Journal of AgriSearch **4**(4):231-236
An Open Access International Peer Reviewed Quarterly
ISSN : 2348-8808 (Print), 2348-8867 (Online)
http://dx.doi.org/10.21921/jas.v4i04.10199

Genetic variability, correlation and path analysis in Fennel (*Foeniculum vulgare* Mill.) genotypes

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ARTICLE INFO

Received on	:	30.10.2017
Accepted on	:	25.11.2017
Published online	:	30.11.2017

ABSTRACT

To know the extent and pattern of genetic variability exist in fennel (*Foeniculum vulgare* Mill.), a study were undertaken for at ICAR-National Research Centre on Seed Spices, Ajmer (Rajasthan) India. Analysis of variance was worked out and it was recorded that most of trait understudy were found significant whereas test weight (g), seed yield per plot (kg) and essential oil were found non-significant. Results revealed that maximum PCV along with GCV were found for number of umbels per plant (24.65), seed yield per plot (21.74) and number of secondary branches (20.93). Very high heritability was observed for seed yield per plot (96.1) and number of umbels per plant (94.9). Likewise genetic advance was recorded highest for number of umbels per plant (24.25) and seed yield per plot (0.53). Seed yield was significantly and positively correlated with number of umbellets per umbel (0.329*), test weight (0.371*) and essential oil (0.371*) at genotypic and phenotypic level. Path coefficient analysis exhibit that number of umbels per plant (7.09) had highest positive direct effect on funnel seed yield.

Keywords: Variability, heritability, genetic advance, correlation, path, fennel

INTRODUCTION

Fennel (*Foeniculum vulgare* Mill.) belongs to family Apiaceae and cross-pollinated crop. It is a diploid species having chromosome number 2x= 22 its centre of origin in Europe and Mediterranean region (Agarwal *et al.,* 2001). Fennel is cultivated throughout the temperate and subtropical region in the world mainly in the countries like Romania, Russia, Hungary, Germany, France, Italy, India, Malaysia, and the USA. In India, it is mainly grown in the states of Gujarat and Rajasthan in a cold weather crop in our country in semi-arid and arid crop but it can be cultivated and to some extent in U.P., Karnataka, A.P., Punjab, M.P., Bihar, Haryana and J & K. Total area under the crop in India is about 46,760 ha with production of 78,570 tonnes (Anonymous,2015). In Rajasthan, fennel occupies an area of 27587 ha with an annual production of 30717 q (Anonymous, 2015). 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. The importance of fennel based on its medicinal value and export potential as spices was recognized long back but it remained neglected for a long time from scientific attention for its improvement in its productivity as well as its quality (Choudhary *et al.,* 2017). The success of any breeding methodology for improving morphological characters depends primarily on the existence of high magnitude of genetic variability and its efficient utilization. If not present, then its creation and management become essential to crop breeding Chopra (1989). Equally, information regarding genetic architecture of a population, especially on the nature and magnitude of the gene action, is of vital use to a plant breeder.

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MATERIALS AND METHODS

Nineteen genotypes of fennel (*Foeniculum vulgare* Mill*)* were evaluated in Randomized Block Design (RBD) with three replications during *Rabi* season of 2015-16 and 2016-17 at the research farm of ICAR-National Research Centre on Seed Spices, Tabiji, Ajmer (Rajasthan). Each genotype was grown in a plot and row to row distance was 50 cm and plant to plant distance was maintained 25 cm. The observation was recorded on five randomly selected plants for thirteen characters *viz*., days to germination, king umbel anthesis, days to 50% flowering, king umbel diameter, plant height, number of primary branches, number of secondary branches, number of umbels per plant, number of umbel lets per umbel, number of seeds per umbellet, test weight, seed yield per plot and essential oil.

The values were estimated for variation among the germplasm and checks, analysis of variance was carried out as per the procedure suggested by Panda and Sukhatme (1963). Heritability in abroad sense was calculated by the formula given by Hanson *et al.* (1956) and the genetic advance (GA) was calculated by the following formula as suggested by Johnson *et al.* (1955).

RESULTS AND DISCUSSION

Growth and Development

The analysis of variances for all the characters studied has been presented in Table 1. Mean sum of squares among treatment was found significant for the characters *viz*., days to germination, king umbel anthesis, days to 50% flowering, king umbel diameter, plant height, number of primary branches, number of secondary branches, number of umbels per plant, number of umbellets per umbel and number of seeds per umbellet. It was found non- significant for the characters *viz*., test weight, seed yield per plot and essential

oil. Similar results are also reported by Lal (2007), Chandra *et al.* (2008).The average seed yield per plot was 1.21kg and the ranged was observed to be 0.70 to 1.64. The average plant height was found to be 151.97 cm, whereas plant height ranged from 135.66 to 168.00 cm and the average number of umbels per plant was found to be 50.33 and the ranged was observed to be 32.33 to81.00. In all the other traits the average performance and range of variation were also high. The estimates of the phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) for all the characters indicating the effect of the environment on the expression of the characters. The estimate of PCV and GCV indicated the existence of afairly high degree of variability for a number of umbels per plant (PCV: 24.65 and GCV: 24.01) and seed yield (PCV: 22.17 and GCV: 21.74). High magnitude of PCV and GCV was also reported for seed yield by Dashora and Sastry (2011) and moderate for number of secondary branches per plant (PCV:20.93 and GCV:18.79) ,number of umbellets per umbel (PCV:16.52 and GCV:12.91), days to germination (PCV:13.89 and GCV:11.76), number of primary branches (PCV:12.01 and GCV:10.57), king umbel diameter (PCV:10.82 and GCV:7.94), number of seeds per umbellet (PCV:9.93 and GCV 6.69),essential oil (PCV: 8.81 and GCV: 4.53) and days to 50% flowering (PCV: 7.62 and GCV: 6.75), suggesting that these characters were least affected by environment selection should be done these characters. These observations draw support from the high value of heritability recorded for these characters. The findings are in close harmony with the result of Lal (2007), Meena *et al.* (2010), Dashora and Sastry (2011) and Kumar *et al.* (2017). Low variance values were recorded for king umbel anthesis (PCV: 4.39 and GCV: 3.55), test weight (PCV: 5.73 and GCV: 2.78) and plant height (PCV: 7.61 and GCV: 6.48). The findings are in close harmony with the result of Agnihotri *et al.* (1997) and Kumar *et al.* (2017). High heritability in abroad sense is helpful in identifying appropriate character for selection and enables the breeder to select superior genotypes on the basis of phenotypic expression of quantitative characters.

Table 1: Analysis of variance for different characters in fennel genotypes (mean sum of squares)

Source of variation	D.F.	Days to germination	King umbel anthesis	Days to 50% flowering	King umbel diameter (cm)	Plant height (cm)	Number of primary branches	Number of secondary branches	Number of umbels per plant	Number of umbellets per umbel	Number of Seeds per umbellet	Test weight (g)	Seed yield Per plot (kg)	Essential oil %
Replication	2	0.017	2.22	13.38	7.45	288.66	0.76	16.43	19.45	3.60	57.16	0.15	0.001	0.092
Treatments	18	3.017**	2.87**	110.93**	5.82**	328.23**	2.57**	78.81**	446.04**	32.25**	12.51**	0.24	0.212	0.048
Error	36	0.35	0.43	9.27	1.29	36.53	0.22	5.83	7.87	5.64	3.57	0.12	0.002	0.023

** *Significant at p =0.01* * Significant at p =0.05

Coefficient of Variations, Heritability Study and Genetic Advance

The estimated values of heritability in abroad sense were classified as very high (above 90%), high (75-90%), medium (50-75%) and low (less than 50%). Analysis of heritability in abroad sense was high heritability for seed yield per plot (96.1%) and number of umbels per plant (94.9%). High heritability recorded for number of secondary branches per plant (80.7 %), days to 50 % flowering (78.5%) followed by number of primary branches per plant (77.4 %). If heritability of a character is high (> 75%), selection for such a character should be fairly easy.Similar result was found in the findings of Lal (2007), Dashora and Sastry (2011) and Kumar *et al.* (2017). Medium heritability recorded for plant height (72.7%), days to germination (71.7%), king umbel anthesis (65.3%), number of umbellets per umbel (61.1%) and king umbel diameter (53.9%). Similar findings also reported by Ali *et al.* (1993) in coriander. Low heritability recorded for number of seed per umbellet (45.4%), essential oil (26.4%) and test weight (23.7%). This is indicative of the fact that characters are rather more influenced by the environment and may not respond much to selection (Table 2). Genetic advance as percentage of mean ranged between (2.79 %) for test weight to (48.18 %) number of umbels per plant. The highest estimate of genetic advance as percentage of mean was recorded for number of umbels per plant (48.18%) and seed yield per plot (43.90%). Similar result was found in the findings of Ali *et al.* (1993), Meena *et al.* (2010) and Dashora and Sastry (2011). Whereas, number of secondary branches per plant (34.76%), number of umbellets per umbel (20.80%), days to germination (20.51%) and number of primary branches per plant (19.16%), showed the moderate value of genetic advance as percentage of mean in my studied. Whereas, low estimates were observed for test weight (02.79%), essential oil (4.79%), king umbel anthesis (5.51%), number of seeds per umbellet (9.29%), days to 50% flowering (12.31%), king umbel diameter (12.01%) and plant height (11.39). The results were in close proximate to that of Jain *et al.* (2002) for days to 50% flowering.

Table 2: Genotypic and phenotypic coefficient of variation heritability and genetic advance in fennel

Characters	Grand Mean	Range		Coefficient of Variations		Heritability % (BS)	Genetic Advance (5%)	GA as % of Mean (5%)
		Min.	Max.	Phenotypic	Genotypic			
Days to germination	8.01	6.33	10.0	13.89	11.76	71.7	1.65	20.51
King umbel anthesis	25.40	23.66	27.66	4.39	3.55	65.3	1.50	5.91
Days to 50% flowering	86.28	75.66	99.00	7.62	6.75	78.5	10.63	12.31
King umbel diameter (cm)	15.46	12.40	18.93	10.82	7.94	53.9	1.86	12.01
Plant height (cm)	151.97	135.66	168.00	7.61	6.48	72.7	17.32	11.39
Number of primary branches	8.35	6.19	9.56	12.01	10.57	77.4	1.60	19.16
Number of secondary branches	26.24	12.13	34.00	20.93	18.79	80.7	9.12	34.76
Number of umbels per plant	50.33	32.33	81.00	24.65	24.01	94.9	24.25	48.18
Number of umbellets per umbel	23.05	18.00	31.67	16.52	12.91	61.1	4.79	20.80
Number of Seeds per umbellet	25.79	22.33	30.73	9.93	6.69	45.4	2.39	9.29
Test weight (g)	7.08	6.46	7.50	5.73	2.78	23.7	0.19	2.79
Seed yield per plot (kg)	1.21	0.70	1.64	22.17	21.74	96.1	0.53	43.90
Essential oil %	2.02	1.77	2.222	8.81	4.53	26.4	0.09	4.79

Phenotypic and genotypic correlation

The phenotypic and genotypic correlation between the yield and its yield attributing characters in fennel are given in (Table 3). In the present investigation character association at genotypic and phenotypic level for days to 50% flowering had highly significant and positive correlated with king umbel diameter, plant height (cm), number of primary branches, number of secondary branches, number of umbels per plant, number of umbellate per umbel and number of seeds per umbellet. Character association at agenotypic and phenotypic level for the diameter of king umbel was highly significant positive correlated with plant height, number of umbels per plant, number of umbellate per umbel and number of seeds per umbellet and had significant negative correlated with test weight. Character association at agenotypic and phenotypic level for plant height had significant positive correlation with number of primary branches, number of secondary branches, number of umbels per plant, number of umbellate per umbel and number of seeds per umbellet. Character association at agenotypic and phenotypic level for number of primary branches was highly significant and positive correlated with number of secondary branches and test weight and secondary branches highly significant and positive correlated with test weight and essential oil.

Character association at genotypic and phenotypic level for number of umbels per plant highly significant and positive correlated with number of seeds per umbellet and it had significant and negative correlated with essential oil (-0.559 and -0.377). Character association at genotypic and phenotypic level for number of umbellets per umbel significant and positive correlated with number of seeds per umbellet, essential oil and seed yield per plot. Character association at genotypicand phenotypic level for number of seeds per umbellet significant and negative correlated with test weight (-0.536 and -0.354). Character association at genotypicand phenotypic level for test weight significant and positive correlated with seed yield per plot (kg). Character association at genotypic and phenotypic level for essential oil had found significant positive correlated with seed yield per plot (0.371 and 0.267). If the value of genotypic correlation coefficient is higher than phenotypic correlation coefficient, it means that there is strong association between these two characters genetically, but the phenotypic value is lessened by the significant interaction of environment. Similar results were found in the findings of Agnihotri *et al*. (1997), Lal (2007), Meena *et al*. (2010), Dashora and Sastry (2011), Ali *et al*. (1993) and Yogi *et al*. (2013).

Path coefficient analysis

In the present investigation path coefficient analysis was carried out for the character under study using genotypic and phenotypic correlation coefficient and taking seed yield per plant as the dependent variable, in order to see the casual factor and so as to identify the components which are responsible for producing seed yield per plant (Table 4). In general, the genotypic direct, as well as indirect effects, were slightly higher in magnitude as compared to corresponding phenotypic direct and direct effects indicating that the masking effects of the environment.

Path coefficient analysis of different characters contributing towards seed yield per plant showed that number of umbels per plant had highest positive direct effect followed by king

Table 3: Phenotypic and genotypic correlation coefficient between different characters in fennel

Characters	Level	King umbl eanth esis	Days to 50% flow ering	King umbel diameter (cm)	Plant height (cm)	Number of primary branches	Number of secondary branches	Number of umbels per plant	Number of umbel lets per umbel	Number of seeds per umbel let	Test weight (gm)	Essential oil (%)	Seed yield per plot (kg)
Days to germination	P	-0.247	-0.093	-0.149**	-0.195	-0.041	0.127	-0.151	0.066	-0.096	0.211	0.447***	-0.019
	G	-0.277*	-0.107	-0.533***	-0.221	-0.053	0.142	-0.146	0.069	-0.128	0.172	0.646***	-0.025
King umbleanth esis	P		0.172	0.197	0.059	0.237	0.241	-0.250	-0.252	0.004	-0.077	0.263*	0.180
	G		0.189	-0.232	0.053	0.271*	0.257	-0.288*	-0.325*	-0.011	-0.091	0.478***	0.202
Days to 50 % flowering	P			0.488***	0.738***	0.403**	0.426***	0.508***	0.351**	0.466***	-0.085	0.080	-0.236
	G			0.583***	0.824***	0.447***	0.458***	0.534***	0.445***	0.569***	-0.134	0.147	-0.249
King umbel diameter (cm)	P				0.459***	0.021	0.111	0.407**	0.634***	0.424**	-0.272*	-0.009	0.177
	G				0.519***	0.021	0.112	0.460***	0.754***	0.569***	-0.650***	-0.002	0.194
Plant height (cm)	P					0.427***	0.462***	0.414**	0.515***	0.418**	-0.050	0.067	-0.178
	G					0.458***	0.495***	0.446***	0.565***	0.469***	-0.019	0.122	-0.182
Number of primary branches	P						0.646***	0.335*	-0.024	-0.172	0.509***	0.013	-0.185
	G						0.697***	0.349*	-0.050	-0.235	0.810***	0.039	-0.210
Number of secondary branches	P							0.134	0.146	-0.057	0.434***	0.237	0.133
	G							0.146	0.155	-0.040	0.659***	0.397**	0.132
Number of umbels per plant	P								0.187	0.542***	0.119	-0.377**	-0.003
	G								0.207	0.639***	0.179	-0.559***	-0.002
Number of umbellets per umbel	P									0.378**	-0.107	0.238	0.299*
	G									0.413**	-0.197	0.372**	0.329*
Number of seeds per umbellet	P										-0.354**	-0.107	0.002
	G										-0.536***	0.009	0.008
Test weight (g)	P											0.020	0.239
	G											-0.144	0.371**
Essential oil (%)	P												0.267*
	G												0.371**

*** *Significant at p =0.001* ** *Significant at p =0.01* * Significant at p =0

umbel anthesis, plant height, days to germination, number of umbellets per umbel and number of secondary branches per plant. Correlation coefficient values at par with seed yield per plot and direct selection for these traits would be rewarding in higher breeding efficiency for improving yield. Thus these traits might be reckoned as the most important component traits of seed yield. The results are in propinquity with Bhandari and Gupta (1997), Vijayalatha and Chezhiyan (2004), and Patel and Patel (2015).

Whereas, number of seeds per umbellet had the highest negative direct effect on seed yield per plot followed by anumber of primary branches per plant, test weight, days to 50% flowering, essential oil and king umbel diameter. The positive indirect effect on seed yield per plot was observed for king umbel diameter, days to 50% flowering, number of primary branches per plant, number of umbellets per umbel, test weight, essential oil and number of seeds per umbellet. This independent character are depended on seed yield. If the correlation is mainly due to indirect effects of the character through another component trait, indirect selection through such trait will be effective in yield improvement. The result is in preponderating with Bhandari and Gupta (1997).Path coefficient analysis revealed that number of umbellets per umbel, test weight, number of umbels per plant, number of

Table 4: Path coefficients showing direct and indirect effects of different characters on seed yield in fennel

Characters	Level	Days to germination	King umblean thesis	Days to 50% flowering	King umbel diameter (cm)	Plant height (cm)	Number of primary branches	Number of secondary branches	Number of umbels per plant	Number of umbellets per umbel	Number of seeds per umbellet	Test - weight (g)	Essential oil (%)	Seed yield per plot (kg)
Days to germination	P	**0.064**	-0.015	-0.006	-0.027	-0.012	-0.003	0.008	-0.009	0.004	-0.006	0.013	0.028	-0.019
	G	**6.603**	-2.386	-0.924	-4.588	-1.901	-0.463	1.224	-1.254	0.601	-1.098	1.477	5.555	-0.025
King umbleanthesis	P	-1.199	**0.372**	0.139	-0.159	0.048	0.191	0.195	-0.202	-0.204	0.003	-0.063	0.213	0.180
	G	-5.501	**7.032**	3.752	-4.593	1.054	5.366	5.098	-5.721	-6.446	-0.228	-1.812	6.489	0.202
Days to 50% flowering	P	0.059	-0.109	**-0.638**	-0.311	-0.471	-0.257	-0.272	-0.324	-0.224	-0.297	0.054	-0.051	-0.236
	G	0.684	-1.204	**-6.368**	-3.715	-5.247	-2.843	-2.915	-3.397	-2.834	-3.620	0.853	-0.936	-0.249
King umbel diameter (cm)	P	-0.147	-0.069	0.171	**0.350**	0.161	0.007	0.039	0.142	0.222	0.148	-0.095	-0.003	0.177
	G	0.088	0.038	-0.097	**-0.166**	-0.086	-0.003	-0.018	-0.076	-0.125	-0.094	0.107	0.000	0.194
Plant height (cm)	P	0.025	0.007	-0.094	-0.059	**-0.128**	-0.055	-0.059	-0.053	-0.066	-0.053	0.006	-0.008	-0.178
	G	-1.515	0.365	5.650	3.562	**6.857**	3.140	3.397	3.057	3.872	3.222	-0.625	0.839	-0.182
Number of primary branches	P	0.033	-0.190	-0.324	-0.017	-0.343	**-0.804**	-0.519	-0.269	0.019	0.138	-0.409	-0.010	-0.185
	G	1.149	-5.778	-9.538	-0.464	-9.784	**-21.362**	-14.905	-7.472	1.071	5.015	-17.313	6.038	-0.210
Number of secondary branches	P	0.041	0.078	0.139	0.036	0.150	0.210	**0.325**	0.044	0.048	-0.018	0.141	0.077	0.133
	G	1.304	2.355	4.194	1.027	4.539	6.393	**5.162**	1.339	1.416	-0.375	6.038	-0.838	0.132
Number of umbels per plant	P	-0.117	-0.192	0.392	0.314	0.319	0.258	0.104	**0.370**	0.144	0.418	0.092	-0.291	-0.003
	G	-4.240	-8.390	7.221	7.406	6.970	6.177	4.251	**7.093**	6.020	7.616	5.229	3.632	-0.002
Number of umbellets per umbel	P	0.033	-0.125	0.175	0.317	0.257	-0.012	0.073	0.093	**0.366**	0.188	-0.053	0.119	0.299*
	G	0.663	-3.037	4.227	7.165	5.364	-0.479	1.469	1.997	**5.501**	3.927	1.875	-16.278	0.329*
Number of seeds per umbellet	P	0.034	-0.001	-0.165	-0.149	-0.147	0.061	0.020	-0.191	-0.133	**-0.353**	0.125	0.038	0.002
	G	3.816	0.344	-16.994	-17.019	-14.046	7.017	1.224	-19.126	-12.351	**-29.891**	7.350	3.510	0.008
Test weight (g)	P	0.089	-0.032	-0.036	-0.115	-0.021	0.216	0.184	0.051	-0.045	-0.150	**0.350**	0.008	0.239
	G	-1.469	0.781	1.147	5.566	0.780	-6.935	-5.639	-1.538	1.689	4.588	**-8.558**	-0.278	0.371**
Essential oil (%)	P	0.065	0.038	0.012	-0.001	0.009	0.001	0.035	-0.056	0.035	-0.158	0.003	**0.147**	0.267*

seeds per umbellet are the most important characters contributing towards yields and hence purposeful balanced selection based on these traits, would be more rewarding for improvement of fennel.

CONCLUSION

It is concluded that very good amount of variability exists in 19 genotypes of fennel (*Foeniculum vulgare* Mill.) which was reflected in the genetic variability study, correlation and path coefficient analysis. The genotypic and phenotypic study revealed that the seed yield was significantly and positively correlated with number of umbellets per umbel. Heritability was found very high for seed yield. Path coefficient analysis suggests that seed yield was positively and directly affected by plant height, number of umbellets per umbel and number of secondary branches per plant.

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Citation:

Meena RS and DhakarL. 2017. Genetic variability, correlation and path analysis in fennel (*Foeniculum vulgare* Mill.) genotypes. *Journal of AgriSearch* **4** (4): 231-236