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Correlation and Path Coefficient Analysis of Phenological, Agronomic and Morphological Traits of Cumin and Ajwain Populations in Iran

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ABSRACT

Trachyspermum ammi (L.) and *Cuminum cyminum* area herbaceous herbs belong to the family of Apiaceae and belonging to the family Apiaceae, are one of the earliest cultivated herbs in Asia, Africa and the Mediterranean countries. They are widely used in foods, beverages, perfume, and pharmaceutical industries. This research was carried out in a randomized complete block design with three replications at Research Station of the Agricultural Research and Education Center of Khorasan Razavi, Iran during 2012-2013. In this experiment, genotypes of Ajwain (27) and Cumin (24) from different parts of the country were collected by the Natural Resources Genes Bank of Iran. This study aims to evaluate the morphological and phenological traits and also to measure essential oil percentage, yield and yield components of herbs for achieving superior germplasms. Seed samples were first cultivated in the greenhouse and then transferred to the field and cultivated in drip irrigation conditions. Studies showed there was a difference among investigated ecotypes of Ajwain and Cumin for following characters including plant height, number of branches, number of umbels, number of umbellate in umbels, biological yield, single plant yield, and for number of secondary branches and oil content at 5% probability level. In Ajwain genotypes, the highest direct positive effect (0.39) on the essential oil yield was observed for the total plant weight, which had a positive and high correlation (r=0.53) with day to maturing stage. The number of branches and number of umbels per plant had the most direct effect on grain yield and essential oil**,** and therefore were identified as a suitable criterion for determining the production ability of cumin genotypes. As plant biomass has the highest positive direct effect on the yield of essential oil of genotypes, the selection of these traits should be considered with greater attention and emphasis in breeding programs. Cluster analysis and PCA were used for distance between accessions and to emphasize variation and bring out strong patterns in the dataset. The first two components were justified 71% in cumin and 78% of the total changes in variables. Traits of canopy cover, plant height, plant weight and essential oil percentage were the most important traits in cumin. The flowering stage, Seedling stage, 1000 seed weight and essential oil percentage were the important traits of component one in the Ajwain accessions. Cluster 2 contained the accession with the maximum yield of essential oil.

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1. Introduction

The study of the phenological and morphological characteristics of the medicinal plants has led to a better understanding of the extent and mode of growth and development in different species and ecotypes. Maximum growth rates within any particular stage of fruit growth and secondary metabolites are not similar in early- maturing to late – maturing of ecotypes or cultivars in the whole growth stages. The number of active substances could be done based on this feature (Niazian *et al.*, 2017). Native species are a potentially important source of genetic variation for the improvement of the cultivated Cumin and Ajwain. A lack of evaluation data for characters of economic importance is one constraint to their use in breeding programmes. Here, variation in selected phenological and agro-morphological characters in 24 and 27 accessions of cumin and Ajwain are reported.

a) Ajwain (Trachyspermum ammi L.)

Ajwain, Ajowan, or *Trachyspermum ammi* with synonyms name *as Trachyspermum copticum*, *Ammi copticum*, and *Carum copticum* —also known as ajowan caraway, oomam in Tamil, ajman, bishop's weed, or carom—is an annual herb in the family of Apiaceae. It is one of the most important and economical medicinal plants with a number of chromosomes 2n = 18, with a height of less than one meter (30-90 cm) that can be found in arid and semi-arid regions of Iran for agriculture in conditions of water scarcity (Dalkani *et al.*, 2011).

Ajwain is distributed in a different parts of Iran as Baluchestan, Tabriz, Isfahan, between Izeh and Dez at , Shiraz, Baghighin, Makran, Torbat Heydarieh, Alborz mountains and Sistan at altitude 1800-3300 m. The reaction of the ecotypes is different against cold weather and frozen stress. The electrolyte leakage was different among Ajwain ecotypes after exposure to freezing temperatures. Studies have shown at -7.5° C temperature, the survival rate of the two ecotypes of Neishasbor and Torbat Heidariya were reduced to less than 20%, while the survival rate of the Birjand ecotype was about 60% at that temperature. It seems that it is more tolerant to freezing stress than the other ecotypes (Nezami *et al.*, 2013).

Essential oil of Ajwain ecotypes is 2-4%. The number of chemical compounds in the essential oils has been reported 9 to 17 in different sources (Eblagh *et al.*, 2014). It has both antioxidant and antimicrobial properties, and hence it can be used as a food preservative. Essential compounds are composed of 9 monoterpenes which include, 7 hydrocarbons (97.1%) and 2 alcohols (2.9%). The major components were thymol, carvacrol, alpha and betapinone and terpinene, and paracymon. The predominant monoterpenes were y-terpinene (35%), a-phellandrene (31.4%), ô-carene (19.3%), p -mentha -1,3,8 triene (8.8%), p-cumin-7-ol (2.7%), ß-pinene (1.9%), ß-myrcene (0.4%), cis-myrtenol (0.2%) and Ot-pinene (0.3%), some other other compounds (Ghorbanzadeh and Mehrjerdi, 2017). The percentage of essential oil of the plant is affected by the selection of genotypes and farm management (Ranjan *et al.*, 2011).

The emergence of phenological stages in each plant results from environmental and genetic factors that have a direct effect on plant performance. Among environmental factors, the temperature has a significant effect on the phenology of plants. In medicinal plants, in addition to economic yield, secondary metabolites are also important. Therefore, in order to achieve the desired yield and the amount of acceptable active ingredients in each plant, it is necessary to record and study the emergence of different growth stages as well as the effective combinations of plants and their changes for quantitative and qualitative production during their growth (Qureshi and Eswar, 2010).

The Correlation and path analysis were estimated among 28 germplasms for 10 characters in Ajwain (*Trachyspermum ammi* L.). The results revealed that seed yield was positively and significantly correlated with a number of umbellate plant^{-1}. Path coefficient analysis revealed that a number of umbellate plant^{-1} had a maximum positive direct effect on seed yield plant^{-1} (Mirzahosseini *et al.*, 2017).

b) Cumin (Cuminum cyminum L.)

Cumin (*Cuminum cyminum* L.) is an aromatic herb from the Apicaceae family. Its dried seeds are used as the second most popular spice in the world. It is native to the regions from the eastern Mediterranean to India. In Iran and India, it is commonly known as zireh-e sabz. Turkey is an important producer of cumin but suffers from *Fusarium oxysporum f.sp. cumini, F. solani, F. equiseti, M. phaseolina,* and *Alternaria alternate*. Control with Mancozeb gave the highest seed germination (94%) and minimum pre- and post-emergence mortality (2.0 and 1.5%, respectively) followed by Captan, Thiram and Carbendazim (Kishor *et al.*, 2000; Özer and Bayraktar, 2015). It is necessary to study the variation among cumin genotypes probably to find the resistant ecotypes and some superior ones. Cumin seed is a mixture of united and separated mericarps, yellowish green/brown in color, elongated ovoid, and 3–6 mm in length. The surface has five primary ridges alternating with four less distinct secondary ridges bearing numerous short hairs. Some seeds have a short stalk (Sahana *et al.*, 2011).

49 diverse cumin ecotypes were tested by Mortazavian et al. (2018) under normal and water stress conditions and reported that ecotypes from Maneh (Northern Khorasan), Shahmirzad (Semnan), and Rafsanjan (Kerman) were identified with high yield in water stress condition and as the most favorable candidates for further research in cumin breeding programs.

A cytological study was carried out on zira in Iran, comprising *Bunium persicum*, *B. cylidricum*, *B. chaerophylloids*, *Cuminum cyminum* and *Carum carvi*. Somatic chromosome number determined were 2n =14, 20, 12 and 14 respectively. High coefficient of correlation for total chromosome length indicated the presence of a homogenous group. Cluster analysis of karyotype data also showed the similarity between some of the populations (Sheidai *et al.*, 1996).

The purpose of this research was to study the populations of ecotypes of Cumin and Ajwain which were received from the Iranian Natural Resources Gene Bank Seeds. In addition, this research was aimed to evaluate the phenological, morphological and agronomic characteristics and classify early, late and medium maturity ecotypes of Ajwain (Trachyspermum ammi L.) and Cumin (Cuminum cyminum) as well as an assessment of the essential oils extracted from different ecotypes for both plants.

2. Materials and Methods

The genotypes of Ajwain (27) and Cumin (24) were received from different parts of Iran and also from the Natural Resources Genes Bank of Iran and planted in the cold green houses at a research farm in Mashhad. Gene banks is a source for the right seed and look into several issues in order to improve levels of germplasm distribution and its utilization, duplication of plant identity, and access to database, for pre-breeding activities. In winter, the collected seeds were sown in the cold greenhouse to have at least 120 seedlings from each plant accessions. The seedlings were transplanted to the farm and planted in the plots 2 x 5 meter with 4 rows for each ecotype in March 2016 (Tables 1,2). The experiments were carried out in a randomized plots experimental design with 3 replicates of each treatment. The farm was located in Razavi Khorasan province in Torq station, Mashhad. The study ran for two years in 2016 and 2017.

Irrigation was performed weekly in a dripping manner. The fertilization was done according to the recommended values using 50 kg of urea fertilizer + 150 kg of triple super phosphate per hectare prior to a planting operation. Weed was controlled mechanically by 2-3 times during growth period.

At the flowering time in the first and second year, morphological characteristics such as the percentage of settling, stem length, number of stems per plant, and crown growth were measured in this study. The fresh and dry weights were collected and measured for each sample. Seed size, yield components, biomass and grain yield and essential oil percentage were measured in all the cultured germplasm. All phenological stages including stem elongation time, flowering time and seeding time were counted and recorded during the growth period. Essential oils were extracted by hydro distillation method using 30-gram sample and the Clevenger-type apparatus.

Principal components analysis (PCA) was used

The main purpose of the analysis is to summarize the number of variables and reduce the amount of data, so that the attributes that are most diverse and important with the particular task are identified.

Table 1
Collecting site of 27 Ajwain ecotypes by natural resources gen bank in Iran.

Row	Collecting area	Code	Row	Collecting area	Code
1	Karaj	906	15	Tehran	15130
2	Esfahan	943	16	Arak 7	15226
3	Unknown	1085	17	Shahedieh	15484
4	Karaj	3883	18	Ilam	20055
5	Qom	7893	19	Yazd	31831
6	Mobarakeh	10124	20	Sarbisheh 1	37251
7	Ardebil	10569	21	Qaen 1	37477
8	Shiraz	12313	22	Birjand 1	37483
9	Arak 1*	14492	23	Birjand 2	37492
10	Arak 2	14525	24	Qaen 2	37529
11	Arak 3	14548	25	Boshruyeh	38913
12	Arak 4	14593	26	Birjand 3	38924
13	Arak 5	14594	27	Sarbisheh 2	38929
14	Arak 6	14743			

(*) show different accession from the same area

Table 2
Collecting site of 24 Cumin ecotypes by natural resources Genes Bank in Iran.

No	City	code	No	City	code
1	Boshruyeh 1*	14524	13	Arak 1	22074
2	Boshruyeh 2	14589	14	Arak 2	31672
3	Birjand 1	14598	15	Arak 3	37473
4	Birjand 2	14654	16	Arak 4	37503
5	Birjand 3	14656	17	Arak 5	37561
6	Birjand 4	14665	18	Arak 6	38904
7	Tehran	14991	19	Markazi 1	38911
8	Khash	15151	20	Markazi 2	40766
9	Bojnord	15154	21	Markazi 3	14663a
10	Kerman 1	15310	22	Markazi 4	14663b
11	Kerman 2	15316	23	Markazi 5	37488a
12	Kermanshah	18307	24	Sarbisheh	37488b

(*) show different accession from the same area

Statistical analysis including analysis variances, correlation, stepwise regression, PCA and path analysis was performed using SPSS24 and AMOS24 software (Blunch, 2008).

3. Results and Discussion

The results of analysis of variance showed that there were significant differences ($p<0.05$) among different measured characters in both species. Phenological traits of stem elongation, number of stem branches, plant height, crown and cover area, flower number, 50% flowering, physiological maturity were difference in the ecotypes of Ajwain and also in Cumin ecotypes. Also showed a diver in yield and yield components, number of umbels, number umbellate in umbels, seed number per umbellate, seed weight per plant, plant biomass weight, 1000- seed weight, essential oil percentage and essential oil yield in the both Ajwain and Cumin ecotypes.

The highest percentage of essential oil of Ajwain reported in various research was 2-4% (Eblagh *et al.*, 2014) but in this research, the range of essential oils varied from 3 to 11.2%, the highest one was collected from the Arak ecotypes.

3.1. Ajwain

Ajwain germplasms were significantly difference ($p<0.05$) for 50% flowering time in 1.5 months, plant biomass 72-245 g/plant, seed yield 38-61.3 g/plant, and essential oil 3.08-11.22%. The 45-day variation in flowering time and 69-day physiologic maturity was found among Ajwain ecotypes, which could be considered in plant breeding programs (Table 3) .

3.1.1 Correlation Analysis of traits in Ajwain

The very significant ($p\leq0.01$) positive correlation of essential oil yield was observed with essential oil percentage, plant weight, grain yield per plant, total plant weight and harvest index. Significantly ($p<0.01$) Negative and moderate correlations observed between stemming stage, 50% flowering stage, seed setting, physiological maturing, and number of branches with the essential oil percentage. The results are similar with the findings of other researchers for the positive relation of essential oil with plant biomass and seed yield of the plant (Zarezadeh *et al.*, 2007; Niazian *et al.*, 2018). According to high correlation between grain and oil yields, breeding for these two traits can be consistent in Iranian ecotypes of Ajwain. Oil content percentage in ecotypes from South and Center were more than other parts of Iran (Niazian *et al.*, 2017).

In this study, the grain yield was positively correlated with 1000-seed weight, a number of days to flowering, and with plant height had a significant negative correlation ($r=-0.40$) (Table 4). While other researchers indicated a positive correlation among grain yield and plant height, number of secondary branches, number of flowering days and number of branches but there was a negative significant correlation with 1000-seed weight (Neghab and Mehrjerdi, 2017).

3.1.2 Stepwise regression for Ajwain traits

In stepwise regression analysis, the essential oil yields as the dependent variable was checked against other traits. Days to stemming was the first trait to enter the regression model and explained26 % of variations in essential oil yield alone. Traits of plant weight, plant height and days to maturity stage were also entered in the model and explained a total of 55% of the dependent traits (essential oil yield) (Table 5). In this study, the grain yield and essential oil had a positive and significant correlation with the biological yield of the plant. This result is in the line with the results of other researchers (Zarezadeh *et al.*, 2007; Niazian *et al.*, 2018). The analysis shows that there is a high correlation between geographical diversity, environmental conditions, and the percentage of essential oil and chemical changes in Ajwain. So that the content of essential oil such as thymol is high in poor condition and in dry and semiarid conditions, because phenols are less susceptible to non-phenolic compounds, moisture, and deep soil with organic matter (Rahimmalek *et al.*, 2009).

3.1.3 Path analysis of traits in Ajwain

In path analysis, the essential oil yield was considered as an independent variable and compared with biological yield per plant, plant height, number of days to stem and number of days to physiological treatment as independent variables (Table 6). Based on stepwise regression and path analysis, the essential oil yield of each plant was influenced by direct and indirect effects with days to stemming stage, a number of days to physiological maturity, plant height and plant weight. Considering the coefficient of determination (55%), the majority of changes in the essential oil content of the germinated seeds were related to these four traits. The plant weight had the highest direct positive effect (39%) on the essential oil yield, which has a positive and high correlation ($r=53\%$) with the number of days to maturity. Plant height and days to stemming stage had a direct negative effect on the essential oil yield. Indirect effects showed that with increasing plant height and plant weight the essential oil was increased in ecotypes (Table 6). Investigations on Apiaceae family show that yield components such as the number of umbel per plant, number of seeds per umbellate and 1000-seed weight are the most important traits for determining the yield (Ranjan *et al.*, 2011).

The results showed that Ajwain ecotypes have a high variation in different agro morphology characters, and can be a good source for new breed varieties.

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Table 3.

Analysis variance of agronomical and morphological characters of Ajwain accessions.

S.O.V	df	Stemming stages	Physiological maturity	Seed setting	Plant height	Canopy cover	Branches	50% Flowering stage	Umbellate/ umbel	No. Seed/ umbellate	Plant biomass	Plant seed yield	1000 seed weight	Essential oil %	Essential oil yield /plant
R	2	14.93	23.62	2.37	43.39	5358787.4	1.42	21.71	1.31	41.73.42	34777.90	95.81	0.002	3.85	0.008
Accessions	26	307.024**	803.55**	15.01**	374.61**	84503103**	8.21**	432.54**	16.9**	8168.78**	6392.24**	546.38**	0.175**	18.63**	0.032**
Error	52	3.72	14.98	4.56	423.6356	62368147.22	3.55	3.73	26505.96	3546.25	1787.5	54.49	0.028	1.013	0.002
CV	-	5.4	3.2	3.2	6.64	16.47	20.56	2.3	21.92	13.37	17.36	51.46	21.73	17.22	33.53

* and ** significant difference at $p < 0.05$ and $p < 0.01$

Table 4.

Pearson's correlation coefficients (r) between phenological, morphological traits of yield and yield components of Ajwain accessions.

Traits	Stemming stage	50% Flowering stage	Plant height	Canopy cover	Seed setting	Physiological maturing	Branches	Umbellate/ umbel	No. Seed/ umbellate	Plant biomass	Plant seed yield	1000 seed weight	Essential oil %
50% Flowering stage	0.51**												
Plant height	0.01	-0.44**											
Canopy cover	-0.52**	-0.51**	0.40**										
Seed setting	0.16	0.66**	-0.34**	-0.30**									
Physiological maturing	0.17	0.64**	-0.28**	-0.33**	0.95**								
Branches	0.13	0.33**	-0.15	-0.07	0.18	0.10							
Umbellate/ umbel	0.004	-0.19	0.36**	0.005	-0.25**	-0.21	0.15						
No.Seed/ umbellate	-0.17	-0.33**	0.16	0.13	-0.42**	-0.41**	0.001	0.75**					
Plant biomass	-0.16	-0.09	0.03	0.39**	0.08	0.10	0.03	0.01	0.13				
Plant seed yield	-0.24**	0.32**	-0.41**	-0.02	0.49**	0.53**	0.10	-0.21	-0.11	0.33**			
1000 seed weight	0.16	0.32**	-0.32**	-0.16	0.47**	0.51**	0.16	-0.28**	-0.37**	0.19	0.27*		
Essential oil %	-0.53**	-0.63**	0.21	0.48**	-0.46**	-0.46**	-0.26**	0.09	0.35**	0.37**	-0.09	-0.32**	
Essential oil yield /plant	-0.52**	-0.05	-0.29**	0.24**	0.20	0.25*	-0.01	-0.12	0.09	0.49**	0.86**	0.18	0.37**

** Significant correlation at % 1 probability

Table 5
Results of stepwise regression analysis in Ajwain accessions with dependent variable as Essential oil yield (g/plant)

Traits	R^2	$R2_{partial}$	F
Stemming stage	0.261	0.261	**29.22
Plant biomass	0.428	0.167	**30.88
Plant height	0.510	0.082	**28.75
Physiological maturity	0.552	0.042	**20.61

Table 6
Path analysis of essential oil yield of Ajwain accessions with remaining traits from stepwise regression model.

Trait	Direct effect	İndirect effect				Total effects
		Stemming stage	Plant biomass	Plant height	Physiological maturing	
Stemming stage	-0.5		-0.06	-0.003	0.04	-0.53
Plant biomass	0.393	0.08		-0.01	0.023	0.49
Plant height	0.232	-0.01	0.011		-0.065	-0.29
Physiological maturing	0.231	-0.086	0.039	0.064		0.25

Residual effect =0.644

3.1.4 Cluster analysis

The cluster analysis performed on 27 Ajwain accessions and by selecting 14 traits and cutting dendrograms at 8/8 Euclidean distance, showed (Figure 1) that the accessions are classified into four groups based on their degree of affinity. The cluster 1 with 10 accession, cluster 2 with 3 accessions, cluster 3 with 10 appendages, and cluster 4 with 4 alternatives were distinguished among the accessions.

3.1.5. Principal components analysis (PCA)

Given the existing correlation between the data (Table 4), the greater the correlation is expected between the variables in Ajwain accessions, the specific values obtained from components 1 to 4 are 38%, 21%, 10%, and 8% respectively (Figure 2), which justifies a total of 78% of the total variance of the variables. The first, second and third components with more variance, justify the major changes (Table 7). The relative values of the specific vector coefficients in the first component showed that the stemming stage, flowering stage, physiological maturity and 1000-seed weight and the essential oil percentage were the most important traits to manage the yield of the essential oil. This component mainly indicates the variables responsible for the phenological variables (Table 7).

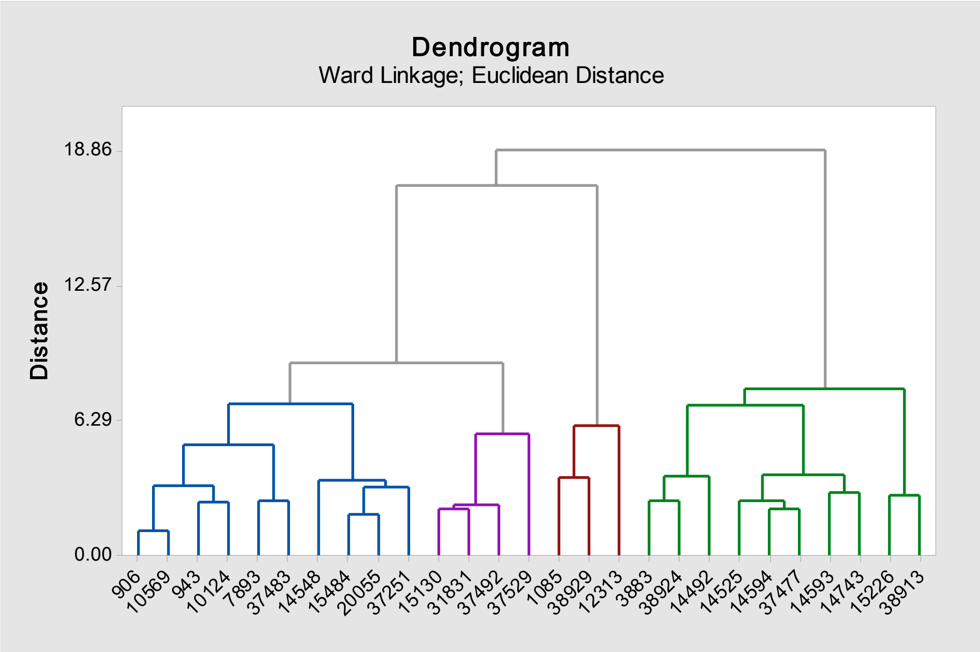

Figure 1
Dendrogram of cluster analysis by method of Ward linkage for 27 Ajwain accessions for all traits

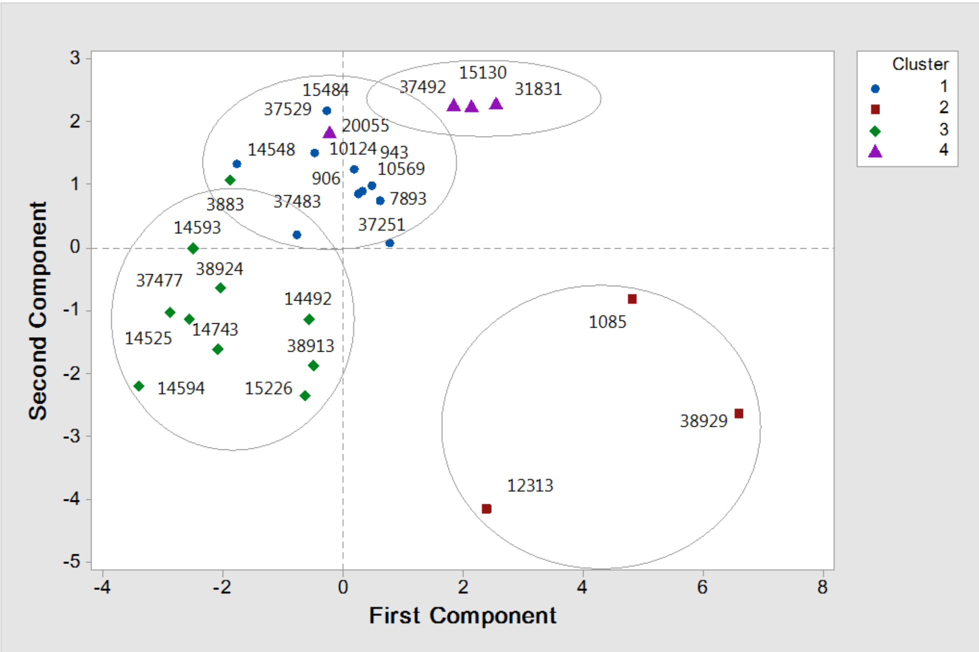

Figure 2
Distribution diagram of 24 cumin accessions based on data analysis on the first and second components in four clusters

Table 7
Specific values, variance rate of special vectors by the principal components analysis (PCA) of the main components in 27 accessions

Variable	PC1	PC2	PC3	PC4
50% Flowering stage	**0.341**	0.228	-0.003	-0.144
Seed setting	**0.373**	0.03	-0.02	-0.218
Physiological maturity	**0.375**	0.001	0.023	-0.224
1000 seed weight	**0.292**	0.006	-0.175	-0.044
Essential oil percentage	**-0.261**	-0.377	-0.049	0.061
Seed yield	0.294	**-0.381**	0.171	-0.072
Essential oil yield	0.13	**-0.532**	0.122	-0.018
No.Seed/ umbellate	-0.273	-0.158	**0.415**	-0.325
Biological yield	0.035	-0.365	**-0.428**	-0.322
HI	0.292	-0.281	**0.361**	0.085
Canopy cover	-0.191	-0.326	**-0.439**	-0.057
Plant height	-0.269	0.073	-0.154	**-0.307**
Stemming stage	0.142	0.145	-0.266	**-0.473**
Umbellate/umbel	-0.24	0.082	0.385	**-0.576**
Eigenvalue	5.3258	3.0167	1.4404	1.1836
Proportion	0.38	0.215	0.103	0.085
Cumulative	0.38	0.596	0.699	0.783

3.2. Cumin (Cuminum cyminum)

According to the results, there was a significant variation (p<0.05) among the genotypes in terms of traits including phenological (number of planting days to stem length of 41-28 days, 50% flowering 37- 57 days and maturity of 92-101 days) and morphological characteristics. The number of stem branches of the genotypes was significantly (p<0.05) different (3.5-5.7). The observed differences in the yield components were: number of umbels per plant 8.7-8.5, number of umbellate in umbel 3-4, seeds in the umbellate 23-13, 1000- seed weight 2.8-4.2 g, total plant biomass as 6-22 g, the seed yield of each plant 2-8 g, the essential oil percentage 0.99-3.11 and the essential oil yield 0.02-0.2 g/plant, which were significant at p<0.05 (Table 8).

3.2.1. Correlation analysis of traits in Cumin

The essential oil yield had a positive and significant (p<0.01) correlation with essential oil percentage, plant weight, plant height and grain yield per plant. The grain yield was also significantly (p<0.01) correlated with total dry weight of each plant and essential oil yield (p<0.01). The essential oil percentage had a positive and significant (p<0.01) correlation with essential oil yield and 1000 seed weight (Table 9). This finding is consistent with the essential oil yield of fennel has a positive and significant(p<0.05) correlation with grain yield, essential oil percentage and percentage of α-pinene, camphine, mirsen, fenchone and camphor components by Safarnejad (2011). In another research on cumin, the correlation among time to planting and harvest with 1000-seed weight, stem height at flowering stage with 1000-seed weight, 1000-seed weight with percentage of essential oil and grain yield with percentage of essential oil of grain were significantly (p<0.05) positive (Toxopeus and Lubberts, 1999).

The essential oil yield, which is the economic component of the plant, had a significant (p<0.01) positive correlation with the biological yield of the plant (r=0.72), plant yield (r=0.86), Canopy cover (r=0.49), plant height (r=0.37) and number of umbellate per umbel (Table 8). On the other hand, plant height had the same correlation with biological yield (r=0.41), essential oil (r=0.44), and crown cover (r=0.43) and grain yield per plant (r=0.33). The essential oil percentage had the same correlation (p<0.01) with umbellate number in plant (r=0.33) and 1000-seed weight (r=0.53). There was a high positive correlation between grain yield and biological yield, and both traits are correlated with essential oil yields. For a high essential oil yield, high vegetative growth plants are needed. Therefore, with this regard to the correlations observed (Table 9), it can be concluded that to achieve a good yield, plants with good vegetative growth are required for selection in plant breeding program.

3.2.2. Stepwise regression for cumin traits

The results of Stepwise linear regression analysis showed that the plant biomass was the first trait that entered the regression model and explained alone 51% of the variations in essential oil yield (Table 10). Three more characters were entered to the regression model like 1000- seed weight, Canopy cover and umbellate per umbel and explained 60% of dependent traits (essential oil yield). In other similar studies on cumin, 1000-seed weight, umbel number, seed per umbel and number of stem branches were affected the grain yield and entered in the model (Afshar *et al.*, 2016).

3.2.3. Path coefficient of Cumin traits

In order to identify the direct and indirect effects of traits on grain yield, path analysis was performed based on the variables entered into the final regression stage. The number of branches and number of umbels per plant had the most direct effect on grain yield and essential oil, and therefore were determined as a suitable criterion for determining the production ability of cumin genotypes.

It can be seen from the results of Table (9), the grain weight per plant has the most direct positive effect on essential oil yield and selection of genotypes with a high biomass can increase essential oil yield. This trait was indirectly influenced by the weight of 1000- seed weight, number of umbellate and canopy cover. Based on the results of Table (11), 72% of the variation of essential oil yield was determined by direct and indirect effects of plant weight. Some of yield components such as number of umbel per plant, number of seeds per umbellate and 1000-seed weight are important for determining yield (Ehsanipour *et al.*, 2013). Other studies reported by Afshar (2016) that the number of branching stems, the weight of 1000 seed, number of umbels, number of seeds per umbellate, were attributed to the regression model. The most direct effects were the number of umbel per plant (0.7) and 1000-seed weight (0.19). High direct effect of plant biomass on essential yield was also reported by Figueiredo *et al* (2008).

3.2.4 Cluster analysis

Cluster analysis of 15 traits with 24 cumin accessions and dendrogram cutting in the Euclidean distance of 6.8. were divided cumin accessions into two groups, so that cluster 1 with 10 accessions and cluster 2 with 14 accessions were distinguished from one another (Figure 3). Most of the accessions in the central province of Arak. The cluster represented a grouping based on morphological data to some extent consistent with the geographic location of the site of the accessions. The distribution of 24 cumin acres in Figure 4 is based on the two main components. The results are similar to the dendrogram obtained from cluster analysis. Cumin accessions in cluster II (Table 3), like the 15310 accession of Tehran province, have higher seed yield, essential oil content and yield.

3.2.5 Principal components analysis (PCA)

In the PCA, for the main components of the cumin, 15 traits were used on 24 cumin accessions. The parameters of the analysis were included in the analysis of the specific values, the percentage of variance, and the coefficients of the specific vectors for the main components of cumin were mentioned in Table 12. In cumin accessions, the specific values from components 1 to 4 were 33%, 14%, 14% and 11% respectively, which justifies 71% of the total variance of variables, respectively. The relationships between traits with first and second components were shown (Figure 4), which showed that plant height, dry weight of the plant and oil percentage had a more positive and significant effect on the first and second components (Table 12).

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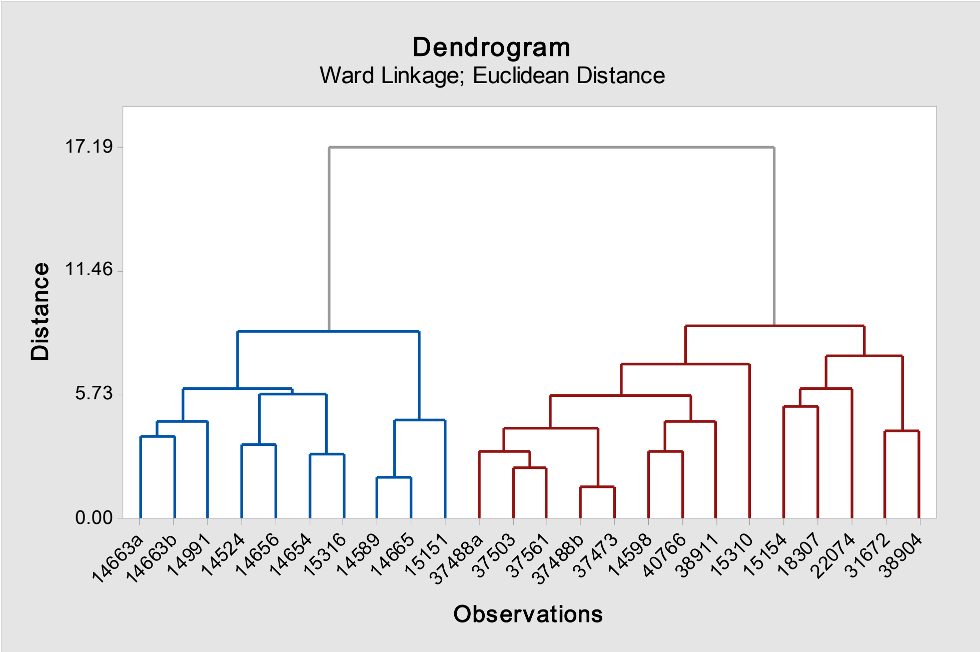

Figure 3
Dendrogram of cluster analysis by method of Ward linkage for 24 cumin accessions for all traits

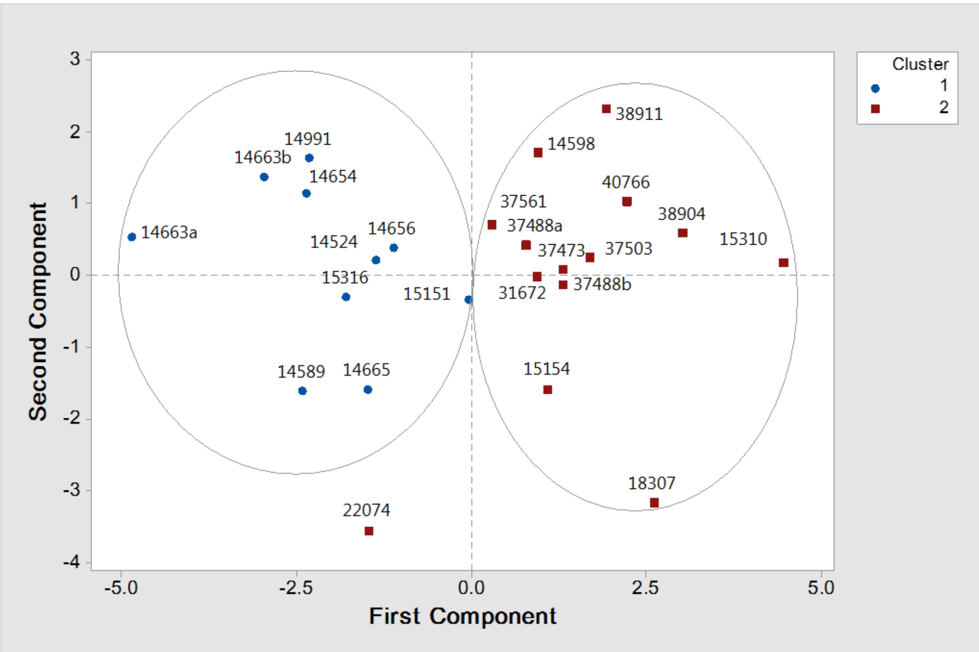

Figure 4
Distribution diagram of 24 cumin accessions based on data analysis on the first and second components in four clusters

Table 8
Analysis variance of agronomical and morphological characters in salinity treatments.

S.O.V	df	*Physiological maturity*	Seed setting	Plant height	Canopy cover	Branches	50% Flowering stage	Stemming stage	Umbellate/ umbel	No. Seed/ umbellate	Plant biomass	Plant seed yield	1000 seed weight	Essential oil %	Essential oil yield /plant
R	2	1.35	2.37	1.26	4604916.28	0.326	106.17	58.60	0.129	8.97	4.99	1.03	0.296	0.041	0.0078
Accessions	23	10.90**	15.01**	24.12**	1394266.12**	1.16^{ns}	110.99**	88.42**	0.322**	18.89**	62.86**	7.75**	0.489**	0.797**	0.0011**
Error	46	5.68	4.65	5.35	534430.19	0.725	38.9	37.59	0.107	4.97	12.36	1.89	0.093	0.136	0.0029
CV	-	3.1	3.2	9.12	28.74	18.70	16.39	69.85	8.75	12.18	26.62	32.15	8.62	16.30	18.34

Table 9
Correlation coefficients between phenological, morphological traits of yield and yield components of cumin

Traits	Stemming stage	Flowering stage	Canopy cover	Plant height	Physiological maturity	No.Umbel / p	Branches	Umbellate / umbel	No.Seed / umbellate	Plant biomass	Plant seed yield	1000 seed weight	Essential oil%
Flowering (50)	.701**												
Canopy cover	-.493**	-.323**											
Plant height	.025	-.069	.432**										
Physiological maturity	.013	-.030	-.119	-.139									
No.Umbel / plant	.178	-.025	-.062	.229	-.171								
No. branching stems	-.062	.029	.106	-033	.066	-.074							
Umbellate / umbel	.088	.140	.148	.127	.005	.010	.214						
No.Seed / umbellate	.088	.078	.194	.102	.116	-.012	.377**	.767**					
Plant biomass	-.176	-022	.292*	.407**	-.018	.120	.212	.194	.148				
Plant seed yield	-.263*	-.076	.372**	.331**	-.098	-.185	.252*	.206	.155	.725**			
1000 Seed weight	-.066	-.228	.040	.273*	.124	.064	.099	.127	.200	.238*	.183		
Essential oil%	-127	-.245*	.208	.436**	-.042	.299*	.098	.306**	.156	.325**	.146	.529**	
Essential oil yield	-.205	-.133	.366**	.485**	-.111	.083	.279*	.324**	.223	.718**	.858**	.401**	.586**

*and ** Significant correlation at 5% and 1% probability

Table 10

Results of stepwise regression analysis in Cumin germplasms with dependent variable as Essential oil yield (g / plant)

Traits	R^2	$R^2_{partial}$	F
Plant biomass	0.509	0.509	74.67**
1000 seed weight	0.560	0.051	46.18**
Canopy cover	0.584	0.024	34.24**
Umbellate per umbel	0.602	0.018	27.88**

Table 11

Path analysis of essential oil yield with remaining traits from stepwise regression model.

Traits	Direct effects	Indirect effects				Total effects
		Plant biomass	1000 seed weight	Canopy cover	Umbellate/umbel	
Plant biomass	0.583		0.056	0.047	0.03	0.717
1000 seed weight	0.235	0.138		0.006	0.019	0.4
Canopy cover	0.162	0.162	0.009		0.023	0.365
Umbellate per umbel	0.156	0.113	0.029	0.024		0.324

Residual effect =0.613

Table 12

Specific values, variance rate of special vectors by the principal components analysis (PCA) of the main components in 24 cumin accessions

Variables	PC1	PC2	PC3	PC4
Canopy cover	**0.31**	-0.17	-0.14	0.04
Plant height	**0.32**	0.26	-0.03	-0.09
Biological yield	**0.34**	0.17	-0.09	0.19
Seed yield	**0.36**	-0.11	-0.35	0.03
Essential oil percentage	**0.34**	0.22	0.25	-0.23
Essential oil yield	**0.42**	0.03	-0.14	-0.04
No.Umbel / plant	0.05	**0.43**	0.28	0.27
Stemming stage	0.15	**-0.41**	0.12	0.02
HI	0.09	**-0.41**	-0.35	-0.25
Physiological maturity	-0.07	-0.28	**0.35**	-0.24
Umbellate / umbel	0.24	-0.28	**0.35**	0.27
No.Seed / umbellate	0.15	-0.32	**0.45**	0.21
Flowering stage	-0.12	-0.03	-0.12	**0.61**
Umbellate / umbel	0.28	0.00	-0.05	**0.30**
1000 Seed weight	0.23	0.16	0.27	**-0.37**
Eigenvalue	4.97	2.06	2.02	1.62
Proportion	0.33	0.14	0.14	0.11
Cumulative	0.33	0.47	0.60	0.71

4. Conclusion

As plant biomass has the highest positive direct effect on the yield of Ajwain essential oil and a high negative correlation with days to the stemming stage, the selection of these traits should be considered with greater attention and emphasis in breeding programs. They were determined as suitable criterion and characters in plant breeding to produce the best of Ajwain genotypes.

Traits of plant biomass, number of umbellate in umbel, canopy cover and 1000-seed weight had the most direct effect on the essential oil yield of cumin. They were determined as suitable criterion and characters in plant breeding to produce the best of cumin accessions.

The cluster 2 contained with cumin accessions the maximum yield of essential oil. Therefore, in order to study the indigenous Cumin and Ajwain populations as well as the selection of traits, the above results should be carefully considered and emphasized in corrective programs.

This emphasizes that the selection based on plant biomass will be more effective in improving essential oil and seed yield.

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