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Determination of Relationship between Yield Components in Rosemary (*Rosmarinus officinalis* L.) Genotypes

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Abstract: The purpose of this study is to determine similarities/dissimilarities of rosemary genotypes and plant characteristics by different statistical methods, and effectiveness the plant characteristics on drug leaf yield and essential oil yield in Rosemary *(Rosmarinus officinalis* L.). Plant height, fresh leaf/fresh herb, drug leaf/fresh herb, essential oil content, fresh herb yield, fresh leaf yield, drug leaf yield and essential oil yield were measured. Data were evaluated by different statistical analyses methods such as correlation, factor, double dendrogram, biplot, agglomerative hierarchical cluster and regression. Results revealed that the essential oil content and fresh herb yield were determined as the most important parameters to be considered. When the essential oil yield is considered as the target criterion; fresh leaf/fresh herb, the drug leaf/fresh leaf, the essential oil content and the fresh leaf yield will increase success of rosemary breeding.

Keywords: Rosemary *(Rosmarinus officinalis* L.), Agglomerative hierarchical cluster, Biplot, Correlation, Factor, Double dendrogram, Genotypes, Regression, Statistical analyses methods.

Biberiye *(Rosmarinus officinalis* L.) Genotiplerinde Verim Komponentleri Arasındaki İlişkinin Belirlenmesi

Öz: Bu çalışmanın amacı, biberiye genotiplerinin ve bu genotiplere ait bitkisel özelliklerinin benzerlik/farklılıklarını farklı istatistiksel yöntemlerle belirlemek; biberiye genotiplerinde *(Rosmarinus officinalis* L.)'de drog yaprak verimi ve uçucu yağ verimi üzerine etkili olan bitkisel özellikleri ortaya çıkararak ıslahta kullanılabilirtliklerini belirlemektir. Bu bağlamda çalışmada ele alınan bitki boyu, taze yaprak/taze herba, drog yaprak/taze herba, uçucu yağ oranı, taze herba verimi, taze yaprak verimi, drog yaprak verimi ve uçucu yağ verimi değerleri korelasyon, faktör, double dendrogram, biplot, aglomeratif hiyerarşik kümeleme ve regresyon gibi farklı istatistiksel analiz yöntemleri ile değerlendirimiştir. Çalışma sonuçlarına göre uçucu yağ oranı ve taze herba veriminin, göz önünde bulundurulması gereken en önemli parametreler olarak belirlenmekle beraber; uçucu yağ verimi hedef kriter olarak kabul edildiğinde bu kriterler üzerinde ettili olan taze yaprak/taze bitki, drog yaprak/taze yaprak, uçucu yağ oranı ve taze yaprak veriminin biberiye ıslah çalışmalarında kullanımının islah başarısını artıracağı sonucuna varılmıştır.

Anahtar Kelimeler: Biberiye *(Rosmarinus officinalis* L.), Aglomeratif hiyerarşik kümeleme, Biplot, Korelasyon, Faktör, Double dendrogram, Genotipler, Regresyon, İstatistik analiz yöntemleri.

1. Introduction

Rosemary (*Rosmarinus officinalis* L.), one of the important species of the Lamiaceae/Labiatae family, has great preliminaries as a medicinal aromatic plant. The plant is distributed in the natural flora of the Mediterranean basin (Ceylan, 1987; Aslan et al. 2015). Rosemary is known in different parts of Turkey by names such as bush yard, hasbal and akpüren. In addition, there are various chemotypes of rosemary such as 1.8-cineole (eucalyptol) (Turkey, Greece, Yugoslavia, Italy, Morocco, and Tunisia), camphor-borneol (Spain) and α-pinene-verbanone (France and Corsica) (De

Mastro et al. 2004). Rosemary having a strong taproot and a plant height of 50-100 cm, needle-shaped leaves and pale blue flowers is an evergreen, perennial, in bush form and cross-fertilization plant (Malayoğlu, 2010; Hussain et al. 2010). Rosemary that is commercially cultivated in France, Spain, Portugal, and Greece, has been gathered from the natural flora and presented to both the domestic and foreign markets in Turkey. The amount of rosemary, mainly collected from natural flora in Mersin and Adana regions and presented to the internal market and exported show great fluctuations depending on the years in Turkey (Aslan et al. 2015). Rosemary, naturally distributing in Turkey's Aegean and Mediterranean coasts, is intensely presence in the maquis shrubland of Çanakkale, Mersin, Adana and Tarsus provinces. Rosemary is widely used in aromatherapy and folk medicine because of the essential oils it contains, as well as being used as an ornamental plant in different regions of the world (Baytop, 1984; Bai et al. 2010). Rosemary has well known a medicinal plant and has been used as anti-oxidant, anti-cancer, antidiabetic, anti-inflammatory, antimicrobial, antifungal, antimutagenic, antispasmic, wound healing, strengthening capillaries of hair and protecting the liver. On the other hand, its essential oil is used as a raw material in aromatherapy, perfumery and cosmetics industry (Gülbaba et al. 2002). The quality and efficacy of medicinal aromatic plants vary depending on the ratio of bioactive substances in the drug used and the presence of specific chemical compounds in the main seconder metabolite and the relative proportion of these compounds in the active substance. As is known, there are two sources of medical aromatic plants presented to the market. Either the product presented to the market is collected directly from natural flora or it is cultivated in the field (Hussein et al. 2006; Begum et al. 2013).

Rosemary (*Rosmarinus officinalis* L.) has attracted attention as an important medicinal aromatic plant in recent years. Therefore, there is a need to improve new varieties in order to meet the increasing demand for quality and standard products. In this context, it is necessary to develop rosemary-related breeding programs, to work with a wide range of genetic material, and to apply them inbreeding programs by determining effective yield and quality elements (Gülbaba et al. 2002). Breeding programs in medicinal and aromatic plants should include effective plant characteristics such as plant height, essential oil content and yield, fresh herb yield, fresh leaf yield and drug leaf yield, and effectiveness of plant characters should be determined by different analysis methods (Ceylan, 1987; Baydar, 2013). Plant height, essential oil contents, and yields, essential oil composition, drug leaf yield mostly determine drug quality of plant (Malayoğlu, 2010). Fresh leaf yield, drug leaf yield, and essential oil yield were reported as close related characters with high yielding and quality plants (Solomon and Beemnet, 2011).

Different plant characteristics have been successively used in different plant breeding programs (Mulas et al. 1998; Johnson and Franz, 2002; Munnu, 2004) and various statistical methods comprising correlation, regression, factor analysis, cluster analysis in determining effectiveness of plant characters (Begum et al. 2013). The purpose of this study is to determine similarities/dissimilarities of rosemary genotypes and plant characteristics by different statistical methods, and effectiveness the plant characteristics on drug leaf yield and essential oil yield in Rosemary *(Rosmarinus officinalis* L.)

2. Material and Methods

This study was carried out in the experimental area of Eskişehir Osmangazi University Agricultural Faculty Field Crops Department in 2018. Ten rosemary genotypes, used in this study as seedling materials, were collected from different regions of Mersin-Adana region of Turkey between 1 March and 7 April of 2017. The regions in which naturally grown rosemary genotypes were collected in our country were given in the map in Figure 1.

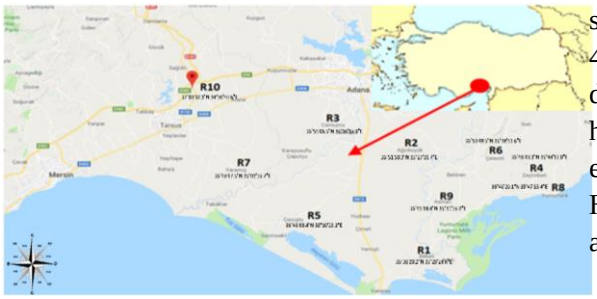


Figure 1. Rosemary (*Rosmarinus officinalis* L.) genotypes-gathered locations
Şekil 1. *Biberiye (Rosmarinus officinalis L.) genotiplerinin toplandığı lokasyonlar*

Seedling materials, gathered, were transplanted to field with width of 75 cm and row space of 40 cm in 20 April 2017 and allowed to grow. No fertilization was done on the experimental plots. The weed struggles were made by hand hoe to obtain well crop growth in the plant-growing period. Two times irrigation (first in transplanting, second in flowering stage) was applied. No irrigation was made in maturation period due to 475 mm annual precipitation (plants in mature period can overcome water stress). The plants were harvested from a height of 40 cm on 25 April 2018 during the flowering period of 50%. Plant samples were dried in drying oven at 35 oC for 48 hours. Plant height, fresh leaf/fresh herb, drug leaf/fresh herb, essential oil content, fresh herb yield, fresh leaf yield, drug leaf yield and essential oil yield (Tesi, 1994; Johnson and Franz, 2002; Ceccarini et al. 2002; Gülbaba et al. 2002; Hussain et al. 2010) were measured.

In order to determine the essential oil content, 100 g drug leaf samples in 1.0 L water from each genotype were extracted by hydro-distillation for 3 hours using Clevenger apparatus according to the standard procedure described in European Pharmacopoeia (Stainier, 1975) for determining the oil content (v/w, %).

Data were evaluated by statistical analyses methods, correlation (Dewar, 1996), factor (Tosi Mojarad et al. 2005), double dendrogram (Anonymous., 2018), biplot (Gower and dan Hand, 1996), agglomerative hierarchical cluster (Jobson, 1992) and regression (Harvey and Pagel, 1991) and Minitab 17, MS Excel, NCSS and SPSS statistical softwares were used.

3. Results and Discussion

The minimum, maximum and average values of ten different rosemary genotypes were given in Table 1.

Table 1. The minimum, maximum and average values of ten different rosemary genotypes
Çizelge 1. *On farklı biberiye genotiplerinin minimum, maksimum ve ortalama değerleri*

Variable	Minimum	Maximum	Mean
Pl. He. (cm) A_1	45.00	61.00	52.70±4.79
Fr. L./Fr Herb (%) A_2	64.50	85.10	73.47±5.19
Drug Leaf/Fr. Herb (%) A_3	23.56	35.10	30.06±3.12
Essen.Oil Cont. A_4	0.40	0.70	0.52±0.09
Fr. Herb Yield (ton/ha) A_5	40.57	50.38	44.84±2.47
Fr. Leaf Yield (ton/ha) A_6	26.17	42.87	33.06±4.23
Drug Leaf Yield (ton/ha) A_7	8.37	13.74	11.84±1.59
Essen. Oil Yield (l/ha) A_8	47.82	88.06	61.36±13.45

Correlation table related to plant components {plant height (A_1), fresh leaf/fresh herb (A_2), drug leaf/fresh herb (A_3), essential oil content (A_4), fresh herb yield (A_5), fresh leaf yield (A_6), drug leaf yield (A_7) and essential oil yield (A_8)} in ten rosemary genotypes were given in Table 2.

Correlation Analysis is successfully applied methods to reveal the relationship between the examined components and gives satisfactory information to the researcher in terms of the outcome (Dewar, 1996; Leilah and Al-Khateeb, 2005). It is also used successfully in agricultural researches and breeding programs (Leilah and Al-Khateeb, 2005). As can be seen from Table 2, positive and significant ($p<0.05$) relationships were determined between A_1-A_7 and A_8, A_2-A_7 and A_8, A_4 and A_8, A_5-A_7 and A_8, A_6-A_7 and A_8. Besides, positive and significant ($p<0.01$) relationships were found between A_1-A_2, A_5 and A_6, A_2-A_5 and A_6, A_3 and A_7. As a result,

parameters closely related to drug leaf yield (A_7) and essential oil yield (A_8) were determined as plant height (A_1), fresh leaf/fresh herb (A_2), drug leaf/fresh herb (A_3), essential oil content (A_4), fresh herb yield (A_5) and fresh leaf yield (A_6).

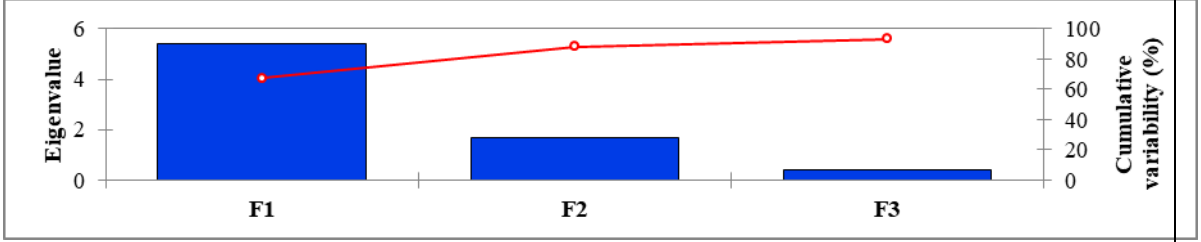
Table 2. Correlation table related to plant components in rosemary (*Rosmarinus officinalis* L.) genotypes

Çizelge 2. *Biberiye (Rosmarinus officinalis L.) genotiplerinde bitki komponentlerine ait korelasyon tablosu*

	A_1	**A_2**	**A_3**	**A_4**	**A_5**	**A_6**	**A_7**
Fr. L./Fr Herb (%) A_2	0.904**						
Drug Leaf/Fr. Herb (%) A_3	0.430**ns**	0.503**ns**					
Essen.Oil Cont. A_4	0.192**ns**	0.255**ns**	-0.371**ns**				
Fr. Herb Yield (ton/ha) A_5	0.904**	0.959**	0.503**ns**	0.255**ns**			
Fr. Leaf Yield (ton/ha) A_6	0.898**	0.939**	0.477**ns**	0.276**ns**	0.962**ns**		
Drug Leaf Yield (ton/ha) A_7	0.680*	0.774*	0.936**	-0.160**ns**	0.774*	0.755*	
Essen. Oil Yield (l/ha) A_8	0.638*	0.759*	0.297**ns**	0.748*	0.759*	0.762*	0.530**ns**

Table 3. Factor analysis of parameters in in rosemary (*Rosmarinus officinalis* L.) genotypes

Çizelge 3. *Biberiye (Rosmarinus officinalis L.) genotiplerinde parametrelerin faktör analizi*



Variables	**F_1**	**F_2**	**Communality**
Pl. He. (cm) A_1	**0.869**	0.019	0.756
Fr. L./Fr Herb (%) A_2	**0.984**	0.043	0.970
Drug Leaf/Fr. Herb (%) A_3	0.589	**-0.607**	0.715
Essen.Oil Cont. A_4	0.261	**0.916**	0.908
Fr. Herb Yield (ton/ha) A_5	**0.984**	0.043	0.970
Fr. Leaf Yield (ton/ha) A_6	**0.976**	0.069	0.958
Drug Leaf Yield (ton/ha) A_7	**0.849**	-0.485	0.956
Essen. Oil Yield (l/ha) A_8	**0.790**	0.458	0.833
Latent Root	5.41	1.66	7.07
Factor Variance (%)	67.58	20.76	88.33

Variables	**Loading**	**% Total Communality**	**Suggested Factor Name**
Factor$_1$			***Fr. L./Fr Herb (%) A_2***
Pl. He. (cm) A_1	**0.869**	0.756	***Fr. Herb Yield (ton/ha) A_5***
Fr. L./Fr Herb (%) A_2	**0.984**	0.970	***Fr. Leaf Yield (ton/ha) A_6***
Fr. Herb Yield (ton/ha) A_5	**0.984**	0.043	
Fr. Leaf Yield (ton/ha) A_6	**0.976**	0.069	
Drug Leaf Yield (ton/ha) A_7	**0.849**	-0.485	
Essen. Oil Yield (l/ha) A_8	**0.790**	0.458	
Factor$_2$			
Drug Leaf/Fr. Herb (%) A_3	**-0.607**	**-0.607**	***Essen.Oil Cont. A_4***
Essen.Oil Cont. A_4	**0.916**	**0.916**	

Factor Analysis, as a statistical method, reveals the relationship of the common core factors in terms of the values obtained as a result of observations in the studies carried out. This analysis method, used for a long time, has been used successfully in agricultural studies as well as in many branches of science and has successfully been applied in determining the importance levels of the elements examined and the close and distant relations between the elements. Moreover, this method is effectively used to reveal more important parameters in many parameters examined (Golabady and Arzani, 2003; Tosi Mojarad et al. 2005). Factor analysis of the parameters examined in 10 different rosemary genotypes was given in Table 3.

As can be seen from the factor analysis was given in Table 3, Factor 1 and Factor 2, which account for a cumulative 88.33% as a scree plot, were taken into account. Hence, these two factors account for approximately 88% of the test, so the considerations on these two factors were taken into consideration. Plant height (A_1), fresh leaf/fresh herb (A_2), fresh herb yield (A_5), fresh leaf yield (A_6), drug leaf yield (A_7) and essential oil yield (A_8) in Factor 1; drug leaf/fresh herb (A_3) and essential oil content (A_4) in Factor 2 were determined as effective plant components. So, factor analysis revealed that fresh leaf/fresh herb (A_2), essential oil content (A_4), fresh herb yield (A_5) and fresh leaf yield (A_6) should be taken into account as important parameters in agronomy and breeding programs in rosemary (*Rosmarinus officinalis* L).

Double Dendrogram, as a different cluster analysis, is an analysis method, which allows the analysis of the values in two different directions. It reveals the similarity/difference between the parameters in the row and column and reveals the interaction distribution of both parameters. In this method, it is possible to see the similarity and difference between the parameters in both directions. Variables with similar scalars form a cluster close to each other and a double dendrogram map is formed as a two-way dendrogram (Anonymous, 2018). The double dendrogram of the parameters and genotypes, examined in rosemary was given in Figure 2.

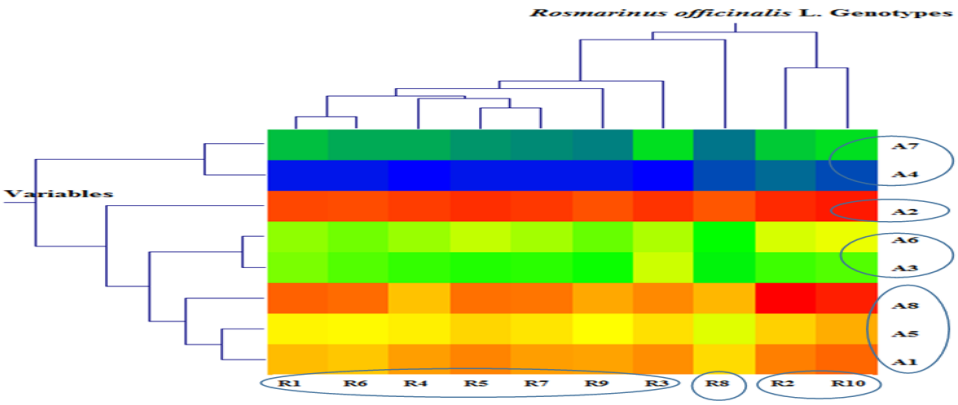


Figure 2. The double dendrogram of the parameters and genotypes, examined in rosemary (*Rosmarinus officinalis* L.)
Şekil 2. *Biberiye (Rosmarinus officinalis* L.*)'de ölçülen genotiplerin ve parametrelerin double dendrogram analizi*

Though, drug leaf yield (A_7) and essential oil content (A_4) formed one group, other group had fresh leaf yield (A_6) and drug leaf/fresh herb (A_3). Essential oil yield (A_8), fresh herb yield (A_5) and plant height (A1) joined in same group, and fresh leaf/fresh herb (A_2) was alone. In rosemary (*Rosmarinus officinalis* L.) genotypes, R_2 and R_{10} created same group; R_1, R_3, R_4, R_5, R_6, R_7 and R_9 placed in same group. R_8, alone had one another group (Figure 2).

According to this analysis, parameters, drug leaf/fr. herb (A_3), essential oil content (A_4) and fresh herb yield (A_5), could be taken into account in the development of promising genotypes inbreeding and agronomic programs on rosemary *(Rosmarinus officinalis* L.).

The Biplot Analysis, that can be considered in the principal component and factor analysis or is itself a separate meaning, is an important method of analyzing the similarities/differences between the studied components and the secondary components considered, and also in determining the stability of these components. This method of analysis takes into account the Eigenvalues and reveals the closeness and distance of the parameters according to their distances to the axes (Gower and dan Hand, 1996). In this context, Biplot analysis, showing the similarities/ differences of the Rosemary genotypes and the data examined on these genotypes, their performance and their stability status, were given in Figure 3.

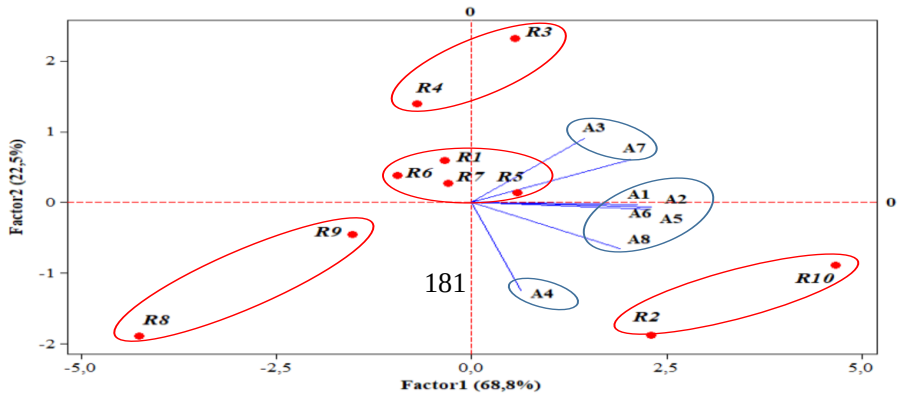


Figure 3. Biplot analysis related to rosemary genotypes and plant parameters
Şekil 3. *Biberiye genotipleri ve bitki parametrelerine ait Biplot analizi*

In Rosemary genotypes, R_2 and R_{10} formed a similar group, R_8 ve R_9, R_4 and R_3 created a similar two-membered group. In addition, R_1, R_5, R_6, R_1, R_5, R_6, and R_7 also formed a group. On the other hand, if the parameters examined on the Rosemary genotypes were considered, A_4 formed a separate group, while A_3 and A_7 formed a binary group. Apart from this, A_1, A_2, A_5, A_6, and A_8 were in the same group. In the light of these explanations, plant characteristics, plant height (A_1), fresh leaf/fresh herb (A_2), drug leaf yield (A_7) and essential oil yield (A_8) as a stable and high value parameters in all rosemary genotypes could be safely handled in genotype development and breeding programs.

The Agglomerative Hierarchical Cluster Analysis is a method of analysis that identifies the similarities/differences of the examined variables, revealing the homogeneity groups of the post-analysis generated variables. In this method, two different groups of variables are examined and it is possible to determine which group they enter according to similarity and closeness. The main disadvantage of this method is that as the number of examined parameters increases, the explanatory power of the dendrogram decreases, but when the number of variables is considered, it can be successfully used (Jobson, 1992). The agglomerative hierarchical cluster analysis of the parameters examined on the Rosemary genotypes is given in Figure 4.

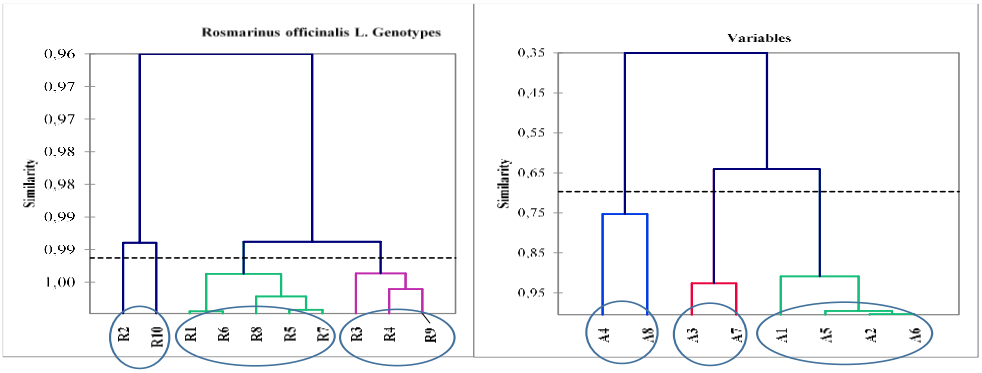


Figure 4. The agglomerative hierarchical cluster analysis of the parameters examined on the rosemary genotypes
Şekil 4. *Biberiye genotiplerinde ölçülen parametrelerin agglomerative hierarchical cluster analizi*

As shown in Figure 4, while R_2 and R_{10} formed a group in the Rosemary genotypes, the genotypes R_3, R_4, and R_9 showed similarity by entering the same group. Multiple groups with other similarities were identified as genotypes of R_1, R_5, R_6, R_7, and R_8. If parameters are examined, A_4 and A_8 and A_3 and A_7 formed two separate groups. The other parameters A_1, A_2, A_5, and A_6 formed multiple groups. As a result of agglomerative hierarchical cluster analysis, drug leaf/fresh herb (A_3) and essential oil content (A_4) were found as effective plant parameters. The similarities/dissimilarities of the rosemary genotypes by using different statistical analysis methods (Double dendrogram, Biplot and Agglomerative hierarchical cluster analyses) were given in Table 4.

Table 4. The similarities/dissimilarities of the rosemary genotypes by using different statistical analysis methods
Çizelge 4. *Biberiye genotiplerinin farklı istatistik analiz metotları kullanılarak ortaya konan benzerlik ve farklılıkları*

Analyses	**Similarities of *Rosmarinus officinalis* L. Genotypes**									
Double Dendrogram	R2	R10	R1	R5	R6	R7	R3	R4	R9	R8
Biplot	R2	R10	R1	R5	R6	R7	R3	R4	R8	R9
Agglo.. Hier.Clust.	R2	R10	R1	R5	R6	R7	R3	R4	R8	R9

R_2 and R_{10}, and R_1, R_5, R_6, and R_7 were in the same group in all three-analysis methods. In the double dendrogram analysis, R_3, R_4 and R_9 formed a group, while R_8 differed from other genotypes. In the biplot and agglomerative hierarchical cluster analyses, R_3 and R_4 formed one group while the R_8 and R_9 genotypes formed another group. As a result of all three analyzes, R_2 and R_{10} were identified as similar genotypes while the other groups R_1, R_5, R_6 and R_7 were similar genotypes in terms of the parameters examined. R_3 with R_4 and R_8 with R_9 were also shown as similar genotypes. These genotypes identified in the light of these explanations can be successfully used inbreeding and agronomic studies, taking into account the similarities and differences. In addition, breeding programs can be carried out more easily by demonstrating the similarities and differences of genotypes in studies to be carried out. As a matter of fact, determination of the genetic pool which is available in the breeding studies carried out on the Rosemary plant which is in need of research, revealing the variation between them due to the different parameters and revealing promising genotypes by considering the similarities/ differences according to these parameters will increase the chance of success of the breeding program

(Gülbaba et al. 2002; Solomon and Beemnet, 2011). Using different statistical analysis methods, the efficiency scores of the parameters examined on the rosemary genotypes are shown, and the state of the parameters that are the most influential result of these analysis methods was given in Table 5.

Table 5. Efficiency scores of the parameters examined on the Rosemary genotypes using different statistical analysis methods

Çizelge 5. *Biberiye genotiplerinde incelenen parametrelerin farklı istatistiksel analiz yöntemleri kullanılarak ortaya konan verimlilik puanları*

	Correlation	Factor	Double Dend.	BiPlot	Agglo. Hi.Clu.	Freq.
Pl. He. (cm) A_1	*			*		2
Fr. L./Fr Herb (%) A_2	*	*		*		3
Drug Leaf/Fr. Herb (%) A_3	*		*		*	3
Essen. Oil Cont. A_4	*	*	*		*	4
Fr. Herb Yield (ton/ha) A_5	*	*	*	*		4
Fr. Leaf Yield (ton/ha) A_6	*	*		*		3

Essential Oil Content — Fresh Herb Yield (ton/ha)

When the table was examined, although most of the plant parameters examined were found as effective components in correlation, factor and biplot analyses. The main decision-making methods of analysis were assigned as double dendrogram and agglomerative hierarchical cluster analysis. As a result of these analysis methods, essential oil content (A_4) fresh herb yield (A_5) was shown as effective parameters to be considered inbreeding and breeding programs to be carried out with rosemary plant. Besides, other studies similar to the results obtained in this study indicate that plants with high levels of fresh herb yield and essential oil content are evaluated as promising genotypes (Solomon and Beemnet, 2011). Rosemary *(Rosmarinus officinalis* L.) has become an increasingly important plant in recent years as a medicinal and aromatic plant for both personal and industrial purposes. Just as in the world, Rosemary is wildly collected from nature and used in our country. This plant breeding and genotype development studies to be carried out accordingly are very new and detailed investigations have to be done. In this context, there is a strong need to improve breeding practices and to develop varieties (Mulas et al. 1998).

Multiple regression analysis measures the effect of independent variables on dependent variables, especially inbreeding and agronomic studies, and a statistic that is used as a factor in predicting the estimated number of dependent variables in agricultural studies (Anonymous, 2009). Especially inbreeding studies, the target parameters such as fresh herb yield, yield, leaf yield, this method is a useful method for revealing the shapes and degrees of influence of other independent parameters on the dependent parameter (Johnson and Franz, 2002). In many studies wheat and barley, yield parameters such as number of plant per m2, number and weight of grains per spike and grain filling period were found to have a significant effect on the yield; by using effective plant components estimating yield with more than 80% accuracy could be possible. It was reported that in estimating the oil yield with high correlation in the sunflower, plant height, table diameter, number of grain in the table could be effectively used (Munnu, 2004). Fresh herb yield, drug leaf yield, and essential oil yield are mostly used as target parameters in studies conducted with medicinal and aromatic plants and these three parameters are widely used in determining the quality of the plant (Anonymous, 2009). In our study, assuming essential oil yield as a dependent variable, the effect of the independent variables on essential oil yield by the multiple regression analysis was given in Table 6.

Table 6. The effect of the independent variables on essential oil yield by the multiple regression analysis in rosemary genotypes

Çizelge 6. *Biberiye genotiplerinde bağımsız değişkenlerin uçucu yağ verimi üzerine olan etkisine ait çoklu regresyon analizi*

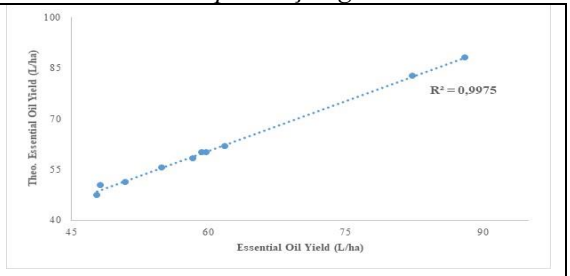
Essential Oil Yield as a Dependent Variable				
Source	**Deg. of Fr.**	**Sum of Squares**	**Mean of Squares**	**F Values**
Regression	6	1626.61	271.10	1009.00**
Residual Error	3	0.81	0.27	
Total	9	1627.42		
Predictor		**Coefficient**	**T**	**P**
Constant		-221.44	-6.81	0.006
Pl. He. (cm) A_1		-0.1533	-1.36	0.266
Fr. L./Fr Herb (%) A_2		3.979	3.72	0.034
Drug Leaf/Fr. Herb (%) A_3		1.9907	3.90	0.030
Essen.Oil Cont. A_4		121.551	48.00	0.001
Fr. Leaf Yield (ton/ha) A_6		-3.512	-2.92	0.043
Drug Leaf Yield (ton/ha) A_7		-0.712	-0.55	0.619

Essential Oil Yield (L/ha): -221.0-0.153***Pl. He.(A_1)**+3.98***Fr. L./Fr.Herb(A_2)**+1.99***Drug Leaf/Fr. Herb(A_3)**+122.0***Ess.Oil Cont. (A_4)**–**3.51*Fr.Leaf Yield(A_6)-0,71*Fr.Leaf Yi.(A_7), R^2:** 99.3%

Table 7. The theoretical calculated values of the essential oil yield in rosemary genotypes

Çizelge 7. *Biberiye genotiplerinde uçucu yağ veriminin teorik olarak hesaplanmış değerleri*

Essential Oil Yield (L/ha)	**Theoretical Essential Oil Yield (L/ha)**
61.80	61.93
88.05	88.05
54.94	55.42
47.82	47.41
59.35	60.12
59.80	60.11
58.32	58.29
48.23	50.42
50.90	51.18
82.36	82.59



In Table 6, the effects of fresh leaf/fresh herb ($p<0.05$), drug leaf/fresh leaf (0.05), essensial oil content ($p<0.01$) and fresh leaf yield ($p<0.05$) were determined as significant. To estimate essential oil yield, such regression formula could be used. Regarding this issue, the theoretically calculated values of the essential oil yield in rosemary genotypes were given in Table 7.

4. Conclusions

As a result, rosemary *(Rosmarinus officinalis* L.) plant is an important medicinal and aromatic plant and has positive effects on human health. Increasing the use of this plant for both domestic and industrial purposes makes a significant contribution to the individual's healthy living in society. In addition to this, it is necessary to improve the breeding activities and to develop novel genotypes in order to meet the increasing demand of rosemary plant. In Turkey, studies about this issue are insufficient and it is necessary to increase the breeding activities through state and private institutions. Increase inbreeding activities by itself is inadequate and it is essential to increase the success of rosemary breeding studies and to ensure that the applicability of the factor parameters is feasible. In our study, the essential oil content and fresh herb leaf yield were determined as the most important parameters to be considered. When the essential oil yield is considered as the target criterion, taking the consideration such parameters, fresh leaf / fresh herb, the drug leaf / fresh leaf, the essential oil content and the fresh leaf yield will increase success of rosemary breeding. This is a topic that needs to be addressed in a wide range of dimensions, and more detailed work is needed.

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