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Research Article

Effects of Environmental Variations on Yield of Oriental Tobaccos**

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Abstract. The study was conducted to determine the impacts of environmental variations on yield and yield related properties of tobacco. The experimental layout was in the randomized blocks with three replicates in four different locations (Erbaa-Evciler, Erbaa-Karayaka, Gümüşhacıköy, Bafra) using 21 lines and four standard varieties that stand out with their different characteristics. The variation in plant height, number of leaves, leaf width, leaf length and leaf yield of genotypes were investigated at different ecologies. All the parameters investigated of the genotypes have been significantly affected by changing environmental conditions. Plant height ranged from 49.33 cm to 177.32 cm, the number of leaves from 21.83 to 47.10 per plant, leaf width from 6.83 to 16.31 cm, leaf length from 13.01 to 28.93 cm, and yield ranged from 79.17 kg^{-1} to 238.98 kg da^{-1}. The results for the performances of genotypes in all environments showed that 5 lines (ERB-11, ERB-14, ERB-16, ERB-21, ERB-35) for plant height, 6 lines (ERB-6, ERB-7, ERB-11, ERB-14, ERB-16, ERB-35) for the number of leaves, 10 lines (ERB-9, ERB-16, ERB-17, ERB-18, ERB-19, ERB-21, ERB-25, ERB-26, ERB-27, ERB-30) for leaf width, 1 line (ERB-16) in for leaf length and 13 lines (ERB-6, ERB-7, ERB-9, ERB-13, ERB-16, ERB-18, ERB-19, ERB-21, ERB-25, ERB-27, ERB-30, ERB-35, ERB-38) for yield come to the fore.

Çevresel Varyasyonların Oryantal Tütünlerin Verimi Üzerine Etkileri

Anahtar kelimeler:
Basma tütünü, genotip x çevre, morfolojik karakterler, *Nicotiana tabacum* L.

Özet. Çalışma tütünün verim ve verim ile ilişkili özelliklerini çevre değişkenliklerinin nasıl etkilediğini belirlemek amacıyla yapılmıştır. Araştırma, farklı özellikleri ile öne çıkan 21 hat ve dört standart çeşit ile dört farklı lokasyonda (Erbaa-Evciler, Erbaa-Karayaka, Gümüşhacıköy, Bafra) tesadüf blokları deneme deseninde üç tekrarlı olarak yürütülmüştür. Farklı genotiplerin bitki boyu, yaprak sayısı, yaprak eni, yaprak boyu ve kuru yaprak verimi karakterlerinin, farklı ekolojilerde ortaya koyduğu varyasyon incelenmiştir. İncelenen parametrelerin tümünde genotiplerin değişen çevre koşullarından önemli derecede etkilendiği belirlenmiştir. Bitki boyu 49.33 cm ile 177.32 cm, yaprak sayısı 21.83-47.10 adet/bitki, yaprak eni 6.83-16.31 cm, yaprak boyu 13.01-28.93 cm ve verim 79.17 kg da^{-1} ile 238.98 kg da^{-1} aralığında değişmiştir. Tüm çevrelerde gösterdikleri performansları ile bitki boyu bakımından 5 hat (ERB-11, ERB-14, ERB-16, ERB-21, ERB-35), yaprak sayısı bakımından 6 hat (ERB-6, ERB-7, ERB-11, ERB-14, ERB-16, ERB-35), yaprak eni bakımından 10 hat (ERB-9, ERB-16, ERB-17, ERB-18, ERB-19, ERB-21, ERB-25, ERB-26, ERB-27, ERB-30), yaprak boyu bakımından 1 hat (ERB-16) ve verim bakımından 13 hat (ERB-6, ERB-7, ERB-9, ERB-13, ERB-16, ERB-18, ERB-19, ERB-21, ERB-25, ERB-27, ERB-30, ERB-35, ERB-38) öne çıkmıştır.

** The article is summarized from the PhD thesis of the corresponding author.

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INTRODUCTION

High levels of oriental tobacco production and export in Turkey are related to the quality improvement of tobacco grown provided to cigarette blends. Basma-type tobaccos of this group are small-partly medium-sized, leaves are light red and dark yellow tones. The aroma is the most important characteristic of Basma-type tobaccos (Camas *et al.,* 2009a). Although adaptation and breeding studies recently have been conducted on Basma tobacco types in Turkey (Camas *et al.,* 2009b), in general, the effects of cultural practices on leaf yield and quality have been determined (Camas *et al.,* 2009a, 2009b, 2011; Yilmaz and Kinay, 2011; Ozcan, 2014; Kurt and Ayan, 2014; Kinay and Yilmaz, 2016).

Temperature and precipitation are the main factors affecting the growth and development ratio, productivity and chemical composition of the tobacco plants (Dimitrova, 2005). Morphological features of tobacco plants generally depend on the genetic structure of species and characteristics of the climate, while the impact of soil structure is less effective. Tomov (1990) stated that climate conditions significantly affect plant height, whereas the effect on the number of leaves is quite low. The study carried out by Korubin-Aleksoska (2003) to determine the effect of environmental changes on oriental tobacco revealed that the plant height is the most affected plant characteristic. Sadeghi *et al.* (2011) investigated the yield performances of 15 hybrid tobacco in eight different environments, and 87.89% of the variation was attributed to environmental effects, 2.36% to the genotype and the rest to the genotype x environment interaction. Color, leaf sizes and smoking characteristics may vary depending on environmental conditions. Leaf form, the color of flowers etc., which do not change depending on external factors, are genetic features and the leaf form is used especially in the type diagnosis (Peksuslu, 1998). Researchers studying in the Marmara (Dolek, 1984) and Black Sea region tobaccos (Karpat, 1989) reported that plant shape, plant height, the number of leaves and leaf sizes have been changed by the year and environment; however, the leaf form was not changed.

Important natural stressors in terms of quality criteria in oriental tobacco are high temperature, water shortage and mineral nutrient deficiency (Senbayram *et al.,* 2005). The presence of heavy metals, excessive salinity, insufficient precipitation, and nitrogen are the important stress factors, and plants suffer yield losses while creating a defense mechanism to overcome the adverse effects of stress (Lambers *et al.,* 2000). The mechanisms developed by plants against these stressors are reducing photosynthesis and leaf area, thickening the leaf, shading the lower leaves by increasing the number of leaves, and narrowing the leaf angle to escape from the sun (Smith *et al.,* 2004). The stress created in different growth periods of the plant by reducing the irrigation water reduced the plant height, the number of leaves and the leaf area during the rapid vegetative growth and product formation periods of tobacco plants (Cakir and Cebi, 2006).

The oriental tobaccos have a very large variation due to the environmental conditions and different cultivation techniques in addition to the inherited structures. The leaf quality is an important attribute of a genotype, which results from the interaction of genotype and environmental conditions, and even the processes from planting until final product in the factory. The quality of a green leaf is a consequence of the common effects of subsequent processes such as curing, ageing and manufacturing processes. Therefore, each of the tobacco type is an ecotype specific to the region where commonly grown. In this study, the variations in characteristics of tobacco lines collected from the regions where Turkey Basma tobacco grown and genetically separated and the effects of different ecologies on these variations have been investigated.

MATERIALS AND METHODS

Information of Locations

The research was carried out in four different locations in the Central Black Sea Region where intensive tobacco production takes place. The locations were chosen from tobacco grown areas with different altitudes. Two of the locations were located in Erbaa town, within the borders of Evciler village (40°36'43.48"N, 36°36'5.25"E) with an altitude of 581 m and Karayaka village (40°44'16.45"N, 36°33'58.31"E) with an altitude of 302 m. The altitudes of Bafra (41°33'45.29"N, 35°52'18.35"E) and Gümüşhacıköy (40°53'1.03"N, 35°12'47.98"E) experimental fields were 26 m and 848 m, respectively.

Soil Structure of Locations

Soil texture in Evciler location was clay loam, while the other three locations had sandy loam texture. Salt content of the soils was quite low, and all experimental fields were slightly alkaline. Soils in Gümüşhacıköy had a moderate organic matter content which was the highest organic matter content among four locations. Bafra and Karayaka soils had low and Evciler soil had a very few organic matter. Evciler, Gümüşhacıköy and Bafra soils were moderately calcareous, while Karayaka was calcareous. Soils in all experimental locations were rich in available potassium content. Phosphorus concentrations of Karayaka soil was moderate, while other three locations had a low level of phosphorus (Table 1).

Table 1. Soil analysis results of the locations.
Çizelge 1. Lokasyonların toprak analiz sonuçları.

Properties	Locations			
	Evciler	**Karayaka**	**Gümüşhacıköy**	**Bafra**
P_2O_5 (kg da^{-1})	5.13 Low	6.18 Modarate	4.85 Low	3.45 Low
K_2O (kg da^{-1})	169.70 High	175.30 High	156.80 High	137.17 High
Lime (%)	10.2 Modarate calca.	2.39 Calcareous	5.17 Modarate calca.	12.73 Modarate calca.
Org. Mat. (%)	0.95 Very low	1.43 Low	2.36 Modarate	1.76 Low
pH	7.99 Slightly alkaline	7.81 Slightly alkaline	7.98 Slightly alkaline	7.61 Slightly alkaline
EC (dS m^{-1})	0.25 Very low	0.13 Very low	1.12 Very low	0.72 Very low
Texture	Clay loam	Sandy loam	Sandy loam	Sandy loam

*Soil samples were analyzed in Tokat GOP University, Agriculture Faculty laboratories.

Climatic Data of Locations

The temperature values, compared to long-term, during the seven-month period including the seedlings, field and curing periods of tobacco were decreased by 25.2% in Erbaa, 19.3% in Gümüşhacıköy and 4.1% increase in Bafra. The temperature decreased in months of April and May in Bafra and in April and October in Gümüşhacıköy, while in Erbaa a colder July and October were experienced compared to previous years (Table 2).

Table 2. Monthly climate datas of the vegetation period of the locations.
Çizelge 2. Lokasyonların vejetasyon dönemine ait aylık iklim verileri.

Months		Erbaa			Gümüşhacıköy			Bafra		
		L. Y.	**2017**	**D.**	**L. Y.**	**2017**	**D.**	**L. Y.**	**2017**	**D.**
April	^{0}C	14.2	12.4	**-1.8**	11.0	10.0	**-1.0**	11.2	9.9	**-1.3**
	mm	55.4	45.2	**-10.2**	56.9	43.6	**-13.3**	57.7	63.0	**5.3**
	%	58.6	65.2	**6.6**	58.7	62.9	**4.2**	79.0	85.8	**6.8**
May	^{0}C	18.1	17.0	**-1.1**	14.4	14.4	**0**	15.5	15.0	**-0.5**
	mm	62.2	50.5	**-11.7**	75.5	70.9	**-4.6**	47.2	53.6	**6.4**
	%	60.7	71.6	**10.9**	59.6	69.5	**9.9**	79.4	87.6	**8.2**
June	^{0}C	21.6	21.4	**-0.2**	18.2	18.4	**0.2**	20.1	20.3	**0.2**
	mm	48.4	94.5	**46.1**	74.9	87.3	**12.4**	34.6	45.9	**11.3**
	%	58.1	73.6	**15.5**	58.9	79.2	**20.3**	74.9	84.7	**9.8**
July	^{0}C	23.9	20.8	**-3.1**	20.7	21.3	**0.6**	22.8	23.5	**0.7**
	mm	24.6	1.2	**-23.4**	26.6	8.4	**-18.2**	31.0	0	**-31**
	%	55.4	74.2	**18.8**	53.3	55.5	**2.2**	73.1	95.2	**22.1**
August	^{0}C	23.8	25.9	**2.1**	21.1	22.3	**1.2**	22.9	24.3	**1.4**
	mm	9.9	1.0	**-8.9**	11.3	9.2	**-2.1**	47.3	24.8	**-22.5**
	%	55.6	65.8	**10.2**	50.9	67.7	**16.8**	74.5	75.2	**0.7**
September	^{0}C	20.5	22.2	**1.7**	17.4	20.8	**3.4**	19.5	21.2	**1.7**
	mm	16.1	2.9	**-13.2**	13.0	13.2	**0.2**	59.7	13.0	**-46.7**
	%	57.9	61.6	**3.7**	53.9	51.7	**-2.2**	76.8	75.2	**-1.6**
October	^{0}C	15.4	13.9	**-1.5**	12.3	12.2	**-0.1**	15.4	15.4	**0**
	mm	41.7	26.9	**-14.8**	45.4	23.9	**-21.5**	96.8	21.8	**-75**
	%	63.2	77.0	**13.8**	61.4	64.5	**3.1**	78.7	72.0	**-6.7**

L. Y.; Long years (1963-2016), D.; The difference between 2017 and 1963-2016 years; ^{0}C; Temperature, mm; Precipitation, %; Relative humidity

The relative humidity, compared to long term averages was increased in Gümüşhacıköy except for September and in Bafra except for September and October. The average relative humidity in the seven-month period, compared to long term was increased by 19.4% in Erbaa, 13.7% in Gümüşhacıköy and 7.5% in Bafra town. Bafra location is located on the coastline of Black Sea region; therefore, the location draws attention due to the high relative humidity values compared to other locations (Table 2).

The precipitation in Erbaa decreased by 18.4% (45.2 mm) in the seedling period compared to the long-term average and the producers completed their planting operations in May. Erbaa region received about twice as much (95.2%) rainfall (94.5 mm) in June compared to the long-term, while the precipitation significantly reduced (1.2 mm) in July. The precipitation in Gümüşhacıköy during seedling period lower compared to the long-term, whereas the precipitation in June (87.3 mm) was increased by 16.5%, which partially delayed the planting in the region. Then, a period of low rainfall was started as in Erbaa location. In contrast to the other three locations, a different production process from the long-term has been experienced in Bafra. The precipitation increased by 9.2% in April and 13.5% in May, which led to fast seedling development and the appearance of the diseases. The planting of seedling was delayed in the region due to the 24.6% excess precipitation (45.9 mm) experienced in June. The producers, who had problems especially in the preparation of the field due to the increasing rainfall were able to complete the planting process only in the second week of July. Precipitation did not occur in July at Bafra, and the rainfall during the following months was lower compared to the long-term averages (Table 2).

Material

The material of the study composed of 25 tobacco genotypes including 21 Basma tobacco lines identified as Basma type in Turkey and four standard tobacco varieties/lines (Kurt, 2019).

Methods

Seedlings of the genotypes were grown in a float system with peat medium within foam viols. Fertilizer containing 6 kg da^{-1} N, 4 kg da^{-1} P_2O_5 and 6 kg da^{-1} K_2O was applied to the fields before planting the seedlings (Yilmaz and Kinay, 2011). The experimental layout was a randomized block design with three replications. The seedlings were planted with a 45 cm inter-row and 12 cm intra-row spacings on 5 m long plots. The distance between the blocks was 1 m and two rows of each plots were planted as edge effects. The seedling planting was performed on May 21, 2017 in Evciler, May 19, 2017 in Karayaka, July 4, 2017 in Bafra and June 29, 2017 in Gümüşhacıköy.

The harvest of matured leaves was completed in 3 different priming periods, and each harvest at the locations was completed in one day. The curing was carried out by the sun-cured method, and the leaves lined up on the strings were hung after a day or two with no shade in direct sunlight. The cured tobacco has been clustered and placed in a closed room. The morphological observations were recorded and all the leaves harvested from the net plot area were weighed for yield, and their moisture content was fixed to 17% and their yield per decare was calculated in kg.

The data obtained in the locations were not homogeneous; therefore, the locations were subjected to variance analysis separately using the SAS software. Duncan's multiple comparison test was used to compare the parameters obtained in different locations and graphed with GraphPad Prism 8 program.

RESULT AND DISCUSSION

Plant Height (cm)

The difference in location had a significant ($p<0.01$) effect on the plant heights of tobacco lines and varieties. Plant height of Basma tobacco was reported between 67 and 119 cm (Camas *et al.,* 2009b) and 125.1 to 137.1 cm (Yilmaz and Kinay, 2011). The plant height of Xanthi 2A variety ranged from 136 to 159 cm in Bafra (Kurt and Ayan, 2014) and from 73.1 to 81.9 cm in Erbaa (Kınay and Yılmaz, 2016). The length of Xanthi 81 varieties in Erbaa ecological conditions was between 85 and 89 cm (Ozcan, 2014). The studies conducted on Basma type tobacco (Peksuslu, 1998; Camas, 1998; Camas *et al.,* 2011; ATEA, 2012) revealed that the length of plant height can be considered as the moderate-tall group.

The plant height of tobacco has a strong and positive relationship with the number of leaves and the yield (Aytac, 2016). Tomov (2005) reported that climatic conditions have a significant impact on plant height of tobacco, and similarly, Korubin-Aleksoska (2003) indicates that plant height is the most affected characteristic of oriental tobacco under varying environmental conditions. The results related to variability in the averages of genotype and location confirm this finding. The plant height at four locations varied from 49.33 cm to 177.32 cm, which indicates a high range of variability. The highest mean plant height was obtained in Gümüşhacıköy location (145.15 cm) that was 133.55% (62.15 cm), 21.55% (119.42 cm) and 14.91% (126.32 cm) higher than the plant height obtained in Evciler, Karayaka and Bafra locations, respectively (Figure 1; Table 3). The results of soil analysis for the experimental sites also support this information. The experimental site with the highest organic matter content (2.36%) was in Gümüşhacıköy. Soils in Bafra (1.76%) and Karayaka (1.43%) were lower than Gümüşhacıköy, while higher than Evciler (0.95%) (Table 1).

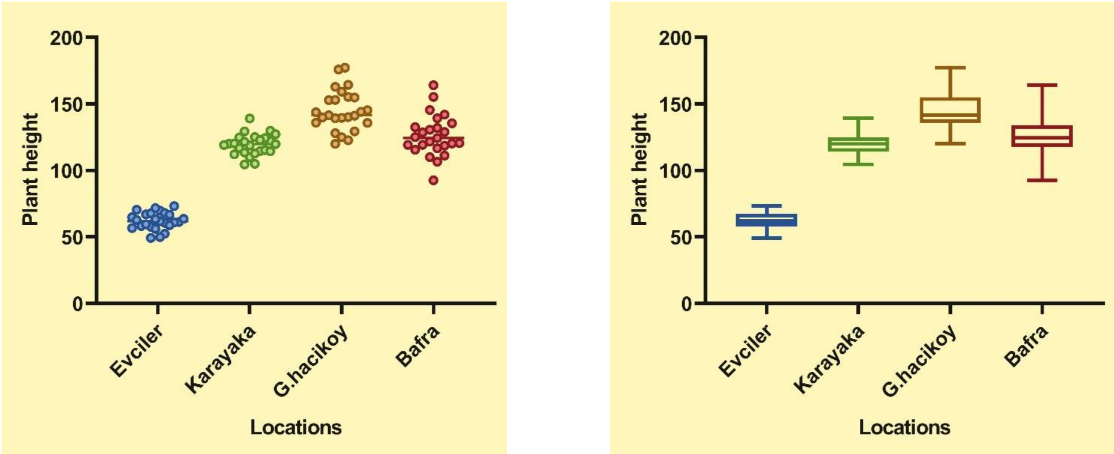

Figure 1. Variation of plant height according to averages of locations of different tobacco genotypes.
Şekil 1. Farklı tütün genotiplerinin lokasyon ortalamalarına göre bitki boyu varyasyonları.

Number of Leaves (per plant)

The mean number of leaves and the analysis results for different tobacco lines and varieties were given in Table 3. The difference in locations had a significant impact ($p<0.01$) on the number of leaves. The number of leaves in the previous studies was reported between 25 and 30 (Camas, 1998) and 30-35 leaves per plant (Peksuslu et al., 2012) in Canik 190-5 cultivar. The number of leaves for Nail population in this study was between 24.47 and 30.33 leaf plant^{-1}, and for Canik 190-5 variety between 23.80 and 37.07 leaf plant^{-1}. Xanthi 2A variety has been used as plant material in some studies and the number of leaves was reported ranging from 28 to 30 leaf plant^{-1} (ATEA, 2012), from 31 to 35 leaf plant^{-1} (Kurt and Ayan, 2014), from 26.5 to 27.5 leaf plant^{-1} (Kinay and Yilmaz, 2016). Similarly, the number of leaves for Xanthi 81 variety was between 30 and 32 leaf plant^{-1} in ATEA (2012) and between 26.9 and 28.5 leaf plant^{-1} in Ozcan (2014). The number of leaves for Xanthi 2A was found between 21.83 and 30.87 leaf plant^{-1} and for Xanthi 81 between 22.73 and 39.30 leaf plant^{-1} (Figure 2; Table 3). The results revealed that the number of leaves that can increase or decrease in parallel with the plant height may vary with the changing environmental conditions, and our results were in accordance with the previous studies.

Camas *et al*. (2009b) reported that the number of commonly grown Basma type tobacco in Erbaa was between 25.30 and 34.80 per plant. The average number of commercial leaves per plant for Basma tobacco was reported as 30 (Camas *et al*., 2011; Yilmaz and Kinay, 2011). The average leaf number for genotypes was between 27.20 and 34.88 leaf plant^{-1}, and for the locations was between 24.89 and 34.56 leaf plant^{-1} which were compatible with previous studies (Figure 2; Table 3).

The number of leaves is a criterion related to the genetic structure, however, the different products with various characteristics can be obtained in oriental tobacco by using the same seed due to the effect of environmental factors (Peksuslu *et al.,* 2012). A significant part of the variation in autogamy plants was attributed to the environmental conditions (Usturali *et al.,* 1998). The same type of seeds can produce higher number of leaves in a location rich in available nutrient and water compared to the environment that has nutrient deficiency and lack of available water (Kinay and Yilmaz, 2016). Changes in the number of leaves in plants of the same genotype under varying environmental conditions can be seen in Table 3.

The number of leaves varied between 21.83 and 47.10 leaf plant^{-1}. Similar to the plant height, Gümüşhacıköy is the location where the highest number of leaves is obtained. The highest number of leaves, similar to the plant height was obtained in Gümüşhacıköy location. The greater light intensity in high altitudes reported causing the formation of high number of leaves (Sencar and Gokmen, 2004). The extreme cases such as the increase in temperature increases the number of leaves in upper hand groups of plant, which shades the lower leaves (Smith *et al.*, 2004).

Table 3. Data about the plant height and number of leaves characters of genotypes and results of statistical analysis according to locations.
Çizelge 3. Genotiplerin bitki boyu ve yaprak sayısı ile ilgili verileri ve lokasyonlara göre istatistiksel analiz sonuçları.

Genotypes	Plant height (cm)					Number of leaves (per plant)				
	Evciler	Karayaka	G.Hacıköy	Bafra	Means	Evciler	Karayaka	G.Hacıköy	Bafra	Means
ERB-5	60.67 af	116.83 bf	135.92 g	120.63 jm	**108.51**	24.63 af	32.37 cf	33.77 hi	31.87 ei	**30.66**
ERB-6	58.33 bf	110.10 ef	140.30 eg	116.67 ln	**106.35**	25.67 ad	30.27 gk	40.10 c	29.60 jl	**31.41**
ERB-7	61.93 af	114.63 cf	152.88 d	118.74 km	**112.05**	24.90 ae	32.17 cf	40.37 c	32.87 de	**32.58**
ERB-9	69.70 ad	118.80 be	153.05 d	119.37 km	**115.23**	25.57 ae	31.47 dh	37.57 de	28.37 jl	**30.74**
ERB-11	67.10 ad	120.17 be	177.32 a	121.73 jl	**121.58**	26.37 ac	30.13 gk	45.13 b	30.50 fj	**33.03**
ERB-12	67.83 ad	122.33 be	141.55 eg	135.46 ef	**116.80**	25.97 ac	30.83 ei	34.83 gi	32.60 df	**31.06**
ERB-13	57.63 cf	124.53 bd	141.35 eg	132.66 fg	**114.04**	23.67 cf	33.73 bc	32.97 ij	32.37 eg	**30.68**
ERB-14	61.23 af	129.87 ab	155.32 cd	145.52 c	**122.99**	24.77 af	34.80 ab	39.30 cd	35.70 b	**33.64**
ERB-15	61.00 af	124.93 bd	120.02 i	155.33 b	**115.32**	24.40 af	31.67 dg	30.60 km	35.67 b	**30.58**
ERB-16	64.93 ae	139.10 a	145.38 e	164.22 a	**128.41**	26.87 ab	36.13 a	35.17 fh	40.73 a	**34.73**
ERB-17	63.47 ae	113.60 df	135.76 g	111.36 no	**106.05**	25.23 ae	28.73 jk	33.43 hj	28.23 kl	**28.91**
ERB-18	56.07 df	104.63 f	129.42 h	110.12 o	**100.06**	24.17 bf	27.93 l	28.87 mn	27.83 l	**27.20**
ERB-19	58.83 bf	115.43 cf	125.14 hi	119.39 km	**104.70**	25.17 ae	30.20 gk	29.17 ln	29.17 jl	**28.43**
ERB-21	73.27 a	129.40 ab	159.25 bc	142.06 cd	**125.99**	27.30 a	32.63 ce	31.70 jk	32.03 eh	**30.92**
ERB-23	59.63 bf	121.57 be	144.21 ef	132.00 fg	**114.35**	24.07 bf	30.17 gk	36.07 eg	32.83 de	**30.78**
ERB-25	71.70 ab	127.30 ac	128.15 h	130.68 gh	**114.46**	26.60 ac	33.53 bc	30.00 km	33.10 ce	**30.81**
ERB-26	68.17 ad	125.27 bd	122.81 i	128.66 gi	**111.23**	26.03 ac	31.00 di	25.83 o	32.60 df	**28.87**
ERB-27	62.73 af	112.17 df	139.56 fg	106.53 o	**105.25**	25.10 ae	29.33 il	26.60 o	29.83 il	**27.72**
ERB-30	70.53 ac	112.77 df	154.85 cd	125.30 hj	**115.86**	25.53 ae	30.57 fj	34.00 hi	29.83 il	**29.98**
ERB-35	63.70 ae	120.33 be	176.02 a	129.01 gi	**122.27**	24.93 ae	32.73 cd	47.10 a	34.73 bd	**34.88**
ERB-38	52.57 ef	119.13 be	162.96 b	120.35 jm	**113.75**	22.50 ef	29.57 hl	36.77 ef	30.10 hk	**29.73**
Xanthi 2A	49.97 f	119.97 be	139.28 fg	92.63 p	**100.46**	21.83 f	29.30 il	30.87 kl	28.33 jl	**27.58**
Nail	66.80 ad	123.00 be	143.81 ef	115.64 mn	**112.31**	24.47 af	29.67 hl	27.40 no	30.33 gk	**27.97**
Canik 190-5	56.67 df	114.53 cf	164.50 b	139.30 de	**118.75**	23.80 bf	28.43 kl	37.07 ef	35.03 bc	**31.08**
Xanthi 81	49.33 f	105.03 f	139.87 eg	124.54 ik	**104.69**	22.73 df	29.63 hl	39.30 cd	33.23 ce	**31.23**
Means	62.15	119.42	145.15	126.32	**113.26**	24.89	31.08	34.56	31.90	**30.61**
Std. means	55.69	115.63	146.87	118.03	**109.05**	23.21	29.26	33.66	31.73	**29.46**
Lines means	63.38	120.14	144.82	127.90	**114.06**	25.21	31.43	34.73	31.93	**30.83**
$LSD_{0.05}$	11.23	11.01	5.01	5.13		2.55	1.64	1.75	1.87	
CV (%)	11.01	5.61	2.10	2.47		6.23	3.21	3.09	3.58	
	Mean square and significance									***df***
Genotype	124.65**	186.19**	698.21**	714.78**		5.38**	12.42**	89.57**	26.86**	24
Error	46.76	45.01	9.29	9.77		2.40	1.00	1.14	1.30	48

*Values followed by different letters in each column are significantly different (*p<0.05) according to Duncan test; Std. means: Standarts means; LSD: Least significant difference; CV: Coefficent of variation; *df:* Degree of freedom; **p<0.01

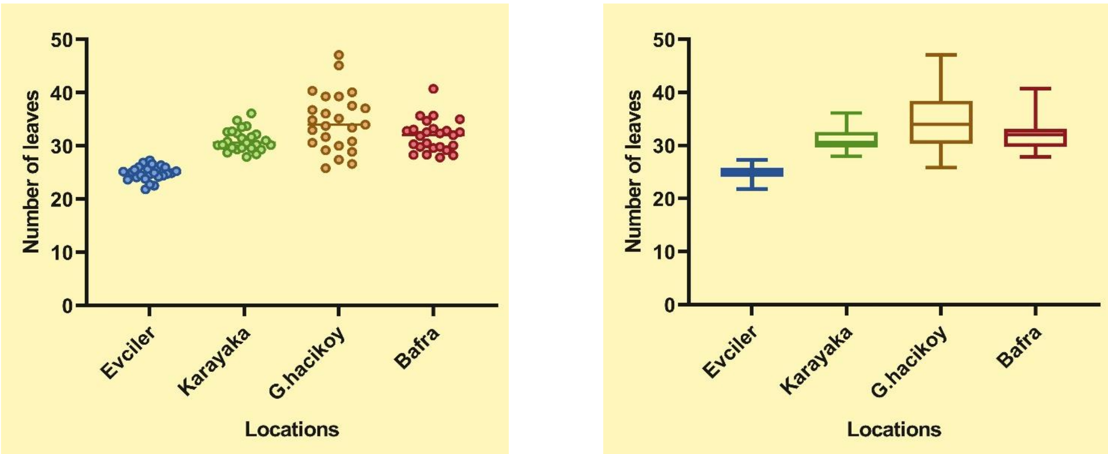

Figure 2. Variation of number of leave according to averages of locations of different tobacco genotypes.
Şekil 2. Farklı tütün genotiplerinin lokasyon ortalamalarına göre yaprak sayısı varyasyonları.

Soil organic matter content was higher in Gümüşhacıköy was higher compared to other locations. Planting of seedlings during spring rains, continuity of the rains for a while after the planting, and more favorable growth and development conditions compared to other locations in the transplanting and development period may explain the increase of vegetative characteristics such as the number of leaves. The number of leaves, which was 34.56 leaf plant^{-1} in Gümüşhacıköy, is 38.85% higher compared to the Evciler (24.89 leaf plant^{-1}), 8.34% higher compared to the Karayaka (31.08 leaf plant^{-1}) and 8.34% higher compared to the Bafra (31.90 leaf plant^{-1}) (Table 3). Sekin (1986) reported that drought following early rains caused a weak root structure and punier plant development. Similarly, Cakir and Cebi (2006) reported that water stress during vegetative rapid growth and product formation periods reduced the plant height, number of leaves and leaf area. Fewer number of leaves in Evciler might be related to the drought, which was identified during the study and tried to be compensated by irrigation, and the weak soil structure.

Leaf Width (cm)

The mean leaf widths and analysis results of different tobacco lines and varieties were given in Table 4. The results indicated that location has a significant impact ($p<0.01$) on leaf width of the genotypes. The mean leaf width of the lines were between 9.07 and 13.77 cm. These values are compatible with the previous studies reporting leaf width in the range of 9.50-14.50 cm (Camas *et al.*, 2009b; Yilmaz and Kinay, 2011).

The average leaf width of Nail populations in Erbaa (Kinay, 2014) and Bafra (Caliskan, 2006) conditions (12.08 and 9.27, respectively) was similar to our findings (between 9.44 and 14.75 cm, mean 12.71 cm).

The leaf width of Xanthi 2A variety was determined as 9.50 cm (Kinay and Yilmaz, 2016) and 8.65 cm (Kurt and Ayan, 2014), and for Xanthi 81 as 10.70 cm (Ozcan, 2014). The mean leaf width of the Xanthi Djebel XDj-1 variety was reported as 8.4 cm (Korubin-Aleksoska *et al.*, 2014). The mean leaf widths of Xanthi 2A and Xanthi 81 varieties were 12.42 and 11.37 cm, respectively. The differences in leaf width con be attributed to the higher number of experimental sites compared to the previous studies. Because the increase in leaf width was observed in locations other than Erbaa (Evciler, Karayaka) conditions where previous studies have been carried out (Figure 3; Table 4).

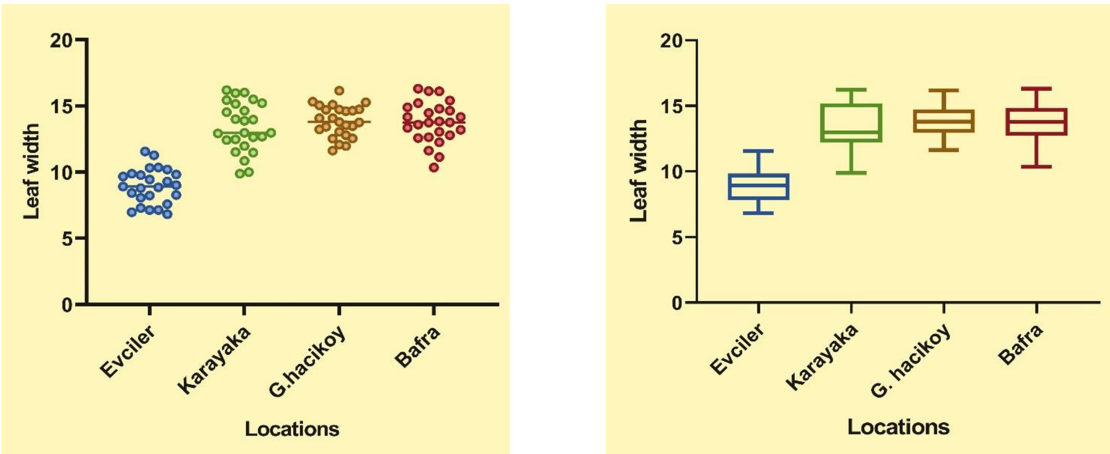

Figure 3. Variation of leaf width according to averages of locations of different tobacco genotypes.
Şekil 3. Farklı tütün genotiplerinin lokasyon ortalamalarına göre yaprak eni varyasyonları.

Oriental tobaccos have small to medium leaf sizes. The increase in leaf sizes increases the intercellular spaces and causes the number of glandular hairs in which the aromatic substances on the lower and upper leaf surfaces are secreted (Zorba, 2008). The Nail population, Canik 190-5 variety, Xanthi 2A and Xanthi 81, as well as all the tobacco types grown in the Central Black Sea region, are considered genotypes with small-medium leaf size group (Camas, 1998; Peksuslu, 1998; Camas *et al.,* 2011; ATEA, 2012; Peksuslu *et al.,* 2012).

Leaf yield of tobacco has a direct relationship with the length of the plant, the number of leaves per plant, the width and length of the leaves (Butorac *et al.,* 1999). Therefore, researchers reported that the leaf width has an increasing effect on the wet or tobacco yield (Dyulgerski and Dimanov, 2012). Aytac (2016) also indicated a positive relationship between leaf width and tobacco yield. Similar to the other characteristics, leaf width is affected by environmental changes and may differ depending on the presence of stress factors or the appropriate growth conditions.

The average leaf width was 12.49 cm, and similar to the plant height and leaf number, Gümüşhacıköy location provided the highest contribution to the increase in leaf width and followed by Bafra location (Figure 3; Table 4). The increase in leaf width was attributed to the similar reasons as the plant height and the number of leaves. The organic matter content in Gümüşhacıköy and Bafra locations were higher than the other two locations. The precipitation in all locations was not balanced, however, the precipitation during the vegetation period in Gümüşhacıköy was 34.3 mm higher than the other locations (Table 2).

Table 4. Data about the leaf width and leaf lenght characters of genotypes and results of statistical analysis according to locations.
Çizelge 4. Genotiplerin yaprak eni ve yaprak boyu ile ilgili verileri ve lokasyonlara göre istatistiksel analiz sonuçları.

Genotypes	Leaf width (cm)					Leaf lenght (cm)				
	Evciler	Karayaka	G.Hacıköy	Bafra	Means	Evciler	Karayaka	G.Hacıköy	Bafra	Means
ERB-5	6.97 gh	10.00 g	12.56 fi	12.79 hj	**10.58**	13.73 gi	22.31 df	21.65 fh	24.78 af	**20.62**
ERB-6	9.88 ad	12.97 ag	14.08 bf	11.63 jl	**12.14**	15.48 di	22.37 df	24.52 ae	22.89 eg	**21.31**
ERB-7	8.23 ch	11.47 eg	13.06 ei	12.65 hk	**11.35**	14.52 ei	23.13 cf	23.37 cg	23.26 dg	**21.07**
ERB-9	11.28 ab	15.16 ad	13.43 dh	12.26 ik	**13.04**	19.45 ab	27.27 ad	25.02 ad	22.80 eg	**23.64**
ERB-11	8.85 ch	12.69 ag	13.47 dh	13.75 di	**12.19**	16.49 bh	25.34 af	24.82 ae	24.54 bf	**22.80**
ERB-12	7.14 gh	10.86 fg	14.09 bf	13.05 gj	**11.29**	13.01 i	21.58 ef	24.09 af	25.11 af	**20.95**
ERB-13	9.67 ae	12.93 ag	12.80 fi	13.60 di	**12.25**	17.50 af	25.74 af	23.37 cg	24.84 af	**22.86**
ERB-14	6.83 h	11.97 dg	13.80 bg	10.36 l	**10.74**	14.69 di	25.22 af	23.86 bf	20.78 g	**21.14**
ERB-15	8.92 ch	13.98 af	11.98 hi	13.77 di	**12.16**	16.13 ci	27.75 ac	22.22 eg	26.48 ad	**23.14**
ERB-16	11.57 a	16.03 ab	11.63 i	16.13 ab	**13.84**	20.23 a	28.87 ab	21.73 fh	28.09 a	**24.73**
ERB-17	10.32 ac	16.21 a	12.54 fi	15.42 ac	**13.62**	19.30 ac	27.82 ac	20.94 gh	26.10 ae	**23.54**
ERB-18	8.28 ch	14.54 ae	14.61 ae	14.90 ae	**13.08**	15.07 di	25.51 af	23.72 bf	25.84 ae	**22.54**
ERB-19	10.36 ac	15.44 ad	14.74 ae	14.79 af	**13.83**	17.26 af	25.17 af	24.23 af	25.85 ae	**23.13**
ERB-21	10.20 ac	15.97 ac	12.09 gi	16.31 a	**13.64**	17.41 af	28.93 a	19.60 h	27.32 ab	**23.31**
ERB-23	8.07 dh	12.65 ag	15.33 ab	13.36 ei	**12.35**	15.48 di	25.62 af	26.07 ab	25.86 ae	**23.26**
ERB-25	9.02 cg	15.22 ad	13.23 ei	15.22 ad	**13.17**	16.25 bi	26.11 af	22.84 dg	25.62 ae	**22.71**
ERB-26	9.30 bf	12.97 ag	13.55 ch	16.12 ab	**12.98**	15.51 di	22.70 cf	26.13 ab	26.46 ad	**22.70**
ERB-27	9.82 ad	15.51 ad	15.10 ad	14.18 ch	**13.65**	17.04 ag	27.69 ac	25.70 ac	23.86 cg	**23.57**
ERB-30	9.78 ad	14.01 af	14.72 ae	14.48 cg	**13.25**	17.45 af	23.68 bf	26.67 a	26.69 ac	**23.62**
ERB-35	8.79 ch	14.65 ae	13.77 bg	12.58 hk	**12.45**	16.04 ci	24.47 af	25.61 ac	22.06 fg	**22.05**
ERB-38	7.30 fh	13.88 af	16.16 a	11.14 kl	**12.12**	14.23 fi	26.29 ae	26.77 a	20.86 g	**22.04**
Xanthi 2A	7.58 eh	12.43 cg	15.05 ad	14.64 bg	**12.42**	14.63 ei	25.65 af	26.13 ab	25.72 ae	**23.03**
Nail	9.44 be	12.48 bg	14.75 ae	14.17 ch	**12.71**	17.79 ae	23.91 af	25.56 ac	25.18 af	**23.11**
Canik 190-5	8.43 ch	11.52 eg	15.28 ac	13.21 fj	**12.11**	18.02 ad	25.81 af	26.14 ab	26.62 ad	**24.15**
Xanthi 81	7.14 gh	9.88 g	14.64 ae	13.84 ci	**11.37**	13.19 hi	20.94 f	26.15 ab	24.63 bf	**21.23**
Means	8.93	13.42	13.86	13.77	**12.49**	16.24	25.20	24.28	24.89	**22.65**
Std. means	8.15	11.58	14.93	13.96	**12.15**	15.91	24.08	25.99	25.54	**22.88**
Lines means	9.07	13.77	13.65	13.74	**12.56**	16.30	25.41	23.95	24.77	**22.61**
$LSD_{0.05}$	1.77	2.95	1.46	1.39		2.78	4.29	2.25	2.81	
CV (%)	12.07	13.37	6.42	6.13		10.44	10.37	5.65	6.87	
				Mean square and significance						***df***
Genotype	5.31**	10.42**	4.21**	7.05**		11.06**	14.62*	11.28**	10.80**	24
Error	1.16	3.22	0.79	0.71		2.87	6.83	1.88	2.93	48

*Values followed by different letters in each column are significantly different (*p<0.05) according to Duncan test; Std. means: Standarts means; LSD: Least significant difference; CV: Coefficent of variation; *df:* Degree of freedom; **p<0.01

Leaf Length (cm)

The mean leaf length values and analysis results of different tobacco lines and varieties are given in Table 4. The effect of location on leaf length was slightly important (p<0.05) for Karayaka location while very important (p<0.01) for other locations. The leaf length of the Basma tobacco was reported between 11.40-19.30 cm (Camas *et al*., 2009b) and 25.10-26.90 cm (Yilmaz and Kinay, 2011). The average leaf size of Basma tobacco in some other studies was 20 cm and considered as small-medium size leaf (Peksuslu, 1998; Camas, 1998; Camas *et al*., 2011). The mean leaf length of the lines measured in this study ranged between 16.24 and 25.20 cm and was in agreement with previous studies.

Leaf length values of the standards used ranged from 14.63 to 26.13 cm for Xanthi 2A, from 17.79 to 25.56 cm for Nail, from 18.02 to 26.62 cm for Canik 190-5 and from 13.19 to 26.15 cm for Xanthi 81. The leaf length of Xanthi 2A variety in Erbaa was determined between 15.40 and 20.40 cm (Kinay and Yilmaz, 2016) and in Bafra between 15.7 and 18.6 cm (Kurt and Ayan, 2014). The mean leaf length of Xanthi Djebel XDj-1 variety was reported as 17 cm (Korubin-Aleksoska *et al*., 2014). The leaf length of Nail population ranged between 17.69

and 24.46 cm (Kinay, 2014), between 17.80 and 19.10 cm for Xanthi 81 variety (Ozcan, 2014). The leaf lengths caused by different ecological conditions are slightly different from the results of previous studies (Table 4).

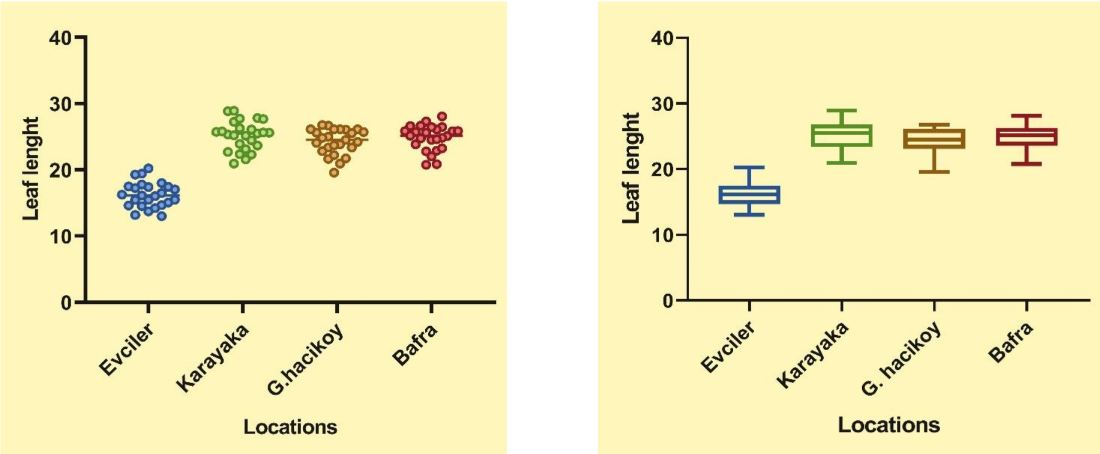

Figure 4. Variation of leaf lenght according to averages of locations of different tobacco genotypes.
Şekil 4. Farklı tütün genotiplerinin lokasyon ortalamalarına göre yaprak boyu varyasyonları.

Leaf size is an important distinctive characteristic of oriental tobaccos. For Black Sea Region tobaccos, the leaf lengths up to 15 cm are considered small leaf sized, those between 15 and 25 cm are considered as medium leaf sized and those longer than 25 cm are considered as broad leaf sized. All genotypes in this study are considered medium leaf sized group. In addition, leaf length was reported to have a strong positive relationship with plant height, leaf width and especially the yield (Aytac, 2016). Some researchers reported that the effect of leaf width on yield is higher compared to the leaf length (Kara, 1993; Dyulgerski and Dimanov, 2012; Kınay, 2014). Sencar and Gokmen (2004) reported that ecology in addition to the ecology has significant impact on the leaf length. The ecology has also been considered an important feature affecting the tobacco yield along with plant height, leaf width and the number of leaves (Butorac *et al*., 2004; Gixhari and Sulovari, 2010); therefore, investigated as an important feature in many studies conducted on tobacco.

The overall average leaf length in this study was 22.65 cm. The highest leaf height was measured in Karakaya location, unlike plant height, number of leaves and leaf width, followed by Bafra and Gümüşhacıköy. The lowest leaf length as in plant height, leaf number and leaf width values were measured in Evciler, which had the lowest soil organic material and more calcareous characteristics than other locations. Since Evciler and Karakaya were located within the same district border, the climate data was used common for both locations. However, Evciler location had a drier season than Karayaka during the research period. Because the total rainfall in Bafra and Karayaka locations was 222.15 mm during the vegetation period and 256.50 mm in Gümüşhacıköy location (Table 2). Therefore, the drought that followed the precipitation in Evciler location had a negative effect on the development period of the vegetative parts, shortened the vegetation (Cakir and Cebi, 2006), and leaf length as in the plant height, leaf number and leaf width parameters has also decreased (Figure 4; Table 4).

Yield (kg da^{-1})

The mean yield values and the results of analysis for the different tobacco lines and varieties were given in Table 5. The effect of location on the yields of genotypes was slightly significant ($p<0.05$) in Gümüşhacıköy and very important ($p<0.01$) in other locations.

Plant height, number of leaves, leaf width and leaf length are the important characteristics affecting the tobacco yield (Butorac *et al.,* 1999). The yield is generally low in representatives of quality smoking oriental tobacco. The number of leaves sometimes up to 100 may indicate an increase in yield without decreasing the quality, while the increase in leaf sizes decreases the quality. The variation in leaf yield occurred parallel to the plant height, leaf number and leaf sizes of genotypes. The increasing effect of leaf length on yield is less than the effect of leaf width (Dyulgerski and Dimanov, 2012) which is due to the additive gene effect of leaf width character (Kinay, 2014). Therefore, the effect of variability in leaf length on yield was low, and the effects of plant height, number of leaves and leaf width were higher.

The variation in yield and related characteristics of local tobacco populations which have been adapted to the ecology where it is grown over time and become ecotype, is important for the selection. The spread of foreign origin varieties to meet the sector needs, co-production of previously existing types with the foreign origin varieties, and transition of seedling and seed led to the development of ecotypes adapted to the region. The yield values during this period were determined between 77 and 148 kg da^{-1} (Camas *et al.*, 2009b). The mean yield values reported by Kinay (2014), who carried out breeding studies in Basma type tobacco in Erbaa and Bafra, were between 132.93 and 150.24 kg da^{-1} in Bafra and 140.26 and 168.64 kg da^{-1} in Erbaa. The tobacco yields in the for 2014, 2015 and 2016 annual reports of TAPDK were ranging from 94.04 to 100.55 kg da^{-1} in Amasya and from 89.44 to 98.14 kg da^{-1} in Tokat (TADB, 2019). The yield values in this study had a considerable high variation ranging from 79.17-237.33 kg da^{-1}. The yield values obtained are clearly high, considering the yield values reported in previous studies and official records.

Table 5. Data about the yield character of genotypes and results of statistical analysis according to locations.
Çizelge 5. Genotiplerin verim ile ilgili verileri ve lokasyonlara göre istatistiksel analiz sonuçları.

Genotypes	**Yield (kg da^{-1})**				
	Evciler	**Karayaka**	**G.Hacıköy**	**Bafra**	**Means**
ERB-5	107.98 fj	162.41 be	200.32 ae	201.07 bg	**167.94**
ERB-6	146.32 b	159.81 ce	208.14 ae	209.00 ae	**180.82**
ERB-7	134.24 bd	196.97 ac	211.20 ae	203.59 af	**186.50**
ERB-9	161.78 a	192.64 ad	216.47 ae	201.92 bf	**193.20**
ERB-11	121.27 dg	179.07 be	207.39 ae	195.48 ch	**175.80**
ERB-12	95.46 jl	177.77 be	222.10 ad	198.06 bh	**173.35**
ERB-13	97.19 jk	210.13 ab	226.23 ac	193.40 ei	**181.74**
ERB-14	112.56 fi	182.30 be	201.09 ae	179.21 gi	**168.79**
ERB-15	116.81 eh	196.30 ac	174.05 e	218.75 ab	**176.47**
ERB-16	129.36 ce	207.46 ac	204.01 ae	226.11 a	**191.74**
ERB-17	100.89 ik	164.38 be	223.80 ad	191.71 ei	**170.19**
ERB-18	119.49 eh	200.37 ac	214.45 ae	214.65 ad	**187.24**
ERB-19	140.26 bc	195.92 ac	183.92 be	205.21 af	**181.33**
ERB-21	166.63 a	205.31 ac	224.94 ac	217.20 ac	**203.52**
ERB-23	82.22 lm	166.96 be	193.04 ae	215.01 ad	**164.31**
ERB-25	140.84 bc	197.54 ac	180.55 ce	201.03 bg	**179.99**
ERB-26	122.64 df	174.95 be	200.01 ae	211.61 ae	**177.30**
ERB-27	122.42 df	237.33 a	231.91 a	211.20 ae	**200.72**
ERB-30	140.68 bc	205.85 ac	228.48 ab	207.85 ae	**195.71**
ERB-35	114.22 fi	201.17 ac	233.54 a	183.49 fi	**183.11**
ERB-38	90.19 km	165.57 be	238.98 a	217.11 ac	**177.96**
Xanthi 2A	79.17 m	147.66 de	178.09 de	172.89 i	**144.46**
Nail	105.88 hj	171.73 be	217.81 ae	177.58 hi	**168.25**
Canik 190-5	107.34 gj	168.90 be	233.04 a	202.18 bf	**177.87**
Xanthi 81	82.11 lm	143.38 e	223.21 ad	190.07 ei	**159.69**
Means	117.52	184.48	211.07	201.82	**178.72**
Std. means	93.63	157.92	213.04	185.68	**162.57**
Lines means	122.07	189.53	210.70	204.89	**181.80**
$LSD_{0.05}$	13.00	39.97	37.83	19.02	
CV (%)	6.73	13.19	10.91	5.74	
	Mean square and significance				***df***
Genotype	1693.12**	1480.94**	1038.15*	576.15**	24
Error	62.69	592.80	530.92	134.21	48

*Values followed by different letters in each column are significantly different (*p<0.05) according to Duncan test; Std. means: Standarts means; LSD: Least significant difference; CV: Coefficent of variation; *df:* Degree of freedom; **p<0.01

The mean yield values of the standards varied between 93.63-213.04 kg da^{-1}. The yield value of Xanthi 2A under Erbaa conditions was reported between 66.90 and 127.60 kg da^{-1} (Camas *et al.*, 2011) and 127.34 and 139.01 kg da^{-1} (Kinay, 2014), while under Bafra conditions between 94.00 and 127.00 kg da^{-1} (Kurt and Ayan,

2014) and 84.57 and 124.55 kg da^{-1} (Kinay, 2014). Nail population had a yield between 90 and 150 kg da^{-1} (Camas, 1998) and 126.58 and 148.50 kg da^{-1} under Bafra conditions, and between 155.74 and 174.90 kg da^{-1} (Kinay, 2014) under Erbaa conditions. The yield of Canik 190-5 varied between 135.55 and 168.65 kg da^{-1} under Erbaa conditions and between 111.25 and 196.28 kg da^{-1} under Bafra conditions (Kinay, 2014). The yield values of Xanthi 81 variety was reported between 125.00-150.00 kg da^{-1} (ATEA, 2012) and 130.60 and 202.20 kg da^{-1} (Ozcan, 2014). The yield values of Xanthi 2A ranged from 79.17 to 178.09 kg da^{-1}, Nail from 105.88 to 217.81 kg da^{-1}, Canik 190-5 from 107.34 and 233.04 kg da^{-1} and Xanthi 81 from 82.11 and 223.21 kg da^{-1}. Similar to the yields of tobacco lines, the yields of standards obtained in this study were higher than the yields of aforementioned studies.

The oriental tobacco has a large variation in yield resulting from the environmental conditions and different culture techniques as well as the genetic structure. Majority of (87.89%) of the variation in tobacco yield was attributed to the changes in environmental conditions (Sadeghi *et al*., 2011). Water stress reduces the number of leaves, plant height, leaf area and thus the yield (Cakir and Cebi, 2006) In other words, tobacco yield is reduced while creating a defense mechanism to overcome the negative impacts of different stress sources (Lambers *et al.,* 2000).

Production capacities of soils have a strong relationship with the organic matter content. High content of organic matter is desirable for Virginia and Burley tobaccos, which have broad blade and high yields (Er and Yildiz, 2014). The mean yield values of the locations (Figure 5, Table 5) were in agreement with the soil organic matter contents of the locations (Table 1).

The differences in altitude, vegetation period and temperature between the locations are important for leaf anatomy. Populations grown at different altitudes vary morphologically, anatomically and ecologically (Gonuz and Ozorgucu, 1999). The intensity of the incoming light and the duration of illumination increase as the altitude increases due to traveling of light through an air layer with a lower thickness. In addition, the number of solid particles and amount of water mist are also low within the air of high altitude (Kevseroglu, 1999). The relationship between light intensity and chlorophyll is positive (Ryu *et al*., 1989). The light intensity and the duration of illumination increase in parallel to the increase in altitude and therefore the amount of net photosynthesis increase, amount of CO_2, humidity and temperature changes that affect the amount of dry matter produced (Sencar and Gokmen, 2004; Kinay, 2014).

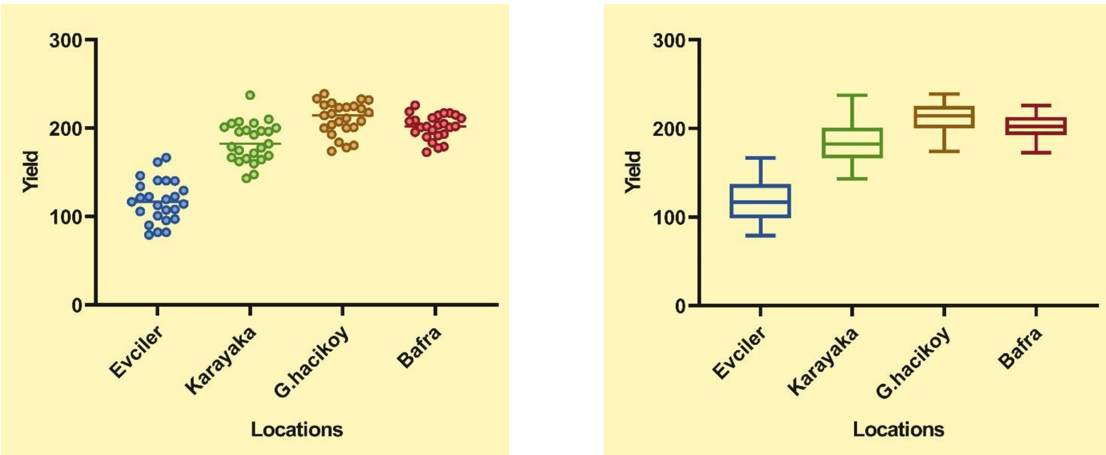

Figure 5. Variation of yield according to averages of locations of different tobacco genotypes.
Şekil 5. Farklı tütün genotiplerinin lokasyon ortalamalarına göre verim varyasyonları.

The difference in altitude causes variation in climatic conditions such as temperature, humidity, wind and precipitation, which also indirectly affects vegetation time (Akbulut *et al*., 2017). The cooler air compared to the long-term averages delays the transition of plants from vegetative to generative period, causes the long time vegetative plant grow and thus encourages the increase in plant height and other related features (Boydak et al., 2018). All lines identified as temporary within the scope of the study (ERB-6, ERB-7, ERB-9, ERB-16, ERB-19, ERB-21, ERB-25 and ERB-35) also had yield values than the overall yield, that confirms the above given information. Therefore, despite limited to the altitudes studied, factors delaying the vegetation have caused an observed increase in the leaf tobacco yield. The varieties were reported to produce high dry matter and starch content in cool climatic conditions and high altitudes (Ozcan, 2018). The increase in the amount of dry matter accumulated in the leaf increases the leaf thickness (Bruck *et al.*, 2008), and the increased leaf thickness results in an increase in yield.

The share of precipitation in the yield variation can reach 80% (Erskine and Ashkar, 1993). Annual rainfall especially in arid and semi-arid climates is the most important climate factor affecting the yield (Floret *et al.*, 1982). Water deficiency plays a more active role in the decrease of tobacco yield than nutrient deficiency. Because, plants can take up the nutrients only if there is enough water in soil. This is not an important problem for the plants grown in lowland, where plant roots can penetrate easily into deeper layers and use the water in the lower layers (Senbayram *et al.*, 2005). The leaves can reach the maximum sizes in case of rapid growth and continuity of the water required to keep the plant in turgor. However, these leaves become fine and fragile. Rainfall causes to occur more elastic leaves according to irrigation. The drought after the early rainfalls results in weak root structure and puny plants, and consequently a decrease in tobacco yield. The oriental tobacco plant, which cannot tolerate the lack of water during the seedling period, needs water, especially after and during blooming period. Continuity of drought during the vegetation period decreases the yield while increasing the fragrance and aroma in the tobacco. The drought in extreme periods significantly reduces the yield even if the total precipitation in the vegetation process is sufficient (Sekin, 1986; Eser and Gecit, 2010). The variability in climate was presented in Table 2. Despite the appropriate parameters such as light, temperature and altitude, the yield obtained in the Evciler location was affected from drought, in addition, the yield also decreased due to the low organic matter content of soil.

Despite the disadvantageous of Bafra location in terms of light and temperature, soils in Bafra location had the second highest soil organic matter content (Table 1). In addition, the increase in yield can also be attributed to the high concentration of CO_2 at low altitudes and the longer vegetation period in Bafra. The moisture content at low altitude locations continuously increases with evaporation occurring at open water surfaces and soils and transpiration by plants. The evaporation and transpiration ratio increase as the relative humidity of the air decreases (Eser and Gecit, 2010). The turgor of the plant does not decrease in humid conditions and growth-development continues (Kevseroglu, 1999), thus the yield increases compared to lower humid environments (Silim *et al.*, 1993). The higher yield in Bafra is also related to the higher relative humidity (Table 2) compared to the other locations.

CONCLUSION

The tobacco plant has a high adaptability and demonstrates unique characteristics in the commonly grown regions. The quality increases in high altitude and arid lands and yield increases towards the lowlands. Despite the higher cost of raw materials compared to the other tobacco types, Central Black Sea region tobacco is the demanded type of oriental tobacco. Although the seeds of the adapted types/varieties suitable for the region can be obtained from the contracted companies, the producers continue to use the degenerated tobacco seeds obtained from their own or neighboring lands. Genotypes with substantially different characteristics from each other and from the origins appear in the region due to the transportation and exchange activities of producers, mechanical mixing and foreign pollination during the production of these seeds. Breeding studies aimed to obtain high-yielding and highly qualified varieties are needed to eliminate especially the yield and quality problems. In this study, 21 Basma type tobacco lines, which stand out with some characteristics, have been tested in four locations where the production is common, with the standards, their performances were monitored and the effects of ecological changes were determined. Clear differences in tobacco yields have been obtained among the locations and the effects of locations with different ecological conditions (light, humidity, precipitation, elevation, temperature etc.) was significant on leaf yield of tobacco. In addition to the genetic potentials, the aforementioned reasons had distinctive impacts on the yield differences of the genotypes. Producing with the desired characteristics can be possible by identifying the characteristics of the grown line/variety and providing the suitable production conditions.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DECLARATION OF AUTHOR CONTRIBUTION

The article is summarized from the PhD thesis of the corresponding author. D.K. designed the experiments, conducted the experiments, performed the analyses, and collected the data. G.Y. and A.K. advised on the preparation of materials. D.K. did the statistics evaluations and wrote the manuscript. G.Y. and A.K. did read and edited the manuscript.

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