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Trait association and path coefficient analysis for seed yield in fennel (*Foeniculum vulgare* Mill.)

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Abstract

Fennel (*Foeniculum vulgare* Mill.) is an important spice crop cultivated under diverse agro-climatic conditions. Seed yield, being a complex trait highly influenced by multiple interrelated traits; therefore, correlation and path coefficient study help to identify important yield contributing traits for their use in fruitful crop improvement and selection. The present study was conducted using 30 diverse genotypes of fennel to calculate correlation and path coefficients. The research experiment was carried out in randomized block design with three replications at Research Farm, Department of Genetics and Plant Breeding, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat during the season *Rabi* 2023-24. The result showed seed yield per plant to have significant positive correlation with seed width, test weight and seed length, while highly significant negative correlation was recorded with days to 50 % flowering and days to maturity at both genotypic and phenotypic levels. Path coefficient study revealed the highest positive direct effects on seed yield per plant were exhibited by umbels per plant followed by plant height, seed length, primary branches per plant, tillers per plant, test weight and seeds per umbellate. Therefore, selection for such traits would be useful to bring out seed yield improvement in fennel.

Keywords: Fennel, seed yield, correlation analysis, path coefficient analysis, genetic improvement

Introduction

India is known in the world as the 'Home of Spices'. Spices play a very important role in the economy of our country as some of them are exported to earn foreign exchange. Seed spices occupy a prominent place in the total basket of spices of the country and play a significant role in the Indian economy. Seed spices include all those annuals whose dried seeds are used as spices *viz.*, fennel, fenugreek, coriander, cumin, ajwain, dill and nigella. Fennel (*Foeniculum vulgare* Mill.) belonging to the family Apiaceae, is a cross-pollinated crop and a diploid species with chromosome number 2n =22. It is one of the most important seed spice crops grown in India. Being an aromatic plant, it is commercially cultivated as an annual herb, the seeds of which are used for flavouring purposes. It is native to Southern Europe and the Mediterranean region. It is an annual, aromatic herb of 100-180 cm in height having a slender, branched, smooth stem that becomes hollow at maturity with distinct veins. Leaves are alternate, decompounded and have sheathed petiole. The inflorescence is a terminal-bearing compound umbel subtended by involucres of bracts. Flowers are small, hermaphrodite, complete, regular and pentamerous. The fruit commonly known as seed is a schizocarp of two mericarps attached to dividing carpophores. A fully grown fruit is 4 to 8 mm long. The size and the colour of the fruit depend upon the stage of harvesting. The fish string-like leaves are valued as a source of flavour to garnish and also possess diuretic properties. The root is regarded as a purgative. Fennel seeds are used in diseases like cholera, bile disturbances, nervous disorders, constipation, dysentery and diarrhoea and are also used for control of diseases attacking the chest, lungs, spleen, kidney and in colic pain (Girija Lakshman, 1952) [4].

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

Materials and Methods

The present experiment was carried out at Research Farm, Department of Genetics and Plant Breeding, N. M. College of Agriculture, NAU, Navsari during *Rabi* 2023-24. Initially nursery was prepared by sowing the seeds of thirty genotypes on raised beds and 30 days old seedlings were transplanted in a Randomized Block Design with three replications. Each genotype was transplanted in row-to-row spacing of 45 cm and plant-to-plant spacing of 30 cm. The genotypes were randomly allotted to the plots in each replication. All the recommended agronomical practices along with necessary plant protection measures were followed timely for the successful raising of the crop. The observations were recorded on five randomly selected plants from each block and in each replication except for days to 50 % flowering and days to maturity. Selected plants were tagged before the first flower emergence. Data for days to 50 % flowering and days to maturity were recorded on a plot basis. Data for other characters were collected from the arbitrarily selected five plants on an individual plant basis for different characters and their averages were used in the statistical analysis. Genotypic (r_g) and phenotypic (r_p) correlation coefficients were estimated using the standard procedure suggested by Miller *et al.* (1958) [11]. The phenotypic correlation was tested using the method suggested by Fisher (1936) [3]. The cause-and-effect relationship between two variables cannot be known from a simple correlation coefficient. Therefore, path analysis suggested by Wright (1921) and Dewey and Lu (1959) [2, 16] was adopted for partitioning the genotypic correlation between variables with seed yield into direct and indirect effects of those variables on the yield. Genotypic correlation coefficients of twelve variables with yield were used to estimate the path coefficients for the direct effect of various independent characters on dependent character seed yield per plant.

Results and Discussion

Correlation Coefficient Analysis: Seed yield per plant had showed highly significant and positive correlation with seed width (r_g= 0.504 and r_p= 0.402) and test weight (r_g= 0.500 and r_p= 0.446) at both genotypic and phenotypic levels (Table-1 & 2). This trait had showed significant positive genotypic correlation and highly significant positive phenotypic correlation with the trait seed length (r_g= 0.449 and r_p= 0.331). Umbellates per umbel (r_g= 0.027 and r_p= 0.033) and seeds per umbellate (r_g= 0.240 and r_p= 0.129) were non-significant and positively correlated at both genotypic and phenotypic level. Plant height (r_g= -0.034 and r_p= 0.016) showed non-significant negative correlation at genotypic level and non-significant positive correlation at phenotypic levels with seed yield per plant. It had showed highly significant and negative correlation with days to 50 % flowering (r_g= -0.475 and r_p= -0.435) at both genotypic and phenotypic levels. Days to maturity (r_g= -0.416 and r_p= -0.351) had showed significant and negative correlation at genotypic level while highly significant and negative correlation at phenotypic level with seed yield per plant. Tillers per plant (r_g= -0.317 and r_p= -0.272) had showed non-significant and negative correlation at genotypic level while highly significant and negative correlation at phenotypic level with seed yield per plant. This trait had showed non-significant and negative correlation with the traits, umbels per plant (r_g= -0.038 and r_p= -0.074), primary branches per plant (r_g= -0.207 and r_p= -0.156) and secondary branches per plant (r_g= -0.217 and r_p= -0.204) at both genotypic and phenotypic levels.

Table 1: Genotypic correlation coefficient of seed yield per plant with other characters

	Days to 50% flowering	Plant height (cm)	Tillers per plant	Primary branches per plant	Secondary branches per plant	Umbels per plant	Umbellates per umbel	Seeds per umbellate	Seed length (mm)	Seed width (mm)	Test weight (g)	Days to maturity	Seed yield per plant (g)
DFF	1.000**												
PH	0.570**	1.000**											
TPP	0.502**	0.274^{NS}	1.000**										
PBPP	0.105^{NS}	0.311^{NS}	0.087^{NS}	1.000**									
SBPP	0.339^{NS}	0.523**	0.380*	0.546**	1.000**								
UPP	0.116^{NS}	0.317^{NS}	0.090^{NS}	0.349^{NS}	0.889**	1.000**							
UPU	0.187^{NS}	0.439*	0.046^{NS}	0.272^{NS}	-0.161^{NS}	-0.303^{NS}	1.000**						
SPU	0.146^{NS}	0.744**	0.038^{NS}	0.084^{NS}	-0.169^{NS}	-0.285^{NS}	0.948**	1.000**					
SL	-0.228^{NS}	-0.371*	-0.311^{NS}	-0.498**	-0.305^{NS}	-0.131^{NS}	-0.138^{NS}	-0.299^{NS}	1.000**				
SW	-0.596**	-0.494**	-0.420*	-0.453*	-0.457*	-0.192^{NS}	-0.049^{NS}	0.028^{NS}	0.717**	1.000**			
TW	-0.509**	-0.331^{NS}	-0.286^{NS}	-0.241^{NS}	-0.108^{NS}	0.015^{NS}	-0.243^{NS}	-0.124^{NS}	0.577**	0.560**	1.000**		
DM	0.948**	0.549**	0.418*	0.066^{NS}	0.320^{NS}	0.131^{NS}	0.196^{NS}	0.120^{NS}	-0.112^{NS}	-0.513**	-0.438*	1.000**	
SYPP	-0.475**	-0.034^{NS}	-0.317^{NS}	-0.207^{NS}	-0.217^{NS}	-0.038^{NS}	0.027^{NS}	0.240^{NS}	0.449*	0.504**	0.500**	-0.416*	1.000**

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

Table 2: Phenotypic correlation coefficient of seed yield per plant with other characters

	Days to 50% flowering	Plant height (cm)	Tillers per plant	Primary branches per plant	Secondary branches per plant	Umbels per plant	Umbellates per umbel	Seeds per umbellate	Seed length (mm)	Seed width (mm)	Test weight (g)	Days to maturity	Seed yield per plant (g)
DFF	1.000**												
PH	0.474**	1.000**											
TPP	0.465**	0.212*	1.000**										
PBPP	0.052^{NS}	0.206^{NS}	0.068^{NS}	1.000**									
SBPP	0.302**	0.367**	0.352**	0.334**	1.000**								
UPP	0.079^{NS}	0.253*	0.083^{NS}	0.273**	0.813**	1.000**							
UPU	0.168^{NS}	0.361**	0.046^{NS}	0.151^{NS}	-0.096^{NS}	-0.229*	1.000**						
SPU	0.094^{NS}	0.431**	0.051^{NS}	-0.003^{NS}	-0.123^{NS}	-0.188^{NS}	0.566**	1.000**					
SL	-0.152^{NS}	-0.208*	-0.172^{NS}	-0.243*	-0.167^{NS}	-0.067^{NS}	-0.088^{NS}	-0.142^{NS}	1.000**				

SW	-0.525**	-0.409**	-0.343**	-0.254*	-0.372**	-0.115^{NS}	-0.002^{NS}	0.064^{NS}	0.567**	1.000**			
TW	-0.470**	-0.272**	-0.262*	-0.177^{NS}	-0.104^{NS}	0.003^{NS}	-0.221*	-0.063^{NS}	0.427**	0.519**	1.000**		
DM	0.908**	0.469**	0.373**	0.025^{NS}	0.248*	0.076^{NS}	0.191^{NS}	0.083^{NS}	-0.093^{NS}	-0.458**	-0.405**	1.000**	
SYPP	-0.435**	0.016^{NS}	-0.272**	-0.156^{NS}	-0.204^{NS}	-0.074^{NS}	0.033^{NS}	0.129^{NS}	0.331**	0.402**	0.446**	-0.351**	1.000**

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

DFF = Days to 50% flowering; PH = Plant height (cm); TPP = Tillers per plant; PBPP = Primary branches per plant; SBPP = Secondary branches per plant; UPP = Umbels per plant; UPU = Umbellates per umbel; SPU = Seeds per umbellate; SL = Seed length (mm); SW = Seed width (mm); TW = Test weight (g); DM = Days to maturity; SYPP = Seed yield per plant (g)

The research findings were similar with that of outcomes of Kumar *et al*. (2017) and Singh (2020) [7, 8] for test weight, Prajapati *et al.* (2022) and Kumawat *et al.* (2020) [8, 12] for seeds per umbellate, Singh *et al.* (2020) and Jat and Choudhary (2022) [5, 8] for umbellates per umbel and days to 50 % flowering, Jat and Choudhary (2022) [5] for days to maturity and Kumar *et al*. (2017), Kumawat *et al.* (2020) and Jat and Choudhary (2022) [5, 7, 8] for plant height at genotypic level. In the present investigation, it has been found that the amount of genotypic correlation was higher as compared to their corresponding phenotypic correlations for majority of the characters, which reflects the less environmental influence and existence of inherent relation among the characters under study. Genotypic correlation coefficients were higher than phenotypic correlation coefficients, which might be due to the masking effect of environment in the total expression of the genotypes which results in reduced phenotypic association. The significant and desired directional inherent and observable correlation was registered between seed yield and seed width, test weight and seed length. This showed that these three traits having inherent relationship with seed yield, which also depicted their importance in the seed yield enhancement and can be done by improving those characters.

Path Coefficient Analysis: In the present investigation, efforts have been made to identify the effective component traits of seed yield per plant in thirty diverse genotypes of fennel with aid of genotypic path analysis. The studies revealed that highest positive and direct influence on seed yield per plant was exerted by umbels per plant (1.6263) followed by plant height (1.1461), seed length (0.7042), primary branches per plant (0.7039), tillers per plant (0.6695), test weight (0.2671) and seeds per umbellate (0.0354) which explains that these attributes might provide expected advance during selection for seed yield (Table-3). Similar results were found by Sefidan *et al.* (2014), Jeeterwal *et al.* (2015), Singh *et al.* (2020), Jat and Chaudhary (2022), Prajapati *et al.* (2022), Rajput *et al.* (2022) and Kumhar *et al.* (2023) [6, 8, 9, 12, 14].

Table 3: Direct and indirect effects (Genotypic path matrix) of twelve characters on seed yield per plant

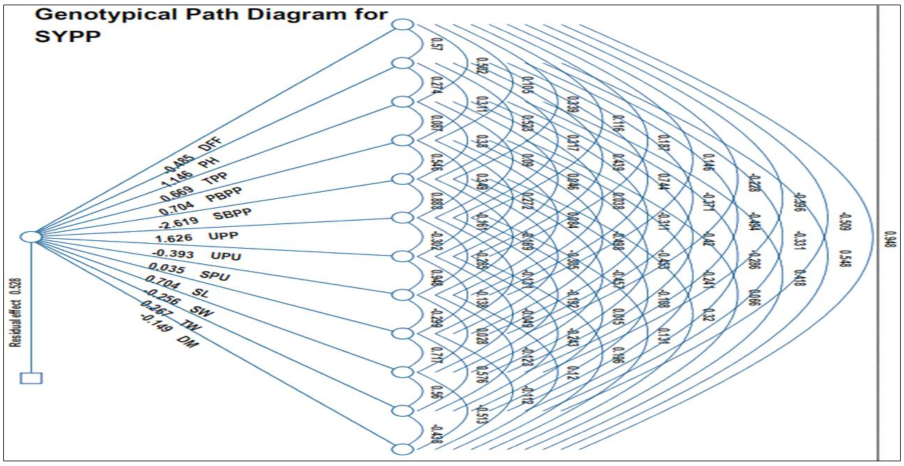
	Days to 50% flowering	**Plant height (cm)**	**Tillers per plant**	**Primary branches per plant**	**Secondary branches per plant**	**Umbels per plant**	**Umbellates per umbel**	**Seeds per umbellate**	**Seed length (mm)**	**Seed width (mm)**	**Test weight (g)**	**Days to maturity**	**Seed yield per plant (g)**
DFF	-0.4846	0.6529	0.3362	0.0738	-0.8878	0.1883	-0.0734	0.0052	-0.1607	0.1524	-0.1360	-0.1416	-0.4753**
PH	-0.2761	1.1461	0.1832	0.2190	-1.3695	0.5148	-0.1724	0.0263	-0.2615	0.1262	-0.0883	-0.0819	-0.0340^{NS}
TPP	-0.2433	0.3135	0.6695	0.0612	-0.9962	0.1458	-0.0181	0.0013	-0.2188	0.1074	-0.0764	-0.0624	-0.3165^{NS}
PBPP	-0.0508	0.3566	0.0582	0.7039	-1.4296	0.5677	-0.1067	0.0030	-0.3506	0.1159	-0.0643	-0.0099	-0.2066^{NS}
SBPP	-0.1643	0.5994	0.2547	0.3843	-2.6187	1.4449	0.0633	-0.0060	-0.2150	0.1169	-0.0288	-0.0478	-0.2170^{NS}
UPP	-0.0561	0.3628	0.0600	0.2457	-2.3266	1.6263	0.1188	-0.0101	-0.0921	0.0490	0.0040	-0.0196	-0.0377^{NS}
UPU	-0.0905	0.5029	0.0308	0.1913	0.4222	-0.4919	-0.3928	0.0335	-0.0970	0.0125	-0.0648	-0.0293	0.0270^{NS}
SPU	-0.0706	0.8526	0.0253	0.0593	0.4421	-0.4636	-0.3724	0.0354	-0.2105	-0.0071	-0.0330	-0.0180	0.2396^{NS}
SL	0.1106	-0.4256	-0.2081	-0.3505	0.7995	-0.2126	0.0541	-0.0106	0.7042	-0.1833	0.1540	0.0167	0.4485 *
SW	0.2888	-0.5656	-0.2812	-0.3190	1.1975	-0.3119	0.0192	0.0010	0.5047	-0.2557	0.1497	0.0766	0.5039 **
TW	0.2468	-0.3788	-0.1916	-0.1696	0.2820	0.0245	0.0953	-0.0044	0.4059	-0.1433	0.2671	0.0654	0.4995 **
DM	-0.4593	0.6286	0.2797	0.0464	-0.8379	0.2131	-0.0770	0.0043	-0.0788	0.1311	-0.1170	-0.1494	-0.4160 *

Residual Effect = 0.2788

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

DFF = Days to 50% flowering; PH = Plant height (cm); TPP = Tillers per plant; PBPP = Primary branches per plant; SBPP = Secondary branches per plant; UPP = Umbels per plant; UPU = Umbellates per umbel; SPU = Seeds per umbellate; SL = Seed length (mm); SW = Seed width (mm); TW = Test weight (g); DM = Days to maturity; SYPP = Seed yield per plant (g)

Some of the traits also exhibited negative direct effect on seed yield per plant *viz*., secondary branches per plant (-2.6187) followed by days to 50 % flowering (-0.4846), umbellates per umbel (-0.3928), seed width (-0.2557) and days to maturity (-0.1494). But these traits are known to have indirect positive influence on seed yield per plant *via* other characters. Similar results were also reported by Jeeterwal *et al.* (2015), Meena and Dhaker (2017), Kumawat *et al.* (2020), Jat and Chaudhary (2022) and Kumhar *et al.* (2023) [6, 8, 9, 10, 12] for days to 50 % flowering, Dashora and Sastry (2011) and Jeeterwal *et al.* (2015) [1, 6] for umbellates per umbel and Prajapati *et al.* (2022) [12] for days to maturity. Whereas, in some cases, correlation coefficient was positive but it has negative direct effect on seed yield per plant which was observed for traits like umbellates per umbel and seed width indicating that the indirect effects was cause of correlation. So, it is preferable to consider other factors simultaneously for further improvement. In this experiment, the residual effect at genotypic level was 0.2788 which suggested that there might be some component traits responsible to influence the seed yield per plant than those considered in this study.



DFF = Days to 50% flowering; PH = Plant height (cm); TPP = Tillers per plant; PBPP = Primary branches per plant; SBPP = Secondary branches per plant; UPP = Umbels per plant; UPU = Umbellates per umbel; SPU = Seeds per umbellate; SL = Seed length (mm); SW = Seed width (mm); TW = Test weight (g); DM = Days to maturity; SYPP = Seed yield per plant (g)

Fig 1: Genotypic path diagram for seed yield imparted by the component characters

Conclusion

Seed yield per plant exhibited significant and positive associations withseed width, test weight and seed length at both genotypic and phenotypic levels. Therefore, due weightage should be given to these traits for yield improvement in fennel breeding. Path coefficient analysis showed that umbels per plant, plant height, seed length, primary branches per plant, tillers per plant, test weight and seeds per umbellate exhibited high and positive direct effects on seed yield per plant. Thus, these traits were considered as the most important seed yield contributors and hence more emphasis should be given to these traits for improving seed yield in fennel.

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