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Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 202219(2):1251-1260. **OPEN ACCESS**

Evaluation of the relationships between the yield and yield components of Trachyspermum cultivars (*Trachyspermum copticum* L) under drought stress through multivariate analysis

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The present experiment was conducted to evaluate the relationships between the yield and yield components of Trachyspermum cultivars (*Trachyspermum copticum* L) under drought stress through multivariate analysis in winter 2021 in a farm in Germi County on nine Trachyspermum ecotypes under the two conditions of normal irrigation and drought stress until the 10% flowering stage in the form of randomized complete blocks design in three iterations. The irrigations were conducted once every eight days for the normal irrigation treatment and once every 16 days for the drought stress irrigation until harvest. Results of simple ANOVA of the normal and drought stress treatments indicated significant differences between the genotypes in terms of all the studied traits at 1% and 5% significance levels. The highest grain yields were observed in the Yazd2 ecotype under normal irrigation and better stress drought conditions with an average of 1433 and 917.67 kg/hectare, respectively. The lowest figures observed for this trait were associated with the Isfahan1 ecotype under normal irrigation and drought stress with averages of 788 and 531.67 kg/hectare, respectively. Grain yield had a significant and positive relationship with plant height under normal irrigation conditions and a significant and positive relationship with essential oil yield under drought stress. The significance of the coefficient of determination in the successful regression equations indicated the effectiveness of these traits in increasing grain yield. The aforementioned equations suggested that plant height under normal irrigation conditions and essential oil yield under drought stress conditions had positive and significant impacts on the yield, considering that they explained 78.61% and 83.04% of the change in data under normal irrigation and drought stress conditions, respectively, and (36.2%, 23.41%, and 19.005%) and (29.72%, 28.37%, and 24.94%) of total changes under normal irrigation and drought stress conditions, respectively. The most influential factors in grain yield under normal irrigation conditions included the traits of plant height, grain count, and grain yield, respectively, which had the largest positive coefficients. On the other hand, these traits influencing grain yield the most under drought stress conditions included the traits of grain yield, biological yield, and essential oil content, respectively, which had the largest positive coefficients and were determined as the grain yield factors. In the normal irrigation treatment, the first cluster included the genotypes of Kerman1, Khorasan1, Yazd1, and Isgahan1 which were superior to the other two groups in terms of the traits of plant height, grain count, and grain yield. Under the drought stress conditions, the second cluster included the genotypes of Kerman2, Isfahan2, and Yazd2 which were superior to the other two groups in terms of the traits of plant height, essential oil content, and biological yield. The first cluster in the normal irrigation treatment and the second cluster in the drought stress treatment ranked first among the other groups in terms of yield. Thus, the superior genotypes of these clusters can be cross-bred to increase the grain yield.

Keywords: drought stress, Trachyspermum, multivariate analysis

INTRODUCTION

Medicinal herbs have long been of special significance in providing public health and wellbeing and preventing and treating disease. These parts of the natural resources have a history as old as human life and have been among the most important food and medicine resources over generations (Gholamin and Khayatnezhad 2020, Khayatnezhad and Gholamin 2020, Si, Gao et al. 2020, Bi, Chen et al. 2021, Guo, She et al. 2021, Peng, Khayatnezhad et al. 2021). Historically, plants have had a great significance in the development of communities, and extensive research has been carried out to discover herbal drugs and natural medicinal products, which has particularly increased over the recent years. The most important reasons for this are the confirmation of the harmful side effects of chemical drugs on the one hand and their contribution to the environmental pollution that is damaging the earth on the other. Moreover, World Health Organization has reported that over 80% of the world population –specifically those living in poor and remote areas- cover most of their medical needs through medicinal herbs (Aminin, 2001). Trachyspermum (Sprague – Trachys Permumammi) is an annual herbaceous plant from the Carum copticum family that grows wild in eastern India, Iran, Pakistan, and Egypt (Gholamin and Khayatnezhad 2020, Chen, Khayatnezhad et al. 2021, Huang, Wang et al. 2021, Khayatnezhad and Gholamin 2021, Sun and Khayatnezhad 2021, Tao, Cui et al. 2022). Trachyspermum goes by many names such as ajowan caraway and bishop's weed in traditional medicine books. The active components of Trachyspermum essence include thymol, para-cementan, and gamma-terpinene (Chauhan et al. 2012) which have antibacterial and antifungal effects and have proven to influence the activity of the digestive enzymes in small intensities and pancreas (Cheng, Hong et al. 2021, Gholamin and Khayatnezhad 2021, Li, Mu et al. 2021, Liu, Wang et al. 2021, Ma, Ji et al. 2021). This plant is used in pharmaceuticals and the production of antitussives, antihypertension, platelet-lowering, and liver protection drugs (Esmaeili & Ghobadianpour, 2016). Thymol –which is among the active ingredients found in this plant- has medicinal effects on reducing blood pressure. Gamma-terpinene is another component of the essential oil obtained from this plant which is used in perfumery. Para-cementan is another component of the plant’s essential oil whose most significant biological feature is that it can carry various drugs through skin pores (Gholamin and Khayatnezhad 2020, Ren and Khayatnezhad 2021, Xu, Ouyang et al. 2021, Li, Khayatnezhad et al. 2022, Wang, Ma et al. 2022, Zhang, Khayatnezhad et al. 2022). The secondary metabolites seek to direct the genetic processes under the influence of environmental factors. Environmental factors play a significant part in the quality and quantity of the products obtained from medicinal herbs (Khorshid & Soudi, 2001). Drought stress is among the most important complications for crops in arid and semi-arid regions of the world and is the most significant non-biological stress which reduces crop production in these areas (Gholamin and Khayatnezhad 2020, Zhao, Wang et al. 2021, Zheng, Zhao et al. 2021, Zhu, Liu et al. 2021, Zhu, Saadati et al. 2021).With an average precipitation rate of 240mm, Iran is considered among the arid and semi-arid regions (Zare et al. 2005). The arid and semi-arid climate in Iran has impacted most regions of the country, and the recent droughts have exacerbated the problem (Safikahni et al. 2001). Crops in Iran are often cultivated under environmental drought stresses -except for those cultivated in the northern areas of the country- and suffer from drought, salinity, cold, and heat stresses (Hosseini et al. 2006). Precipitation prediction is difficult in regions such as Iran with low and variable precipitation rates from year to year. The grain yield also fluctuates under such conditions (Mohammadi et al. 2006). Mediterranean plants are always exposed to a combination of environmental stresses such as the shortage of available water, temperature changes, heavy rainfall, and nutrient deficiency (Pourdad et al. 2008).

Drought tension is among the most important factors limiting the growth and yield of plants in arid and semi-arid regions of Iran and the world. Drought stress inhibits the photochemical activities of the plant, changes the chlorophyll content in the leaves, and reduces the activity of the enzymes in the Calvin cycle in photosynthesis (Khayatnezhad and Nasehi 2021, Wang, Ye et al. 2021, Yin, Khayatnezhad et al. 2021, Zhang, Khayatnezhad et al. 2021). The effects of the stress do not manifest immediately after the stress is applied since plants have protective mechanisms to delay or stop thermodynamic and chemical disruptions inside their cells (Mazhabi et al. 2002). Given the climatic situation of Iran which categorized is as among the arid and semi-arid regions of the world and the water crisis in these regions selection of the plants compatible with such conditions is of utmost importance which requires the cultivation of drought-resistant plants with low water needs (Safarnezhad, 2006). Grain yield is a quantitative trait controlled by many genes which are not of high heritability due to the interactive effect that the environment and genotype have on it. Thus, selecting a cultivar based on grain yield – especially in the early generations- may not be very effective (Richards, 1996). Grain yield is the most significant economic trait of the plant which is the result of yield components and other associated traits (Jia, Khayatnezhad et al. 2020, Karasakal, Khayatnezhad et al. 2020, Khayatnezhad and Gholamin 2020, Hou, Li et al. 2021, Shi, Khayatnezhad et al. 2021, Sun, Lin et al. 2021). Identification of these components and their relationship with grain yield can help select the high-yield varieties. Moreover, understanding the traits affecting production and yield can be of great use in farm management and breeding programs (Hosseinpour et al. 2003). Correlation and regression analysis of the yield components are useful tools to determine the valuable genotypes (Le et al. 2006). The correlation between the traits is of great significance in plant breeding since it determines the type and intensity of the relationship between two or several traits (Pourmoradi & Mirzaie-Nodoushan, 2011). In other words, determining the correlation between various traits – particularly yield and its components- and examining their causal relationships provides the breeders with the opportunity to select the best combination of components that results in the greatest yield (Doffing & Knight, 1992). Morphological traits are easily and accurately measurable and have a high heritability, which is why selection based on these traits is a reliable and fast way to filter the plant population and increase their yield (Karasakal, Khayatnezhad et al. 2020, Khayatnezhad and Gholamin 2021, Ma, Khayatnezhad et al. 2021, Wang, Shang et al. 2021, Wang, Khayatnezhad et al. 2022). Better control of the environmental effects in breeding programs to improve yield can be implemented through the indirect selection of traits that have a high correlation with yield and are less sensitive to environmental change (Dawari, 1991). Determining the correlation between various traits such as grain yield and its components and identifying their causal relationships enables the breeders (Kouchaki, 2001) to select the best combination of components that will lead to the highest yield (Sarmadnia, 2006). Stepwise regression can be used to eliminate the impact of insignificant traits on the yield and only examine the traits that explain a considerable degree of change in the yield (Fayyaz & Talebi, 2013). In the causality analysis method, the correlation coefficients between the independent traits are analyzed into the components that measure the direct and indirect effects on the dependent variable (Farshadfar, 2005). Cluster analysis can be used to identify the traits based on the similarity and dissimilarity of groups and subgroups (Abdi 2021, Alizadeh 2021, Karasakal 2021, Mohammadzadeh 2021, Radmanesh 2021, Radmanesh 2021). This technique is used for selection in plant breeding programs (El0Deeb, 2000). Many reports suggest that grain yield maximizes when the number of spikes per unit of the area reaches a specific amount (Mohammadi et al. 2003). Bahramnezhad et al. (2011) reported that the number of umbel per plant, weight per thousand grains, grain count per umbel, and the grain length explain a total of 89% of the linear changes in grain yield. These researchers suggested that the grain count per umbel had the greatest direct effect on the grain yield of L. Cuminum cyminum. Ghanbari et al. (2014) reported that the traits of grain count per plant, umbel count per plant, and weight per thousand grains had the greatest impact on grain yield and could explain over 93% of the total change in grain yield. Maleki et al. (2017) reported that the traits of umbel count per plant and grain count per umbel explained 53% of the total changes in grain yield in Pimpinella anisum. Trachyspermum is of great significance in arid and semi-arid regions where it is usually grown through rain-fed irrigation. Few studies have been conducted on the influence of drought stress on this plant's yield and yield components in Ardebil province. The present study seeks to investigate the relationship between the yield and yield components of Trachyspermum under normal and stress conditions to identify the traits affecting grain yield and incorporate them into Trachyspermum breeding programs in the area.

MATERIALS AND METHODS

The present study was conducted in winter 2021 on a research farm in Germi County. Nine Trachyspermum ecotypes were investigated under normal and drought stress conditions in the form of a randomized complete blocks research design with three iterations. The experiment location had a semi-arid and cold climate. The plant is usually cultivated in autumn from late November to February. Plants cultivated in Iran usually cannot cover their water needs through precipitation considering that the rainfall rate is quite low in the country, and drought stress is inevitable during certain times of the year since it influences the roots throughout the life of the plant germination to the final growth stages. Farm irrigation was conducted similarly for the two normal and drought stress treatments until the 10% flowering stage. From this point on, irrigation was conducted after 50mm evaporation from the Class A pan from the normal treatment and after 100mm evaporation for the stress drought treatment, so that the normal treatment plants were irrigated every eight days and the stress drought treatment plants were irrigated every 16 days. 10 plants were randomly selected from each treatment, and the traits of umbel count, grain count per umbel, and plant height were measured. The water distillation method was conducted using a Clevenger to measure the traits of weight per thousand grains (gr), biological yield (kg/hectare), grain yield (kg/hectare), and essential oil yield (kg/hectare). Variance analysis was conducted in the form of randomized complete blocks, simple correlation coefficients between all traits were determined, and stepwise regression was used to determine the traits that influenced grain performance the most. The conducted statistical analysis included variance analysis, simple correlation coefficient, and stepwise regression, all of which were obtained from SPSS16, MSTAT-C, and Minintal15 software.

RESULTS AND DISCUSSION

Results of simple variance have been demonstrated under normal conditions (Table 1) and drought stress (Table 2). Significant differences were observed between the genotypes in terms of all the studied traits at 1% and 5% significance levels. Other studies conducted on umbelliferae have reported similar results (Bahraminejad et al. 2011; Ehsanipour et al. 2011; Ghanbari et al. 2014; and Maleki et al. 2017). . The highest grain yields were observed in the Yazd2 ecotype under normal irrigation and better stress drought conditions with an average of 1433 and 917.67 kg/hectare, respectively. The lowest figures observed for this trait were associated with the Isfahan1 ecotype under normal irrigation and drought stress with averages of 788 and 531.67 kg/hectare, respectively (Tables 3 & 4).

Tables 5 and 6 demonstrated the results of correlation between the traits under normal conditions and drought stress, respectively. Grain yield had a significant and positive relationship with plant height under normal irrigation conditions and a significant and positive relationship with essential oil yield under drought stress. Essential oil content has a significant and negative relationship with the umbel count under drought stress conditions. Essential oil essence had a significant and positive relationship with weight per thousand grains under drought stress, but the same relationship was significant and negative under normal conditions.

Results of stepwise regression under both normal and drought stress conditions examined the grain yield as the function variable (Y) and the other traits as dependent variables. As Tables 7 and 8 demonstrate, results suggested that plant height explained the largest part of the changes in grain yield under normal conditions and essential oil yield under drought stress with determination coefficients of 0.72 and 0.75, respectively. Plant height is (X1) under normal conditions and essential oil yield is (X1) under drought conditions. The following equation can thus be obtained:

$Y_{Normal} = -2648.57 + 55.621^{*}X_1$

$Y_{Drought\ Stress} = -270.65 + 32.248^{**}X_1$

The significance of the coefficient of determination is the regression equations above indicate the effectiveness of these traits in grain yield. The equations above suggest that plant height under normal conditions and essential oil yield under drought stress left positive impacts on grain yield.

Factor analysis

Factor analysis is among the most important multivariate statistical analyses. Many statistical methods are used to study the relationship between dependent and independent variables, but factor analysis is different. In other words, factor analysis explores the simple patterns in the relationships between the variables (Asghari Aboueshaq, 2005). The criterion for the selection of factors is based on the number of roots larger than one, and since the number of the initial variables used in factor analysis was 8, the selection of three factors for the experiment complied with the principles based on the F< (P+1)*2 where P and F stand for the number of variables and factors, respectively (Tousi Mojarad et al. 2005; Mollasadeghi et al. 2011). Traits with the same sign which are subsets to the same factor are all influenced by an unknown factor. Each factor does not have an individual existence but is rather the product of a set of processes and characteristics that influence it (Mollasadeghi et al. 2011). Tables 9 and 10 indicated the main results of factor analysis for normal and drought stress conditions. Factor analysis was conducted based on principal component analysis. Three factors with roots larger than one were significant for both treatments and explained around 78.61% and 83.04% of the changes in data under normal and drought stress conditions, respectively, and (36.2%, 23.41%, and 19.005%) and (29.72%, 28.37%, and 24.94%) of total changes under normal irrigation and drought stress conditions, respectively.

Given that the Varimax rotation maximized the variance between the factors, the factors that explain the largest portion of the changes between the traits are of the greatest significance and should thus be studied. Therefore, the effective traits in each factor are identified and the factors are also named after the most influential trait they include. This method makes genetic improvement of the factors possible through their respective traits (Tadesses & Bekele, 2001). Varimax rotation was used for a simpler interpretation. Table 11 suggests that under normal conditions, the traits of plant height, grain count, and grain yield had the largest positive coefficients in the first factors, respectively. In the second factor, the traits of umbel count, biologic yield, and essential oil content had large and positive coefficients. In the third factor, the traits of weight per thousand grains and essential oil yield had large positive and negative coefficients while other traits had low figures. Thus, this factor was named as the one effective on essential oil given its higher factor load in this regard (Table 11). Table 12 suggests that under drought stress, the traits of umbel count, weight per thousand grains, and essential oil yield had large positive and negative coefficients in the first factor, as a result of which the factor was named the one affecting yield components. In the second factor, the traits of grain yield, biologic yield, and essential oil content had large and positive coefficients and the factor was thus named the grain yield factor. In the third factor, the traits of plant height and grain co ount had large positive and negative values while the other traits had low figures (Table 12).

Table 1: Results of analysis of variance of evaluated traits under normal conditions

Source	df	Mean of Squares							
		Plant height	Number of umbrellas	Number Of seeds	1000 grain weight	Biological yield	Grain yield	Essential oil	Essential oil percentage
Replication	2	7.566**	1.489*	20.37**	0.023**	2582**	509.04**	0.875*	0.284**
Genotypes	7	35.06**	238.6**	476.7**	0.298**	298239**	208416.3*	10.375**	0.259**
Error	14	0.114	0.279	0.042	0.001	36	29.32	0.161	0.004
C. V %									

* and ** Significantly at p < 0.05 and < 0.01, respectively.

Table 2: Results of analysis of variance of evaluated traits under drought stress conditions

Source	df	Mean of Squares							
		Plant height	Number of umbrellas	Number of seeds	1000 Grain weight	Biological yield	Grain yield	Essential oil	Essential oil percentage
Replication	2	9.448*	0.093ns	8.042**	0.017**	3844.6**	276.32*	1.542**	0.039**
Genotypes	7	50.94**	88.15**	396.6*	0.125**	133714.5**	52059.8**	39.47**	0.296**
Error	14	1.734	0.047	0.042	0.0001	120.5	61.83	0.113	0.001
C. V %									

* and ** Significantly at $p < 0.05$ and < 0.01, respectively.

Table 3: Comparison of the mean of the evaluated traits under normal conditions

Genotypes	Plant Height (cm)	Number Of umbrellas	Number of seeds	1000 grain Weight (gr)	Biological Yield (kg/ha)	Grain yield (kg/ha)	Essential oil (kg/ha)	Essential Oil percentage
Kerman 1	64.00 f	34.40 c	60.67 g	0.73 f	2999.67 e	953.67 f	37.67 bc	2.96 d
Kerman 2	63.07 g	25.10 g	58.33 h	1.46 c	3015.67 d	786.00 g	35.67 e	3.25 bc
Yazd 1	68.00 d	26.40 f	71.67 d	1.40 d	3147.33 b	1396.67 b	36.67 d	2.58 e
Yazd 2	68.83 c	44.67 b	69.67 e	1.49 c	3105.33 c	<u>1433 a</u>	35 ef	<u>3.54 a</u>
Khorasan 1	70.67 b	30.40 d	67.67 f	1.63 b	<u>3612 a</u>	1180 d	37.33 cd	3.17 c
Khorasan 2	<u>73.67 a</u>	<u>48.60 a</u>	<u>99.67 a</u>	<u>1.68 a</u>	2484 h	1361.33 c	38.33 b	3.30 b
Esfahan 1	66.67 e	27.77 e	74.67 b	1.63 b	2847.33 f	788.00 g	34.33 f	3.31 b
Esfahan 2	67.73 d	27.07 ef	72.67 c	1.17 e	3106.67 c	1094.67 f	<u>40 a</u>	3.35 b

Means that have at least one letter in common do not differ significantly at the 5% level of the LSD test.

Table 4: Comparison of the mean of the evaluated traits under drought stress conditions

Genotypes	Plant height (cm)	Number of umbrellas	Number of seeds	1000 grain weight (gr)	Biological Yield (kg/ha)	Grain yield (kg/ha)	Essential oil (kg/ha)	Essential Oil percentage
Kerman 1	48 cd	22.83 b	52 f	0.50 g	2193.33 g	564.67 f	25.67 f	3.41 f
Kerman 2	47 d	15.17 e	48 g	0.94 d	2459 d	709.33 e	27.67 e	<u>4.25 a</u>
Yazd 1	<u>57.67 a</u>	14.40 f	61 b	0.85 e	<u>2737.33 a</u>	845 b	32.67 c	3.96 b
Yazd 2	49.67 c	<u>30.93 a</u>	54 e	0.60 f	2595 b	<u>917.67 a</u>	<u>35.33 a</u>	3.30 g
Khorasan 1	53.67 b	23.20 b	58 c	0.98 c	2303 f	701.67 e	31.33 d	3.50 e
Khorasan 2	55 b	23.00 b	<u>85 a</u>	0.99 c	2094.33 h	753.67 d	33.00 c	3.49 e
Esfahan 1	54 b	22.13 c	56 d	<u>1.04 a</u>	2398.33 e	531.67 g	27.33 e	3.61 d
Esfahan 2	46.83 d	17.00 d	52 f	1.02 b	2510.33 c	797.90 c	34.67 b	3.69 c

Means that have at least one letter in common do not differ significantly at the 5% level of the LSD test.

Table 5: Simple correlation coefficients between the evaluated traits under normal conditions

	Plant height	Number of umbrellas	Number of seeds	1000 Grain weight	Biological yield	Grain yield	Essential oil	Essential oil percentage
Plant height	1							
Number of umbrellas	0.624	1						
Number of seeds	.836**	0.625	1					
1000 grain weight	0.584	0.181	0.494	1				
Biological yield	-0.139	-0.475	-0.637	-0.075	1			
Grain yield	.722*	0.591	0.479	0.224	0.047	1		
Essential oil	0.297	0.055	0.277	-0.701*	0.001	0.225	1	
Essential oil percentage	0.181	0.41	0.182	0.318	-0.185	-0.109	-0.115	1

* and ** Significantly at $p < 0.05$ and < 0.01, respectively

Table 6: Simple correlation coefficients between the evaluated traits under drought stress conditions

	Plant height	Number of umbrellas	Number Of seeds	1000 grain weight	Biological yield	Grain yield	Essential oil	Essential oil percentage
Plant height	1							
Number of umbrellas	-0.037	1						
Number of seeds	0.628	0.147	1					
1000 grain weight	0.294	-0.458	0.269	1				
Biological yield	0.063	-0.286	-0.478	-0.031	1			
Grain yield	0.065	0.083	0.129	-0.091	0.575	1		
Essential oil	0.166	0.2	0.31	0.752*	0.389	.888**	1	
Essential oil percentage	-0.053	-.868**	-0.269	0.407	0.408	0.029	-0.225	1

* and ** Significantly at $p < 0.05$ and < 0.01, respectively

Table 7:Standard component regression coefficients and coefficients explaining the traits related to grain yield under normal irrigation conditions

Model	Unstandardized Coefficients		Standardized Coefficients	t	sig
	B	Std.Error	Beta		
(Constant)	-2648.57	1478.77		-1.791	0.123
Plant height	55.621	21.77	0.722	2.554	0.043

Table 8:Standard component regression coefficients and coefficients explaining the traits related to grain yield under drought stress conditions

Model	Unstandardized Coefficients		Standardized Coefficients	t	sig
	B	Std.Error	Beta		
(Constant)	-270.65	212.54		-1.273	0.25
Essential oil	32.248	6.825	0.888	4.725	0.003

Table 9: The results of factor analysis under normal irrigation conditions for the first 3 factors that became significant

factors	Total	% of Variance	Cumulative%
1	2.896	36.200	36.200
2	1.873	23.410	59.610
3	1.520	19.005	78.615

Table 10: The results of factor analysis under drought stress conditions for the first 3 factors that became significant

factors	Total	% of Variance	Cumulative%
1	2.378	29.725	29.725
2	2.270	28.374	58.099
3	1.995	24.940	83.039

Table 11: Roots of factor decomposition after varimax rotation under normal conditions

Extraction	3	2	1	Factor Traits
.951	.092	.183	.953	**Plant height**
.711	.043	.603	.589	**Number of umbrellas**
.880	.009	.601	.721	**Number of seeds**
.859	.780	.045	.499	**1000 grain weight**
.840	.052	-.915	-.012	**Biological yield**
.809	-.135	-.102	.883	**Grain yield**
.736	-.799	.074	.303	**Essential oil**
.503	.492	.511	.012	**Essential oil percentage**

Table 12: Factors of decomposition roots after varimax rotation under drought stress conditions

Extraction	3	2	1	Factor Traits
.627	.779	.114	.082	**Plant height**
.876	-.004	.056	-.935	**Number of umbrellas**
.891	.916	.004	-.227	**Number of seeds**
.671	.560	-.042	.596	**1000 grain weight**
.827	-.351	.732	.409	**Biological yield**
.933	.051	.962	-.062	**Grain yield**
.913	.299	.888	-.186	**Essential oil**
.906	-.139	.030	.941	**Essential oil percentage**

The further the parents are genetically in a breeding program, the greater the degree of segregation in their offspring will be. The principal goal of cluster analysis is to determine the genetic distance of the hybrids from one another so that the researcher can first classify the genotypes based on cluster analysis and select several genotypes from superior clusters based on the desired traits and limit the cross-breeding blocks instead of spending an excessive amount of time and effort into a multitude of random cross-breeding to find the desirable genotype by chance. In the normal irrigation treatment, the first cluster included the genotypes of Kerman1, Khorasan1, Yazd1, and Isgahan1 which were superior to the other two groups in terms of the traits of plant height, grain count, and grain yield. Under the drought stress conditions, the second cluster included the genotypes of Kerman2, Isfahan2, and Yazd2 which were superior to the other two groups in terms of the traits of plant height, essential oil content, and biological yield. The second group included the genotypes of Khorasan 2 and Yazd 1, and the third group included the genotypes of Kerman 2 and Isfahan 1. The first cluster in the normal irrigation treatment and the second cluster in the drought stress treatment ranked first among the other groups in terms of yield. Thus, the superior genotypes of these clusters can be cross-bred to increase the grain yield.

Under drought stress conditions, the genotypes of Kerman1, Isfahan1, Khorasan1, and Khorasan2 had the highest value in terms of umbel count, weight per thousand grains, and essential oil yield in the first cluster, while the genotypes of Kerman2, Isfahan2, and Yazd1 in the second group were superior to the other two groups in terms of grain yield, biologic yield, and essential oil content. This cluster ranked first among the groups. The superior genotypes from this cluster can thus be used in cross-breeding. Eventually, the yazd2 genotype fell into the third group alone (Figure 2).

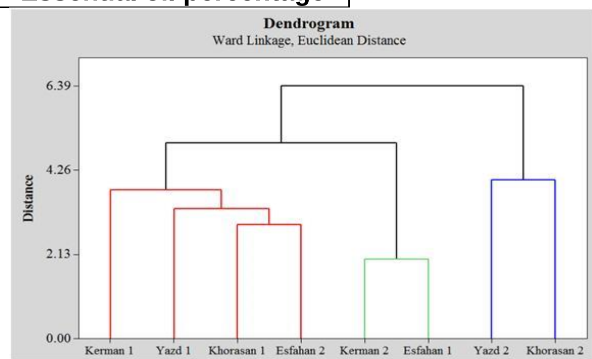

Figure 1: Dendrogram obtained from cluster analysis by Ward method based on the evaluated traits by stepwise regression method under normal conditions

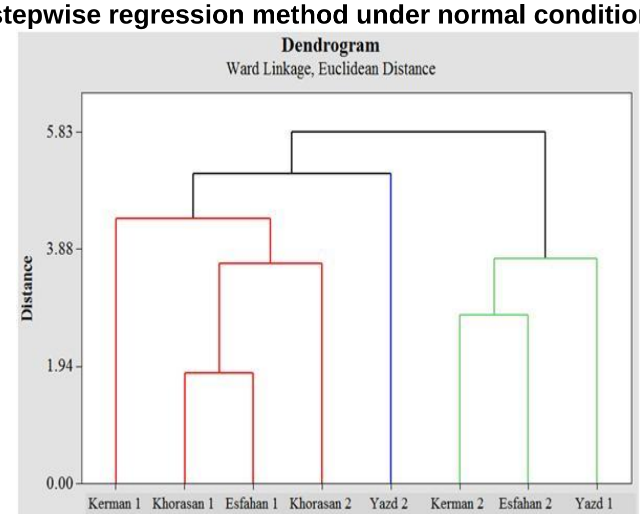

Figure 2 : Dendrogram obtained from cluster analysis by Ward method based on the evaluated traits by stepwise regression method under drought stress conditions

CONCLUSION

Under the drought stress conditions, the second cluster included the genotypes of Kerman2, Isfahan2, and Yazd2 which were superior to the other two groups in terms of the traits of plant height, essential oil content, and biological yield. The first cluster in the normal irrigation treatment and the second cluster in the drought stress treatment ranked first among the other groups in terms of yield. Thus, the superior genotypes of these clusters can be cross-bred to increase the grain yield.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

ACKNOWLEDGEMENT

This paper was from 1399-598658 Project, 2021, Young researchers Club.

AUTHOR CONTRIBUTIONS

Mani Alizadeh conducted, planned, Analyzed the data, wrote manuscript and interpreted the results and involved in manuscript preparation. All authors read and approved the final version.

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