after sowing. Plant height of different varieties ranged from 114.73 cm (RF 125) to 158.93 cm (RF 145).

Plant height of fennel varieties ranged from 183.26 cm (RF 145) to 121.2 cm (RF 125) (Table 4) and mean recorded for plant height is 151.87 cm at 120 DAS. It recorded moderate PCV (11.67%) and low GCV (9.76%). Estimates of broad sense heritability were found to be high (69.88%) coupled with moderate GA as per cent mean (16.80%) (Table 3).

**Table 3: Estimates of variability and genetic parameters for growth and yield traits in fennel varieties**

Character	Range		Mean	variation		Heritability (%)	GA	GA as per cent mean (GAM)
	Min.	Max.		PCV (%)	GCV (%)			
Plant height (cm)	121.20	183.26	151.87	11.67	9.76	69.88	25.52	16.80
Number of primary branches	7.20	11.70	8.32	15.92	12.71	63.82	1.74	20.92
Days to first flowering	52.33	58.33	56.23	5.71	2.03	12.62	0.83	1.48
Days to 50 per cent flowering	66.66	73.33	69.92	6.18	3.29	28.30	2.52	3.60
Days to maturity	131.00	143.33	139.50	2.53	2.4	90.08	6.55	4.69
Number of umbels per plant	16.93	30.26	20.96	20.78	15.33	54.43	4.88	23.30
Number of umbellets per umbel	22.63	35.58	26.95	14.74	13.46	83.31	6.82	25.30
Number of seeds per umbellet	25.59	33.82	28.94	10.43	6.69	41.12	2.56	8.83
Fresh weight of umbel (g)	21.37	30.53	25.66	11.09	8.76	62.34	3.65	14.24
Dry weight of umbel (g)	8.87	12.67	10.63	11.53	8.58	55.53	1.40	13.18
Fresh weight of plant (g)	297.96	446.00	369.61	13.24	11.89	80.70	81.33	22.00
Dry weight of plant (g)	106.22	157.53	131.19	12.69	11.60	83.55	28.66	21.84
Seed yield per plant (g)	18.02	31.33	21.72	21.28	16.31	58.70	5.59	25.74
Seed yield per plot (g)	1081.33	1880.00	1303.22	21.29	16.30	58.66	335.23	25.72
Seed yield per ha (kg ha <sup>-1</sup> )	1802.20	3133.33	2172.01	21.29	16.30	58.66	558.72	25.72
Harvest index (%)	17.90	26.25	21.54	17.24	11.45	44.08	3.37	15.66
Test weight (g)	8.37	10.41	9.05	10.06	4.07	16.34	0.31	3.39
Oil yield (kg ha <sup>-1</sup> )	21.92	52.02	33.86	25.70	21.52	70.08	12.56	37.11

PCV = Phenotypic co-efficient of variation GCV = Genotypic co-efficient of variation GA =Genetic Advance



**Fig. 1. Genotypic and phenotypic coefficient of variation for eighteen characters in fennel**

X1- Plant height (cm)

X2- Number of primary branches

X3- Days to first flowering

X4- Days to 50% flowering

X5- Days to maturity

X6- Number of umbels per plant

X7- Number of umbellets per umbels

X8- Number of seeds per umbellet

X9- Fresh weight of umbel (g)

X10- Dry weight of umbel (g)

X11- Fresh weight of plant (g)

X12- Dry weight of plant (g)

X13- Seed yield per plant (g)

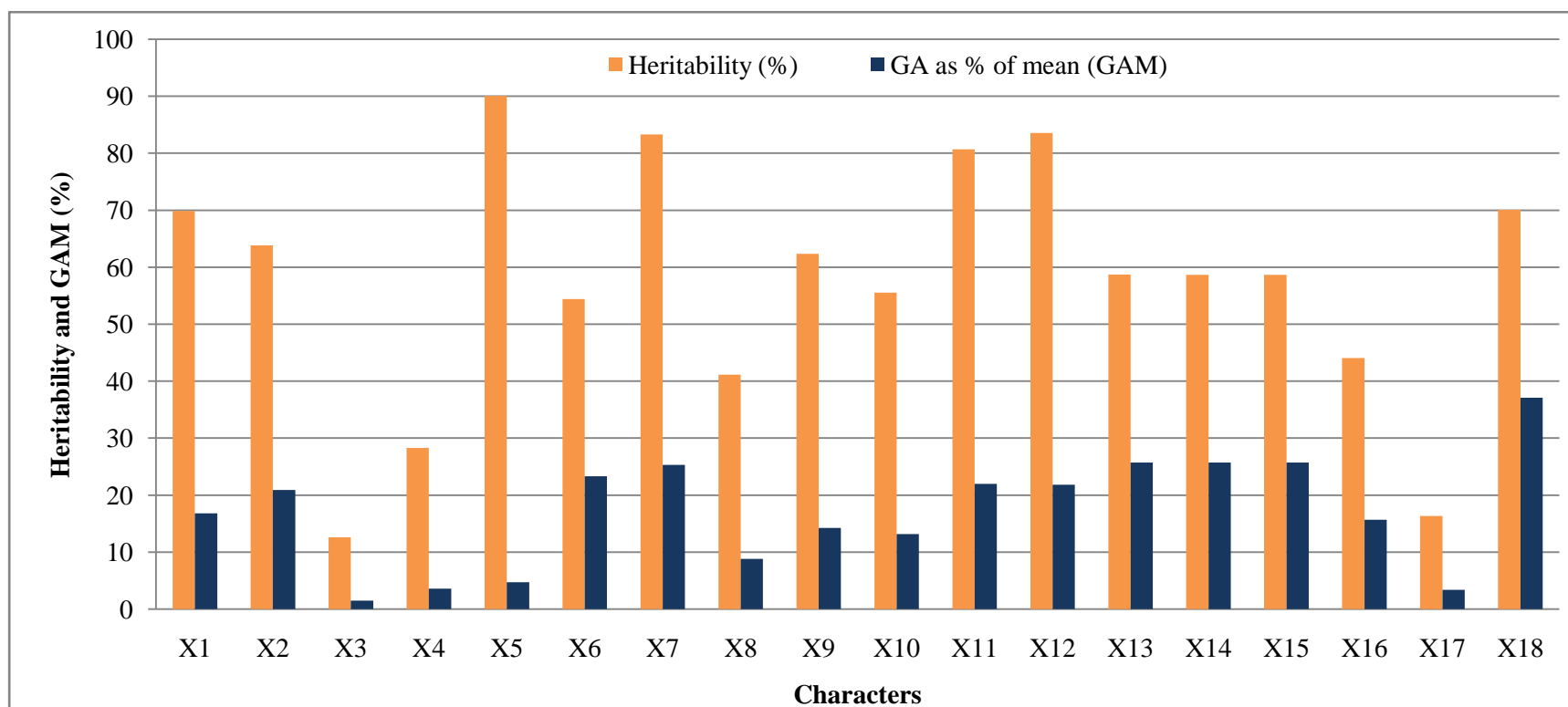
X14- Seed yield per plot (g)

X15- Seed yield per hectare (kg)

X16- Harvest index (%)

X17- Test weight (g)

X18- Oil yield (kg ha<sup>-1</sup>)



**Fig. 2. Heritability and genetic advance as per cent mean for different characters in fennel**

X1- Plant height (cm)

X2- Number of primary branches

X3- Days to first flowering

X4- Days to 50% flowering

X5- Days to maturity

X6- Number of umbels per plant

X7- Number of umbellets per umbels

X8- Number of seeds per umbellet

X9- Fresh weight of umbel (g)

X10- Dry weight of umbel (g)

X11- Fresh weight of plant (g)

X12- Dry weight of plant (g)

X13- Seed yield per plant (g)

X14- Seed yield per plot (g)

X15- Seed yield per hectare (kg)

X16- Harvest index (%)

X17- Test weight (g)

X18- Oil yield (kg ha<sup>-1</sup>)

**Table 4: Means of plant height, number of primary branches and flowering parameters in fennel varieties**

Treatment	Plant height (cm)				Number of primary branches per plant			Days to first flowering	Days to 50 % flowering
	30 DAS	60 DAS	90 DAS	120 DAS	60 DAS	90 DAS	120 DAS		
<b>CO -1</b>	16.27	106.40	141.67	165.27	5.20	7.00	8.93	58.33	71.67
<b>GF -2</b>	15.93	102.13	143.00	151.46	4.73	6.33	7.80	57.33	66.66
<b>GF -11</b>	15.53	99.40	153.33	159.00	5.20	6.80	7.46	59.00	68.00
<b>GF -12</b>	14.46	99.93	139.46	147.13	4.93	7.26	8.53	57.33	68.33
<b>RF -157</b>	12.80	81.93	135.00	160.86	5.20	6.60	8.33	56.00	68.00
<b>RF -125</b>	11.93	74.13	114.73	121.20	4.86	6.06	7.33	53.66	67.33
<b>RF -281</b>	13.86	82.60	126.80	141.13	5.13	6.46	8.80	57.66	68.00
<b>RF -205</b>	14.40	83.06	121.13	140.46	4.93	5.86	7.26	52.33	66.66
<b>RF -143</b>	14.13	77.60	140.73	156.80	5.20	7.40	8.20	56.33	73.00
<b>RF – 178</b>	13.26	82.93	132.93	156.46	5.60	6.80	8.40	58.00	71.00
<b>RF -101</b>	14.66	90.20	143.73	154.53	4.86	6.40	7.80	56.66	70.00
<b>RF -145</b>	18.33	110.33	154.93	183.26	7.23	9.7	11.70	53.33	73.33
<b>F-test</b>	*	*	*	*	*	*	*	-	*
<b>SEm ±</b>	1.28	5.84	7.63	5.70	0.42	0.53	0.46	1.73	2.11
<b>CD at 5%</b>	3.80	17.04	22.27	16.64	1.24	1.54	1.34	NS	6.17

DAS – Days After Sowing

#### **4.2.2 Number of primary branches per plant**

The present investigation revealed a significant difference among the varieties for number of primary branches per plant (Table 4) and the values were significant at 60 days after sowing. Number of primary branches per plant in fennel varieties ranged from 4.73 (GF 12) to 7.23 (RF 145) with a mean of 5.31.

Significant difference between the varieties was observed for this trait at 90 days after sowing. Number of primary branches per plant in different varieties ranged from 5.86 (RF 205) to 9.7 (RF 145) with a mean of 6.85.

Number of primary branches per plant ranged from 7.26 (RF 205) to 11.7 (RF 145) (Table 4) and recorded mean for this trait was 8.32. It recorded moderate PCV (15.92%) and moderate GCV (12.7%). High heritability (63.82%) coupled with high GA as per cent mean (20.92%) were recorded for this parameter (Table 3).

#### **4.2.3 Fresh weight of umbel (g)**

Fresh weight of umbel ranged from 21.37 g (RF 101) to 30.52 g (RF 145) (Table 5) and mean fresh weight of umbel was 25.66 g. Moderate PCV (11.09%) and low GCV (8.76%) were registered for this attribute along with high heritability (62.34%) and moderate GA as per cent mean (14.24 %).

#### **4.2.4 Dry weight of umbel (g)**

Dry weight of umbel ranged from 8.87 g (RF 101) to 11.74 g (GF 12) (Table 5) and mean of 10.63 g. Moderate PCV (11.53%) and low GCV (8.58%) were noticed for this attribute along with moderate heritability (55.53%) and moderate GA as per cent mean (13.18 %).

#### **4.2.5 Fresh weight of plant (g)**

Fresh weight of plant ranged from 297.96 g (RF 125) to 445.67 g (RF 145) (Table 5) and mean was 369.61. Moderate PCV (13.24%) and GCV (11.89%) were noticed for this attribute along with high heritability (80.70%) and high GA as per cent mean (22.0%).

**Table 5: Mean values of yield and quality parameters in fennel varieties**

Treatment	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16
<b>CO 1</b>	24.40	27.23	30.03	143.00	419.34	147.64	19.04	1142.67	1904.40	8.93	17.97	1.66	31.44	65.69	27.05	11.36
<b>GF 2</b>	20.13	30.93	28.36	141.33	326.73	115.23	20.93	1256.66	2094.40	9.15	20.65	1.40	29.41	69.75	24.96	10.25
<b>GF 11</b>	21.13	27.76	32.34	141.33	372.41	131.60	21.41	1285.33	2142.16	8.46	21.48	1.46	31.08	67.75	25.43	10.62
<b>GF 12</b>	23.06	29.72	29.54	141.33	361.71	130.16	26.84	1610.60	2684.43	9.14	25.86	1.93	52.02	63.61	28.54	11.74
<b>RF 157</b>	16.93	25.31	29.20	140.33	410.31	144.35	18.80	1128.33	1880.50	8.68	18.53	1.60	30.11	54.76	25.55	10.57
<b>RF 125</b>	18.40	23.24	26.52	131.00	297.96	106.22	18.70	1121.00	1868.33	9.74	23.91	1.69	31.47	22.87	22.16	9.17
<b>RF 281</b>	19.20	22.63	27.38	140.00	343.71	121.33	19.82	1189.33	1982.20	10.40	19.46	1.94	38.86	44.98	24.51	10.13
<b>RF 205</b>	19.60	24.86	27.56	138.66	327.53	115.70	21.69	1303.33	2172.20	8.37	22.39	1.34	29.09	51.69	26.05	10.81
<b>RF 143</b>	21.33	27.69	27.56	137.00	395.70	140.63	24.08	1445.00	2408.30	8.98	23.95	1.63	39.31	29.76	26.09	10.79
<b>RF 178</b>	19.40	23.64	29.38	136.33	404.33	143.55	19.91	1195.00	1991.66	8.62	20.13	1.10	21.92	51.91	25.61	10.57
<b>RF 101</b>	17.60	24.77	25.59	140.33	329.53	119.71	18.02	1081.33	1802.20	9.61	17.90	1.68	30.48	23.56	21.37	8.875
<b>RF 145</b>	30.26	35.58	33.82	143.33	445.67	157.52	31.33	1880.00	3133.33	8.54	26.24	1.33	41.11	40.7	30.52	11.36
<b>F-test</b>	*	*	*	*	*	*	*	*	*	-	*	*	*	-	*	*
<b>SEm ±</b>	1.70	0.94	1.34	0.64	12.41	3.90	1.71	102.99	171.65	-	1.60	0.06	2.75	-	1.01	0.47
<b>CD at 5%</b>	4.98	2.75	3.92	1.88	36.39	11.40	5.03	302.05	503.42	NS	4.7	0.17	8.06	-	2.96	1.38

\*Significant at 5 per cent probability level

\*\* Significant at 1 per cent probability level,

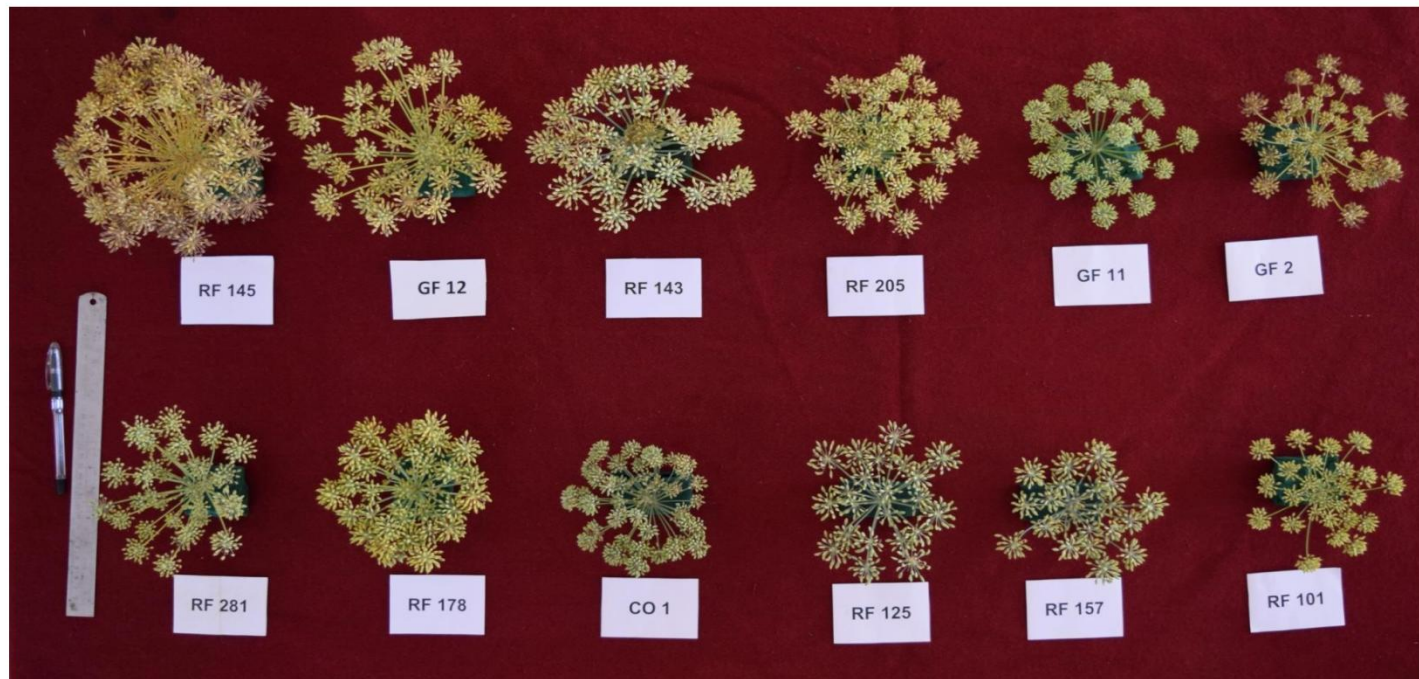
NS = Non significant

X-1: Number of umbels per plant  
X-2: Number of umbellets per umbel  
X-3: Number of seeds per umbellet  
X-4: Days to maturity

X-5: Fresh weight of plant (g)  
X-6: Dry weight of plant (g)  
X-7: Seed yield per plant (g)  
X-8: Seed yield per plot (g)

X-9: Seed yield per ha (kg)  
X-10: Test weight (g)  
X-11: Harvest index (%)  
X-12: Oil content (%)

X-13: Oil yield (kg ha<sup>-1</sup>)  
X-14: Anethole content (%)  
X-15: Fresh weight of umbel (g)  
X-16: Dry weight of umbel (g)



**Plate 5. Variability of umbel in different fennel varieties**

#### **4.2.6 Dry weight of plant (g)**

Dry weight of plant ranged from 106.22 g (RF 125) to 157.52 g (RF 145) among 12 varieties (Table 5) and 131.19 g of mean dry weight of plant. Moderate PCV (12.69%) and GCV (11.60%) were noticed for this character along with high heritability (83.55%) and high GA as per cent mean (21.84 %).

#### **4.2.7 Days to first flowering**

Days required for first flowering (Table 4) ranged from 52.33 (RF 205) to 59.00 days (GF 11) and mean number of days required to first flowering was 56.23 days. It recorded low estimates of PCV (5.71%) and GCV (2.03%) associated with moderate estimates of heritability (12.62%) and low GA as per cent mean (1.48%) (Table 3).

#### **4.2.8 Days to 50 per cent flowering**

Number of days required for fifty per cent flowering (Table 4) ranged from 66.66 days (RF 205 and GF 2) to 73.33 days (RF 145) a mean of 69.90 days. The PCV and GCV were low (6.18 and 3.29%, respectively) coupled with low broad sense heritability (28.30%) and GA as per cent mean (3.60%).

#### **4.2.9 Days to maturity**

Number of days taken to mature (Table 5) by different fennel varieties ranged from 131 (RF 125) to 143 (CO 1) days and mean of 139.50 days was recorded. PCV and GCV were found to be low (2.53 and 2.4%, respectively). High estimates of broad sense heritability (90.08%) and low GA as per cent mean (4.69) were recorded for this attribute.

#### **4.2.10 Number of umbels per plant**

Number of umbels per plant (Table 5) ranged from 16.93 (RF 157) to 30.26 (RF 145) in different varieties and mean number of umbels per plant was 20.96. The estimates of PCV and GCV were high (20.78%) and moderate (15.33%) respectively. Moderate heritability (54.43%) coupled with high GA as per cent mean (23.30%) was recorded for number of umbels per plant.

#### **4.2.11 Number of umbellets per umbel**

Number of umbellets per umbel ranged (Table 5) from 22.63 (RF 281) to 35.58 (RF 145) in different varieties and mean recorded for this trait was 26.95. Estimates of PCV and GCV were moderate (14.74% and 13.46%, respectively). The estimates of high heritability (83.31%) coupled with high GA as per cent mean (25.30) was observed for this character.

#### **4.2.12 Number of seeds per umbellet**

Number of seeds per umbellet (Table 5) of 12 fennel varieties ranged from 25.59 (RF 101) to 33.82 (RF 145) and mean number of seeds per umbellet recorded was 28.94. The estimates of PCV and GCV were moderate (10.43%) and low (6.69%), respectively with moderate heritability (41.12%) and low GA as per cent mean (8.83%) (Table 3).

#### **4.2.12 Test weight (g)**

Test weight ranged (Table 5) from 8.37 g (RF 205) to 10.4 g (RF 281) and mean weight of 1000 seeds in different varieties was 9.05 g. The PCV and GCV were moderate and lower (10.06 and 4.07%, respectively) coupled with high heritability (16.34%) and moderate GA as per cent mean (3.39%).

#### **4.2.13 Harvest index (%)**

Harvest index (Table 5) in different varieties ranged from 17.9 per cent (RF 101) to 26.24 per cent (RF 145) and mean value for this trait recorded was 21.54 per cent. Estimates of PCV and GCV were moderate (17.24% and 11.45%, respectively). The broad sense heritability was found to be moderate (44.08%) and moderate GA as per cent mean (15.66%) was recorded for this attribute.

#### **4.2.14 Seed yield per plant (g)**

Seed yield per plant (Table 5) in different varieties ranged from 18.02 g (RF 101) to 31.33 g (RF 145) and mean was 21.74 g per plant. The estimates of high PCV (21.28%) and moderate GCV (16.31%) were observed and it was also associated with moderate heritability (58.70%) and high GA as per cent mean (25.74%).

#### **4.2.15 Seed yield per plot (g)**

Seed yield per plot (Table 5) ranged from 1081.33 g (RF 101) to 1880.0 g (RF 145) and mean was 1303.22 g per plant. The estimates of PCV was higher (21.29%) and GCV was moderate (16.30%) for the trait which moderate heritability (58.66%) and high GA as per cent of mean (25.72%).

#### **4.2.16 Seed yield per hectare (kg ha<sup>-1</sup>)**

Seed yield per hectare (Table 5) in different varieties ranged from 1802.2 kg (RF 101) to 3133.33 kg (RF 145) and mean seed yield per hectare recorded was 2172.01 kg. Higher (21.29%) PCV and moderate GCV (16.30%) coupled with moderate heritability (58.66%) and high GA as per cent mean (25.73%) (Table 3) was registered for per hectare seed yield.

#### **4.2.17 Oil yield (kg ha<sup>-1</sup>)**

Oil yield (Table 5) ranged from 21.92 kg (RF 178) to 52.02 kg (GF 12) and the mean oil yield was 33.86 kg. The estimates of PCV and GCV were high (25.7 and 21.52%, respectively) coupled with high heritability (70.08%) and high GA as per cent mean (37.11%).

#### **4.2.19 Oil content (%)**

Present study revealed a significant difference among the fennel varieties for oil content (Table 5) and it ranged from 1.10 (RF 178) to 1.94 per cent (RF 281).

#### **4.2.20 Anethole content (%)**

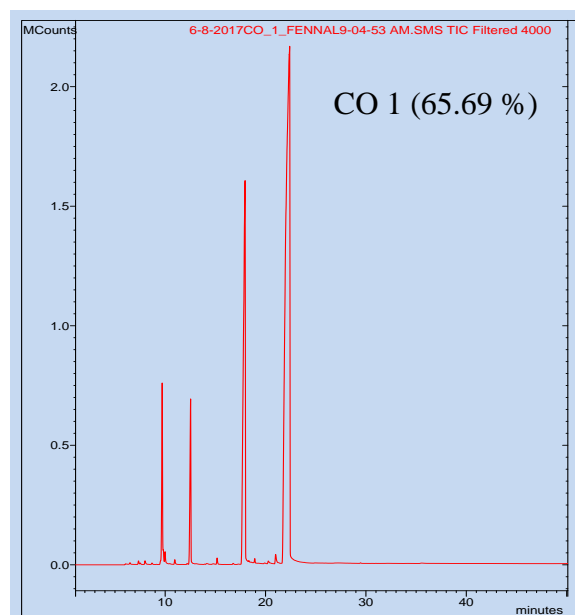
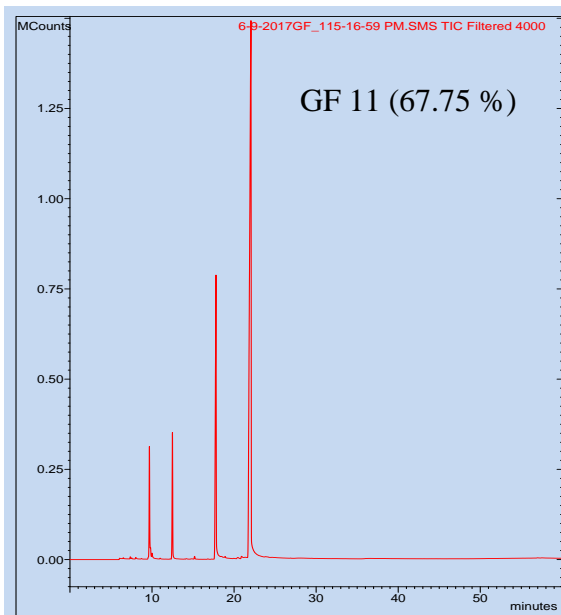
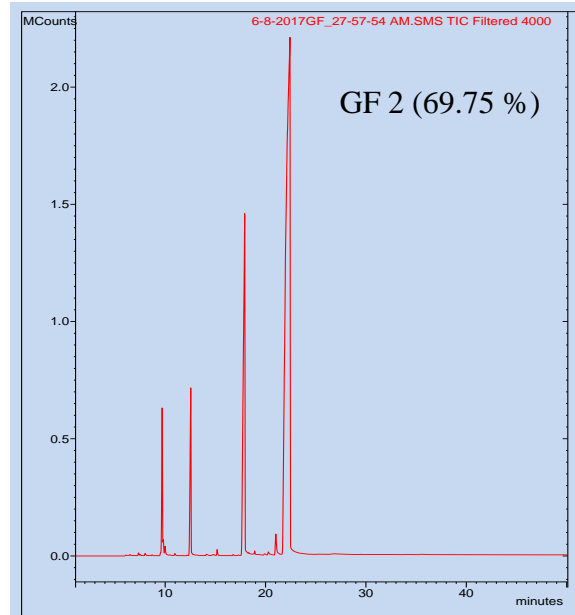
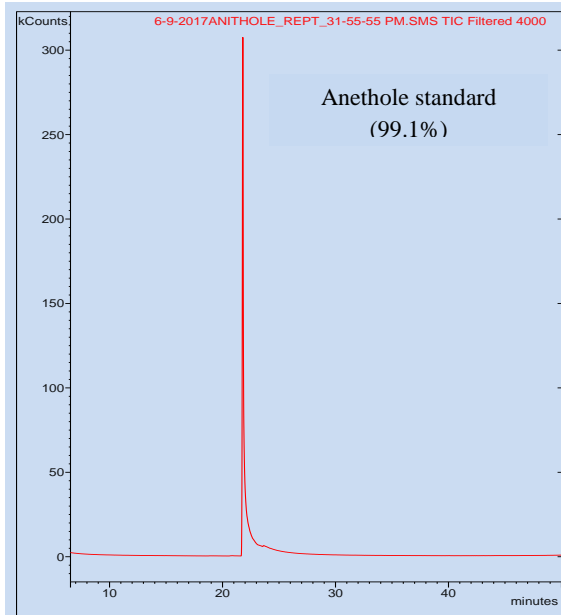
Anethole estimated in different fennel varieties (Table 5) which ranged from 22.87 (RF 125) to 69.75 per cent (GF 12) (Fig. 3).

### 4.3 Character association among different attributes

Phenotypic and genotypic correlation coefficients were determined to obtain information on the relationship existing among the different characters in 12 fennel varieties. Genotypic correlation coefficients and phenotypic correlation coefficients for seed yield and related characters in fennel varieties are presented in Table 6, 7 and figure 4. It was observed that genotypic correlation coefficients were higher than that of phenotypic correlation coefficients. Inter-character correlation at genotypic and phenotypic levels among seed yield per plant and its attributes were worked out to know the nature of association existing among characters. Analysis of phenotypic and genotypic coefficients of correlation for various characters is presented below.

Seed yield per plant recorded significant and positive association with dry weight of umbel (0.888 and 0.706 respectively), number of umbels per plant (0.860 and 0.774), number of umbellets per umbel (0.845 and 0.776), harvest index (0.842 and 0.786), number of primary branches per plant (0.737 and 0.660), number of seeds per umbellet (0.690 and 0.556), days to 50 per cent flowering (0.560 and 0.292), plant height (0.497 and 0.478), dry weight of plant (0.472 and 0.448) and days to maturity (0.384 and 0.340) both at genotypic and phenotypic levels (Table 6 and 7).

Plant height showed significant and positive genotypic and phenotypic correlation (Table 6 and 7 respectively) with dry weight of plant (0.893 and 0.857 respectively), days to 50 per cent flowering (0.843 and 0.523), number of seeds per umbellet (0.783 and 0.650), days to maturity (0.748 and 0.675), number of primary branches per plant (0.743 and 0.672), dry weight of umbel (0.712 and 0.573), dry weight of plant (0.605 and 0.857), number of umbellets per umbel (0.667 and 0.636) and number of umbels per plant (0.659 and 0.611).



**Fig. 3. Chromatographs showing anethole content in standard and essential oil of top three fennel varieties**

**Table 6: Genotypic correlation coefficients for seed yield and related traits in fennel varieties**

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
<b>X2</b>	0.743**	<b>1.00</b>									
<b>X3</b>	0.843**	0.791**	<b>1.00</b>								
<b>X4</b>	0.748**	0.515**	0.187	<b>1.00</b>							
<b>X5</b>	0.659**	0.893**	0.755**	0.538**	<b>1.00</b>						
<b>X6</b>	0.667**	0.674**	0.469**	0.621**	0.872**	<b>1.00</b>					
<b>X7</b>	0.783**	0.710**	0.532**	0.617**	0.848**	0.768**	<b>1.00</b>				
<b>X8</b>	0.712**	0.798**	0.480**	0.592**	0.925**	0.803**	0.941**	<b>1.00</b>			
<b>X9</b>	0.893**	0.755**	0.926**	0.497**	0.631**	0.466*	0.774**	0.779**	<b>1.00</b>		
<b>X10</b>	-0.025	0.351*	0.249	-0.154	0.592**	0.572**	0.344*	0.570**	0.060	<b>1.00</b>	
<b>X11</b>	-0.575	-0.143	-0.274	-0.253	-0.384	-0.451	-0.705	-0.615	-0.532	-0.333	<b>1.00</b>
<b>X12</b>	0.497**	0.737**	0.560**	0.384*	0.860**	0.845**	0.690**	0.888**	0.472**	0.842**	-0.445

\*Significant at 5 per cent level

\*\*Significant at 1 per cent level

X1- Plant height (cm)

X2- Number of primary branches

X3- Days to 50 % flowering

X4- Days to maturity

X5- Number of umbels per plant

X6- Number of umbellets per umbel

X7- Number of seeds per umbellet

X8- Dry weight of umbel (g)

X9- Dry weight of plant (g)

X10- Harvest index (%)

X11- Test weight (g)

X12- Seed yield per plant (g)

**Table 7: Phenotypic correlation coefficients for seed yield and its related characters in fennel varieties**

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
<b>X2</b>	0.672**	<b>1.00</b>									
<b>X3</b>	0.523**	0.533**	<b>1.00</b>								
<b>X4</b>	0.675**	0.467**	0.222	<b>1.00</b>							
<b>X5</b>	0.611**	0.704**	0.444**	0.472**	<b>1.00</b>						
<b>X6</b>	0.636**	0.607**	0.278	0.564**	0.739**	<b>1.00</b>					
<b>X7</b>	0.650**	0.547**	0.172	0.467**	0.625**	0.589**	<b>1.00</b>				
<b>X8</b>	0.573**	0.608**	0.432**	0.538**	0.728**	0.609**	0.606**	<b>1.00</b>			
<b>X9</b>	0.857**	0.675**	0.612**	0.472**	0.568**	0.446**	0.594**	0.643**	<b>1.00</b>		
<b>X10</b>	-0.021	0.281	0.061	-0.158	0.504**	0.492**	0.334*	0.418*	0.039	<b>1.00</b>	
<b>X11</b>	-0.426	-0.044	-0.060	-0.163	-0.170	-0.377	-0.441	-0.410	-0.365	-0.164	<b>1.00</b>
<b>X12</b>	0.478**	0.660**	0.292	0.340*	0.774**	0.776**	0.556**	0.706**	0.448**	0.786**	-0.310

\*Significant at 5 per cent level

\*\*Significant at 1 per cent level

X1- Plant height (cm)

X2- Number of primary branches

X3- Days to 50 % flowering

X4- Days to maturity

X5- Number of umbels per plant

X6- Number of umbellets per umbel

X7- Number of seeds per umbellet

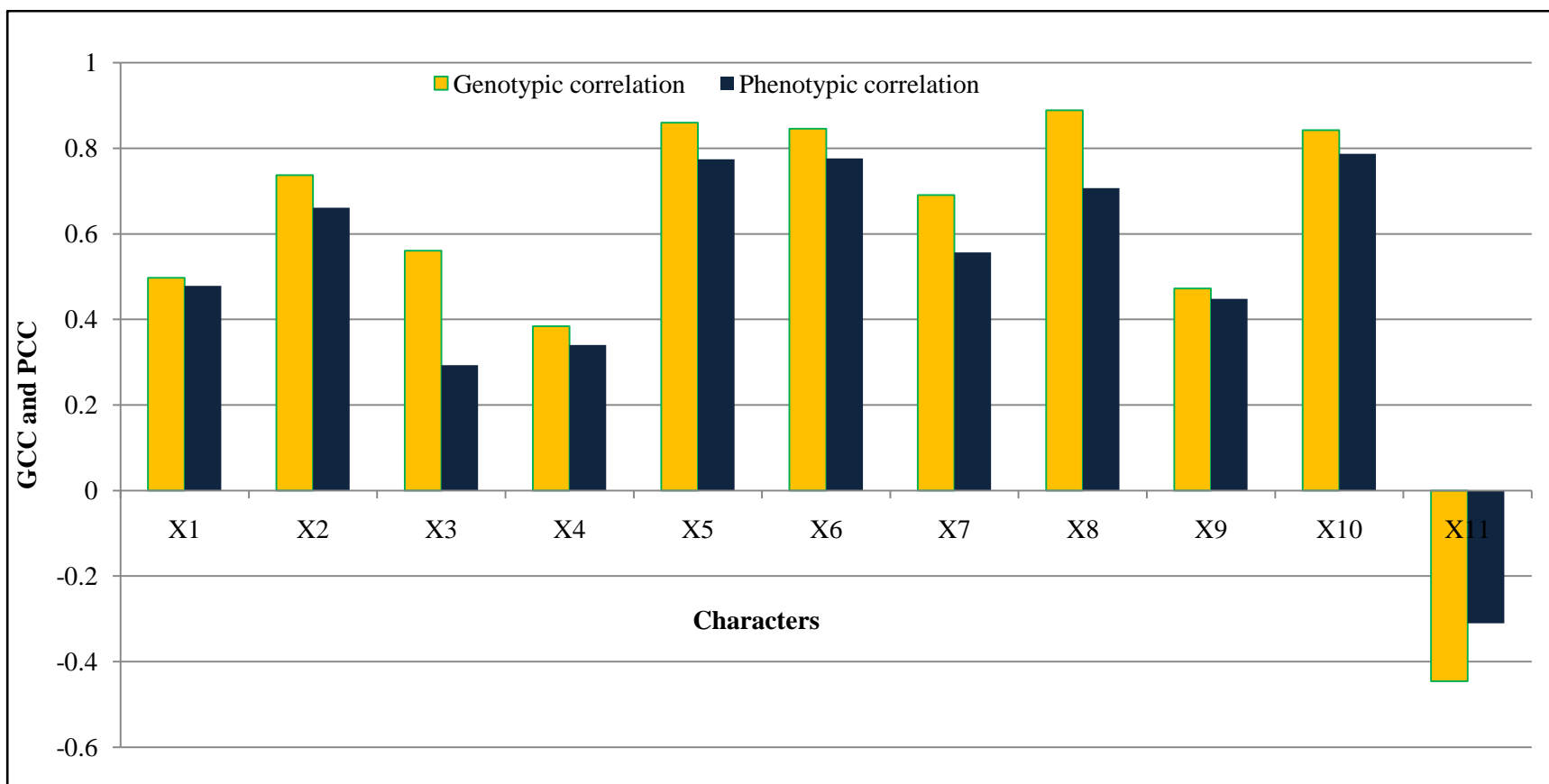
X8- Dry weight of umbel (g)

X9- Dry weight of plant (g)

X10- Harvest index (%)

X11- Test weight (g)

X12- Seed yield per plant (g)



**Fig. 4. Genotypic and phenotypic correlation coefficient for seed yield per plant in fennel**

X1- Plant height (cm)

X2- Number of primary branches

X3- Days to 50 % flowering

X4- Days to maturity

X5- Number of umbels per plant

X6- Number of umbellets per umbel

X7- Number of seeds per umbellet

X8- Dry weight of umbel (g)

X9- Dry weight of plant (g)

X10- Harvest index (%)

X11- Test weight (g)

X12- Seed yield per plant (g)

Number of primary branches per plant recorded significant and positive genotypic and phenotypic correlation with number of umbels per plant (0.893 and 0.704 respectively), dry weight of umbel (0.798 and 0.608), days to 50 per cent flowering (0.791 and 0.533), dry weight of plant (0.755 and 0.675), number of seeds per umbellet (0.710 and 0.547), number of umbellets per umbel (0.674 and 0.607), days to maturity (0.515 and 0.467) and harvest index (0.351) (Table 6 and 7 respectively).

Days to 50 per cent flowering recorded positive and highly significant genotypic and phenotypic correlation (Table 6 and 7 respectively) with dry weight of plant (0.926 and 0.612), seed yield per plant (0.560 genotypically), number of umbels per plant (0.755 and 0.444), number of seeds per umbellet (0.532 genotypically), number of umbellets per umbel (0.469 genotypically) and dry weight of umbel (0.480 and 0.432).

Days to maturity showed positive and significant genotypic and phenotypic correlation with number of umbellets per umbel (0.621 and 0.564 respectively), number of seeds per umbellet (0.617 and 0.467), dry weight of umbel (0.592 and 0.538), number of umbels per plant (0.538 and 0.472) and dry weight of plant (0.497 and 0.472) (Table 6 and 7 respectively).

Number of umbels per plant recorded significant and positive genotypic and phenotypic correlation (Table 6 and 7 respectively) with dry weight of umbel (0.925 and 0.728), number of umbellets per umbel (0.872 and 0.739), number of seeds per umbellet (0.848 and 0.625), dry weight of plant (0.631 and 0.568) and harvest index (0.592 and 0.504 respectively).

Number of umbellets per umbel recorded significant and positive genotypic and phenotypic correlation with dry weight of umbel (0.803 and 0.609 respectively), number of seeds per umbellet (0.768 and 0.589) and dry weight of plant (0.466 and 0.446) (Table 6 and 7 respectively).

Number of seeds per umbellet recorded significant and positive genotypic and phenotypic correlation (Table 6 and 7 respectively) with dry weight of umbel (0.941 and 0.606), dry weight of plant (0.774 and 0.594) and harvest index (0.344 and 0.334 respectively).

Dry weight of umbel showed significant and positive genotypic and phenotypic correlation with dry weight of plant (0.779 and 0.643 respectively) and harvest index (0.570 and 0.418) (Table 6 and 7 respectively).

Test weight recorded significant and negative genotypic and phenotypic correlation (Table 6 and 7 respectively) with seed yield per plant (-0.445 and -0.310).

#### **4.4 Path coefficient analysis**

The correlation values denote only the nature and extent of association existing between the pair of characters. A dependent character like yield is influenced by several component characters, which mutually associated with one another. Each component has two path action, viz., direct effect on yield and indirect effects on yield through other components which are not influenced by correlation.

Genotypic and phenotypic paths were worked out considering seed yield per plant as dependent character and its attributes as independent characters viz, plant height (cm), number of primary branches per plant, days to 50 per cent flowering, days to seed maturity, number of

umbels per plant, number of umbellets per umbel, number of seeds per umbellet, dry weight of plant (g), dry weight of umbel (g), harvest index (%) and test weight (g).

#### **4.4.1 Genotypic path analysis**

##### **4.4.1.1 Plant height (cm)**

Plant height exhibited positive direct effect (0.117) on seed yield per plant. It also showed positive indirect effect on seed yield per plant through dry weight of plant (0.010), days to 50 per cent flowering (0.099), number of seeds per umbellet (0.009), days to maturity (0.008), number of primary branches per plant (0.008), dry weight of umbel (0.008), number of umbellets per umbel (0.007), number of umbels per plant (0.007) and harvest index (0.0003). However, it recorded negative indirect effect on seed yield per plant through test weight (-0.006) (Table 8).

##### **4.4.1.2 Number of primary branches per plant**

Number of primary branches per plant exhibited positive direct effect (0.431) on seed yield per plant (Table 8) and positive indirect effect on seed yield per plant through number of umbels per plant (0.385), dry weight of umbel (0.344), days to 50 per cent flowering (0.341), dry weight of plant (0.326), plant height (0.320), number of seeds per umbellet (0.306), number of umbellet per umbel (0.291), days to maturity (0.222) and harvest index (0.151). However, showed negative indirect effect on seed yield per plant through test weight (-0.062).

##### **4.4.1.3 Days to 50 per cent flowering**

Days to 50 per cent flowering recorded negative direct effect (-0.315) on seed yield per plant (Table 8) and negative indirect effect on seed yield per plant through days to maturity (-0.059), harvest index (-0.078), number of umbellets per umbel (-0.148), dry weight of umbel (-0.151), number of seeds per umbellet (-0.168), plant height (-0.266) and dry weight of plant (-0.292). However showed positive indirect effect on seed yield per plant through test weight (0.086).

##### **4.4.1.4 Days to seed maturity**

Days to seed maturity showed negative direct effect (-0.183) on seed yield per plant, which also showed negative indirect effect on seed yield per plant through days to 50 per cent flowering (-0.034), dry weight of plant (-0.091), number of primary branches per plant (-0.0094), number of umbels per plant (-0.098), number of seeds per umbellet (-0.113), number of umbellets per umbel (-0.1139), dry weight of umbel (-0.108), plant height (-0.137). However, it recorded positive indirect effect on seed yield per plant through test weight (0.046) and harvest index (0.028) (Table 8).

**Table 8: Genotypic path analysis for seed yield per plant in fennel varieties**

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	r <sub>g</sub>
<b>X1</b>	<b>0.011</b>	0.008	0.009	0.008	0.007	0.007	0.009	0.008	0.010	0.000	-0.006	0.497**
<b>X2</b>	0.320	<b>0.431</b>	0.341	0.222	0.385	0.291	0.306	0.344	0.326	0.151	-0.062	0.737**
<b>X3</b>	-0.266	-0.250	<b>-0.315</b>	-0.059	-0.238	-0.148	-0.168	-0.151	-0.292	-0.078	0.086	0.560**
<b>X4</b>	-0.137	-0.094	-0.034	<b>-0.183</b>	-0.098	-0.113	-0.113	-0.108	-0.091	0.028	0.046	0.384*
<b>X5</b>	0.408	0.554	0.468	0.334	<b>0.620</b>	0.541	0.526	0.573	0.391	0.367	-0.238	0.860**
<b>X6</b>	0.279	0.283	0.197	0.260	0.366	<b>0.419</b>	0.322	0.337	0.195	0.240	-0.189	0.845**
<b>X7</b>	-1.063	-0.964	-0.722	-0.838	-1.152	-1.043	<b>-1.350</b>	-1.278	-1.051	-0.468	0.958	0.690**
<b>X8</b>	0.537	0.603	0.363	0.447	0.698	0.607	0.711	<b>0.755</b>	0.588	0.430	-0.465	0.888**
<b>X9</b>	0.110	0.093	0.114	0.06	0.078	0.057	0.096	0.096	<b>0.124</b>	0.007	0.066	0.472**
<b>X10</b>	0.0002	-0.002	-0.001	0.0009	-0.003	-0.003	-0.002	-0.003	-0.0004	<b>-0.006</b>	0.002	0.842**
<b>X11</b>	0.294	0.073	0.140	0.129	0.196	0.230	0.360	0.314	0.272	0.170	<b>-0.511</b>	-0.445

Residual effect: **0.1449**, Diagonal values are direct effects; above and below diagonal are indirect effects.

\*Significant at 5 per cent level and \*\*Significant at 1 per cent level

r<sub>g</sub>: Correlation values for seed yield per plant

X1- Plant height (cm)

X2- Number of primary branches

X3- Days to 50 % flowering

X4- Days to maturity

X5- Number of umbels per plant

X6- Number of umbellets per umbel

X7- Number of seeds per umbellet

X8- Dry weight of umbel (g)

X9- Dry weight of plant (g)

X10- Harvest index (%)

X11- Test weight (g)

X12- Seed yield per plant (g)

#### **4.4.1.5 Number of umbels per plant**

Number of umbels per plant showed positive direct effect (0.620) on seed yield per plant (Table 8). Further, it exhibited positive indirect effect on seed yield per plant through dry weight of umbel (0.573), number of primary branches per plant (0.554), number of umbellets per umbel (0.541), number of seeds per umbellet (0.526), days to 50 per cent flowering (0.468), plant height (0.408), dry weight of plant (0.391), harvest index (0.367) and days to maturity (0.334). However, it showed negative indirect effect on seed yield per plant through test weight (-0.238).

#### **4.4.1.6 Number of umbellets per umbel**

Number of umbellets per umbel recorded positive direct effect (0.419) on seed yield per plant (Table 8), which also showed positive indirect effect on seed yield per plant via number of umbels per plant (0.366), dry weight of umbel (0.337), number of seeds per umbellet (0.322), number of primary branches per plant (0.283), days to maturity (0.260), plant height (0.279), harvest index (0.240), days to 50 per cent flowering (0.197) and dry weight of plant (0.195). However, it showed negative indirect effect on seed yield per plant through test weight (-0.189).

#### **4.4.1.7 Number of seeds per umbellet**

Number of seeds per umbellet recorded negative direct effects (-1.350) on seed yield per plant, which had negative indirect effect on seed yield per plant through harvest index (-0.468), days to 50 per cent flowering (-0.722), days to maturity (-0.838), number of primary branches per plant (-0.009), number of umbellet per umbel (-1.043), dry weight of plant (-1.051), plant height (-1.063), number of umbels per plant (-1.152) and dry weight of umbel (-1.278). However, it recorded positive indirect effect on seed yield per plant through test weight (0.958) (Table 8).

#### **4.4.1.8 Dry weight of umbel (g)**

Dry weight of umbel exhibited positive direct effect (0.755) on seed yield per plant (Table 8), also had positive indirect effects on seed yield per plant through number of seeds per umbellet (0.711), number of umbels per plant (0.698), number of umbellets per umbel (0.607), number of primary branches per plant (0.603), dry weight of plant (0.588), plant height (0.537), days to maturity (0.447), harvest index (0.430) and days to 50 per cent flowering (0.363). However, it also exhibited negative indirect effect on seed yield through test weight (-0.465).

#### **4.4.1.9 Dry weight of plant (g)**

Dry weight of plant exhibited positive direct effect (0.124) on seed yield per plant. Further, it showed positive indirect effects on seed yield per plant through days to 50 per cent flowering (0.114), plant height (0.110), dry weight of umbel (0.096), number of seeds per umbellet (0.096), number of primary branches per plant (0.093), number of umbels per plant (0.078), test weight (0.066), days to maturity (0.061) and number of umbellets per umbel (0.057) (Table 8).

#### **4.4.1.10 Harvest index (%)**

Harvest index recorded negative direct effect (-0.006) on seed yield per plant (Table 8) which also showed positive indirect effect on seed yield per plant through test weight (0.002), days to maturity (0.0009) and plant height (0.0002). However, it recorded negative indirect on

seed yield per plant through dry weight of plant (-0.0004), days to 50 per cent flowering (0.001), number of primary branches per plant (-0.0021), number of seeds per umbellet (-0.002), number of umbellets per umbel (-0.003), dry weight of umbel (-0.003) and number of umbels per plant (-0.003).

#### **4.4.1.11 Test weight (g)**

Test weight exhibited negative direct effect (-0.511) on seed yield per plant and had positive indirect effects on seed yield per plant through number of seeds per umbellet (0.360), dry weight of umbel (0.314), plant height (0.294), dry weight of plant (0.272), number of umbellets per umbel (0.230), number of umbels per plant (0.196), harvest index (0.170), days to 50 per cent flowering (0.140), days to maturity (0.129) and number of primary branches per plant (0.073) (Table 8).

### **4.4.2 Phenotypic path analysis**

#### **4.4.2.1 Plant height (cm)**

Plant height showed positive direct effect (0.201) on seed yield per plant (Table 9) which also showed positive indirect effect on seed yield per plant through dry weight of plant (0.173), days to maturity (0.136), number of primary branches per plant (0.135), number of seeds per umbellet (0.131), number of umbellets per umbel (0.128), number of umbels per plant (0.123), dry weight of umbel (0.115) and days to 50 per cent flowering (0.105) while it showed negative indirect effect on seed yield per plant through harvest index (-0.004) and test weight (-0.086).

#### **4.4.2.2 Number of primary branches per plant**

Number of primary branches per plant showed positive direct effect (0.263) on seed yield per plant, having positive indirect effect on seed yield per plant through number of umbels per plant (0.185), dry weight of plant (0.177), plant height (0.176), dry weight of umbel (0.160), number of umbellet per umbel (0.159), number of seeds per umbellet (0.144), days to 50 per cent flowering (0.140), days to maturity (0.122) and harvest index (0.074) (Table 9) whereas it showed negative indirect on seed yield per plant through fresh test weight (-0.011).

#### **4.4.2.3 Days to 50 per cent flowering**

Days to 50 per cent flowering recorded negative direct effect (-0.088) on seed yield per plant (Table 9). Further, it also showed negative indirect effect on seed yield per plant through harvest index (-0.005), number of seeds per umbellet (-0.015), days to maturity (-0.019), number of umbellets per umbel (-0.024), dry weight of umbel (-0.038), number of umbels per plant (-0.039), plant height (-0.046), number of primary branches per plant (-0.047) and dry weight of plant (-0.054). However, it also showed positive indirect effect on seed yield per plant through test weight (0.005).

**Table 9: Phenotypic path analysis for seed yield per plant in fennel varieties**

Characters	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	r <sub>p</sub>
<b>X1</b>	<b>0.201</b>	0.135	0.105	0.136	0.123	0.128	0.131	0.115	0.173	-0.004	-0.086	0.478**
<b>X2</b>	0.176	<b>0.263</b>	0.140	0.122	0.185	0.159	0.144	0.160	0.177	0.074	-0.011	0.660**
<b>X3</b>	-0.046	-0.047	<b>-0.088</b>	-0.019	-0.039	-0.024	-0.015	-0.038	-0.054	-0.005	0.005	0.292
<b>X4</b>	0.152	0.105	0.050	<b>0.225</b>	0.106	0.127	0.105	0.121	0.106	-0.035	-0.036	0.340*
<b>X5</b>	0.061	0.070	0.044	0.047	<b>0.100</b>	0.074	0.062	0.073	0.057	0.050	-0.017	0.774**
<b>X6</b>	-0.006	-0.006	-0.002	-0.005	-0.007	<b>-0.010</b>	-0.006	-0.006	-0.004	-0.005	0.003	0.776**
<b>X7</b>	-0.125	-0.105	-0.033	-0.090	-0.120	-0.113	<b>-0.193</b>	-0.117	-0.114	-0.064	0.085	0.556**
<b>X8</b>	0.051	0.016	0.011	0.014	0.019	0.016	0.016	<b>0.026</b>	0.017	0.011	-0.010	0.706**
<b>X9</b>	0.017	0.013	0.012	0.009	0.011	0.009	0.012	0.013	<b>0.020</b>	0.0008	-0.007	0.448**
<b>X10</b>	-0.015	0.210	0.046	-0.118	0.376	0.368	0.250	0.312	0.029	<b>0.746</b>	-0.123	0.786**
<b>X11</b>	0.047	0.004	0.006	0.018	0.019	0.042	0.049	0.045	0.040	0.018	<b>-0.111</b>	-0.310

Residual effect: **0.2579**, Diagonal values are direct effects; above and below diagonal are indirect effects.

\*Significant at 5 per cent level and \*\*Significant at 1 per cent level

r<sub>p</sub>: Correlation values for seed yield per plant

X1- Plant height (cm)

X2- Number of primary branches

X3- Days to 50 % flowering

X4- Days to maturity

X5- Number of umbels per plant

X6- Number of umbellets per umbel

X7- Number of seeds per umbellet

X8- Dry weight of umbel (g)

X9- Dry weight of plant (g)

X10- Harvest index (%)

X11- Test weight (g)

X12- Seed yield per plant (g)

#### **4.4.2.4 Days to maturity**

Days to maturity showed positive direct effect (0.225) on seed yield per plant, which also showed positive indirect effect on seed yield per plant through plant height (0.152), number of umbellets per umbel (0.127), dry weight of umbel (0.121), number of umbels per plant (0.106), dry weight of plant (0.106), number of seeds per umbellet (0.105), number of primary branches per plant (0.105) and days to 50 per cent flowering (0.050) (Table 9). However, it showed negative indirect effect on seed yield per plant through harvest index (-0.035) and test weight (-0.036).

#### **4.4.2.5 Number of umbels per plant**

Number of umbels per plant showed negative direct effect (0.100) on seed yield per plant, and also exhibited positive indirect effect on seed yield per plant through number of umbellets per umbel (0.074), dry weight of umbel (0.073), number of primary branches per plant (0.070), number of seeds per umbellet (0.062), plant height (0.061), dry weight of plant (0.057), harvest index (0.050), days to maturity (0.047) and days to 50 per cent flowering (0.044). However, it showed negative indirect effect on seed yield per plant through test weight (-0.017).

#### **4.4.2.6 Number of umbellets per umbel**

Number of umbellets per umbel recorded negative direct effect (-0.010) on seed yield per plant (Table 9) which also exhibited negative indirect effect on seed yield per plant through days to 50 per cent flowering (-0.002), dry weight of plant (-0.004), harvest index (-0.005), days to maturity (-0.005), number of primary branches per plant (-0.006), dry weight of umbel (-0.006), number of seeds per umbellet (-0.006), plant height (-0.006) and number of umbels per plant (-0.007). However, it also showed positive indirect effect on seed yield per plant through test weight (0.003).

#### **4.4.2.7 Number of seeds per umbellet**

Number of seeds per umbellet recorded negative direct effect (-0.193) and negative indirect effect on seed yield per plant through days to 50 per cent flowering (-0.033), harvest index (-0.064), days to maturity (-0.090), number of primary branches per plant (-0.105), number of umbellets per umbel (-0.113), dry weight of plant (-0.114), dry weight of umbel (-0.117), number of umbels per plant (-0.120) and plant height (-0.125) (Table 9). However, it showed positive indirect effect on seed yield per plant through test weight (0.085).

#### **4.4.2.8 Dry weight of umbel (g)**

Dry weight of umbel showed positive direct effect (0.026) and indirect effects on seed yield per plant through plant height (0.051), number of umbels per plant (0.019), dry weight of plant (0.017), number of primary branches per plant (0.016), number of umbellets per umbel (0.016), number of seeds per umbellet (0.016), days to maturity (0.014), days to 50 per cent flowering (0.011) and harvest index (0.011). However, it showed negative indirect effect on seed yield through test weight (-0.010) (Table 9).

#### **4.4.2.9 Dry weight of plant (g)**

Dry weight of plant had positive direct effect (0.020) on seed yield per plant (Table 9) and also positive indirect effects on seed yield per plant through plant height (0.017), number of primary branches per plant (0.013), dry weight of umbel (0.013), days to 50 per cent flowering (0.012), number of seeds per umbellet (0.012), number of umbels per plant (0.011), days to maturity (0.009), number of umbellets per umbel (0.009) and harvest index (0.0008). However, it had negative indirect effect on seed yield through test weight (-0.007).

#### **4.4.2.10 Harvest index (%)**

Harvest index recorded positive direct effect (0.746) on seed yield per plant. It also exhibited positive indirect effect on seed yield per plant through number of umbels per plant (0.376), number of umbellets per umbel (0.368), dry weight of umbel (0.312), number of seeds per umbellet (0.250), number of primary branches per plant (0.210), days to 50 per cent flowering (0.046) and dry weight of plant (0.029) (Table 9) however it showed negative indirect effects on seed yield per plant through plant height (-0.015) and test weight (-0.123) .

#### **4.4.2.11 Test weight (g)**

Test weight exhibited negative direct effect (-0.111) on seed yield per plant (Table 9) and recorded positive indirect effects on seed yield per plant through number of seeds per umbellet (0.049), plant height (0.047), dry weight of umbel (0.045), number of umbellets per umbel (0.042), dry weight of plant (0.040), number of umbels per plant (0.019), harvest index (0.018), days to maturity (0.018), days to 50 per cent flowering (0.006) and number of primary branches per plant (0.004).

## V. DISCUSSION

The crop improvement largely depends on the genetic variability. Existence of genetic variability for different characters including quantitative traits has its own significance for survival of crop species in nature.

Before initiation of any genetic improvement work, it is necessary to find out the nature and magnitude of variability for economic characters, so that the desirable traits can be combined into few recombinants for further breeding process. The information on the nature and degree of genetic variability, heritability and correlation among various traits that contribute towards yield would help in choosing the right type of varieties for crop improvement. Information regarding the genetic variability for growth and yield components in fennel is scanty. Hence, the present experiment was conducted to study the variability, correlation and path analysis among 12 fennel varieties for different characters and suitability of fennel varieties for Eastern dry zone of Karnataka. The results obtained are discussed under appropriate headings.

5.1 Analysis of variance

5.2 Genetic components of variation

5.3 Character association among different parameters

5.4 Path coefficient analysis

### 5.1 Analysis of variance

Analysis of variance indicated a very wide variation among the varieties studied for growth, yield and quality traits, except days to first flowering and test weight (Table 2). The extent of genetic variation observed in the present study was quite high and same can be used for increasing the productivity. A wide range of variability observed for the characters indicates the scope for selection of suitable initial breeding material for further improvement and provide an opportunity for selecting desirable variety for different characters.

### 5.2 Genetic components of variation

#### 5.2.1 Performance of fennel varieties in terms of growth, yield and quality parameters

The information on growth, yield and quality parameters is important in selecting varieties for genetic improvement, as it gives an overall *per se* performance of varieties. Mean performance indicated a wide range of variation among the varieties for all the growth, yield and quality parameters studied.

##### 5.2.1.1 Growth parameters

The varieties differed with respect to growth parameters (Table 4). The variety RF 145 followed by CO 1 were vigorous in growth in terms of plant height and number of primary branches. Differential response to plant height and number of primary branches might be due to genetic constitution of varieties and their adaptability to a prevailing environment. Similar variation in different varieties of fennel for plant height and number of branches was observed by Singh *et al.* (2003), Agarwal *et al.* (2003) and Malik *et al.* (2009).

### **5.2.1.2 Reproductive parameters**

The variety RF 145 recorded the maximum fresh and dry weight of plant and umbel followed by CO 1. These results are attributed to higher growth parameters (Table 4). These results are inline with the findings of Thakral and Tehlan (2006) and Sengupta *et al.* (2014) in fennel.

Number of days to first flowering was less in variety RF 205. Hence, this variety is an early type in this zone. GF 12 and RF 205 took less days to 50 per cent flowering (Table 4). This might be due to better and efficient utilization of nutrients in a relatively hostile environment which might have resulted in early termination of vegetative phase and initiation of reproductive phase as compared to late flowering varieties. Singh *et al.* (2003), Singh *et al.* (2006), Malik *et al.* (2009) and Yadav *et al.* (2013) observed differences among the fennel varieties for flowering characters.

### **5.2.1.3 Yield parameters**

With respect to yield attributes, the maximum number of umbels per plant, number of umbellets per umbel and number of seeds per umbellet were recorded in RF 145 followed by CO 1 and GF 12. Whereas, minimum test weight was recorded in RF 281 followed by RF 125. Maximum harvest index was recorded in RF 145 followed by GF 12. Varieties *viz.*, RF 145, GF 12, RF 143 and RF 205 recorded higher seed yield per plant, seed yield per plot and seed yield per hectare (Table 5). Singh *et al.* (2003), Malik *et al.* (2009), Meena and Singh (2013) and Senaguptha *et al.* (2014) in fennel varieties, Sarada and Giridhar (2005), Singh and Singh (2005) and Palani kumar and Rajamani (2012) in coriander varieties, Pushpa *et al.* (2012) in fenugreek varieties and Meena *et al.* (2015b) in ajwain varieties reported similar trend. Varieties RF145, GF12, CO1 and RF205 found to be better performers with respect to seed yield per plant, seed yield per plot and seed yield per hectare which could be used in further improvement.

### **5.2.1.4 Quality parameters**

With respect to oil content RF 281 and GF 12 recorded maximum content of essential oil followed by RF 125 and RF 101. With regard to anethole content, GF 2, GF11 and CO 1 recorded maximum anethole content (Table 5 and Fig. 3). GF12 recorded fairly high seed yield. These findings are in consonance with the report of Agarwal *et al.* (2003) and Singh *et al.* (2003) in fennel varieties.

## **5.2.2 Coefficient of variability**

The genetic improvement of any crop depends mainly on the substantial magnitude of variability in the varieties. To understand the extent to which the observed variations are due to environmental factors and genetic variability, phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were estimated. It is evident from the results that, large amount of variability was noticed for most of the characters under study. The character wise details of these variability parameters are discussed below.

Both genotypic and phenotypic coefficient of variation recorded high values for oil yield. High GCV and moderate PCV were recorded for number of umbels per plant, seed yield per plant, seed yield per plot and seed yield per hectare (Table 3). Similar results were obtained by Megeji and Korla (2002), Sarada and Giridhar (2005), Palanikumar and Rajamani (2012) and Meena *et al.* (2013) in fennel. These observations indicate the existence of substantial variability for these traits.

Moderate PCV and GCV values were reported for number of primary branches per plant, number of umbellets per umbel, fresh weight of plant, dry weight of plant and harvest index. Moderate PCV and low GCV were observed for plant height, dry weight of umbel and fresh weight of umbel. Such results were also reported for these traits in fennel by Bhavanishanker and Abdulkhader (1991), Singh *et al.* (2002), Singh *et al.* (2006) and Meena *et al.* (2010). Low PCV and GCV values were observed for days to first flowering, days to 50 per cent flowering, days to maturity, number of seeds per umbellet and test weight (Table 3). Similar findings have also been reported by Megeji and Korla (2002) and Singh *et al.* (2006) in fennel. In general, it was observed that, the phenotypic coefficient of variation is higher than genotypic coefficient of variation. High GCV and PCV values for traits are indicative of high degree of genetic variability which will provide greater scope for selection.

### 5.2.3 Heritability and genetic advance

The effectiveness of selection for any character does not only depend on the amount of variability, but also with estimates of heritability and genetic advance as per cent mean. It is of great interest to the plant breeder to determine how much of the phenotypic variability present in a particular generation is heritable and the accuracy with which a variety can be evaluated by its phenotypic expression. Heritability may give rare information for selection in the material on hand, but Johnson *et al.* (1955) had shown that, heritability and genetic advance should be jointly considered for reliable selection.

High heritability was observed for number of primary branches per plant, number of umbellets per umbel, fresh weight of plant, fresh weight of umbel, dry weight of plant, oil yield, days to maturity and plant height. Similar findings were also reported by Singh *et al.* (2006), Senagupta *et al.* (2014), Yadav *et al.* (2013) and Sharma *et al.* (2015) in fennel. High values of heritability for all these attributes clarified that they were least affected by environmental modification and selection based on phenotype performance would be reliable. Parameters such as number of umbels per plant, number of seeds per umbellet, dry weight of umbel, seed yield per plant, seed yield per plot, seed yield per hectare and harvest index recorded moderate heritability. Whereas, low heritability was recorded in parameters like, days to first flowering, days to 50 per cent flowering and test weight (Table 3). Similar findings were also reported by Megeji and Korla (2002) in fennel, Prajapati *et al.* (2010) and Saxena *et al.* (2005) in coriander and Patel and Patel (2015) in fennel, High heritability does not mean a high genetic advance for a particular quantitative character. Johnson *et al.* (1955) reported that heritability estimated along with genetic advance would be more rewarding than heritability alone in predicting the consequential effect of selection to choose the best individual.

High values of heritability coupled with high genetic advance as per cent mean were noticed for number of primary branches per plant, number of umbels per plant, number of umbellets per umbel, fresh weight of plant, dry weight of plant and oil yield. Parameters like seed yield per plant, seed yield per plot, seed yield per hectare and number of umbes per plant had moderate heritability with high genetic advance as per cent mean. On other hand, high heritability along with moderate genetic gain were recorded for plant height and fresh weight of umbel. But days to first flowering, days to 50 per cent flowering and test weight recorded low heritability along with low genetic gain. Number of seeds per umbellet recorded moderate heritability along with low genetic gain (Table 3). These results are in conformity with the findings of Verma and Korla (2003) in fenugreek, Meena *et al.* (2010) in coriander and Sengupta *et al.* (2014), Patel and Patel (2015) and Salami *et al.* (2017) in fennel. This indicates that these traits are under the influence of non additive gene action and are less reliable for direct selection in crop improvement.

### 5.3 Correlation studies

Complex association exists among different plant characters and the characters themselves do not exist in isolation. These characters are often correlated with each other either due to pleiotropy or due to genetic linkage (Harland, 1939). The relationship between phenotypic, genotypic and environmental correlations as mentioned by Falconer (1981) emphasized that, for the characters having high heritability, the environmental correlations are expected to be lower than genotypic correlations. Since the phenotypic correlations include a part of genotypic correlation and a portion of environmental correlation corresponding to the heritable portion of variation in two characters. It is therefore, expected that for highly heritable characters, genotypic correlations would be higher than phenotypic correlation, when the correlations are in the same direction. Further, Falconer (1981) stated that, phenotypic correlation can exceed genotypic correlation only, if heritability of two characters were low and environmental correlations were high. Hence, an important strategy designed to break the genetic barriers of yield is the study of character association through correlations. In other words, high positive correlation between two traits makes simultaneous improvement in two or more attributes. Whereas, negative association indicates the need to compromise between desirable characters.

In general, it is evident from the data that, genotypic correlation was higher than the phenotypic correlation indicating strong inherent association of characters and less influence of environmental factors and relative stability of the varieties.

Seed yield per plant had positive and highly significant correlation with dry weight of umbel, number of umbels per plant, number of umbellets per umbel, harvest index, number of primary branches per plant, number of seeds per umbellet, days to 50 per cent flowering and plant height at both genotypic and phenotypic levels. It indicated that, the selection of these highly associated traits with seed yield per plant will help in selecting the plants or varieties with high yield (Table 6 and 7). Similar results have been reported by Yadav *et al.* (2013), Meena *et al.* (2013) and Sharma *et al.* (2015) in fennel.

Plant height and number of primary branches per plant showed highly significant and positive correlation with dry weight of plant, days to 50 per cent flowering, days to maturity, number of umbels per plant, number of umbellets per umbel, number of seeds per umbellet and dry weight of umbel. Whereas, days to 50 per cent flowering and days to maturity recorded significant and positive correlation with dry weight of plant, number of umbels per plant, number of umbellets per umbel, number of seeds per umbellet and dry weight of umbel. It indicated that a strong association was observed among associated traits to increase the seed yield of fennel (Table 6 and 7). Similar observations were reported by Sharma and Bhati (1988), Giridhar and Sarada (2005), Singh *et al.* (2006) and Yadav *et al.* (2013) in fennel.

Number of umbels per plant recorded highly significant and positive correlation with dry weight of umbel, number of umbellets per umbel, number of seeds per umbellet, dry weight of plant and seed yield per plant. Whereas, number of umbellets per umbel recorded highly significant and positive correlation with dry weight of umbel, seed yield per plant, number of seeds per umbellet, harvest index and dry weight of plant. Number of seeds per umbellet exhibited highly significant positive correlation with dry weight of umbel, dry weight of plant and seed yield per plant. Significant negative correlation existed between test weight and seed yield per plant (Table 6 and 7). These results are in conformity with the findings of Velayudham (2004), Giridhar and Sarada (2005), Prabhu and Balakrishnamoorthy (2006) and Bairwa *et al.* (2015) in coriander.

## 5.4 Path coefficient analysis

Correlation values decide only the nature and degree of association existing between pairs of characters. The economic character, yield is dependent on several mutually associated component characters and hence, change in any one of the components is likely to affect the whole network of cause and effect. This in turn might affect the true association of component characters both in magnitude, direction and tend to impair the association of yield and yield attributes. Hence, it has to be analyzed for its action, which is done through path analysis, where the two types of action namely direct effect of component characters on the yield and the indirect effects through other component characters on the yield are obtained which cannot be recorded by the correlation studies (Singh and Choudary, 1979).

If the correlation coefficient between a causal factor and the dependable factor is almost equal to its direct effect, then correlation explains the true relationship and direct selection through its trait will be effective. If the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effect seems to be the cause of positive correlation. In such situations, the indirect causal factors are to be considered simultaneously for selection.

Further, correlation coefficient determines how best the causal factors account for the variability of the dependent factor. If the residual effect is high, some other factors which have not been considered here need to be included in this analysis to account fully for the variation in yield.

In the present investigation, path coefficient analysis for estimation of direct and indirect effects of component traits was carried out by taking seed yield per plant separately, with a set of 11 characters, which were independent towards seed yield per plant.

Genotypic path coefficient analysis for seed yield per plant revealed that the characters namely dry weight of umbel, number of umbels per plant and number of primary branches per plant recorded maximum positive direct effect on seed yield per plant followed by number of umbellets per umbel and dry weight of plant indicating direct selection based on these traits will be rewarding in crop improvement. Characters like days to 50 per cent flowering, number of seeds per umbellet, harvest index and test weight showed negative direct effect on seed yield per plant. Number of seeds per umbellet had significant positive correlation on seed yield per plant, but its direct effect on seed yield per plant was negative (Table 8). Hence direct selection of this trait may not be effective. So, it can be selected through positive indirect effect, particularly test weight and seed yield per plant. These results are in accordance with the findings of Vijayalatha and Cheriyan (2002), Singh *et al.* (2006) and Meena *et al.* (2010) in fennel.

Phenotypic path coefficient analysis for seed yield per plant revealed that the characters namely harvest index and number of primary branches per plant had maximum positive direct effect on seed yield per plant followed by days to maturity, plant height, number of umbels per plant, dry weight of umbel and dry weight of plant indicating direct selection based on these traits will be rewarding in crop improvement programme. Characters such as days to 50 per cent flowering, number of seeds per umbellet, number of umbellet per umbel and test weight showed negative direct effect on seed yield per plant. Number of umbellets per umbel and number of seeds per umbellet had significant positive correlation on seed yield per plant, but their direct effect on seed yield per plant was negative (Table 9). Hence, direct selection of these traits may not be effective. So, it can be selected through positive indirect effect particularly number of primary branches per plant, harvest index and plant height. These results are in accordance with findings of Bhandari and Adarsh gupta (1991), Meena *et al.* (2013) and Megeji and Korla(2012) in fennel.

## **FUTURE LINE OF WORK**

- Multilocation trials may be conducted to know the performance of identified superior varieties across Eastern dry zone of Karnataka.
- The varieties identified may be tested for their ratoonability.
- The varieties identified may be tested for their tolerance to biotic and abiotic stress.
- Agronomic practices may be standardized for the best performing variety- RF 145.

## VI. SUMMARY

An investigation on "Evaluation of fennel (*Foeniculum vulgare* Mill.) varieties under Eastern dry zone of Karnataka" was carried out with 12 Varieties obtained from various institutes of the country was taken up at College of Horticulture, UHS campus, GKVK, Bengaluru. Variability studies, inter character correlation and path coefficient analysis were carried out to know the extent of variability among varieties and relationship among various growth, yield and quality components. The salient findings of the investigation are summarized here under.

The analysis of variance revealed highly significant differences among the varieties for all the characters studied except for days to first flowering and test weight. This indicates an ample scope for selection from the present gene pool for improvement of growth and yield attributing characters in fennel.

On the basis of mean performance, the maximum plant height (183.26 cm) and number of primary branches per plant (11.70) were recorded in RF 145 whereas, minimum number of days for 50 per cent flowering and maturity were recorded in RF 205 and RF 125, respectively. The maximum number of umbels (30.26), umbellets per umbel (35.58), seeds per umbellet (33.82), maximum fresh and dry weight of plant were recorded in RF 145, which also recorded the maximum fresh weight of umbel while GF 12 gave maximum dry weight of umbel. Maximum seed yield per plant (31.33g), seed yield per plot (1880g), seed yield per hectare (3133.33kg) and harvest index (26.24%) were also registered by RF 145.

RF 145 and GF 12 were considered as relatively superior varieties from the present study.

Higher magnitude of genotypic and phenotypic coefficient of variation (GCV and PCV) was observed for traits such as plant spread, fresh and dry weight of plant, seed yield per plant and seed yield per hectare which indicates the wide genetic variation among varieties with respect to all the characters due to strong genetic base. This variation indicates the possibility of selection of varieties for different purposes.

The high estimates of heritability coupled with high genetic advance as per cent mean were observed for characters like number of primary branches per plant, number of umbels per plant, number of umbellets per umbel, fresh weight of plant, dry weight of plant and oil yield. Hence, it can be concluded that selection based on these characters will be more useful for the improvement of fennel.

The partitioning of the correlation coefficient into genetic and phenotypic levels showed that, the correlation coefficient at genotypic level was higher than correlation coefficient at phenotypic level for all the characters, indicating the existence of inherent relationship among the characters. Seed yield per plant was highly significant and positively correlated with dry weight of umbel, number of umbels per plant, number of umbellets per umbel, harvest index, number of primary branches per plant, number of seeds per umbellet, days to 50 per cent flowering and plant height at both genotypic and phenotypic level, indicating the presence of strong relationship. Hence, it is possible to improve the seed yield by selecting the varieties based on associated traits.

Genotypic path analysis for seed yield per plant revealed that, among the growth and yield attributing characters, dry weight of umbel and number of umbels per plant recorded maximum positive direct effect on seed yield per plant followed by number of primary branches per plant, number of umbellets per umbel and dry weight of plant. Positive indirect effect on seed yield per plant was recorded by number of umbels per plant, number of umbellets per umbel and

dry weight of plant indicating direct selection based on these traits will be rewarding in crop improvement.

Phenotypic path analysis for seed yield per plant revealed that, the characters namely harvest index and number of primary branches per plant recorded maximum positive direct effect on seed yield per plant followed by days to maturity, plant height, number of umbels per plant, dry weight of umbel and dry weight of plant. These traits may serve as an effective selection attributes during breeding for higher seed yield in fennel.

Among the varieties studied, RF 145 performed better with respect to majority of growth and yield attributes compare to other varieties. So, this variety may be suitable for commercial cultivation in Eastern dry zone of Karnataka. The varieties with diverse characteristics could be involved in a suitable breeding programme to select superior performing varieties in the successive segregating generation. On the basis of performance of the varieties, RF 145, GF 12, RF 143 and RF 205 were found to be the superior varieties for multiple traits. Hence, these varieties can be used in further crop improvement programme in Eastern dry zone of Karnataka.

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## ANNEXURE – I

Monthly meteorological data of experimental site from October 2016 to April 2017

Months	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Bright sunshine (h)
	Max	Min	I h	II h		
<b>Oct 2016</b>	29.6	18.0	85	48	31	7.9
<b>Nov 2016</b>	29.6	16.2	82	43	0.0	8.5
<b>Dec 2016</b>	27.2	14.7	88	46	64.4	6.9
<b>Jan 2017</b>	27.3	14.5	88.9	39.5	0.0	8.2
<b>Feb 2017</b>	30.6	14.9	84	33	0.0	10.1
<b>Mar 2017</b>	33.0	19.5	82	39	9.8	8.9
<b>Apr 2017</b>	35.1	21.9	83	36	1.6	8.4

## ANNEXURE – II

### Chemical properties and nutrient status of experimental plot

Sl. No.	Particulars	Value
1	pH (1:2.5 soil: water)	6.7
2	Electrical conductivity ( $\text{dsm}^{-1}$ )	0.09
3	Organic carbon (%)	0.31
4	Available nitrogen ( $\text{kg ha}^{-1}$ )	170
5	Available phosphorus ( $\text{kg ha}^{-1}$ )	47
6	Available potassium ( $\text{kg ha}^{-1}$ )	155.4