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Original Article

Evaluation of Fruit Characteristics of Bitter Almond (*Prunus dulcis* var. amara) Genotypes Selected from Hilvan District of Şanlıurfa

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ABSTRACT

The aim of this study was to evaluate the fruit characteristics of selected bitter almond genotypes in Hilvan district of Şanlıurfa, Türkiye. The study was conducted in 2015-2016 and examined 18 bitter almond genotypes grown from seed. Fruit characteristics were determined, including the weight of shelled and kernel almonds, size and various physical properties. The weight of the shelled almonds ranged from 2.20 g to 6.21 g, while the kernel weight ranged from 0.50 g to 1.04 g. The width, length and height of the shell fruits ranged from 15.92 to 24.32 mm, 24.43 to 40.68 mm and 11.29 to14.88 mm, respectively, while the width, length and height of the kernel fruits ranged from 8.90 to 13.57 mm, 17.45 to 28.85 mm and 4.51 to 6.68 mm, respectively. The shape of the kernels was predominantly classified as medium-wide and flat. A weighted scoring method was used to assess the overall quality of the fruit, with scores ranging from 536 to 624 points. In this study, further research is recommended to evaluate the properties of the rootstock of the genotypes and explore their potential in various industries such as cosmetics, pharmaceuticals and food. It is expected that this study will contribute to a better understanding of bitter almond diversity and thus provide important support for future breeding efforts.

Key words: Bitter almond, performance, fruit characteristics, Şanlıurfa.

Şanlıurfa'nın Hilvan İlçesinden Seçilen Acı Badem (*Prunus dulcis* var. amara) Genotiplerinin Meyve Özelliklerinin Değerlendirmesi

ÖZ

Bu çalışmanın amacı, Şanlıurfa'nın Hilvan ilçesinde seçilen acı badem genotiplerinin meyve özelliklerini değerlendirmektir. Çalışma 2015-2016 yıllarında yürütülmüş ve tohumdan yetiştirilen 18 acı badem genotipi incelenmiştir. Kabuklu ve iç badem ağırlığı, irilik ve çeşitli fiziksel özellikler de dahil olmak üzere meyve özellikleri belirlenmiştir. Kabuklu bademlerin ağırlığı 2.20 g ile 6.21 g arasında değişirken, çekirdek ağırlığı 0.50 g ile 1.04 g arasında değişmiştir. Kabuklu meyvelerin eni, boyu ve yüksekliği sırasıyla 15.92 ile 24.32 mm, 24.43 ile 40.68 mm ve 11.29 ile 14.88 mm arasında değişirken, çekirdekli meyvelerin eni, boyu ve yüksekliği sırasıyla 8.90 ile 13.57 mm, 17.45 ile 28.85 mm ve 4.51 ile 6.68 mm arasında değişmiştir. Çekirdeklerin şekli ağırlıklı olarak orta genişlikte ve yassı olarak sınıflandırılmıştır. Meyvelerin genel kalitesini değerlendirmek için ağırlıklı puanlama yöntemi kullanılmış ve puanlar 536 ila 624 puan arasında değişmiştir. Bu çalışmada, genotiplerin anaçlarının özelliklerini değerlendirmek ve kozmetik, ilaç ve gıda gibi çeşitli endüstrilerdeki potansiyellerini keşfetmek için daha fazla araştırma yapılması önerilmektedir. Bu çalışmanın acı badem çeşitliliğinin daha iyi anlaşılmasına katkıda bulunması ve böylece gelecekteki ıslah çalışmaları için önemli bir destek sağlaması beklenmektedir.

Anahtar kelimeler Acı badem,performans, meyve özellikleri, Şanlıurfa

INTRODUCTION

Almond (*Prunus amygdalus* Batsch) is a fruit species belonging to the Rosaceae family known for its high economic value. Thanks to its geographical location and ecological diversity, Turkey has very favorable conditions for almond cultivation (Şimşek & Gülsoy, 2017) Turkey has great potential for almond cultivation. The GAP region in particular, with its favorable climatic conditions, has developed into an important region for almond cultivation. The high summer temperatures are a great advantage for almond cultivation in this region (Kaşka et al., 2005; Şimşek & Osmanoğlu, 2010; Emre & Tapkı, 2022). Almonds are classified pomologically as bitter almonds (*Prunus amygdalus var*. amara) and sweet almonds (*Prunus amygdalus* Dulcis) (Karatay et al., 2014).

Bitter almonds are used in oil production and the cosmetic industry because they contain cyanogenic acid and can have a toxic effect when consumed in excess (Thodberg et al., 2018). In contrast, sweet almonds contain very little or no cyanogenic acid at all (Topçuoğlu & Ersan, 2020). Bitter almond kernels contain amygdalin (C20H27NO11), a colorless and crystalline glycoside (Keser et al., 2014; Del Cueto et al., 2017). These kernels also contain a special enzyme. When the kernel is chewed, crushed or otherwise damaged, this enzyme breaks down the soluble amygdalin in the presence of water and converts it into glucose, hydrocyanic acid and benzaldehyde (Atapour & Kariminia, 2013; Bolarinwa et al., 2014). The genotypes of bitter almonds are used differently due to their higher amygdalin content compared to sweet almonds. Bitter almonds, which are used as raw materials in the cosmetics and pharmaceutical industries, are also used in traditional medicine (Bouzid et al., 2021; Guici et al., 2023).

The use of bitter almonds in almond breeding programs plays an important role in increasing genetic diversity and improving resistance to environmental stresses (Dicenta et al., 2007; Sánchez-Pérez et al., 2010). In addition, when used as rootstock, bitter almonds have been reported to be more resistant to rodents and certain diseases Kodad & Socias I Company, 2008; Wani et al., 2012). Therefore, the evaluation of the agronomic performance of bitter almond genotypes is both economically and scientifically important. In addition, bitter almond genotypes are of great importance as rootstocks in modern fruit production. Although there are numerous studies in the literature investigating the fruit characteristics of sweet almond genotypes (Ağlar, 2005; Şimşek, 2011; Gülsoy & Balta, 2014; Bozkurt, 2017; Büyükfırat et al., 2022). No study was found investigating the fruit characteristics of bitter almond genotypes. In this respect, this study is a first both in our country and worldwide. The aim of this study was to determine the agronomic fruit characteristics of selected bitter almond genotypes from Hilvan district (Şanlıurfa).

MATERIALS AND METHODS

This study was conducted in 2015-2016 in Hilvan district of Şanlıurfa. The plant material used for the study consisted only of almond trees grown from seed. A total of 140 almond trees were selected in the 2015 harvest season. As the study focused on bitter almond types, sweet almonds were eliminated and the performance of the remaining 18 bitter almond types was examined.

During the harvest season (August – September), 30 fruit samples from each type were separated from their shells and dried in the shade. The analyses were carried out in the laboratory of the Department of Horticulture of the Faculty of Agriculture of Dicle University. In the study, which was conducted over two years, the average shelled and kernel fruit weight were weighed on a digital scale with an accuracy of 0.01 g. The width, length, height and shell thickness of shelled and kernel almonds were measured with a digital caliper with an accuracy of 0.01 mm. Some other characteristics of shelled and kernel almonds were determined by observation.

The performance of bitter almond types was determined using the weighted rating method. For this purpose, the weighted rating method defined by Şimşek (1996) and Balta (2002) was appropriately modified and applied. This method aimed to evaluate the almond types based on specific criteria, allowing for a more objective assessment of their performance. In the weighted rating method, total scores were calculated by multiplying the value score of each characteristic by the relative scores and summing the scores separately (Table 1).

Table 1. Criteria taken into account in the weighted evaluation, the value points of these criteria and the relative scores awarded based on the quality status of the fruit.

Criteria and value points	Contribution Shares (%)
Inshell fruit size (3-5-7-9)	10
Shell suture aperture (0-5-9)	8
Shell hardness (1-3-5-7-9)	12
Kernel almond color (1-3-5-7-9)	7
Yield (3-5-7)	20
Kernel almond shell smoothness (1-5-7)	8
Kernel almond hairiness (3-5-7-9)	10
Kernel almond taste (3-5-7)	20
Double kernel ratio (1-5-7)	5
Total	100

RESULTS AND DISCUSSION

Based on the weighted rating of fruit quality characteristics, the 18 examined bitter almond genotypes scored between 536 (HLV136) and 624 (HLV15, HLV114, HLV130) (Table 2).

Table 2. Weighted rating scores according to quality status of bitter almond genotypes

Genotype No	According to quality	Genotype No	According to quality
HLV7	564	HLV98	564
HLV15	624	HLV103	618
HLV23	576	HLV114	624
HLV38	586	HLV118	578
HLV52	598	HLV120	558
HLV58	618	HLV125	584
HLV64	538	HLV130	624
HLV77	606	HLV136	536
HLV90	596	HLV139	596

Although bitter almonds are not consumed directly, almond oil and cyanide derivatives are widely used in the cosmetics and pharmaceutical industries (Čolić et al., 2019; Guici et al., 2023). Therefore, the size and weight of bitter almonds are important factors that increase the raw material yield by providing more oil for these industries

In the 18 bitter almond genotypes examined, the weight of shelled almonds ranged from 2.20 g (HLV120) to 6.21 g (HLV118); the width of shelled almonds ranged from 15.92 mm (HLV139) to 24.32 mm (HLV58 and HLV118); the length of shelled almonds ranged from 24. 43 mm (HLV120) to 40.68 mm (HLV52); height of shelled almonds ranged from 11.29 mm (HLV139) to 14.88 mm (HLV118) (Table 3).

In almonds, there is generally an inverse relationship between the thickness of the shell and the proportion of kernel; as the thickness of the shell increases, the proportion of kernel decreases and vice versa. Therefore, in the industries where bitter almonds are used as raw materials, thin shells and high kernel content are preferred. In the study, the shell thickness of the bitter almond genotypes ranged from 2.47 mm (HLV23) to 4.47 mm (HLV118).

In previous studies, Şimşek and Osmanoğlu (2010) reported that in the promising genotypes selected from Derik district of Mardin, the weight, width, length and thickness of shelled fruit ranged from 1.75 to 4.77 g, 17.11 to 24.90 mm, 26.13 to 35.71 mm and 11.84 to 16.77 mm, respectively. Akçalı (2015) reported that in the almond genotypes growing on the foothills of Mount Erciyes, the length of the fruit shelled was between 19.90 and 40.74 mm, the height between 10.29 and 17.37 mm and the width between 11.79 and 27.62 mm. Büyükfırat et al. (2022), found that in the almond genotypes from the Yeşilyurt (Malatya) region, the average weight of the fruit shelled was between 3.50 g and 12.07 g (44-YE-69), the width between 19.15 and 30.68 mm, the length between 29.79 and 45.38 mm and the thickness between 2.43 mm and 5.26 mm.

Table 3. Shelled fruit characteristics of bitter almond genotypes

Genotype No	Shelled almond weight (g)	Shelled almond width (mm)	Shelled almond length (mm)	Shelled almond height (mm)	Shell thickness (mm)
HLV7	3.06±0.26	18.54±0.45	28.79±1.24	12.83±0.64	2.97±0.29
HLV15	3.33±0.21	18.31±0.77	30.61±0.69	12.22±0.40	2.71±0.15
HLV23	3.00±0.46	19.68±0.36	28.89±1.17	11.59±0.37	2.47±0.11
HLV38	3.74±0.09	20.03±0.62	32.39±0.56	12.52±0.14	3.48±0.07
HLV52	6.01±0.27	23.17±0.76	40.68±1.48	14.38±0.76	4.25±0.41
HLV58	6.16±0.49	24.32±0.91	34.55±1.54	14.33±0.32	3.44±0.20
HLV64	2.29±0.10	16.42±0.41	25.29±0.91	12.77±0.32	2.85±0.52
HLV77	3.48±0.29	19.18±0.86	32.06±1.55	12.07±0.52	3.25±0.62
HLV90	2.75±0.40	17.84±1.10	29.65±0.34	12.24±0.74	2.95±0.58
HLV98	2.93±0.29	18.52±0.57	27.92±0.72	12.86±0.58	2.93±0.09
HLV103	5.49±0.20	22.91±1.09	33.90±1.22	14.36±0.26	3.66±0.29
HLV114	3.06±0.20	17.62±0.44	29.44±0.46	11.89±0.27	2.67±0.33
HLV118	6.21±0.21	24.32±1.35	39.92±1.55	14.88±0.40	4.47±0.15
HLV120	2.20±0.17	15.99±0.55	24.43±0.79	12.41±0.24	2.92±0.06
HLV125	2.64±0.10	17.34±0.58	28.36±0.34	12.21±0.53	2.79±0.23
HLV130	2.53±0.12	17.70±0.78	27.35±0.08	12.21±0.40	3.05±0.19
HLV136	2.29±0.06	16.93±0.93	28.51±1.05	11.46±0.10	2.64±0.34
HLV139	2.41±0.33	15.92±0.92	27.81±1.82	11.29±0.29	2.79±0.28

When evaluating the kernel characteristics of the 18 bitter almond genotypes examined, it was found that the kernel weight was between 0.50 g (HLV130 and HLV139) and 1.04 g (HLV58 and HLV103). The width of the kernel ranged from 8.90 mm (HLV139) to 13.57 mm (HLV58), the length of the kernel between 17.45 mm (HLV120) and 28.85 mm (HLV52), the height of the kernel between 4.51 mm (HLV58) and 6.68 mm (HLV64) and the ratio of the kernel between 16.24 % (HLV118) and 25.54 % (HLV120). No double kernel was observed in any of the genotypes examined (Table 4).

Table 4. Kernel fruit characteristics of bitter almond genotypes

Genotype No	Kernel almond weight (g)	Kernel almond width (mm)	Kernel almond lenght (mm)	Kernel almond height (mm)	Kernel ratio (%)	Double ratio (%)
HLV7	0.60±0.02	11.59±0.62	20.73±1.27	5.30±0.40	19.28±0.60	0
HLV15	0.60±0.02	10.58±0.25	20.25±0.76	4.94±0.15	17.94±0.23	0
HLV23	0.58±0.09	9.85±0.71	19.85±0.86	4.65±0.27	19.45±0.21	0
HLV38	0.76±0.03	11.91±0.45	23.68±0.96	5.47±0.09	20.23±0.39	0
HLV52	1.01±0.05	11.66±0.49	28.85±0.97	5.57±0.17	16.86±0.74	0
HLV58	1.04±0.03	13.57±0.70	24.43±0.29	4.51±0.24	16.93±0.97	0
HLV64	0.55±0.03	9.69±0.26	17.60±0.92	6.68±0.60	23.87±0.43	0
HLV77	0.78±0.07	11.45±0.63	23.76±0.61	5.62±0.20	22.41±0.25	0
HLV90	0.58±0.08	11.40±0.43	19.10±1.00	5.51±0.58	21.08±0.19	0
HLV98	0.64±0.03	12.12±0.35	20.19±0.56	5.40±0.26	21.83±1.20	0
HLV103	1.04±0.02	13.32±0.64	23.76±0.43	4.67±0.19	18.91±0.66	0
HLV114	0.61±0.03	10.29±0.33	18.91±0.79	5.02±0.26	20.08±0.48	0
HLV118	1.02±0.06	11.57±0.91	28.43±1.93	5.67±0.14	16.24±0.52	0
HLV120	0.56±0.03	9.40±0.27	17.45±0.82	6.45±0.02	25.54±0.84	0
HLV125	0.59±0.04	10.19±0.30	19.77±1.04	5.77±0.20	22.18±0.54	0
HLV130	0.50±0.02	10.07±0.82	18.44±0.57	5.54±0.42	19.61±0.13	0
HLV136	0.54±0.01	10.47±0.53	19.15±0.69	5.80±0.21	23.74±0.51	0
HLV139	0.50±0.08	8.90±0.47	18.81±1.00	4.78±0.26	20.54±0.55	0

Table 5. Some physical properties genotypes of bitter almond

Genotype No	SH	SAS	TSSA	WAS	PA	SSO	SAC	FSSA
HLV7	VH	H	P	N	S	C	ML	SM
HLV15	VH	LO	B	N	S	C	ML	SM
HLV23	VH	H	P	N	S	C	ML	SM
HLV38	VH	LO	B	N	S	C	ML	SM
HLV52	VH	LO	B	SW	S	C	ML	L
HLV58	VH	LO	B	N	S	C	ML	L
HLV64	VH	LO	SP	N	S	C	ML	SM
HLV77	VH	LO	B	N	S	C	ML	SM
HLV90	VH	H	P	N	N	C	ML	SM
HLV98	VH	H	P	N	S	C	ML	SM
HLV103	VH	LO	B	N	S	C	ML	ML
HLV114	VH	LO	B	N	S	C	ML	SM
HLV118	VH	LO	B	SW	S	C	ML	L
HLV120	VH	LO	SP	N	S	C	ML	SM
HLV125	VH	LO	P	SW	N	C	ML	SM
HLV130	VH	LO	P	SW	N	C	ML	SM
HLV136	VH	H	P	N	N	C	ML	SM
HLV139	VH	H	P	N	S	C	ML	SM

SH: Shell hardness (VH: Very Hard); SAS: Shelled almond shape (H: Hearth, LO: Long Oval); TSSA: Tip shape of shelled almonds (P: Pointed, B:Blunt,SP:Slightly Pointed); WAS: Wingedness of almonds shelled (N: None, SW: Slightly winged); PA: Protrusion of the abdomen (S: Slightly, N:None); SSO: Shell suture opening (C: Closed); SAC: Shelled almond color (ML: Medium Light); FSSA: Fruit size of shelled almonds (SM: Small, L:Large, ML: Medium Large)

Table 6. Some physical properties of the kernel fruit of bitter almond genotypes

Genotype No	AHS	KAH	KAC	KAT	NAPO (Piece)	KAS	KAWI (%)	KASAWI	KATI (%)	KASATI
HLV7	S	SH	N	B	47.17	SM	55.91	MW	25.57	F
HLV15	S	SH	N	B	47.17	SM	52.25	MW	24.40	F
HLV23	SW	SH	N	B	48.79	SM	49.62	N	23.43	F
HLV38	S	MH	N	B	37.24	SM	50.30	MW	23.10	F
HLV52	SW	MH	N	B	28.02	MS	40.42	N	19.31	F
HLV58	SW	MH	N	B	27.21	MS	55.55	MW	18.46	F
HLV64	SW	MH	N	B	51.45	SM	55.06	MW	37.95	MT
HLV77	S	MH	N	B	36.28	SM	48.19	N	23.65	F
HLV90	SW	SH	N	B	48.79	SM	59.69	MW	28.85	F
HLV98	S	SH	N	B	44.22	SM	60.03	MW	26.75	F
HLV103	SW	MH	N	B	27.21	MS	56.06	MW	19.65	F
HLV114	S	SH	N	B	46.39	SM	54.42	MW	26.55	F
HLV118	SW	MH	N	B	27.75	MS	40.70	N	19.94	F
HLV120	SW	MH	N	B	50.54	SM	53.87	MW	36.96	MT
HLV125	S	SH	N	B	47.97	SM	51.54	MW	29.19	F
HLV130	S	SH	N	B	56.60	SM	54.61	MW	30.04	MT
HLV136	SW	SH	N	B	52.41	SM	54.67	MW	30.29	MT
HLV139	SW	SH	N	B	56.60	SM	47.32	N	25.41	F

AHS: Almond hull smoothness (S: Smooth,SB: Slightly Wrinkled; KAH: Kernel Almond Hairiness (SH: Slightly Hairy, MH: Moderately Hairy); KAC: Kernel Almond Color (D: Dark); KAF: Kernel Almond Taste (B:Bitter); NAPO : Number of Almonds Per Ounce; KAS: Kernel Almond Size (SM: Small, MS: Medium Small); KAWI: Kernel Almond Width Index ; KASAWI: Kernel Almond Shape According to Width Index (MW: Medium-Width, N:Narrow); KATI: Kernel Almond Thickness Index ; KASATI: Kernel Almond Shape According to Thickness Index (F: Flat, MT: Medium Thick)

In all of the 18 bitter almond genotypes examined, the shell hardness was classified as 'very hard '(VH) As for the shape of the almonds shelled, 12 genotypes were classified as 'long oval'(LO) and 6 genotypes as 'heart-shaped' (H) The tip shape of the almonds shelled was observed to be 'pointed' (P) in 8 genotypes, 'blunt' (B) in 8 genotypes and 'slightly pointed'(SP) in 2 genotypes. When examining the wing structure, it was found that 14 genotypes had no wings, (N) while 4 genotypes (HLV52, HLV118, HLV125 and HLV130) had a 'slightly winged' (SW) structure. The degree of abdominal protrusion was classified as 'slight' (S) in 14 genotypes, while 'none' (N) was observed in 4 genotypes (HLV90, HLV125, HLV130 and HLV136) The opening of the shell suture was observed as 'closed' (C) in all genotypes, and the color of the almond of shelled was classified as 'medium light' (ML) in all genotypes. With regard to fruit size, 14 genotypes were classified as 'small', (SM) 3 genotypes (HLV52, HLV58 and HLV118) as 'large' (L) and 1 genotype (HLV103) as 'medium-large' (ML) (Table 5).

In the 18 bitter almond genotypes examined, the smoothness of the kernel almond shell was determined to be “smooth” (S) in 9 genotypes and “slightly wrinkled” (SW) in 9 genotypes. The hairiness of the kernel almond was observed as “slightly hairy” (SH) in 10 genotypes and “moderately hairy” (MH) in 8 genotypes. The kernel almond color was “dark” (D) in all genotypes and the taste was “bitter” (B). The number of almonds per ounce (28.35 grammes) ranged from 27.21 (HLV58 and HLV103) to 56.60 (HLV130 and HLV139). Almond size was classified as “small” (SM) for 14 genotypes and “medium-size” (MS) for 4 genotypes. The kernel width index ranged from 40.42 % (HLV52) to 60.03 % (HLV98). Based on the width index, the kernel shape was categorized as 'medium-width' (MW) for 14 genotypes and 'narrow' (N) for 4 genotypes. The kernel thickness index ranged from 18.46 % (HLV58) to 37.95 % (HLV64). Based on the thickness index, the kernel shape was identified as 'flat' (F) in 14 genotypes and as 'medium thick' (MT) in 4 genotypes (Table 6). These data show that the bitter almond genotypes studied exhibit considerable diversity in terms of their kernel characteristics. In particular, differences between genotypes were found in aspects such as smoothness, hairiness, number of kernels, size and shape indices. This diversity enables selection for different uses and breeding studies. In addition, the bitter taste of all genotypes is an important factor in determining the potential uses and processing requirements of these bitter almond genotypes.

CONCLUSION

While there are many studies on sweet almond genotypes in the literature, there are no studies examining the fruit characteristics of bitter almond genotypes. In this respect this study is considered a first in this field, both in our country and worldwide. This study is the first to investigate the fruit characteristics of bitter almond genotypes in the Hilvan district of Şanlıurfa. 18 bitter almond genotypes examined showed considerable diversity in terms of fruit weight, size and physical characteristics. When evaluated using the weighted scoring method, the genotypes received scores between 536 and 624. Almond cultivation continues to spread in the southeast Anatolia region. As in other fruit-growing areas, rodents are also observed in almond-growing areas. When bitter almond genotypes are used as rootstock in modern almond cultivation, they are less susceptible to rodent damage. Therefore, it is important to study the adaptation of bitter almonds alongside other almond rootstocks in the same environment. Future adaptation studies will provide valuable insights in this regard.

As a result, bitter almond genotypes can improve almond breeding programs by increasing genetic diversity and contributing traits such as disease resistance and drought tolerance. These genotypes are often more resistant to environmental stress factors and can be used as rootstock for sweet almond varieties. The unique flavor and aroma components of bitter almonds can enhance the flavor profile of sweet almonds, while their bioactive compounds have potential applications in the development of functional foods. They are also valuable for almond cultivation in arid regions due to their drought tolerance. It is expected that this study will contribute to a better understanding of bitter almond diversity and thus provide important support for future breeding efforts.

Declaration of Interests

The authors declare that they have no conflict of interest.

Author Contributions

The authors declare that they have contributed equally to the article.

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