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Research Article
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The effect of different altitudeson nut properties and yield in "Chandler" walnut variety

Farklı yükseltilerin "Chandler" ceviz çeşidinde meyve özellikleri ve verime etkisi

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ABSTRACT

Objective: It was aimed to evaluate and interpret nut parameters of "Chandler"walnut variety at two different altitudes according to years.

Material and Methods: Thisresearch was conducted in a commercial orchard located at an altitude of 50 and 750 m in Manisa province during 2017 and 2021 years. "Chandler" walnut variety was used as plant material.

Results: Accordingly, the highest nut weight was determined as 13.89 g at 50 m altitude in 2018. The highest nut width, length, and height values were detected in the same year and altitude. For altitudes of 50 m and 750 m, the shell thickness was thin (1.38 mm and 1.30 mm) in 2020,whereas it was thick (2.16 mm and 1.83 mm) in 2019. A light kernel color was stated at 750 m in 2019. The shrinkage value was found to be much less at 750 m (9.41%). Higher yield was obtained at 50 m altitude. On the other hand, In the principal component analysis, the most important distinguishing features in terms of years were kernel weight for 50 m and kernel ratio for 750 m altitudes.

Conclusion: It was detected that the nut characteristicssuch as kernel ratio, nut length, L* value and shrinkage ratiowere superiordue to the increase in altitude. However, the yield was found to be higher at low altitudes.

ÖZ

Amaç: Bu çalışmada, "Chandler" ceviz çeşidinin iki farklı rakımdaki meyve parametrelerinin yıllara göre değerlendirilmesi ve yorumlanması amaçlanmıştır.

Materyal ve Yöntem: Bu çalışma, 2017 ve 2021 periyodunda, Manisa'da 50 m ve 750 m yükseltide bulunan bir ticari meyve bahçesinde yürütülmüştür. Bitkisel materyal olarak "Chandler" ceviz çeşidi kullanılmıştır.

Araştırma Bulguları: Buna göre, en yüksek meyve ağırlığı, 2018'de 50 m yükseltide, 13,89 g olarak saptanmıştır. En yüksek meyve en, boy ve yükseklik değerleri yine aynı yıl ve yükseltide tespit edilmiştir. 50 m ve 750 m yükselti için kabuk kalınlığı 2020 yılında ince (1.38 mm ve 1.30 mm) buna karşılık 2019 yılında kalın (2.16 mm ve 1.83 mm) olmuştur. Açık iç rengi 2019'da 750 m yükseltide belirtilmiştir. İç büzüşme (%9.41) 750 m'de çok az bulunmuştur. Yüksek verim 50 m yükseltide elde edilmiştir. Temel bileşenler analizinde ise yıllar açısından en önemli ayırt edici özellikler 50 m için iç ağırlığı ve 750 m için iç randımanı olmuştur.

Sonuç: Iç randımanı, meyve uzunluğu, L* değeri ve büzüşme oranı gibi meyve özelliklerin yükseltiye bağlı olarak iyileştiği gözlenmiştir. Ancak düşük yükseltide verimin daha fazla olduğu görülmüştür.

INTRODUCTION

Walnut is an important nut species in the world. It is widely grown in Anatolia. This is the center of origin (Akça et al., 2014). Walnut has been included in diet programs in recent years. It is one of the dried fruits recommended for nutrition and consumed with pleasure due to its fatty acids, vitamins, antioxidants, and mineral substances (Sarikhani et al., 2021). Production areas are also increasing, depending on the trend of consumer interest. There has been an increase in the presence of trees in Türkiye in recent years. This situation also affects the amount of production. Accordingly, walnut production was 325 thousand tons in 2021 and Türkiye ranked 4th after China, USA and Iran (Anonymous, 2023).

With the support of the Ministry of Agriculture and Forestry in Türkiye, new walnut orchards have been established and the production areas and amount have increased. In this context, certified saplings and grant supports have increased the demand for walnut cultivation. Today, the state encourages the establishment of new orchards, especially on treasury lands, thus contributing to the revival of the rural economy (Yurtkulu, 2020). As a result of the economic value of this fruit species and the increasing interest by consumers, producers prefer its cultivation. In recent years, despite the large amount of grafted walnut in the orchard, products cannot be obtained from the trees at the optimum level and quality.

Many new plantations in different ecologies have been established in Türkiye with the “Chandler” walnut variety, which has a yellow kernel color preferred by consumers. With the support of the state, production is carried out in very large areas from sea level to high-altitude state treasury lands (Akça, 2016). As known, efficiency is a significant criterion in production goals. However, the quality characteristics and yield vary according as the species, ecological conditions and altitude (Ersoyol Kırışık et al., 2021). In fruit species yield and quality vary depending on the genotype, ecological conditions and cultural practices. However, the optimum amount and quality can be reached with varieties that adapt to the region. Since fruit growing is a difficult and expensive investment, adaptation studies are of great importance.

On the other hand, the relationship between yield and quality is extremely important in terms of growth (Sakar et al., 2016). As seen in many scientific studies, many features are examined individually and the results are emphasized. In fact, fruit quality characteristics are interrelated. Determining the direction and strength of the relationship between numerical data is important on account of interpreting the whole event.

Multivariate analysis methods help to interpret these relationships and to determine the correlation between variables. With principal component (PC) analysis, independent variables are reduced to smaller component sets. Thanks to this method, highly correlated variables come together so that the principal components that make up the most variation in the data can be determined (Kalaycı, 2016). Since fruit growing is a difficult and expensive investment, it is important to determine the performance of varieties in new growing areas. This research aims to reveal that variation of the “Chandler” walnut cultivar grown at two different altitudes, by means of statistical analysis method, as well as the change of traits according to years.

MATERIALS and METHODS

The current study was conducted in a commercial orchard located at an altitude of 50 m and 750 m in Manisa province, Türkiye. The experimental orchard soil analysis findings are given below (Table 1). Regular irrigation was carried out with a drip irrigation system. Plant nutrition practices were made taking into account soil analysis. The experiment was carried out for 5 years between 2017 and 2021 and the 5-year-old “Chandler” walnut variety was used as plant material. It has a thin shell, smooth, oval shape. It is easy to separate from the shell and is suitable for consumption as dry and fresh walnuts. It has a light kernel color and is a very productive variety (Akça, 2016).

Walnuts were harvested when they had a cracked green pericarp. For the analysis, 30 walnut fruits collected from the tree were separated from their green peels and then dried in the shade. These

examples were used in the analysis. After determining the mean nut and kernel weight on a precision electronic scale, the kernel ratio (%) was found. Shrinkage rate (%) was determined. The width, height, and length of the nut were measured with a digital caliper (0.01 mm). The yield was determined by weighing the total amount of nut in each tree at the time of harvest (kg tree^{-1}). Fruit color was measured by a CR400 model minolta colorimeter in CIE L* a* b* and the values of chrome (C*) and hue angle (h°) were calculated by using the C* =(a*2 + b*2)1/2, h° = tan–1 (b*/a*) formula (Mcguire, 1992).

The study was carried out in 3 replications, with 3 trees in each replication, according to the randomized blocks design. The data were subjected to analysis of variance using IBM® SPSS® Statistics 19 statistical software (IBM, NY, USA). Significant differences between averages were defined by Duncan test at the P<0.05 significant level. In addition, the changes in the mentioned features according to the years were also examined by using principal component analysis methods.

Table 1. Soil analysis results

Çizelge 1. *Toprak analiz sonuçları*

Soil Parameters	50 m				750 m			
	0-30 cm		30-60 cm		0-30 cm		30-60 cm	
pH	7.74	Alkaline	7.85	Alkaline	7.77	Alkaline	7.71	Alkaline
EC (%)	0.046	Salt-free	0.047	Salt-free	0.038	Salt-free	0.048	Salt-free
$CaCO_3$ (%)	9.98	Medium	10.77	Medium	27.13	High	31.92	High
Sand (%)	44.24		44.24		42.24		46.24	
Clay (%)	30.00		30.00		28.00		24.00	
Silt (%)	25.76		25.76		29.76		29.76	
Texture	loamy soil		loamy soil		Clay loam soil		Clay loam sand	
Organic Matter (%)	0.68	Insufficient	0.14	Insufficient	3.39	Sufficient	2.90	Sufficient
N (%)	0.062	Insufficient	0.056	Insufficient	0.123	Sufficient	0.106	Sufficient
P (ppm)	0.80	Insufficient	0.2	Insufficient	0.20	Insufficient	0.40	Insufficient
K (ppm)	358.9	Sufficient	310.4	Sufficient	397.70	Sufficient	329.8	Sufficient
Ca (ppm)	5238	High	5044	High	5529	High	5238	High
Mg (ppm)	632	High	649	High	351.60	High	401.70	High
Na (ppm)	150.4	Normal	37.6	Normal	19.80	Normal	96.10	Normal
Fe (ppm)	6.31	Sufficient	1.14	Insufficient	3.80	Normal	3.34	Normal
Zn (ppm)	0.42	Insufficient	0.54	Insufficient	0.49	Sufficient	0.77	Insufficient
Cu (ppm)	1.34	Sufficient	0.82	Sufficient	1.53	Sufficient	1.33	Sufficient
Mn (ppm)	5.8	Sufficient	3.46	Sufficient	8.12	Sufficient	6.58	Sufficient
B (ppm)	0.32	Insufficient	0.4	Insufficient	0.51	Insufficient	0.54	Insufficient

RESULTS and DISCUSSION

In the evaluation of the nut characteristics of the “Chandler” walnut variety according to years and altitude, it is seen that there is a statistical difference in terms of the examined feature (excluding nut weight and width in 750 m). Accordingly, the highest nut weight (13.89 g) was obtained at 50 m altitude in 2018 (Table 2). Similarly, the highest value in kernel weight (6.73 g) was obtained in the same year and altitude. On the other hand, the lowest value in terms of nut and kernel weight was found in 2020 at the same altitude (9.70 g and 4.78 g). Kernel ratio was determined to be high (51.37%) at 750 m altitude in 2020, whereas it was low (41.79%) at 50 m altitude in 2019. The highest value for nut width, length and height was found at 50 m in 2018 and was determined as 34.16 mm, 36.96 mm and 43.46 mm, respectively. For both altitudes, the shell thickness was thinner in 2020, whereas it was thicker in 2019.

According to the L* value of the color parameters, a light color was detected at 750 m in 2019 (Table 3). The a* value was found to be high at both altitudes in 2020. At 50 m altitude, the b* value changed between 24.62 – 33.6 limit values. The light yellow kernel, which is an important quality indicator in walnuts, was determined to be more effective in 2021. The highest C* value was measured at 50 m in 2021. In addition, the h° value was low at both altitudes in 2020. While the highest shrinkage rate was obtained at 50 m altitude (45.56%) in 2020, shrinkage was not determined in 2019 and 2020 at high altitudes. Yield increased over the years at both altitudes. Accordingly, at 50 m altitude, the yield per tree increased from 1.79 kg to 12 kg, while at 750 m altitude, it increased from 1.11 kg to 10 kg. It was observed that the yield was higher at lower altitudes.

Examined features were evaluated according to altitude and presented in Table 4. Accordingly, kernel ratio, nut length, and L* values expressing light color gave better results at high altitudes. In particular, it was determined that the shrinkage value was approximately a quarter less at 750 m (9.41%) altitude than at 50 m (35.94%). On the other hand, a*, h° value and yield took the first place at low altitudes. It was observed that other features were not affected by altitude (Table 5).

The examined features also differed according to the years, in general, they were statistically effective in 2018. Thus, it was in the first group statistically in terms of all features except a* value and shrinkage. In addition, an increase in yield was recorded over the years. It was stated that year*altitude interaction for values of the properties were significant (excluding shell thickness, L*, a* value and yield).

In this study, it was carried out for 5 years at 2 altitudes in “Chandler” walnut variety, fruit characteristics and yield values changed according to altitude and years. As a matter of fact, the effects of cultivar, ecology and interaction on nut and kernel quality properties were discussed (Forde, 1975). Sarikhani et al., (2021) reported that large nut size and light yellow kernel color highlight that properties may vary with environmental conditions. These quality criteria, which are important in walnuts, were among similar values in our study carried out on the “Chandler”. Also, it was reported that the quality properties of hazelnut cultivars examined in a different study changed depending on altitude (Gülsoy et al., 2019). In another study, they stated that fruit sizes were small in high-altitude varieties, however, positive results were obtained in terms of color values (Koyuncu et al., 2004). Similarly, in another study of the “Chandler” walnut cultivar, characteristics were found to be superior at lower altitudes (Acarsoy Bilgin et al., 2020). In another research carried out at 650, 800 and 900 m altitude in “Chandler”, nut size increased with altitude (Buyuksolak et al., 2020). All these data were parallel to our study. However, in the same study, it was found that the kernel ratio decreased due to the increase in altitude (Buyuksolak et al., 2020), but this characteristic increased in our study.

Moreover, Ergun & Süslüoğlu (2021) emphasize that the average b* value is below 30 (light yellow) in the selected genotypes in their study. In our study, a lighter kernel color was found at high altitudes. Another important quality criterion for this species is kernel ratio and it is an important data of the studies (Ergun & Süslüoğlu, 2021). At the same time, it has been reported that nut kernel ratio is a genetic feature, and is affected by altitude (Amiri et al., 2010). In another study conducted at 4 different altitudes in the Mediterranean Region, the nut weight did not increase according to the altitude, but the kernel ratio increased and the kernel became lighter in color (Bayazıt et al., 2020). Similar findings were obtained in our study. On the other hand, as it is known, high temperature damage causes shrinkage in walnuts. In cold regions (750 m altitude), the shrinkage rate was low (9.41%) due to low summer temperatures. In confirming this, it was observed that the shrinkage rate increased in the low location where summer temperatures are high (Acarsoy Bilgin, 2022).

Table 2. The values of nut properties according to year and altitude

Çizelge 2. *Ceviz özelliklerinin yıllara ve rakımlara göre değerleri*

Altitude	Year	Nut weight (g)	Kernel weight (g)	Kernel ratio (%)	Nut width (mm)	Nut length (mm)	Nut height (mm)	Shell thickness (mm)	Shrinkage ratio (%)
50 m	2017	12.27 b	6.16 b	50.17 a	32.92 a	34.95 b	40.82 b	1.51 a	29.16 a
	2018	13.89 a	6.73 a	48.45 ab	34.16 a	36.96 a	43.46 a	1.49 a	38.33 ab
	2019	11.26 c	4.70 d	41.79 c	30.46 b	30.66 c	36.83 c	2.16 b	28.33 a
	2020	9.70 d	4.70 d	49.31 a	30.04 b	31.29 c	37.30 c	1.38 a	45.56 b
	2021	12.27 b	5.67 c	46.26 b	32.77 a	34.12 b	40.46 b	1.49 a	38.33 ab
750 m	2017	11.85 ab	5.99^{ns}	50.59 ab	31.50^{ns}	34.93 a	41.71 a	1.52 abc	35.00 b
	2018	11.97 ab	5.97	49.99 abc	32.33	34.45 ab	40.11 ab	1.50 ab	8.33 a
	2019	12.08 a	5.54	45.81 c	32.89	34.36 ab	39.38 b	1.83 c	0.00 a
	2020	10.85 b	5.58	51.37 a	32.20	33.67 ab	39.28 b	1.30 a	0.00 a
	2021	11.30 ab	5.24	46.34 bc	31.62	33.03 b	39.12 b	1.63 bc	3.34 a

ns: Non-significance.

Table 3. Effects of color values and yield according to year and altitude

Çizelge 3. *Renk değerleri ve verimin yıllara ve rakımlara göre etkileri*

Altitude	Year	L*	a*	b*	C*	h°	Yield (kg tree^{-1})
50 m	2017	51.34 a	8.75 bc	29.87 bc	31.13 ab	73.68 a	1.79 b
	2018	49.65 a	8.54 bc	30.14 bc	31.33 ab	74.19 a	3.16 b
	2019	50.35 a	7.51 c	28.44 b	29.42 b	75.22 a	11.04 a
	2020	45.56 b	12.80 a	24.62 c	27.76 b	62.53 b	11.66 a
	2021	51.35 a	9.09 b	33.67 a	34.88 a	74.81 a	12.00 a
750 m	2017	52.88 ab	6.95 b	28.42 b	29.28 c	76.28 a	1.11 d
	2018	53.91 ab	7.32 b	28.99 ab	29.92 bc	75.87 a	0.77 d
	2019	55.81 a	6.90 b	29.83 a	30.62 ab	76.97 a	4.66 c
	2020	50.85 b	11.02 a	29.53 a	31.53 a	69.54 b	6.16 b
	2021	52.69 ab	7.45 b	28.58 b	29.54 bc	75.39 a	10.00 a

Table 4. Average values of nut properties

Çizelge 4. *Ceviz özelliklerinin ortalama değerleri*

		Nut weight (g)	Kernel weight (g)	Kernel ratio (%)	Nut width (mm)	Nut length (mm)	Nut height (mm)	Shell thickness (mm)	Shrinkage ratio (%)
Altitude	50	11.88^{ns}	5.61^{ns}	47.20 b	32.07^{ns}	33.61 b	39.77^{ns}	35.94 b	1.60^{ns}
	750	11.61	5.66	48.82 a	32.10	34.01 a	39.92	9.41 a	1.55
Year	2017	12.06 b	6.07 a	50.38 a	32.21 ab	34.93 a	41.26 ab	32.08 c	1.52 a
	2018	12.93 a	6.35 a	49.22 a	33.24 a	35.75 a	41.78 a	23.33 b	1.50 a
	2019	11.67 b	5.12 b	43.80 c	31.67 b	32.57 c	38.10 c	14.35 a	1.99 b
	2020	10.27 c	5.18 b	50.34 a	31.12 b	32.43 c	38.29 c	22.78 b	1.34 a
	2021	11.79 b	5.45 b	46.30 b	32.19 ab	33.50 b	39.79 bc	20.83 b	1.56 a
Year * Alt.		**	**	*	**	**	**	ns	**

*Significant at P<0.05, ** Significant at P<0.01. ns: Non-significance.

Table 5. Average values of color and yield

Çizelge 5. *Renk ve verimin ortalama değerleri*

		L*	a*	b*	C*	h°	Yield (kg tree^{-1})
Altitude	50	49.65 b	9.33 a	29.35 ^{ns}	30.90 ^{ns}	72.08 a	7.93 a
	750	53.23 a	7.93 b	29.07	30.18	74.81 b	4.54 b
Year	2017	52.11 a	7.85 b	29.15 a	30.20 ab	74.98 a	1.45 c
	2018	51.78 a	7.93 b	29.56 a	30.62 ab	75.03 a	1.97 c
	2019	53.08 a	7.21 b	29.14 a	30.02 b	76.09 a	7.85 b
	2020	48.21 b	11.91 a	27.08 b	29.64 b	66.03 b	8.91 b
	2021	52.02 a	8.27 b	31.12 a	32.21 a	75.10 a	11.00 a
Year * Alt.		ns	ns	**	*	**	ns

*Significant at P<0.05, ** Significant at P<0.01. ns: Non-significance.

As a result of PC analysis carried out on the “Chandler” variety, 3 PC were clarified that identified 87.247% of the characteristics for 50 m altitude (Table 6). According to analysis, kernel weight, nut length, height, yield, nut widthand nut weight datas made the highest contribution to PC1, constituting 40.177% of the total variance. The a*, h°, shell thickness, L*, shrinkage and kernel ratio datas contributed to PC2, accounting for 27.470% of the total variance. PC3 explains the C* and b* value with 19.600% of the total variance.

Table 6. Principal component analysis (50 m altitude)

Çizelge 6. *Temel bileşen analizi (50 m yükselti)*

Features	**PC 1**	**PC 2**	**PC 3**
Kernel weight (g)	**0.969**	0.046	0.201
Nut length (mm)	**0.918**	-0.021	0.366
Nut height (mm)	**0.888**	0.008	0.383
Yield (kg tree^{-1})	**-0.888**	-0.175	0.242
Nut width (mm)	**0.858**	0.112	0.407
Nut weight (g)	**0.787**	0.383	0.395
a*	-0.249	**-0.933**	-0.105
h°	0.306	**0.849**	0.400
Shell thickness (mm)	-0.410	**0.808**	-0.202
L*	0.292	**0.676**	0.234
Shrinkage (%)	-0.004	**-0.655**	-0.099
Kernel ratio (%)	0.621	**-0.631**	-0.261
C*	0.217	0.132	**0.948**
b*	0.265	0.329	**0.894**
Eigen value	5.625	3.846	2.744
Variance (%)	40.177	27.470	19.600
Cumulative (%)	40.177	67.647	87.247

Extraction method: principal component analysis. Rotation method: Varimax with Kaiser normalization.

In PC analysis for 750 m height, 4 PC were obtained and they identified 84.062% of the five years with fourteen characteristics (Table 7). According to this analysis, nut length, height and weight, kernel weight and yield datas made the highest contribution to PC1, constituting 27.126% of the total variance. This is the an important component. The h°, a* and L* value contributed to PC2, accounting for 23.920% of the total variance. PC3 accounted for the b* and C* value, nut width and shrinkage contributing 19.303% of the total variance. Kernel ratio and shell thickness contributed to PC4, resulting in 13.713% of the variance.

Rotated factor matrix analysis can be better interpreted and meaningful factors can be obtained. The matrix shows the correlation between the original variable and its factor. Under which factor a variable has the greatest weight, the variable is in close relationship with that factor. In addition, the fact that the eigen values are greater than 1 indicates that the weight values of these axes are reliable (Kalaycı, 2016).

In this current study, in the PC analysis, the most important distinguishing features in terms of years were kernel weight for 50 m and kernel ratio for 750 m. Moreover, distinctive features have been revealed for different genotypes (Acarsoy Bilgin, 2020, Ayar, 2018, Gouta et al., 2019). Thanks to this analysis method, it is possible to select the distinguishing parameters in the data group (Acarsoy Bilgin et al., 2020b; Fallah et al., 2022).

Table 7. Principal component analysis (750 m altitude)

Çizelge 7. Temel bileşen analizi (750 m yükselti)

Features	PC 1	PC 2	PC3	PC4
Nut length (mm)	**0.906**	0.005	0.085	0.120
Nut height (mm)	**0.862**	-0.240	-0.335	-0.022
Nut weight (g)	**0.811**	0.247	0.104	-0.318
Kernel weight (g)	**0.776**	0.058	-0.010	0.491
Yield (kg tree^{-1})	**-0.707**	-0.267	0.068	-0.373
h°	0.101	**0.918**	-0.243	-0.203
a*	-0.112	**-0.901**	0.322	0.200
L*	-0.003	**0.867**	0.207	0.001
b*	-0.096	-0.159	**0.884**	-0.118
C*	-0.132	-0.577	**0.770**	0.044
Nut width (mm)	0.302	0.208	**0.708**	0.040
Shrinkage (%)	0.541	0.125	**-0.689**	0.202
Kernel ratio (%)	0.198	-0.175	-0.090	**0.928**
Shell thickness (mm)	0.004	0.548	0.051	**-0.651**
Eigen value	3.798	3.349	2.702	1.920
Variance (%)	27.126	23.920	19.303	13.713
Cumulative (%)	27.126	51.046	70.349	84.062

Extraction method: principal component analysis. Rotation method: Varimax with Kaiser normalization.

CONCLUSION

Walnut, which is a food with high nutritional value, is valuable in terms of healthy nutrition. "Chandler" variety is consumed with pleasure due to its kernel size, light color, and easy cracking. Genotype is effective on these features. As it is known, yield and quality differs depending on ecological

conditions and cultural practices. Recently, its cultivation in different ecologies and altitudes has become widespread due to its increasing popularity and government support. In addition to evaluating fruit quality characteristics individually, analyzing them with different statistical methods is necessaryin terms of interpretation when their connections with each other are taken into account. In our study, in which data obtained for 5 years were evaluated, the severity and direction of the distinguishing features between numerical data were also determined. It was observed that the nut quality characteristics such as kernel ratio, nut length, L* value and shrinkage ratio also improved depending on the increase in altitude.In contrast, the yield was higher at low altitude. Besides it has been determined that the most important distinguishing features in terms of years are kernel weight for 50 m and kernel ratio for 750 m.

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