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Path analysis of grain yield, some morphological traits and essential oil content in different fennel (*Foeniculum vulgare* Mill.) populations

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Abstract

In order to study of the cause and effect relationship among some morphological and agronomic traits of 19 populations of fennel (*Foeniculum vulgare* Mill.), an experiment was conducted based on randomized complete block design with 3 replications in 2012 at the Research Station of Faculty of Agriculture, University of Tabriz, Iran. Correlation coefficients showed that grain yield had a positive correlation with number of umbel, number of seed per umbel, harvest index, essential oil content and length of first internode. Path analysis using stepwise regression indicated that number of umbel had the most direct and positive effect on grain yield. Therefore, these traits could be used as effective factors to increase grain yield in fennel breeding programs. The studied populations were classified in to two groups with distinct differences for grain yield and the traits which were confirmed to be related to grain yield.

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Introduction

Fennel (*Foeniculum vulgar* Mill.) is one of the most important medicinal plant which belongs to family umbelliferae (Apiaceae) as an annual, biennial or perennials species (Omidbaigi, 2000). Fennel is native of southern Europe and the Mediterranean region and it has wild growing in France, Spain, Portugal, and North Africa and nowadays fennel is cultivated widly in most parts of the world such as India, Japan, China, Brazil, Argentina and Turkey. (Omidbaigi, 2009, Amir-Timuri *et al.* 2012). Trans-anethole, estragole, fenchone and limonene are the major constituents of the essential oil of fennel fruits (Bernath *et al.* 1996, Venskutonis *et al.* 1996). Fennel has a variety of secondary metabolites which is used in treatment of cancer, digestive irregularities, respiratory, skin ulcers (Lucinewton *et al.* 2005, Khazaei *et al.* 2006, Ebeed *et al.* 2010). Recent studies have shown that essential oil of fennel has valuable antioxidant, antidiabetic, antibacterial and antifungal properties (Lucinewton *et al.* 2005, El-Soud *et al.* 2011). In the case of medicinal plants cultivated in Iran, the main causes of low yield are low genetic diversity, lack of appropriate genotypes, dysfunctional system of planting, low harvest index and susceptibility to the disease. (Rahimmalik *et al.* 2009). Kirici *et al.* (2010) studied agronomic traits and essential oil content of four wild fennel populations from Turkey. Their results showed extremely high genetic diversity among all traits except plant height and number of branches per umbels. Bernath*et al.* (1996) evaluated the morphological and physiological traits in the 34 populations of fennel and the results indicated a wide diversity with respect to grain yield and essential oil content.

The objective of this study was to find out the relationship of yield and essential oil with some morphological traits in fennel populations and to partition the observed correlations into their direct and indirect effects. Grouping of fennel populations in terms of grain yield and its related traits was the other aim of this study. These information can be used in breeding programs.

Materials and methods

Morphological and agronomic traits of 15 Iranian Indigenous populations of fennel including Bonab, Birjand, Kashan (Tatmaj), Torbatjam, Ahar-Meshgin (Khorshidabad), Isfahan (Khur and Biabanak), Mogan (khoruslari), Isfahan (Zeeyar), Khorasan (Shirvan), Karaj, Kerman, Lorestan, Neyshabur (gareeneh), Varamin and Hamadan along with four foreign populations of fennel including Germany (1182), Germany (11486), Turkey (Gazianteb), Turkey (Ezmir) were studied. A field experiment was conducted based on randomized complete block design with 3 replications in 2012 at the Research Station of Faculty Agriculture, University of Tabriz, Iran. Each plot consisted of three rows with 1m long. The interrow and interplant spacings were 50 and 25 cm, respectively. The traits such as days to germination, days to 50% flowering, days to 100% flowering, days to maturity, height at 50% flowering, total plant height, biomass, number of internodes in main stem, length of first, longest and last internodes, number of branches, diameter of main stem, number of umbel, length of peduncle, grain yield, 1000 grain weight, essential oil content in 100 gr dry grain, harvest index, number of seed per umbel were measured. Twenty plants per plot were collected and the mean data points were used for statistical analysis by using, MSTATC, Excel and SPSS software's.

Results and discussion

The simple correlation coefficients among above mentioned traits are shown in the Table 1. Grain yield was correlated positively and significantly with number of umbel, number of seed per umbel, harvest index, essential oil content and length of first internode. Lal (2007), Lopes *et al.* (2010) and Safaei *et al.* (2011) reported a positive and significant correlation between essential oil content and grain yield of fennel. Also Singh *et al.* (2005) and Zahid *et al.* (2008) showed that there was a positive and significant correlation between number of umbel and harvest index with grain yield.

Table 1. Correlation coefficients between studied traits in 19 populations of fennel

traits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.days to germination	1																			
2. days to 50% flowering	0.477*	1																		
3. days to 100% flowering	0.468*	0.988**	1																	
4. days to ripening	-0.325	-0.868**	-0.806**	1																
5. height at 50% flowering(cm)	0.143	0.749**	0.770**	0.833**	1															
6. total plant height(cm)	0.279	0.843**	0.873**	0.850**	0.911**	1														
7. biomass (gr/m²)	0.219	0.565**	0.581**	0.755**	0.805**	0.768**	1													
8. No. internode in main stem	0.245	0.922**	0.928**	0.906**	0.851**	0.875**	0.701**	1												
9. length of first internode(cm)	-0.401	-0.917**	-0.914**	-0.787**	-0.614**	-0.666**	-0.472*	-0.869**	1											
10. length of longest internode(cm)	0.301	0.779**	0.820**	0.795**	0.774**	0.915**	0.598**	0.755**	-0.625**	1										
11. length of last internode(cm)	0.239	0.070	0.103	0.139	0.257	0.378	0.269	-0.039	0.147	0.447	1									
12. No. branches	0.584**	0.692**	0.683**	0.776**	0.638**	0.661**	0.778**	0.643**	-0.605**	0.565**	0.352	1								
13. diameter of main stem(mm)	0.401	0.848**	0.845**	0.892**	0.878**	0.876**	0.892**	0.892**	-0.757**	0.719**	0.139	0.807**	1							
14. No. umbel	-0.337	-0.693**	-0.668**	-0.515*	-0.200	-0.352	-0.007	-0.519*	0.733**	-0.494*	0.237	-0.237	-0.341	1						
15. length of peduncle(cm)	0.614**	0.807**	0.824**	0.707**	0.712**	0.862**	0.665**	0.747**	-0.662**	0.832**	0.405	0.679**	0.788**	-0.419	1					
16. grain yield(gr/m2)	-0.179	-0.467*	-0.437	-0.238	0.088	-0.078	0.374	-0.237	0.509*	-0.257	0.279	0.055	0.018	0.847**	-0.320	1				
17.1000 grain weight(gr)	0.139	0.087	0.063	-0.081	-0.193	-0.174	-0.112	0.066	-0.209	-0.228	-0.757**	-0.249	0.039	-0.394	-0.049	-0.207	1			
18.essential oil content(cc)	-0.116	-0.401	-0.379	-0.237	-0.065	-0.154	0.185	-0.401	0.431	-0.195	-0.345	0.123	-0.077	0.440	-0.219	0.567**	-0.213	1		
19. harvest index	-0.359	-0.929**	-0.923**	-0.818**	-0.592**	-0.731**	-0.380	-0.829**	0.891**	-0.772**	-0.051	-0.598	-0.667**	0.797**	-0.667**	0.684**	-0.153	0.459*	1	
20. No. seed per umbel	0.013	-0.078	-0.054	0.229	0.405	0.310	0.635**	0.029	0.172	0.280	0.616**	0.371	0.338	0.412	0.288	0.700**	-0.443	0.571**	0.203	1

* and ** Significant at 0.05 and 0.01 probability level respectively

Dwivedi *et al.* (2008) reported that there is a positive and significant correlation between grain yield and umber of seed per umbel. So, it can be concluded that the increase of traits such as number of umbel, number of seed per umbel, length of first internode and harvest index could increase grain yield and consequently increase the essential oil content. Mean whiles selection on those traits will increase amount of volatile oil content.

Stepwise multiple regression procedure was used to select the traits that have important role in the control of grain yield variation (Table 2).

Table 2. Anova of multiple regression for studied traits

	DF	SS	Ms	F
Regression	3	3806.234	1268.745	87.862**
Residual	15	216.604	14.440	
Total	18	4022.838		

** Significant at 0.01 probability level

In this analysis, number of umbel, number of seed per umbel and 1000 grain weight remained in the final model and were considered as the effective components on the grain yield (Table 3). R^2 value of the model indicated that more than 93% of the total variations of grain yield were justified by these traits. Table 3 shows that regression coefficients of these three traits are significantly positive so, increase in their values will lead to increase in the grain yield.

Table 3. Stepwise regression coefficient for grain yield in 19 fennel populations

Entered traits to model	Regression coefficient	t
No. umbel	0.756	11.108**
No. seed per umbel	0.533	7.637**
1000 grain weight	0.327	4.720**

** Significant at 0.01 probability level

R^2=0.935

Path analysis was performed using results of stepwise regression model for grain yield. The results of path analysis for grain yield are presented in table 4 and fig. 1.

Table 4. Path analysis of grain yield with related traits in 19 populations of fennel.

Entered traits to model	Direct effects	No. umbel	Indirect effect via		Correlation coefficient with grain yield
			No. seed per umbel	1000 grain weight	
No. umbel	0.756	–	0.220	-0.129	0.847
No. seed per umbel	0.533	0.312	–	-0.145	0.700
1000 grain weight	0.327	-0.298	-0.236	–	-0.207

According to results of grain yield path analysis, number of umbel had the most direct effect on the grain yield. The indirect effect of this trait through number of seed per umbel was positive, but via 1000 grain weight was negative. The direct effect of number of seed per umbel on yield was positive, while this trait had the most indirect effect on grain yield through the number of umbel. Indirect effect of number of seed per umbel on yield via 1000 grain weight was negative. Direct effect of the 1000 grain weight on grain yield was positive and low. Indirect effect of the 1000 grain weight on yield via number of umbel and number of seed per umbel were both negative. While simple correlation between 1000 grain weight and grain yield was non-significant, 1000 grain weight had positive direct effect on grain yield. It is clear that the indirect effect of this trait through other variables were negative. Therefore, it can be concluded that direct effect of number of umbel and number of seed per umbel on the increment enhancement of grain yield was more important the other traits.

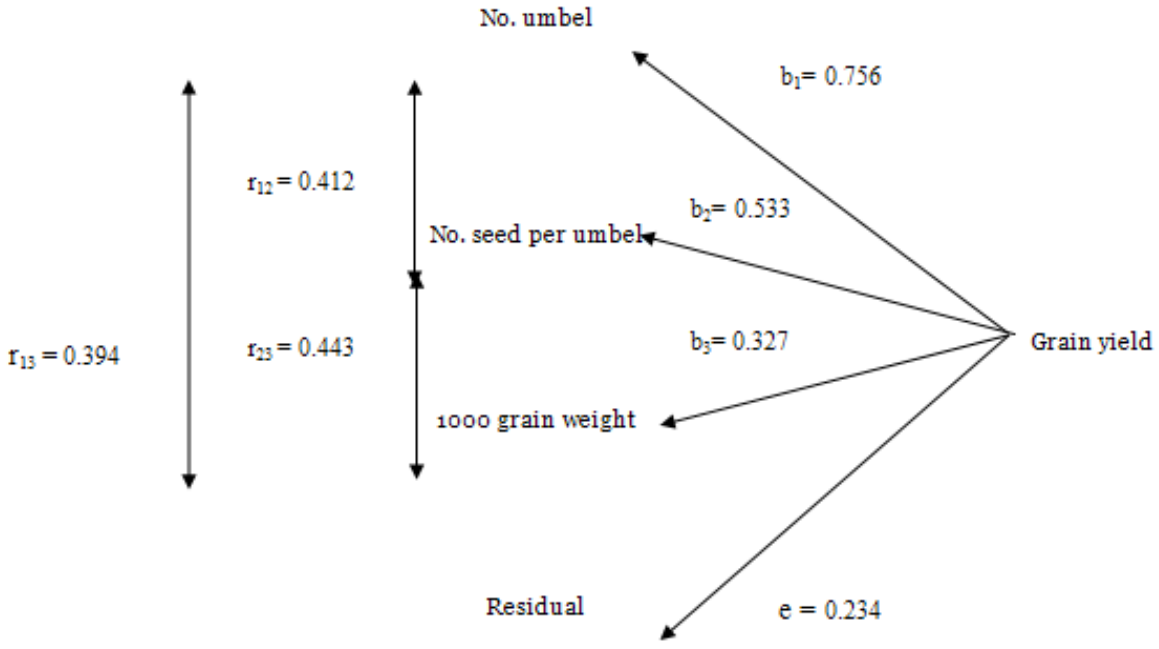

Fig. 1. Path diagram of grain yield and its effective components.

Cluster analysis was performed based on grain yield and its related traits which identified by stepwise regression analysis. The analysis was carried out using Ward's algorithm and standardized data. After clustering the dendrogram at the maximum distance, the 19 populations were located into two main groups including 12 and 7 populations, respectively (Fig. 2). The average of traits for each cluster and the percent of their deviation from ground mean are shown in table 5.

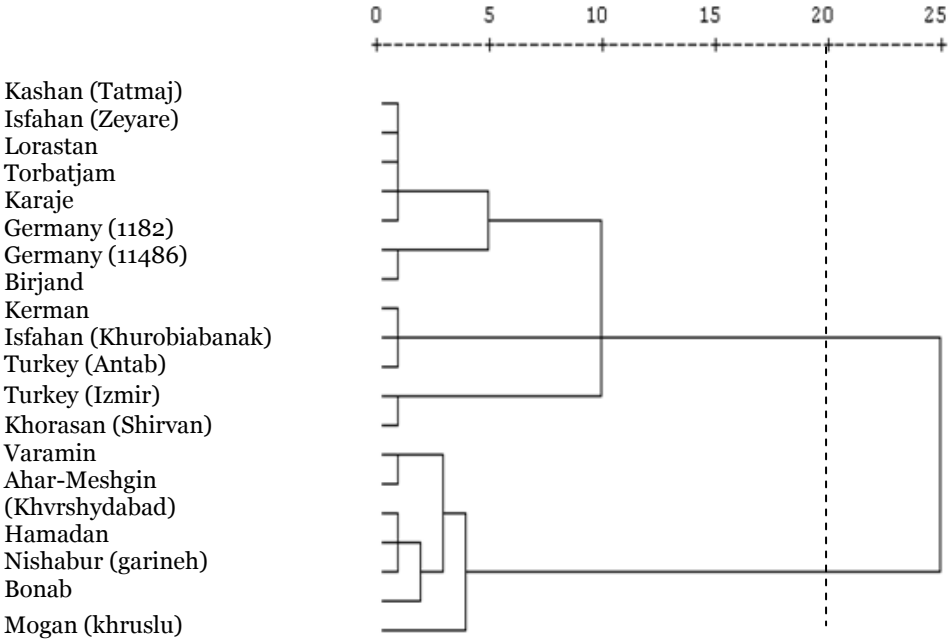

Fig. 2. Dendrogram of cluster analysis for 19 populations of fennel based on grain yield and its related traits

Table 5. The average of traits for each cluster (above number) and the percent of deviation of average of each cluster from total mean (below number)

Clusters	Grain yield	1000 grain weight	No. umbel	No. seeds per umbel
Germany (1182), Germany (11486), Turkey (Gazianteb), Turkey (Ezmir), Karman, Birjand, Kashan (Tatmaj), Torbatjam, Isfahan (Khur and Biabanak), Isfahan (Zeeyare), Khorasan (Shirvan), Karaje, Lorastan, Bonab, Mogan (Khoruslari), Ahar-Meshgin (Khorshidabad), Neyshabur (gareeneh), Varamin, Hamadan	27.649	5.147	29.083	181.758
	-22.532	6.362	-15.036	-14.989
	49.477	4.311	43.053	268.742
	38.627	-10.906	25.776	25.695
Total mean	35.690	5.153	34.230	213.805

The first group had the less values than the total mean for all traits except of 1000 grain weight. Percentage of deviations for 1000 grain weight was positive in this group. This character had negative coefficient in regression equation. Thus, populations of this group had low values for grain yield and yield components. The second group consists of 7 populations. In this group percentage of deviations from total mean was positive for all traits except of 1000 grain weight so, populations of this group can utilize to increase grain yield in breeding programs. Results of cluster analysis showed that there is no complete concordance between geographical resemblances and phonotypical characteristics of fennel populations. Meena *et al.* (2010) showed that the genetic diversity is not related to geographical variations necessarily.

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