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Character association and path analysis for yield improvement in fennel (*Foeniculum vulgare* Mill.)

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ABSTRACT

*A total of 18 genotypes of the fennel (Foeniculum vulgare Mill.) were evaluated for estimation of correlation and path analysis for yield improvement during Rabi season of 2016-17 at Mandor, Jodhpur, Rajasthan. Results indicated that the variation among genotypes was highest for biological yield (54.3-88.3 q ha^{-1}), followed by seed yield (15.8-25.2 q ha^{-1}). The analysis of genotypic (GC) and phenotypic correlations (PC) indicated that the seed yield per ha was significantly and positively correlated with seed yield per plant (GC r=0.978**; PC r=0.842**), number of seeds per umbel (GC r= 0.752**, PC r=0.505*) and number of umbels per plant (GC r=0.543*). Path coefficient analysis suggested that the highest positive direct effect on seed yield per ha was exerted by biological yield per ha (0.953) followed by the number of umbels per plant (0.484), harvest index (0.463), number of seeds per umbel (0.387), 1000-seed weight (0.289), oil content (0.150), days to maturity (0.102) and the number of umbellets per umbel (0.070). Therefore, it is inferred that for initiating breeding programmes of fennel, the primary emphasis should be given for selecting characters having a positive and higher magnitude of correlation and have direct effects on characters associated with higher yield.*

Keywords: Correlation, fennel, genotypes, genetic variability, path analysis

INTRODUCTION

India is a major seed spices producer in the world therefore, it is known as the "Home of Spices". The major seed spices growing areas in India are in semi-arid to arid areas of Gujarat and Rajasthan, contributing more than 80% of total seed spices produced in the country (Chander Mohan *et al.*, 2017). Fennel (*Foeniculum vulgare* Mill., 2n =22) is an important seed spice crop. It is a cross-pollinated crop that belongs to the family Apiaceae. In India, it is mainly grown in Gujarat and Rajasthan as a cold-weather crop. In Rajasthan, fennel is mainly cultivated in the districts of the Southwestern parts. Though the crop is a potential cash crop in Rajasthan, little work has been done on its genetic improvement. A systemic breeding programme requires collection, evaluation, and characterization of the available germplasm to gather basic information about the existence of genetic variability in a particular crop. Genetic variation is helpful in the selection of suitable genotype and breeding programme (Kumawat *et al.*, 2020). As yield is governed by the genetic makeup of genotype and is also affected by the environment. Therefore, indirect selection through component traits will effectively improve the genetic improvement of quantitative traits. Moreover, to determine the nature of the relationships between yield and yield components, path coefficient analysis has also been widely used in plant breeding programs for partitioning the correlation coefficients into their direct and indirect effects (Wright *et al.*, 1921; Dewey and Lu, 1959). Thus, the path coefficient analysis is useful and effective in selecting the simultaneous improvement of the component characters that contribute to yield. Therefore, the present investigation was carried out to estimate the interrelationship at genotypic and phenotypic levels for yield and its contributing traits for developing selection criteria for improving seed yield using path coefficient analysis in fennel genotypes.

MATERIALS AND METHODS

A total of 18 fennel genotypes viz., RF-101,RF-125,RF-143,RF-145, RF-157, RF-178, RF-205, AF-01, AF-02, GF-02, GF-11, GF-12, Hisar Swaroop, Pant Madhurika, Azad Saunf-1, Co-01, Rajendra Saurabh and Sirohi Selection were grown in randomized complete block design with three replications during *Rabi* season of 2016-17 at College of Agriculture, Mandor, Jodhpur. Each genotype was

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planted in an experimental plot size of (4m×3m) with 45 cm x 30 cm row to plant spacing. All the genotpyes were sown on the same date on 4th November 2016, and harvested with the commencement of harvest maturity. The crop was fertilized with 90 kg N and 40 kg P_2O_5 ha^{-1} through urea and diammonium phosphate. One-third of recommended N (30 kg ha^{-1}) and a full dose of P_2O_5 were applied as basal dose, and the remaining 60 kg of N was applied in two equal splits at 30 and 60 DAS along with irrigation. The recommended package of practices was adopted to raise a healthy crop. The crop was irrigated at 12-15 days intervals to maintain optimum moisture. For observations, 10 competitive plants were marked in each plot. Observations were recorded on plant height, dry matter accumulation at maturity, number of effective branches/plant, days to 50% flowering, days to maturity, number of umbels/plant, number of umbellets per umbel, number of seeds per umbel, test weight, seed yield per plant, seed yield per ha, biological yield per ha), harvest index. Essential oil content was determined as per Negahban *et al.* (2015). The data obtained on various characters were subjected to statistical analysis, and phenotypic and genotypic correlation coefficients were computed between pairs of characters, including seed yield per plant as described by Singh and Choudhary (1979). The direct and indirect effects were calculated according to the path analysis suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

RESULTS AND DISCUSSION

The results revealed that the fennel genotypes differed significantly for all the growth parameters, yield attributes, seed yield and essential oil content. This indicated the presence of an adequate amount of variability, which can be helpful in the selection of suitable genotypes. The mean performance of the genotypes showed a wide range of variability for all the parameters studied. The variation was highest for biological yield (54.3-88.3 q ha^{-1} followed by seed yield (15.8-25.2 q ha^{-1}) and the number of seeds per umbel (248-325). This may be due to the existence of diversity in genotypes evaluated. The ranges and coefficient of variations were higher for oil content, dry matter accumulation at maturity, and harvest index. A similar finding was also reported by Jeeterwal *et al.* (2015) and Kumar *et al.* (2017). Genotypic correlation (GC) and phenotypic correlation (PC) among different characters (Table 1) revealed that the seed yield ha^{-1} was significantly and positively correlated with seed yield/plant (GC r=0.978**; PC r=0.842**), number of seeds/ umbel (GC r=0.752**, PC r=0.505*) and number of umbels/plant (GC r=0.543*); whereas association with days to 50% flowering was significantly negative (GC r= -0.554*) while its association with plant height at maturity (GC r= -155; PC r=-0.255) and days to maturity (GC r=-0.341; PC r=-0.060) was negative and non-significant. Correlation coefficients revealed that seed yield per plant had a significant positive correlation with the number of umbels per plant (GC r=0.527*), number of seeds per umbel (GC r= 0.749**) while it had a positive and non-significant correlation with the number of effective branches per plant (GC r=0.331; PC r=0.289). The positive correlation of seed yield per plant was in agreement with earlier reports of Yadav *et al.* (2013), Jeeterwal *et al.* (2015), and Kumar *et al.* (2017).

Seed yield per plant had a highly significant positive correlation with seed yield per ha at both at genotypic (r=0.978**) and phenotypic levels (r=0.842**) and the number of seeds per umbel at genotypic level (r=0.749**). This character also had a significant positive association with the number of umbels per plant (PC r=0.527*). Further, this character exhibited a significantly negative correlation with days to 50% flowering (PC r=-0.496*). Seed yield per ha was correlated significantly and positively with the number of seeds per umbel at the genotypic level (r= 0.752**) and seed yield per plant at both levels (GC r=0.978**; PC r=0.842**). Further, this character also exhibited a significant negative correlation with days to 50% flowering at the genotypic level (r=-0.554*). Similar findings were also reported by Dashora and Sastry (2011). Path coefficient analysis was included in the present investigation to obtain information on different morphological characters direct and indirect effects on seed yield. Since the results of path coefficient analysis based on genotypic correlation were not much different from those obtained from phenotypic correlation, only the results based on phenotypic correlation coefficient are discussed here (Table 2). Path analysis revealed that the direct effects are stronger than indirect effects, and the changes between the genotypic and phenotypic path coefficients were seldom noted (Table 2). Path coefficient analysis suggested that the highest positive direct effect on seed yield ha^{-1} was exerted by biological yield ha^{-1} (0.953) followed by the number of umbels/plant (0.484), harvest index (0.463), the number of seeds/umbel

Table 1: Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients among different characters in fennel

Characters	Plant height at maturity	Dry matter accumulation	Effective branches/ plant	Days to 50% flowering	Days to maturity	Umbels /plant	Umbellets /umbel	Seeds/ umbel	Test weight	Seed yield/ plant	Seed yield /ha	Biological yield/ha	Harvest index (%)	Oil content (%)
Plant height at maturity	**1.000**	0.718**	0.123	0.224	0.338	-0.127	0.078	-0.156	-0.124	-0.199	-0.155	0.670**	-0.722**	0.007
Dry matter accumulation	0.973**	**1.000**	0.502*	0.293	0.410	0.284	-0.015	-0.083	-0.366	0.013	0.062	0.902**	-0.816**	0.107
Effective branches/plant	0.206	0.568*	**1.000**	-0.013	0.079	0.703**	-0.067	-0.051	-0.368	0.289	0.357	0.469*	-0.231	0.153
Days to 50%flowering	0.892**	0.616**	-0.097	**1.000**	0.512*	-0.089	0.042	-0.180	0.015	-0.292	-0.273	0.208	-0.344	-0.114
Days to maturity	0.907**	0.735**	0.139	0.995**	**1.000**	0.004	0.044	-0.210	0.002	-0.206	-0.060	0.393	-0.366	-0.259
Umbels/plant	-0.028	0.391	0.954**	-0.365	-0.019	**1.000**	-0.108	-0.003	-0.324	0.418	0.449	0.307	-0.042	0.145
Umbellets/umbel	0.286	-0.055	-0.132	0.356	0.162	-0.367	**1.000**	-0.190	0.333	0.081	0.036	-0.083	0.068	0.133
Seeds/umbel	-0.233	-0.078	-0.021	-0.679**	-0.423	0.019	-0.307	**1.000**	0.067	0.464	0.505*	0.021	0.258	0.119
1000-seed weight	-0.230	-0.415	-0.507*	-0.020	-0.089	-0.526*	0.684**	0.111	**1.000**	0.300	0.325	-0.247	0.436	0.244
Seed yield/plant	-0.265	0.004	0.331	-0.496*	-0.142	0.527*	0.045	.749**	0.442	**1.000**	0.842**	0.141	0.328	0.379
Seed yield/ha	-0.255	0.040	0.387	-0.554*	-0.341	0.543*	0.028	0.752**	0.332	0.978**	**1.000**	0.163	0.395	0.454
Biological yield/ha	0.951**	0.945**	0.647**	0.601**	0.719**	0.457	0.015	0.018	-0.362	0.156	0.209	**1.000**	-0.829**	0.142
Harvest index	-0.968**	-0.962**	-0.390	-0.837**	-0.854**	-0.160	0.005	0.391	0.537*	0.435	0.337	-0.847**	**1.000**	0.086
Oil content	-0.016	0.099	0.197	-0.290	-0.376	0.173	0.238	0.122	0.275	0.443	0.494*	0.159	0.087	**1.000**

*, **; *$p < 0.05$ and 0.01, respectively*

Table 2: Path coefficient analysis for different characters in fennel

Characters	Plant height (cm)	Dry matter accumulation (g/plant)	No. of effective branches	Days to 50% flowering	Days to maturity	No. of umbels /plant	No. of umbellets /umbel	No. of seeds /umbel	1000-seed weight (g)	Biological yield/ha. (kg)	Harvest index (%)	Oil content (%)
Plant height (cm)	**-0.057**[a]	-0.049	-0.010	-0.029	-0.034	0.004	-0.010	0.011	0.011	-0.047	0.052	0.001
Dry matter accumulation (g/plant)	-0.364	**-0.423**	-0.230	-0.181	-0.240	-0.145	0.016	0.034	0.168	-0.418	0.384	-0.043
No. of effective branches	-0.014	-0.046	**-0.085**	0.004	-0.009	-0.071	0.009	0.003	0.038	-0.049	0.028	-0.016
Days to 50% flowering	-0.052	-0.044	0.005	**-0.104**	-0.086	0.021	-0.017	0.041	0.001	-0.039	0.057	0.020
Days to maturity	0.061	0.058	0.011	0.084	**0.102**	-0.001	0.010	-0.032	-0.004	0.056	-0.061	-0.032
No. of umbel /plant	-0.036	0.166	0.407	-0.097	-0.003	**0.484**	-0.113	0.004	-0.210	0.189	-0.053	0.078
No. of umbellets /umbel	0.013	-0.003	-0.007	0.012	0.007	-0.017	**0.070**	-0.018	0.036	-0.002	0.002	0.013
No. of seeds /umbel	-0.077	-0.031	-0.013	-0.152	-0.120	0.003	-0.096	**0.387**	0.035	0.008	0.130	0.047
1000-seed weight (g)	-0.054	-0.115	-0.131	-0.001	-0.012	-0.125	0.149	0.026	**0.289**	-0.092	0.144	0.076
Biological yield/ha (kg)	0.789	0.941	0.552	0.360	0.524	0.372	-0.029	0.019	-0.304	**0.953**	-0.801	0.146
Harvest index (%)	-0.418	-0.421	-0.152	-0.256	-0.280	-0.051	0.016	0.156	0.231	-0.390	**0.463**	0.041
Oil content (%)	-0.001	0.015	0.027	-0.029	-0.047	0.024	0.028	0.018	0.040	0.023	0.013	**0.150**
Seed yield/ ha (kg)	-0.211	0.048	0.375	-0.388	-0.200	0.499	0.032	0.650	0.331	0.192	0.359	0.482
Partial R^2	0.012	-0.020	-0.032	0.040	-0.020	0.241	0.002	0.252	0.096	0.183	0.167	0.072

R SQUARE = 0.992 RESIDUAL EFFECT = 0.087, Bold faced figures indicates direct effect

(0.387), 1000-seed weight (0.289), oil content (0.150), days to maturity (0.102) and the number of umbellets/umbel (0.070). The magnitude of the correlation coefficient between a causal factor and the effect is almost equal to its direct effect. Hence, the correlations explained the true interrelationship and suggested that a direct selection of these parameters would be effective. Similar findings were reported by Meena *et al.* (2009), Sefidan (2014), and Jeeterwal *et al.* (2015), whereas Cosge *et al.* (2009) reported the positive and highest direct effect of test weight on seed yield in fennel. On the other hand, the direct effect of plant height, dry matter accumulation, number of effective branches, and days to 50% flowering was negative with seed yield. These results agree with earlier reports of Meena *et al.* (2009) and Jeeterwal *et al.* (2015).

It is inferred from the present investigation that for initiating breeding programmes of fennel, the primary emphasis should be given for selection of characters like the number of umbels per plant followed by harvest index, the number of seeds per umbel, 1000-seed weight, days to maturity, and the number of umbellets per umbel as these characters had a positive correlation with seed yield with high direct effect.

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