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Araştırma
(Research)

Assessment of Agronomic Traits and Essential Oil Yield in Various Mint (*Mentha piperita* L.) Genotypes

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Abstract

Objective: *Mentha piperita* L. has long been used in medicine, pharmaceutical industry, food and cosmetic industries due to the bioactive compounds it contains. This study was carried out to determine some agronomic characteristics and essential oil yield of mint genotypes collected from different regions of Ordu province.

Materials and Methods: A total of 44 different genotypes collected from 16 different districts of Ordu province were used in the study. Rooted mint cuttings were grown in unheated plastic greenhouse in balcony type plastic pots. Mint plants were harvested in 3 different periods and shoot length, leaf width, leaf length, colour characteristics, leaf chlorophyll index, total yield and essential oil yield were determined. Principal component analyses were performed using the data obtained from these traits. Unweighted pair group method algorithm (UPGMA) clustering analysis was performed using Euclidean similarity distance and dendrograms of genotypes were formed.

Results: At the end of the study, plant length was 12.2-60.6 cm, leaf width 0.8-4.3 cm, leaf length 1.2-9.8 cm, leaf chlorophyll index 4.75-47.8 cci (SPAD), essential oil yield 0.45-2.9% and total yield 0.1-4.2 t da^{-1} in mint genotypes. As a result of the principal component analysis, the eigenvalues of the first 4 principal component axes were found to be greater than 1. The first 3 axes have high variation percentage compared to other axes. Mint genotypes were divided into 2 main groups and 4 subgroups in the UPGMA dendrogram. While G12 and G33 were the closest mint genotypes, G10 and G11 were found to be genetically distant genotypes.

Conclusion: In the study, genotypes that exhibit potential in terms of total yield and essential oil yield have been identified. As a result of the research, agronomic characteristics and essential oil ratios of different mint genotypes were determined and qualified genotypes that can be material for future breeding studies were determined.

Keywords: Chroma, Hue angle, landraces, morphological characteristics, volatile oil

Çeşitli Nane (*Mentha piperita* L.) Genotiplerinde Agronomik Özelliklerin ve Uçucu Yağ Veriminin Değerlendirilmesi

Öz

Amaç: *Mentha piperita* L. içerdiği biyoaktif bileşikler nedeniyle tıp, ilaç endüstrisi, gıda ve kozmetik endüstrilerinde uzun süredir kullanılmaktadır. Bu çalışma Ordu ilinin farklı bölgelerinden toplanan nane genotiplerinde bazı agronomik özellikler ile uçucu yağ veriminin belirlenmesi amacıyla yürütülmüştür.

Materyal ve Yöntem: Çalışmada Ordu ilinin 16 farklı ilçesinden toplanan, toplam 44 farklı genotip kullanılmıştır. Köklenmiş nane çelikleri ısıtmasız plastik serada balkon tipi plastik saksılarda yetiştirilmiştir. Naneler 3 farklı dönemde hasat edilmiş ve bitkilerde sürgün boyu, yaprak eni, yaprak uzunluğu, renk özellikleri, yaprak klorofil indeksi, toplam verim ve uçucu yağ verimi belirlenmiştir. Bu özelliklere göre temel bileşen analizi yapılmıştır. Öklid benzerlik mesafesi kullanılarak, ağırlıksız çift grup yöntemi algoritması (UPGMA) kümeleme analizi gerçekleştirilmiş ve genotiplerin dendogramları oluşturulmuştur.

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Araştırma Bulguları: Araştırmanın sonunda nane genotiplerinde bitki sürgün boyları 12.2-60.6 cm, yaprak eni 0.8-4.3 cm, yaprak uzunluğu 1.2-9.8 cm, yaprak klorofil indeksi 4.75-47.8 cci (SPAD), uçucu yağ verimi %0.45-2.9 ve toplam verim 0.1-4.2 t da^{-1} aralığında tespit edilmiştir. Yapılan temel bileşen analizi sonucunda ilk 4 temel bileşen ekseninin öz değeri 1'den büyük bulunmuştur. İlk 3 eksen diğer eksenlere göre yüksek varyasyon yüzdesine sahiptir. Oluşan dendogram sonucunda 2 grup, 4 alt grup meydana gelmiştir. Birbirine en yakın genotipler G12 ile G33, en uzak genotipler ise G10 ile G11 genotipleri olmuştur.

Sonuç: Araştırma sonucunda farklı nane genotiplerinin agronomik özellikleri ile uçucu yağ oranları belirlenerek ileride yapılacak ıslah çalışmalarına materyal olabilecek nitelikli genotipler belirlenmiştir.

Anahtar kelimeler: Kroma, Hue açısı, genotip, morfolojik özellikler, uçucu yağ

Introduction

Medicinal and aromatic plants have long been used in medicine, pharmaceutical industry, food and cosmetics industries due to the bioactive compounds they contain. Among these plants, mentha is one of the most popular plants with aromatherapeutic and medicinal properties. The most commonly cultuvated mints are *Menhta piperita* L. and *Menhta spicata* L. Peppermint (*M. piperita*), a perennial aromatic plant belonging to the Lamiaceae family, is a vegetable consumed fresh and dried. Volatile oils obtained from *Mentha* species, mostly *M. piperita* volatile oil, are frequently used in the food industry as flavoring agents and in the pharmaceutical and cosmetic industries due to their antioxidant and anti-microbial properties (Mehdizadeh et al., 2024; Jahan et al., 2024).

M. piperita volatile oil composition includes menthol, menthone, and 1,8-cineole, which can react with free radicals (Mohammadi et al., 2024). The defense of plants against pathogens is one of the critical roles of volatile oils (VOs) in nature, as highlighted researcher (Açıkgöz, 2019; Açıkgöz, 2020). The efficacy of VOs against microorganisms and food contaminants has been reported in various studies, leading to their widespread application in the food and pharmaceutical industries, as noted by Alvand et al. (2024). As a result of food safety concerns, the development of safe natural anti-bacterial agents just like VOs, has become increasingly important (Pinto et al., 2023). In addition, it was determined that *Mentha piperita* L. essential oil concentrations can cause allelopathic effects on some germination characteristics in plants (Yeşil, 2021).

The amount of VOs varies depending on factors climate, soil composition (Kecis et al., 2023), management conditions, harvest time (Gai et al., 2023), cultivation, oil extraction and drying methods (Duarte et al., 2024). Essential oil yield varies in different locations and in mints has different plant characteristics. Additionally, it has been stated that the initial growth phase and harvest time also affect the volatile oil yields and these rates can vary between 0.72% and 3%. (Derwich et al., 2010; Hussain et al., 2010; Moghaddam et al., 2013; Benabdallah et al., 2018).

Understanding the extent of genetic diversity among *Mentha* species and the relationships among them may be useful for both genetic improvement and conservation of these species. It is difficult to distinguish phenotypically similar species using morphological and physiological methods (Reynders and Bollereau, 1994). The reason for this difficulty is that they are phenotypically based and easily affected by environmental conditions. For this reason, morphological and molecular characterisation studies have gained importance. With these studies, differences between genotypes were revealed and genetic material pools were created for further studies (Kabir et al., 2014; Gupta et al., 2017; Panjeshahin et al., 2018; Soilhi et al., 2020; Devi et al., 2022; Roshanibakhsh et al., 2023; Tabar et al., 2024).

Although it is grown on a small scale in all regions of our country, it is produced commercially in the Aegean, Marmara and Mediterranean regions. Vegetables are becoming more and more popular today due to the substances they contain. The increase in demand for consumption makes it necessary to grow these vegetables even when they are not available in the market. One of the main objectives of this study is to bring the mint plants, which is not commercially produced in the Black Sea region, into production by screening the genetic materials in the region.

In this study, local mint genotypes which has a wide plant diversity were determined by field studies in Ordu. The agronomic characteristics and essential oil quantities of mint genotypes collected from the region have not been studied before. According to different harvest dates, the yield and quality characteristics of the plants, as well as the amount of essential oils, were determined. It is aimed to identify and disseminate superior local types of mint, which is important for the pharmaceutical and cosmetic industry as well as for dry and fresh consumption.

Material and Method

Material

Mint genotypes collected from Ordu province were used as experimental plant material (Table 1). The collected mint cuttings were planted the same day in plastic balcony pots filled with a 2:1 (v:v) mixture of peat and perlite and then watered well.

The experiment was conducted in the unheated plastic covered greenhouse of Ordu University, Faculty of Agriculture, Department of Horticulture (Figure 1).

Table 1. Districts and villages where rooted mint cuttings collected from Ordu province were taken

Genotype	District	Village	Genotype	District	Village
G1	Perşembe	Çaytepe	G23	Çaybaşı	Namazlı
G2	Perşembe	Kovanlı	G24	Çaybaşı	Akbaba
G3	Perşembe	Okçulu	G25	Çatalpınar	Kıran
G4	Ünye	Kuşdoğan	G26	Çatalpınar	Dere
G5	Ünye	Saca	G27	Çatalpınar	Merkez
G6	Aybastı	Yeniceli	G28	Fatsa	Gölköy
G7	Aybastı	Hoşkaden	G29	Korgan	Yeşilalan
G8	Kabadüz	Kirazdere	G30	Korgan	Merkez
G9	Kabadüz	Merkez	G31	Kumru	Dumanköy
G10	Çamaş	Hisarbeyli	G32	Kumru	Akçadere
G11	Çamaş	Kocaman	G33	Ulubey	Akpınar
G12	Çamaş	Tepeli	G34	Ulubey	Merkez-1
G13	Gölköy	Çatalarmut	G35	Ulubey	Merkez-2
G14	Gölköy	Kozören	G36	Ulubey	Sarpdere
G15	Gölköy	Emirler	G37	Akkuş	Gökçebayır
G16	Gölköy	Tepealan	G38	Akkuş	Çavralan
G17	Mesudiye	Akkırık	G39	Akkuş	Kirazlı
G18	Mesudiye	Pınarlı	G40	Akkuş	Merkez
G19	Kabataş	Alankent	G41	Gürgentepe	Akmescid
G20	Kabataş	Hoşkadem	G42	Gürgentepe	Muratçık
G21	Çaybaşı	Merkez-1	G43	Gürgentepe	Cumhuriyet
G22	Çaybaşı	Merkez-2	G44	Gürgentepe	Akyurt

Figure 1. Rooted mint cuttings collected from Ordu province

Method

After the mint cuttings were planted, basic fertilization was applied during the production season with an average of 10-15 kg N, 8-10 kg P_2O_5 and 10-12 kg K_2O per decare. Half of the nitrogen fertilizer, all of the phosphorus and potassium fertilizers were applied before the first harvest, and the second half of the nitrogen fertilizer was applied after the first harvest, and the same process was repeated regularly in each harvest period. Weed control was carried out at regular intervals in mint plants. The irrigation of the plants was monitored daily, especially in summer months, and in other months, water needs were monitored and irrigation needs were met at regular intervals. 44 different genotypes were harvested in 3 different periods [spring (April 29, 2015), summer (July 8, 2015), winter (December 28, 2015)]. Plant height has been a factor in the determination of harvest time.

The following measurements on mint genotypes were carried out on 10 plants of each genotype for each harvest period.

Before Harvesting

Plant Shoot Length (cm)

The longest shoot of 10 plants from each genotype was measured in cm with a ruler.

Leaf width (cm)

In 10 leaves of each genotype, measurements were taken from the widest part of the leaf blade with the help of a ruler.

Leaf length (cm)

The length from the petiole to the tip of the leaf in 10 leaves of each genotype was determined with the help of a ruler.

Leaf Color

The color characteristics of the leaves were measured as CIE (Commission Internationale de I'Eclairage) L* a* b* on the top and bottom of the leaves with a Minolta CR-300 colorimeter on 10 mint leaves homogenously selected from each genotype. The colorimeter was calibrated with a standard white plate before the measurements. Hue angle and chroma values were calculated from the color values measured as CIE L* a* b* using the following formulas. Hue °h= tan-1 (b/a) Chroma C*=[(a^2+b^2)]1/2 In the CIE system, L* (lightness) indicates how much the measured surface reflects light, i.e. the lightness and darkness of the color from black to white (0=White; 100=Black), a* value indicates the color changes from red (positive) to green (negative) and b* value indicates the color changes from yellow (positive) to blue (negative). Hue0 indicates the quality of the color (00=red-pink, 900=yellow, 1800=green, 2700=blue). The chroma value indicates the vividness of the color; while a value of 0 indicates a gray-achromatic (colorless) color, the vividness of the color increases as the value increases (McGuire, 1992).

Leaf chlorophyll index value (SPAD)

Leaf chlorophyll content was determined by measuring a total of 10 young leaves of each genotype with a chlorophyll meter (Opti-Sciences Leaf Chlorophyll Meter, USA, CCM-200) which can measure between 0-50^{o}C.

The chlorophyll meter can measure the chlorophyll index value (ccı) (1 cm diameter) between 0 and 200 in the young leaves of the plants (Figure 2).

Figure 2. Measurement of Leaf Chlorophyll Index Value (ccı)

After Harvesting

Essential Oil Yield (%)

25 g of the ground plant samples were taken and placed in 250 ml flasks, 150 ml of distilled water was added and placed in the electric heater. The Clevenger apparatus with a cooler attached to the mouth of the flask was heated in the burette part of the device for 4-5 hours until there was no change in the amount of essential oil. In this way, the essential oils of the plants were obtained by hydrodistillation method, which is the most widely used method (Telci et al., 2006; Yeşil and Kara, 2017).

Then the percentage values of the essential oils were calculated and put into colored bottles and kept at +4 ºC until analysis.

Yield (t da^{-1})

Harvesting was done by mowing the shoots at the soil level of mint plants that reached harvesting height (approximately 30-35 cm). All harvested shoots were weighed and yield in tons/ha was determined.

Statistical analysis

Simple descriptive statistical analyses of the data obtained from the experiment were performed using SPSS 25.0 (IBM Corp, 2017) statistical package program. In addition, principal component analysis (PCA) was performed based on the examined traits of the local mint genotypes collected from Ordu province, the contribution of these traits to the variance in the principal component axes, the eigenvalues of the principal component axes were calculated, and the correlation matrices of the components were found. In addition, in order to reveal the reletadness of the collected mint genotypes, a dendogram of the genotypes was created with the help of UPGMA cluster analysis by Nei (1978) using Euclidean distance coefficient functions based on the difference between pairs in standardized data. Principal Component Analysis (PCA) and cluster analysis were performed with Past software (PAST version 3.11, Norway), which is used to determine phylogenetic relationships (Hammer et al., 2001).

Results and Discussion

Agronomic Traits

The mean, minimum and maximum values, standard deviation and their contribution to the total variance for the agronomic traits examined in the study are given in Table 2 and Table 3.

Table 2. Minimum, maximum and mean values for mint genotypes

	Min.			**Max.**			**Mean**		
Traits	**Spring**	**Summer**	**Winter**	**Spring**	**Summer**	**Winter**	**Spring**	**Summer**	**Winter**
PSL (cm)	17.40	16.35	12.23	60.63	55.00	38.38	33.59	29.38	23.82
LW (cm)	1.10	0.91	0.80	4.35	2.60	2.11	2.02	1.55	1.34
LL (cm)	1.23	2.21	2.03	9.75	6.38	6.10	5.71	3.85	3.55
L	26.97	24.80	21.74	56.31	52.71	52.73	40.02	37.17	34.97
a	-47.81	-22.34	-39.68	-6.35	-8.12	-6.16	-14.18	-14.64	-13.05
b	8.79	9.56	7.74	30.13	29.80	28.92	16.85	17.39	15.28
Chroma	11.91	12.55	10.31	52.37	37.24	43.47	22.14	22.74	20.19
Hue	107.54	116.75	107.54	204.81	199.50	204.64	157.94	157.65	157.63
SPAD (cci)	8.76	7.28	4.74	47.82	40.88	28.10	19.26	17.57	12.96
EOY (%)	0.45	0.56	0.45	2.00	2.88	2.50	0.97	1.23	1.27
TY (t da^{-1})	0.83	0.48	0.10	4.21	3.58	1.61	2.20	1.51	0.50

PSL:Plant Shoot Length, LW:Leaf Width, LL:Leaf Length, L:Lightness, a:Red/green axes, b:Yellow/blue axes, SPAD: leaf chlorophyll concentrations, EOY:Essenital Oil Yield, TY:Total Yield

Table 3. Standard deviation and coefficients of variation for mint genotypes

	SD			**% CV**		
Traits	**Spring**	**Summer**	**Winter**	**Spring**	**Summer**	**Winter**
PSL (cm)	8.66	7.19	5.99	25.8	24.5	25.1
LW (cm)	0.63	0.38	0.32	31.2	24.5	23.9
LL (cm)	1.58	0.93	0.87	27.7	24.2	24.5
L	8.47	7.98	8.01	21.2	21.5	22.9
a	5.14	3.45	4.56	36.2	23.6	34.9
b	4.53	4.43	4.45	26.9	25.5	29.1
Chroma	6.47	5.56	6.05	29.2	24.5	30.0
Hue	32.47	32.32	32.41	20.6	20.5	20.6
SPAD (cci)	7.18	6.39	4.68	37.3	36.4	36.1
EOY (%)	0.31	0.46	0.44	32.0	37.4	34.6
TY (t da^{-1})	0.73	0.59	0.26	33.2	39.1	52.0

SD:Standart Deviation, CV:Cumulative Variance

Plant shoot lengths of mint genotypes varied between 12.23-60.63 cm according to harvest periods. The highest average plant shoot length was obtained from genotype G31 and the lowest average was obtained from genotype G34. As the harvest date was delayed, the change in plant height was limited depending on the developmental stages of the plants. In mint genotypes, the height of plants harvested in winter was lower than those harvested in summer. This situation can be explained by the slower development of plants due to the low sunshine duration and light intensity in the winter months in Ordu province. The results obtained from the study were in accordance with previous studies and it was determined that plant (shoot) length decreased as the harvest time was delayed (Piccaglia et al., 1993; Singh et al., 1998; Telci et al., 2004; Telci and Şahbaz, 2005). In a study, it was revealed that mint shoots obtained in the first harvest were 28% longer than the plants in the second harvest (Ostadi et al., 2020). Although there is a difference in plant shoot lengths depending on the growth performance of the genotypes, the delay in harvest time decreased the shoot length. Telci (2001) determined that plant height values in mint were longer in the first mowing compared to the second mowing and stated that the reason for this was the shorter development period after the first mowing. (2018) reported that plant height varied between 26.00-95.70 cm in different mint (*Mentha* sp.) species in Ordu ecological conditions and plant height decreased by up to 49.42% due to delayed harvest. In the characterisation studies conducted on mint genotypes, plant shoot lengths were found in different value ranges. Yeşil and Kara (2014), recorded plant heights of mint genotypes between 34.71-39.99 cm, Hoque et al. (2014), recorded plant shoot length values between 28.3-84.3 cm with an average of 53.7 cm, Lu et al. (2022), recorded plant shoot length values between 15-75 cm. The average plant shoot length value in our study (28.93 cm) was lower than some studies. In addition, higher plant shoot lengths were recorded in our study compared to the values found by Lianah et al. (2023) between 14-22 cm.

In the study, leaf width values of mint genotypes varied between 0.80-4.35 cm and the average leaf width was determined as 1.63 cm. The lowest average leaf width values were recorded in winter harvest. Leaf width values of the genotypes were between 1.27-2.19 cm. The highest leaf width value was obtained from genotype G13 and the lowest average value was obtained from genotype G30. Leaf width values remained at low levels due to slower leaf development during cold months. Roshanibakhsh et al. (2023) determined leaf width values between 0.2-1.0 cm in Iranian mint populations and the average leaf width value of the populations was found to be 0.55 cm. The leaf width values obtained from our study were found above these results. Hoque et al. (2014) recorded leaf width values between 2.0-3.5 cm with an average of 2.7 cm, Lu et al. (2022) recorded leaf width values between 0.5-5.1 cm. The contribution of leaf width value to the variation in this study was calculated as 26.5%. Roshanibakhsh et al. (2023) found this coefficient to be 29.7%.

When the leaf length data of mint genotypes were analysed, leaf length values in all harvest periods varied between 1.23-9.75 cm. The average leaf length value of mint populations was found to be 4.4 cm. As the number of harvests increased, leaf length values decreased. The lowest mean values were recorded in the winter harvest. When the differences between genotypes were analysed, the mean leaf length values between genotypes were between 2.97-5.78 cm. The highest average leaf length value was obtained from genotype G13 and the lowest average leaf length was obtained from genotype G6. Similar to the results obtained in leaf width, the low level of leaf development in cold months caused a decrease in leaf length values. Roshanibakhsh et al. (2023) determined leaf length values between 0.7-3.3 cm in mint populations and the mean leaf length value of the populations was found as 1.64 cm. The leaf length values obtained from our study were above these results. However, there are also findings with values above our leaf length results. Hoque et al. (2014) determined leaf length values in the range of 3.9-9.9 cm with an average of 7.3 cm, while Lu et al. (2022) determined leaf length values between 1.3-5.4 cm. The contribution of leaf length value to the variation in the study was calculated as 25.5%. Roshanibakhsh et al. (2023) determined this coefficient as 27.2%.

Leaf chlorophyll index values of mint genotypes harvested in 3 different periods differed according to harvest periods. The leaf chlorophyll index value was in the range of 4.74-47.82 cci. As the harvest periods progressed, leaf chlorophyll index value decreased. The reason for this may be the decrease in light intensity and low sunshine hours in Ordu. In previous studies, it was reported that the leaf chlorophyll index value (SPAD) decreased as the harvest period progressed and the duration of the leaves remaining green decreased (Ostadi et al., 2020). When the averages of the chlorophyll index values measured in 3 different harvest periods were compared, the genotype with the highest chlorophyll index was genotype G24, while the lowest leaf chlorophyll index value was recorded from genotype G25.

Color Characteristics

Color values of mint genotypes differed according to harvest periods.

Leaf chroma values were determined in the range of 10.31-52.37 according to harvest periods. While the average chroma value increased in the summer harvest period compared to the spring harvest period, the lowest average chroma values were determined in the winter harvest period. Chroma values, which express color saturation in the leaf, increased after the active growth period of the plant, probably due to the accumulation of dry matter in the plants. When the differences between genotypes were examined, it was observed that the leaves with the highest color saturation in harvest averages were from genotype G10 and the leaves with the lowest saturation were from genotype G22.

Leaf hue angle values of mint genotypes showed changes in different harvest periods. The lowest hue angle value was 107.54 and the highest value was 204.81. Considering the ecology of Ordu, the short sunshine period brings rapid growth in plants. On the other hand, the formation of new shoots and leaves due to later harvesting also supports this situation. Accordingly, a transformation towards yellow color is observed in leaf colors and hue angle values decrease in plants, depending on the genotypes. When the differences between the leaf color traits of mint genotypes were examined, it was determined that G35 genotype had the highest hue angle values while G10 genotype had the lowest hue angle value in harvest averages. As a result of the study, it was observed that the contribution of leaf color traits to the total variation was quite high throughout the harvest periods. The contribution of the color traits examined in the study to the variation varied between 20.6-36.2% considering all harvest periods (Table 2). In previous mint characterization studies, it was determined that leaf color trait had high contributions to variation (Soilhi et al., 2020; Roshanibakhsh et al., 2023).

Essential Oil Yield

The essential oil yields obtained in the study varied between 0.45-2.88% according to the harvest periods. The lowest average values were determined in the spring harvest, when there was a more juicy development during the active growth period compared to other periods. When the differences between the genotypes were examined, it was determined that the average essential oil yield values were between 0.72-1.82%. While the highest essential oil yield was obtained from genotype G29, the lowest average value was obtained from genotype G22.

It has been reported by researchers in previous studies that mint plant, which is one of the perennial herbaceous plants, generally has low essential oil yields in the first harvest. As in the results obtained in this study, essential oil yields were higher in later harvest periods than in the first harvest (White et al., 1987; Court et al., 1993; Telci et al., 2004; Rohloff et al., 2005; Telci and Şahbaz, 2005; Verma et al., 2010).

In a study in which essential oil yields were determined by collecting naturally growing mints in Tokat region, essential oil yields varied between 0.90-2.70% in the 1st harvest period and 1.00-3.00% in the 2nd harvest period. The researchers determined that the percent essential oil content increased as the harvest period progressed (Telci et al., 2004). Despite these results, some researchers have shown in their studies that essential oil yield in mint decreased as the harvest period progressed (Zheljazkov et al., 2010; Ostadi et al., 2020). This is probably due to the fact that the first harvests of Ostadi et al. (2020) were made in the early summer period after the spring period when the plants were better in terms of nutrition and development and at 50% flowering, which may have caused the essential oil content to be high in the first harvests. In the following period, a relative decrease in plant growth due to high temperatures may also cause this situation.

Total Yield

Plant yields per decare of mint genotypes differed from each other in 3 different harvest periods. Yield values were determined between 0.1-4.2 t da^{-1} during the harvest periods. Plant yields were lower during the periods when the air temperature was low compared to the harvests made in spring and summer. The decrease in yield values with delayed harvest in our study is in parallel with previous studies (Piccaglia et al., 1993; Court et al., 1993; Singh et al., 1998). Again, in a study investigating the effects of different harvest periods and different fertilizer applications on yield, it was reported by researchers that the highest dry mint yield was obtained in the first harvest (Telci and Şahbaz, 2005; Ostadi et al., 2020).

In contrast to these results, in some studies, increases in total yield occurred as the harvest periods progressed (Rohloff et al., 2005), which may be related to environmental conditions and plant characteristics. Hoque et al. (2014) obtained an average mint yield of 22.0 t/ha between 16.2-30.4 ha^{-1}.

When the mean yield values of mint genotypes were compared according to harvest periods, the highest yield value was obtained from G18 genotype (2.07 t da^{-1}).

The lowest yield value was calculated in genotype G33 with 0.92 t da^{-1}. Differences in shoot growth characteristics, number of leaves, leaf size, nutrient utilization and photosynthesis rates of the genotypes caused variation in plant yields. In order to increase plant yield in mint genotypes, it is important to determine planting times and harvest periods by considering ecological data. The trait with the highest coefficient of variation was total yield. The contribution of the total yield trait to the variation obtained from the winter harvest was determined as 52% (Table 3).

Principal Component Analysis

The results of Principal Component Analysis applied to the data obtained from agronomic traits are given in Table 4.

Table 4. Contribution of agronomic traits to variance among mint genotypes

	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8	PC 9	PC 10	PC 11
CV (%)	29,8	18,1	14,5	9,9	8,24	6,4	3,9	3,7	2,51	2,34	0,61
TV (%)	29,8	47,9	62,4	72,3	80,54	86,94	90,84	94,54	97,05	99,39	100
EV	3,27	1,98	1,59	1,08	0,9	0,7	0,43	0,4	0,27	0,25	0,06
PSL	0,15	0,63	0,09	-0,58	-0,23	0,22	0,01	0,36	-0,03	0,06	0,03
LW	0,38	0,62	0,31	0,03	-0,34	0,26	0,11	-0,42	0,00	-0,04	-0,01
LL	0,02	0,69	-0,11	0,04	0,65	-0,06	0,12	-0,04	-0,26	0,00	-0,01
L	0,48	-0,42	0,39	-0,24	0,42	0,30	0,19	0,03	0,15	-0,22	0,03
a	0,77	-0,08	-0,33	-0,28	0,16	-0,17	0,11	-0,15	0,16	0,31	0,07
b	0,77	0,00	0,37	0,35	-0,07	-0,11	0,22	0,20	0,01	0,12	-0,15
Chroma	0,86	-0,08	-0,02	0,27	-0,23	-0,21	0,06	0,10	-0,18	-0,15	0,15
Hue	-0,52	-0,03	0,68	0,37	0,11	0,20	0,01	0,05	0,00	0,24	0,12
SPAD	-0,26	0,43	-0,61	0,45	-0,01	0,17	0,24	0,12	0,25	-0,06	0,03
EOY	0,41	-0,43	-0,48	0,15	0,00	0,58	-0,09	0,00	-0,20	0,10	-0,02
TY	0,67	0,41	0,10	0,23	0,21	0,04	-0,50	0,04	0,16	-0,04	0,00

PC: Pricipal Componenet, CV: Variance, TV: Total Variance, EV:Eigen Value, PSL:Plant Shoot Length, LW:Leaf Width, LL:Leaf Length, L:Lightness, a:Red/green axes, b:Yellow/blue axes, SPAD: leaf chlorophyll concentrations, EOY:Essenital Oil Yield, TY:Total Yield

Eigen values of the first 4 principal component axes were found to be greater than 1. When the contribution of the principal component axes to the variance was analyzed, it was seen that the variance explained by the first 3 axes had a higher percentage (29.8%, 18.1% and 14.5%) than the other axes. The 4 principal axes with eigenvalues greater than 1 account for 72.3% of the total variance. The first five axes accounted for more than 80% (80.5%) of the total variance. Soilhi et al. (2020), in their characterization study on Tunisian mint genotypes, reported that the first five axes accounted for more than 80% (88.1%) of the total variation as a result of principal component analysis. In the light of these results, it can be said that agronomic evaluation is effective. In previous studies, it has been stated that the percentage of variance expressed by the first 2 or first 3 principal component axes being higher than 25% may be sufficient for an effective evaluation (Iezzoni and Pritts, 1991). In the first principal component axis, color traits L, a, b and Chroma traits and total yield contributed highly to the variance as traits explaining the differences between genotypes. The first principal component axis expressed 29.8% of the total variance. The second principal component axis explained 18.1% of the total variance with an Eigen value of 1.98 (Table 3). In the second principal component axis, plant shoot height, leaf width and leaf length and total essential oil yield were significant as the traits that caused differences between genotypes. In the third principal component axis, the eigenvalue was determined as 1.59. The third component axis was defined by SPAD and Hue traits and explained 14.5% of the variation. The scatter plot representing the relationship between the 44 genotypes on the first two axes of principal component analysis is given in Figure 3. Hierarchical clustering analysis was used to examine the relationships among mint geenotypes in a broader context (Figure 4). The coefficient of coophenetic correlation obtained from the clustering analysis showed a high correlation between the coophenetic matrix and similarity (r=0.75). This coefficient indicates that the agronomic relationship between genotypes is effectively represented.

Roshanibakhsh et al. (2023) calculated this coefficient as r=0.850 in their mint characterization study. According to the clustering results, mint genotypes were divided into two main groups.

The 1st cluster was divided into 1 subgroup (A) and the 2nd group was divided into 3 subgroups (B, C, D). Genotype G10, which is in group I and represents subcluster A alone, stood out with the highest color saturation. Genotype G6 in subgroup B has the highest plant shoot height.

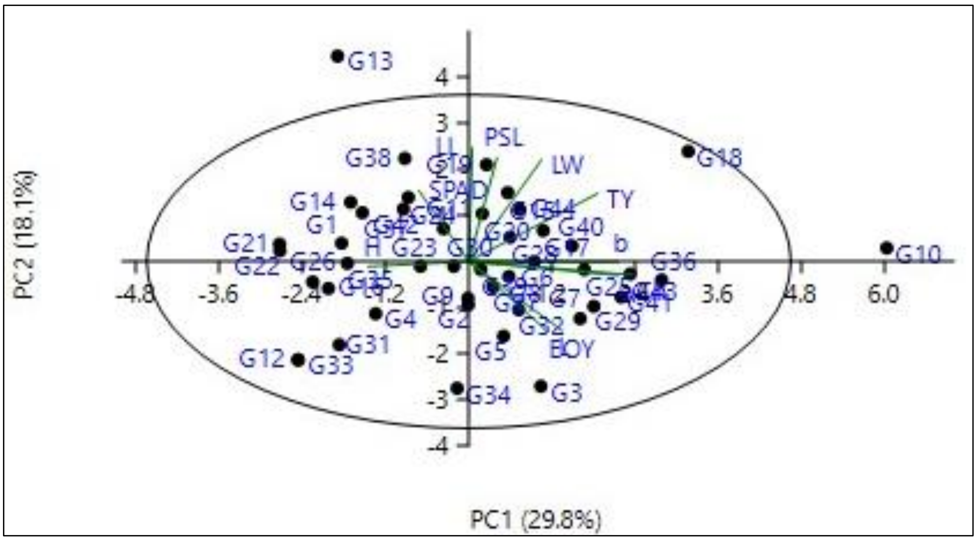

Figure 3. Relationship between 44 mint genotypes based on the first two principal component axes

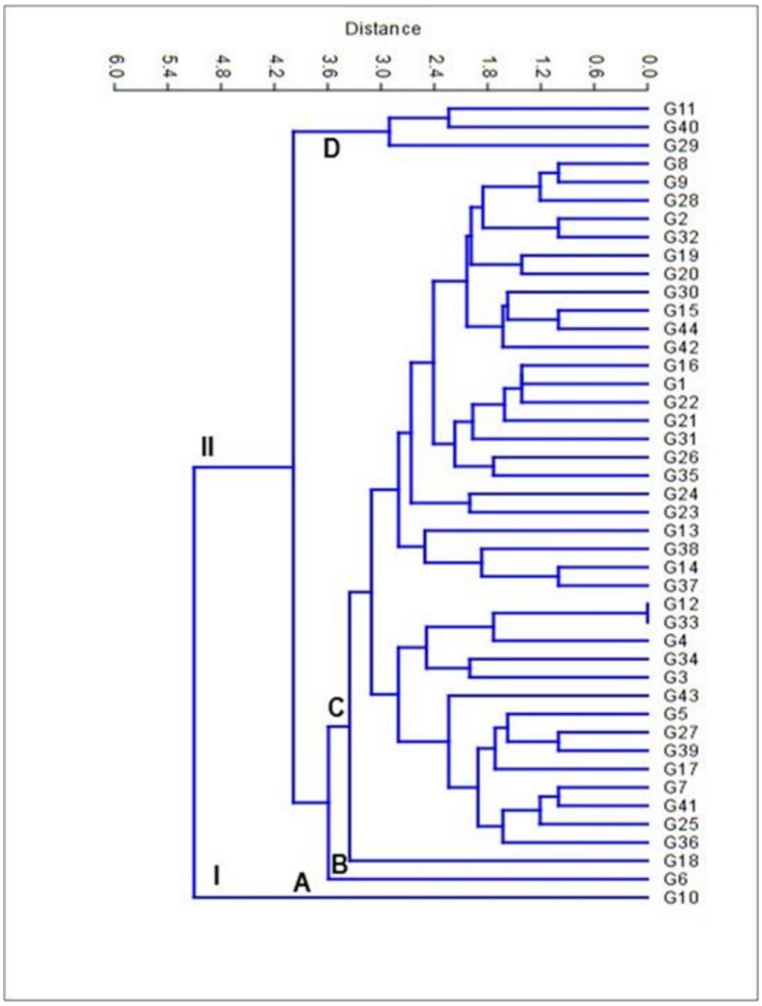

Figure 4. Dendrogram resulting from hierarchical clustering analysis of 44 mint genotypes in terms of agronomic traits using UPGMA clustering method and Euclidean distances

Subgroup C contained the highest number of genotypes with 38 genotypes. In subgroup D, there are 3 genotypes with the highest essential oil yield. In the clustering analysis based on morphological data, it was determined that there was no effect of different ecological regions where the genotypes were obtained and there was sufficient diversity. In the mint characterisation studies carried out, two main groups and 4 subgroups formed under these two main groups were generally formed as a result of the dendogram formed by hierarchical clustering based on Euclidean distances (Soilhi et al., 2020; Roshanibakhsh et al., 2023). In the clustering analysis based on morphological data, it was determined that there was no effect of different ecological regions where the genotypes were obtained and there was sufficient diversity. As a result of the dendogram formed by hierarchical clustering based on Euclidean distances in mint characterisation studies, two main groups and 4 subgroups formed under these two main groups were generally formed (Soilhi et al., 2020; Roshanibakhsh et al., 2023).

As a result of the clustering, the closest genotypes were G12 and G33 genotypes. Although they are in different regions, the similarity distances are very close, suggesting that the genotypes may have been transported between regions. The genotypes with the most distant similarity distances were G11 and G10. The richness of the group formed in the study reveals that the genotypes analysed have a wide variation in terms of agronomic diversity.

Conclusion

The main objective of the study was to determine the differences between different mint genotypes in terms of agronomic characteristics and essential oil contents. The mint characterisation study reveals the originality of this research. The wide variation in the collected mint genotypes is of great importance for future studies.

When the results were interpreted, it was revealed that total yield and essential oil yield of some genotypes had high values compared to the results obtained in previous studies.

The variation in yield, quality characteristics and essential oil yields of mint genotypes collected from different ecologies has led to important findings for future studies. It is important to use genotypes showing high yield characteristics in mint genotypes in future studies for efficient and economical production. The variability of plant yield, shoot length and essential oil content in different harvest periods revealed that different harvest times should be determined according to genotypes.

In addition, genotypes should be tested in different ecologies and nutritional conditions and the results should be evaluated. In future studies, it is important to perform component analysis in essential oil samples. Determining the degree of relatedness between genotypes at the molecular levels of all these predictions and targets may lead us to different results. The local mint genotypes are a step in providing material for future mint breeding programs.

Conflicts of Interest

The authors declare no conflicts of interest.

Authorship Contribution Statement

AKS: Contributed to the collection of plant materials, conducting field studies, taking measurements and observations on plants and writing the manuscript.

AU: Contributed to the planning, establishment, execution, data evaluation and manuscript writing stages of the study.

MAA: Contributed to the measurements, planning of laboratory analyses, essential oil analyses and writing the manuscript.

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