Biological Forum – An International Journal **15(11): 237-242(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Correlation and Path Analysis of Inbred Lines of Fennel (*Foeniculum vulgare* Mill.)

Govardhan Lal Kumhar[1*], Dinesh Kumar Gothwal[2] and Amit Kumar[1]
[1]Department of Genetics and Plant Breeding,
Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan), India.
[2]Department of Genetics and Plant Breeding,
Sri Karan Narendra Agriculture University, Jobner (Rajasthan), India.

(Corresponding author: Govardhan Lal Kumhar)*
(Received: 10 September 2023; Revised: 08 October 2023; Accepted: 19 October 2023; Published: 15 November 2023)
(Published by Research Trend)

ABSTRACT: Correlation studies revealed that seed yield per plant exhibited highly significant and positive correlation with umbels per plant, plant height, branches per plant and umbellets per umbel while it exhibited highly significant and negative correlation with days to 50% flowering and days to maturity. Its association with 1000-seed weight and seeds per umbellet were positive and non-significant. Path analysis at both genotypic and phenotypic levels indicated that the magnitude of both direct and indirect effects was generally low. Among the characters the direct effect of umbels per plant was found to be positive and highest indicating that the correlation of umbels per plant with seed yield per plant was primarily because of the direct effect.

Keywords: Correlation coefficient, Path Analysis, Fennel, Umbels and Umbellets.

INTRODUCTION

Fennel (*Foeniculum vulgare* Mill. 2n =22) belonging to the family *Apiaceae* is an allogamous crop with 82.2 to 95.4% cross-pollination (Ramanujam *et al.*, 1964) and native of Europe and Mediterranean region (Agarwal *et al.*, 2001).

It is a 100-180 cm tall, scented annual plant with a smooth, branching stem that matures hollow in addition to prominent veins. Sheathed, alternating, and decompound leaves. The terminal flower bears a compound umbel that is surrounded by bract involucres. Flowers are pentamerous, complete, complete, hermaphrodite, and tiny. The fruit, also called the seed, is actually a schizocarp made up of two mericarps that are joined by a splitting carpophore. A fruit can grow to a length of 4 to 8 mm. The stage of harvesting determines the fruit's size and color. The entire plant, including the leaves, stalks, bulbs, and seeds, has a lovely perfume. The leaves that resemble fish strings are prized for their flavor garnish and diuretic qualities. The seeds are also chewed and masticated in India, either by themselves or in conjunction with betel leaves (Girija Lakshman, 1952).

About 9.5% protein, 2.0% fat, 42.3% carbs, 18.5% crude fiber, and 13.4% minerals are found in the seeds. Depending on the genotypes or botanical categories, the volatile oil content of the seeds ranges from 0.7% to 6.0%. Anethole and fenchone are the primary components in fennel oil. Alpha-pinene, camphene, alpha-phellandrene, and dipentene are the additional ingredients. To smell soaps and flavor cakes, volatile oil from seeds is extracted (Stanley Redgrove, 1933).

It is generally acknowledged that fennel originated in Southern Europe. It is mostly grown in nations like India, Romania, Russia, Hungary, Germany, France, Italy, Sri Lanka, Malaysia, Japan, Argentina, and the United States, although it is grown all over the temperate and subtropical regions of the world. As a cold-weather crop, it is mostly grown in Gujarat and Rajasthan, as well as to lesser extent in Uttar Pradesh, Karnataka, Andhra Pradesh, Punjab, Madhya Pradesh, Bihar, Haryana, and Jammu & Kashmir. Total area under the crop in India is about 0.91 lakh hectares with production of 1.53 lakh tonnes. (Anonymous, 2016-17). In Rajasthan, it occupies an area of 0.31 lakh hectares with an annual production of 0.35 lakh tonnes (Anonymous, 2016-17). It is mainly cultivated in the districts of Sirohi, Jodhpur, Nagour, Tonk, Dausa and Pali and to a limited extent in Bharatpur, Kota and Ajmer. Though the crop has a potential as a cash crop in Rajasthan, limited work has been done as far as its genetic improvement is concerned.

Inbreds were traditionally developed through continued selfing in selected plants. Recently however, production of dihaploids through either anther or pollen culture is also used. As a matter of fact, a patent on the method of dihaploid production was awarded to Ferrie *et al.* (2009). In the present investigation, inbreds produced through traditional continuous selfing method have been used for evaluation.

Fennel is a cross pollinated crop with high heterozygosity prevailing in the natural population (Ramanujam *et al.*, 1964). Genetic variability is prerequisite for any crop improvement in a crop. The success of any crop improvement programme depends on the magnitude of genetic variability and extent to which desirable characters are heritable.

The knowledge of the magnitude and direction of interrelationship between yield and its component characters has great importance in breeding programme for the selection of desirable types, when correlation studies involve many characters then it becomes difficult to determine the importance of each of the factors. In such cases path coefficient analysis provides an effective clue for this entangling direct as well as indirect effects of characters on dependable characters like seed yield.

MATERIALS AND METHODS

In the present investigation, 120 accessions were evaluated in augmented randomized complete block design with 5 checks. These lines were obtained from "All India Coordinated Research Project on Spices" at S.K.N. College of Agriculture, Jobner. Jobner is located in the semi-arid tropic zone of Rajasthan. Geographically Jobner is situated at a latitude of 20°5′N and longitude of 75°20′E at an altitude of 427 m above the sea mean level.

The inbreds were evaluated during *Rabi* season 2018-19 at Research Farm of S.K.N. College of Agriculture, Jobner in augmented design in six blocks with five checks *viz*., RF-101, RF-125, RF-143, RF-157 and RF-205 assigned randomly to each block. Each inbred and check were sown in a plot of single row of 3 meter length. The row to row and plant to plant distance was maintained 50 cm and 20 cm, respectively by thinning at 25th day after sowing. Non-experimental rows were planted as border rows in each block to eliminate the border effect if any. All the agronomical practices were followed to raise a good and healthy crop. Five plants were randomly selected and tagged before flowering from each line in each block to record the data. Data on days to 50 per cent flowering, days to maturity and test weight were recorded on whole plot basis. The mean data were subjected to analysis of variance following the method suggested by Federer (1956). Various offline and online software's (at IASRI website etc.) were used for required calculations.

RESULT AND DISCUSSION

The present investigation in fennel was carried out to estimate the genetic variability, heritability, genetic advance, association among different characters with each other and with seed yield in a set of 120 fennel accessions along with five checks namely, RF-101, RF-125, RF-143, RF-157 and RF-205.

Character association analysis. The values of all possible correlation coefficients among the characters were calculated both at genotypic and phenotypic level, which are presented in Table 1 and 2, respectively.

The correlations were in general stronger at phenotypic level in comparison to genotypic level, this indicated the strong effect of environment on the expression of characters. The associations at phenotypic level are generally considered, as there is no tangible test for knowing the statistical significance of correlation at genotypic level (Reddy and Sharma 1982; Singh *et al.*, 1998).

At the phenotypic level, the relationship between seed yield per plant and the characteristics branches per plant (0.2860), plant height (0.2080), umbellets per umbel (0.2450), and umbels per plant (0.3280) was shown to be positive and significant. The association between seeds per umbellet (0.1120) and 1000-seed weight (0.1000) was positive but not statistically significant. The number of days until 50% flowering (-0.1510) and the number of days until maturity (-0.0660) also showed a poor and non-significant correlation with the amount of seeds produced per plant.

At the genotypic level, a significant and positive correlation was found between seed yield per plant and the traits of plant height (0.2110), branches per plant (0.2150), umbels per plant (0.3380), and umbellets per umbel (0.2190). In contrast, there is a positive but negligible correlation between the weight of 1000 seeds and the number of seeds per kilogram (0.1010). Days to 50% flowering had a positive and significant correlation with days to maturity (0.6770) at the phenotypic level, as well as a positive and non-significant correlation with branches per plant (0.0400). However, it had a negative and non-significant correlation with seed yield per plant (-0.1510), 1000-seed weight (-1330), seeds per umbellet (-0.380), umbellets per umbel (-0.0020), and umbels per plant (-0.1090). Days to 50% blooming had a positive and substantial connection with days to 50% flowering at the genotypic level.

Days to maturity had a positive and significant correlation with days to 50% flowering at the phenotypic level (0.6770), along with umbels per plant (0.0270) and branches per plant (0.1300), whereas plant height (-0.0350), umbellets per umbel (-0.0730), seeds per umbellet (-0.0440), seed yield per plant (-0.0660), and 1000-seed weight (-0.0590) had negative and non-significant correlations. At the genotypic level, days to maturity had a positive and significant correlation with days to 50% flowering (0.6460), as well as a positive and non-significant correlation with branches per plant (0.1340) and umbels per plant (0.0300). However, days to maturity had a negative and non-significant correlation with umbellets per umbel (-0.1110), seeds per umbellet (-0.2590), plant height (-0.0770), and seed yield per plant (-0.0140).

At phenotypic level, plant height had positive and significant association with umbellets per umbels (0.2740), seed yield per plant (0.2080) and seeds per umbellet (0.3020), similarly, branches per plant (0.1520) showed positive and non-significant correlation with plant height, whereas, negative and non-significant association with days to 50 per cent flowering (-0.0180), days to maturity (-0.0350), umbels per plant (-0.0840) and 1000- seed weight (-0.0310). At genotypic level, plant height had positive and significant association with branches per plant

(0.0.1960), umbellets per umbels (0.2460), seeds per umbellet (0.2370) and seed yield per plant (0.2110), whereas, umbels per plant (-0.0150) and 1000-seed weight (-0.0700) showed negative and non-significant association with plant height.

Branches per plant were positively and significantly correlated with seed yield per plant (0.2860), umbels per plant (0.5500), and seeds per umbellet (0.2500) at the phenotypic level. Similar positive and non-significant correlations were seen for umbellets per umbel (0.0840), days to 50% flowering (0.0400), days to maturity (0.1300), and plant height (0.1520). However, there was a negative and significant correlation between branches per plant and the weight of 1000 seeds (-0.0530). At the genotypic level, the number of branches per plant was positively and significantly correlated with the number of umbels per plant (0.5460), the number of seeds produced per plant (0.2150), and the number of seeds per umbellet (0.1930). The correlations with days to 50% flowering (0.0170), umbellets per umbel (0.0820), and days to maturity (0.1340) were also positive but not statistically significant. There was a weak and insignificant association.

Umbels per plant, branches per plant, and seed output per plant all showed positive and significant correlations at the phenotypic level. Days to maturity (0.0270) showed a positive but unremarkable correlation. Umbellets per umbel had a negative and significant correlation with it (-0.0760). Similar negative and non-significant associations with umbels per plant were seen for days to 50% flowering (-0.1090), seeds per umbellet (-0.0760), 1000-seed weight (-0.1540), and plant height (-0.0840). At the genotypic level, the number of umbels per plant was positively and significantly correlated with the number of branches per plant and the number of seeds produced per plant (0.3380 and 0.5460, respectively). The number of days to maturity (0.5460) was also positively and significantly correlated. It had a negative, significant association with umbellets per umbel (-0.1830) and 1000-seed weight (-0.1820); it also showed a negative, non-significant correlation with umbellets per umbel (-0.1820).

At the phenotypic level, umbellets per umbel had positive and significant associations with plant height (0.2740), seeds per umbellet (0.4370), and seed yield per plant (0.2450). Similarly, branches per plant (0.0840) showed positive and non-significant associations, whereas umbels per plant (-0.1830) had negative and significant associations with umbellets per umbel. The number of umbellets per umbel had a positive and significant link with seed yield per plant (0.2190), seeds per umbellet (0.4650), and plant height (0.2460) at the genotypic level. Similarly, the number of branches per plant (0.0820) and 1000-seed weight (0.0670) had a positive and non-significant correlation. In a similar way, it had a negative and non-significant connection with umbels per plant (-0.1830).

At the phenotypic level, the relationship between seeds per umbellet and plant height (0.3020), branches per plant (0.2500), and umbellets per umbel (0.4370), as well as the relationship between seeds per plant and seed yield (0.1120), was positive and non-significant. The relationship between seeds per umbellet and 1000-seed weight (-0.0430), umbels per plant (-0.0760), days to 50% flowering (-0.0380), and days to maturity (-0.0440) was negative but not statistically significant. At the genotypic level, the number of seeds per umbellet was positively correlated and significant with the number of branches per plant (0.1930), umbellets per umbel (0.4650), and plant height (0.2370), while the number of seeds produced per plant (0.1170) and the weight of 1000 seeds (0.0190) were positively correlated but not significantly so. It significantly and negatively correlated with the number of days until 50% blooming (-0.2170) and the number of days till maturity.

At the phenotypic level, 1000-seed weight had a positive and non-significant relationship with seed yield per plant (0.1000) and umbellets per umbel (0.0630), but a negative and non-significant relationship with the number of days until 50% flowering (-0.1510), days until maturity (-0.0590), plant height (-0.0310), branches per plant (-0.0530), umbels per plant (-0.1540), and seeds per umbellet (-0.0430). The 1000-seed weight had a positive, non-significant relationship with umbellets per umbel (0.0670) and seed yield per plant (0.1010) at the genotypic level. The connection was negative and significant for umbels per plant (-0.1820), but non-significant for days to 50% flowering (-0.1600), days to maturity (-0.0280), plant height (-0.0700), and branches per plant (-0.1350).

Path coefficient analysis. Path coefficient analysis was carried out by taking seed yield as dependent variable and other components as independent variables. The trend in direct and indirect effects of different traits on seed yield was similar at genotypic and phenotypic levels. which are presented in Table 3 and 4, respectively.

The results of path coefficient analysis indicated that at phenotypic level, umbels per plant (0.3675) had the highest positive direct effect on the seed yield followed by umbellets per umbel (0.2717), plant height (0.1714), branches per plant (0.0541), 1000 seed weight (0.1002) and days to maturity (0.0224). Whereas days to 50% flowering (-0.1082) followed by seeds per umbellet (-0.0411) had negative direct effect.

The residual effect at genotypic level was 0.7146, it indicated that more characters should be included in the study and at phenotypic level was 0.7382.

Correlation provides information about degree and direction of association between two characters. It may result due to genetic causes such as pleiotropic effect or linkage or both it may also be due to environmental cause.

RESULT AND DISCUSSION

Character association. The degree and direction of linkage between two characters are revealed via correlation. It may be brought on by genetic factors like pleiotropic impact, linkage, or both, as well as environmental factors. For various traits, including seed yield, correlation coefficients between genotype and

phenotype have been calculated. The findings of the current study showed that, for the majority of the features, the phenotypic correlation coefficient was higher than its genotypic equivalent. This suggests that genetic factors influence correlation coefficient values.

There was a positive and significant correlation between seed yield and the majority of morphological traits in the current study. The seed output per plant was significantly and positively related to umbellets per umbel and umbels per plant. Similar results were obtained for this trait with seed yield per plant by Kathiria *et al.* (1980); Agnihotri *et al.* (1997); Pareek *et al.* (2009).

The relationship between seed output per plant and days to 50% flowering and maturity was unfavourable and non-significant. For days to 50% flowering with seed yield, Agnihotri *et al.* (1997); Meena and Dhaker (2017) reported earlier findings that were similar. In contrast, Choudhary *et al.* (2017); Yadav *et al.* (2013) reported positive and significant correlation of branches per plant and plant height with seed yield, while Rajput *et al.* (2004), Cosge *et al.* (2009); Jeeterwal *et al.* (2015) reported positive and significant correlation for plant height and branches per plant with seed yield per plant.

Path coefficient analysis. The correlation study does not clearly show the interrelationships between the various characters that affect seed yield. The interaction of a multitude of component characters determines how a complicated character, such as seed yield, is expressed. According to Falconer (1981), in such complicated scenarios, path coefficient analysis is a useful technique for examining character association because it is sometimes believed that the relationship between two characters is evidence of pleiotropy rather than linkage. In order to determine the impact of various features towards seed yield, path analysis was carried out using seed yield per plant as the dependent variable. The correlation coefficient was divided into the measures of direct and indirect effects. In light of the available data, the path coefficient analysis is discussed below.

The analysis of path coefficients revealed that 1000-seed weight, umbellets per umbel, days to maturity, and umbels per plant all had a positive direct effect on seed yield per plant. These findings are in accordance with the earlier reports of Singh *et al.* (2003); Sefidan (2014); Kumawat *et al*. (2016); Jeeterwal *et al*. (2015). Contradictory to this Joshi *et al*. (1972) found that the indirect effect of test weight on seed yield per plant were also low. While seeds per umbellet and days to 50 per cent flowering exhibited negative direct effect on seed yield per plant. Similar results were reported by Choudhary (1987); Srivastava *et al*. (2000); Ram *et al.* (2017) for days to 50 per cent flowering, days to maturity, while Agnihotri *et al*. (1997); Jeeterwal *et al.* (2015) reported positive direct effect for branches per plant and plant height on seed yield per plant.

Only umbels per plant had stronger indirect effects via other features on seed yield among the indirect effects. The majority of the other indirect effects had very little effects. According to correlations and path coefficients, umbels per plant, followed by seed weights of 1000 seeds per umbellet, and umbellets per umbel were the key variables that contributed to production. Therefore, increasing umbels per plant and umbellets per umbel should receive more attention.

Table 1: Correlation coefficients between different characters in fennel at genotypic level.

Characters	Days to 50 % flowering	Days to maturity	Plant height(cm)	Branches per plant	Umbels per plant	Umbellets per umbel	Seeds per umbellet	1000-Seed weight(g)	seed Yield per Plant (g)
Days to 50% Flowering	1.0000	0.6460**	-0.0210	0.0170	-0.0980	-0.0340	-0.2170*	-0.1600	-0.1230
Days to maturity		1.0000	-0.0770	0.1340	0.0300	-0.1110	-0.2590**	-0.0280	-0.0140
Plant height (cm)			1.0000	0.1960*	-0.0150	0.2460**	0.2370**	-0.0700	0.2110*
Branches per plant				1.0000	0.5460**	0.0820	0.1930*	-0.1350	0.2150*
Umbels per plant					1.0000	-0.1830*	-0.0920	-0.1820*	0.3380**
Umbellets per umbel						1.0000	0.4650**	0.0670	0.2190*
Seeds per umbellet							1.0000	0.0190	0.1170
1000- seed weight (g)								1.0000	0.1010
Seed yield per plant (g)									1.0000

* Significant at p = 0.05 and ** significant at = 0.01

Table 2: Correlation coefficients between different characters in fennel at phenotypic level.

Characters	Days to 50 % flowering	Days to maturity	Plant height(cm)	Branches per plant	Umbels per plant	Umbellets per umbel	Seeds per umbellet	1000-Seed weight(g)	seed Yield per Plant (g)
Days to 50% Flowering	1.0000	0.6770**	-0.0180	0.0400	-0.1090	-0.0020	-0.0380	-0.1330	-0.1510
Days to maturity		1.0000	-0.0350	0.1300	0.0270	-0.0730	-0.0440	-0.0590	-0.0660
Plant height (cm)			1.0000	0.1520	-0.0840	0.2740**	0.3020**	-0.0310	0.2080*
Branches per plant				1.0000	0.5500**	0.0840	0.2500**	-0.0530	0.2860**
Umbels per plant					1.0000	-0.1830*	-0.0760	-0.1540	0.3280**
Umbellets per umbel						1.0000	0.4370**	0.0630	0.2450**
Seeds per umbellet							1.0000	-0.0430	0.1120
1000- seed weight (g)								1.0000	0.1000
Seed yield per plant (g)									1.0000

* Significant at p = 0.05 and ** significant at = 0.01

Table 3: Direct (diagonal) and indirect effects of different characters on seed yield per plant in fennel at genotypic level.

Characters	Days to 50 % flowering	Days to maturity	Plant height (cm)	Branches per plant	Umbels per plant	Umbellets per umbel	Seeds per umbellet	1000-Seed weight(g)	Correlation With seed Yield per Plant (g)
Days to 50% flowering	**-0.1021**	0.0635	-0.0039	-0.0014	-0.0437	-0.0085	-0.0026	-0.0247	-0.1235
Days to maturity	-0.0657	**0.0987**	-0.0142	-0.0104	0.0135	-0.0280	-0.0031	-0.0044	-0.0137
Plant height (cm)	0.0022	-0.0076	**0.1841**	-0.0153	-0.0067	0.0622	0.0029	-0.0108	0.2110*
Branches per plant	-0.0018	0.0132	0.0361	**-0.0781**	0.2433	0.0207	0.0024	-0.0208	0.2149*
Umbels per plant	0.0100	0.0030	-0.0027	-0.0426	**0.4461**	-0.0464	-0.0011	-0.0281	0.3381**
Umbellets per umbel	0.0034	-0.0109	0.0452	-0.0064	-0.0817	**0.2533**	0.0056	0.0103	0.2189*
Seeds per umbellet	0.0222	-0.0255	0.0436	-0.0151	-0.0411	0.1178	**0.0121**	0.0030	0.1170
1000- seed weight (g)	0.0164	-0.0028	-0.0129	0.0105	-0.0812	0.0169	0.0002	**0.1542**	0.1013

Residual effect: Genotypic =0.74340, * significant at p = 0.05 and ** significant at = 0.01

Table: 4 Direct (diagonal) and indirect effects of different characters on seed yield per plant in fennel at phenotypic level.

Characters	Days to 50 % flowering	Days to maturity	Plant height(cm)	Branches per plant	Umbels per plant	Umbellets per umbel	Seeds per umbellet	1000-Seed weight(g)	Correlation With seed Yield per Plant (g)
Days to 50% flowering	**-0.1082**	0.0151	-0.0031	0.0022	-0.0401	-0.0005	0.0016	-0.0178	-0.1508
Days to maturity	-0.0732	**0.0224**	-0.0060	0.0070	0.0099	-0.0199	0.0018	-0.0078	-0.0659
Plant height (cm)	0.0019	-0.0008	**0.1714**	0.0082	-0.0310	0.0744	-0.0124	-0.0042	0.2076*
Branches per plant	-0.0044	0.0029	0.0261	**0.0541**	0.2022	0.0229	-0.0103	-0.0070	0.2864**
Umbels per plant	0.0118	0.0006	-0.0145	0.0297	**0.3675**	-0.0496	0.0031	-0.0205	0.3283**
Umbellets per umbel	0.0002	-0.0016	0.0469	0.0046	-0.0671	**0.2717**	-0.0180	0.0084	0.2450**
Seeds per umbellet	0.0042	-0.0010	0.0518	0.0135	-0.0280	0.1186	**-0.0411**	-0.0057	0.1122
1000- seed weight (g)	0.0145	-0.0013	-0.0054	-0.0029	-0.0565	0.0171	0.0018	**0.1330**	0.1002

Residual effect: Phenotypic =0.73820, * significant at p = 0.05 and ** significant at = 0.01

CONCLUSIONS

The association analysis revealed that the seed yield per plant was significantly and positively correlated with, branches per plant, plant height, umbellets per umbel and umbels per plant, while days to 50 per cent flowering and days to maturity had negative and non-significant correlation with seed yield per plant. Path coefficient analysis at both genotypic and phenotypic level revealed that 1000- seed weight, plant height, branches per plant, umbellets per umbel, days to maturity and umbels per plant were the important characters for selection of high yielding genotypes as they exerted high positive direct effect as well as showed positive correlation with seed yield per plant, while seeds per umbellet and days to 50 per cent flowering exerted direct and negative effect on seed yield per plant. The direct effect of umbels per plant was found to be positive and highest among the characters, indicating that the correlation of umbels per plant with seed yield was primarily due to the direct effect.

REFERENCES

Agnihotri, P., Dashora, S. L. and Sharma, R. K. (1997). Variability, correlation and path analysis in fennel (*Foeniculum vulgare* Mill.). *Journal of Spices and Aromatic Crops*, *6*(1), 51-54.

Anonymous (2016-17). Area, Production and Productivity of fennel in India. *www.indiaagristat.com*

Anonymous (2016-17). Area, Production and Productivity of fennel in Rajasthan. *www.indiaagristat.com*

Choudhary, C. L. (1987). Association of developmental characters with grain yield in coriander (*Coriandrum sativum* L.) germplasm. M.Sc. (Ag.) Thesis, Sukhadia University, Campus-Jobner, Rajasthan.

Choudhary, G., Ranjan J. K. and Jeeterwal, R. C. (2017). Genetic variability, heritability and correlation studies in fennel (*Foeniculum vulgare* Mill.). *International Journal of Chemical Studies*, *5*(4), 476-478.

Cosge, B., Ipek, A. and Gurbuz, B. (2009). Some phenotypic selection criteria to improve seed yield and essential oil percentage of sweet fennel (*Foeniculum vulgare* Mill *var. Dulce*). *Tarim Bilimleri Dergisi*, *15*(2), 127-133.

Federer, W. T. (1956). Augmented designs. Hawain planters record, Inc., New York, *20*, 191-207.

Ferrie, Alison, M. R., Mykytyshyn, Marie, L. and Bethure, T. (2009). Methods for producing microspore derived doubled haploid apieaceae. Pub. No. US/2009/0100538 A1, pub. Date Apr. 16, 2009. (*http://www.freshpatents.com*, Php accessed Thursday, November 15, 2012).

Girija Lakshman, (1952). Taxonomical studies of a few economic generation in umbelliferae. M.Sc. Thesis, Madras University.

Joshi, B. S., Ramanujam, S. and Joshi, A. B. (1972). Association of yield and other characters in coriander. *Indian Journal of Genetics and Plant Breeding*, *32*(3), 411-420.

Jeeterwal, R. C., Sastry, E. V. D., Rajput, S.S. and Singh. D. (2015). Genetic variability, character associations, path coefficient and divergence analysis in inbreds of fennel (*Foeniculum vulgare* Mill.). *International Journal of Seed Spices*, *5*(2), 51-53.

Kathiria, K. B. (1980). Variability and correlation in a selected and unselected bulk of fennel. M.Sc. (Ag.) Thesis, University of Udaipur, Campus- Jobner (Rajasthan).

Kumawat, S. K., Mundiyara, R., Singh, D. and Sastry, E. V. D. (2016). Studies on genetic variability and correlation for yield and component traits in S_6 progenies of fennel (*Foeniculum vulgare* Mill.). *Trends in Biosciences*, *9*(5), 329-333.

Meena, R. S. and Dhaker, L. (2017). Genetic variability, correlation and path analysis in fennel (*Foeniculum vulgare* Mill.) genotypes. *Journal of Agri Search*, *4*(4), 231-236.

Pareek, B., Singh, D. and Sastry, E. V. D. (2009). Correlation studies in full sib progenies of fennel (*Foeniculum vulgare* Mill.). Published in National Workshop on "*Spices and Aromatic Plants in 21st century India*" held at S.K.N. College of Agriculture, Jobner (Rajasthan), pp. 45.

Rajput, S. S., Singhania, D. L., Singh, D., Sharma, K. C. and Rathore, V. S. (2004). Assessment of genetic variability in fennel (*Foeniculum vulgare* Mill.). Published in National Seminar on "*New Perspective in Commercial Cultivation, Processing and Marketing of Seed Spices and Medicinal Plants"* held at S.K.N. College of Agriculture, Jobner (Rajasthan), pp. 10.

Ram, H., Khan, M. M., Pandey, V. P. and Dwivedi D. K. (2017). Correlation coefficient and path analysis in coriander (*Coriandrum sativum* L.) genotypes. *International Journal of Current Microbiology and Applied Sciences*, *6*(6), 418-422.

Ramanujam, S., Joshi, B. S. and Saxena, M. B. L. (1964). Extent and randomness of cross pollination in some umbelliferous spices of India. *Indian Journal of Genetics and Plant Breeding*, *24*, 62-67.

Reddy, N. S. and Sharma, R. K. (1982). Variability and interrelationship for yield and protein content in inbred lines of bajra. *Crop Improvement*, *9*, 124-128.

Sefidan, A. Y., Valizadeh, M., Aharizad, S. and Sabzi, M. (2014). Path analysis of grain yield, some morphological traits and essential oil content in different fennel (*Foeniculum vulgare* Mill.) populations. *Journal of Diversity and Environmental Science*, *4*(5), 10-15.

Singh, R. P., Garg, D. K. and Sharma, P. C. (1998). Character association in wheat. *Indian Journal Genetics***,** *58*, 219-221.

Singh, Y., Mittal, P. and Katoch, V. (2003). Evolution of fennel (*Foeniculum vulgare* Mill.) genotype under mid-hill, humid sub-temperate condition. *Himachal Journal of Agricultural Research*, *29*(1/2), 48-51.

Srivastava, J. P., Kamaluddin, Srivastava, S. B. L. and Tripathi, S. M. (2000). Path analysis in coriander (*Coriandrum sativum* L.). Published in Centennial Conference on Spices and Aromatic Plants held at Calicut. pp. 71-74.

Stanley Redgrove, H. C. (1933). Spices and condiments. Sir Isaac Pitman and Sons Ltd. London.

Yadav, P. S., Pandey, V. P. and Yadav, Y. (2013). Variability studies in fennel (*Foeniculum vulgare* Mill.). *Journal of Spices and Aromatic Crops*, *22*(2), 203-208.

How to cite this article: Govardhan Lal Kumhar, Dinesh Kumar Gothwal and Amit Kumar (2023). Correlation and Path Analysis of Inbred Lines of Fennel (*Foeniculum vulgare* Mill.). *Biological Forum – An International Journal*, *15*(11): 237-242.