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Research Article

NUT AND KERNEL PROPERTIES OF FIVE PROMISING WALNUT (*Juglans regia* L.) GENOTYPES ADOPTED TO HIGH ALTITUDES

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ABSTRACT. Nut and kernel characteristics of five promising walnut genotypes from Asagikoy and Yelesen districts in the south of Bingol city center in Turkey were evaluated. The genotypes were well-adopted to the harsh climatic conditions above the sea level of 1400 to 1800 m. Inshell nut weight ranges from 9.86 to 15.80 g with a mean of 11.38 g. Kernel weight varies from 5.12 to 6.89 g with a mean of 5.76 g. Kernel percentage is in the range of 48.88 and 58.07%, and the average value is 51.60%. Shell color is mostly brighter but lighter in yellow compared to kernel. Smoothness on the shell surface is rated mild for two genotypes while very unwrinkled for 3 genotypes. Veins on kernel pellicle are very distinctive for 3 genotypes whereas faint for 3 genotypes. The genotypes may be used for the improvement of walnuts to resists or tolerate colds.

Keywords: *Juglans regia, phenological description, walnut germplasm, Bingöl*

INTRODUCTION

Common walnut (*Juglans regia* L) is one of the important tree nut species, rich in fat, carbohydrates and proteins. Thus, it has been served as human nutrition for a long time [1]. Native to central Asia [2], the walnut has spread through temperate zones including Turkey where widely cultivated. Currently, more than 60 countries commercially grow walnut, from China, Iran, the United States, Turkey, Franca and Brazil. China is the leading walnut producer (1.5 MT) accounting more than 40 % of the world walnut production [3].

Besides consumed as fresh or toasted as whole, walnut kernels or seeds are used as ingredient or additive for various confectioneries such as baklava in Turkey. In addition to having ample basic dietary compound, walnut kernels are good source of phytochemicals such as unsaturated fatty acids and phenolics known for high antioxidant capacities. Several health-beneficial effects for walnut kernels have been documented like reducing the incidence of cardiovascular diseases [4], diabetes [5] and same cancer kinds [6]; lowering postprandial oxidative stress [7]; alleviating adiposity and low-grade systemic inflammation [8]; and decreasing total, LDL cholesterol and triglyceride levels whereas rising HDL cholesterol and apolipoprotein A1 portions [9, 10].

In terms of walnut plantation and production, Turkey is one of the important countries in the world. Ranking 4th in the world, Turkey yield 225,000-ton walnuts annually [11]. About 11,251 bearing and 10,004 non-bearing walnut trees are Turkey [11]. Located in

the eastern Turkey, Bingol province is famous with walnut productions. There are almost walnut trees everywhere in Bingol from the city center to an elevation of 1800 m. Most of the walnut trees are grown from seed thus providing an immense amount of germplasm to explore. Very few literatures are available walnut germplasm in Bingol [12, 13].

The aim of the study was to characterize and present some important properties of five promising walnut genotypes that are well-adapted to harsh climatic conditions with an elation of or above 1400 m.

MATERIALS AND METHODS

Plant material

The present study was carried on five promising walnut genotypes (12AK01, 12AK12, 12AK19, 12AK22, 12YE26) selected from 50 genotypes grown from seedling in Asagikoy and Yelesen districts of Bingol city center, Turkey. Asagikoy was located at 38° 51' 23.83" N and 40° 22' 34.97" E with an elevation of 1400-1800 m and Yelesen located 38° 52' 4.13" N and 40° 19' 25.72" E with and elevation of 1400-1800 m.

Nut shape

Nut shape in longitudinal section through suture (elliptic, broad elliptic, long circular, circular, ovate, broad ovate, triangular, triangular, trapezium), in lateral view (circular, oblate, ovate, broas ovate, broad elliptic, triangular), in cross section (reniform, oblate, elliptic, circular), shape of base in lateral view (cuneate, oblate, rounded, truncate), shape of apex in lateral view (obtuse, rounded, truncate, emarginate), length of tip (absent or short, medium, long), extend of pad around suture (on upper half, on upper 2/3, on whole length), prominence of pad suture (weak, medium, strong), width of pad on suture in lateral view (narrow, medium, broad) were evaluated according to UPOV [14]. The shape of nut was classified as round, triangular, broad ovate, ovate, short trapezoid, long trapezoid, broad elliptic, elliptic and cordate [14].

Shell smoothness and shell color

Shell smoothness was evaluated according the scale (1 – 9; 1 very smooth, 9 very rough) prepared from the walnuts of 50 germplasm (Figure 1). Shell color was measured by a color meter (Lobivond) and expressed as L* (lightness) a* (redness) and b* (yellowness).

Fig. 1. *Shell smoothness was evaluated according the picture*

Inshell and kernel weight, kernel percentage

Inshell and kernel wight was measured an expressed as g. Kernel percentage was calculated according the formula of kernel weight/inshell nut wight x 100.

Shell and pellicle thickness and color, and pellicle veins

Shell and pellicle thickness as mm and color was measured expressed as L* (lightness) a* (redness) and b* (yellowness). For veins, visible veins on the half of a kernel was counted.

Statistical analysis

A total 20 fruit were evaluated in order to get the desired properties the genotypes, and the mean value was used. Mean separation among the genotypes was not performed due to the trees being neither on the same plot and nor treated equally; each value is expressed as only mean± standard deviation.

RESULTS AND DISCUSSION

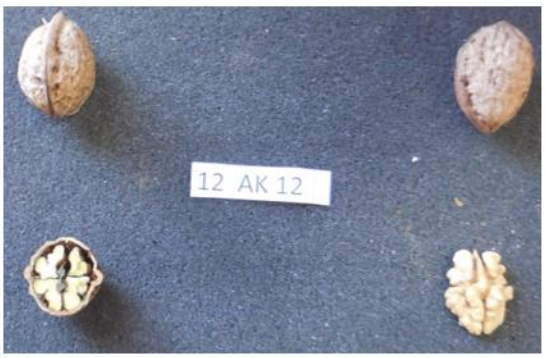
The tree of 12AK01 genotype is located at the elevation of 1556 m (Fig. 2). Nut shape of the genotype is circular/oblate with mild smoothness on the surface. Inshell and kernel weight is 15.80 and 6.98 g with a kernel percentage of 44.20%. The shell has a lighter yellow color (L* 56.60, b* 20.83) compared to kernel color (L* 52.21, b* 28.9). Veins on the kernel are distinctive and visible since the number of the veins is 10 on the half. The shell is 2.44 mm in thickness while the pellicle in 0.22 mm.

Nut shape	
In longitudinal section through suture	Circular
In lateral view	Circular
In cross section	Oblate
Shape of base in lateral view	Oblate
Shape of apex in lateral view (exc. Tip)	Obtuse
Length of tip	Medium
Extent of pad around suture	Upper half
Prominence of pad on suture	Strong
Width of pad on suture in lateral view	Narrow
Shell color	
L*	56.50
a*	7.99
b*	20.83

Altitude (m)	1556
Coordinates	38° 51' 8.6" N - 40° 22' 7.3" E
Shell dimension	
Nut diameter/width (mm)	34.45
Nut height (mm)	34.47
Nut length (mm)	45.41
Nut length index (%)	1.31
Shell smoothness	5
Weight (g)	
Inshell weight (g)	15.80
Kernel weight (g)	6.98
Kernel percentage (%)	44.20
Thickness (mm)	
Shell	2.44
Pellicle	0.22
Pellicle color	
L*	52.21
a*	9.74
b*	28.39
Pellicle veins	10

Fig. 2. *Nut and kernel properties 12AK01 walnut genotypes*

The tree of 12AK12 genotype is located at the elevation of 1540 m (Fig. 3). Nut shape of the genotype is circular/oblate with mild smoothness on the surface. Inshell and kernel weight is 9.72 and 5.12 g with a kernel percentage of 52.64%. The shell has a lighter yellow color (L* 56.02, b* 24.01) compared to kernel color (L* 58.07, b* 29.05). Veins on the kernel are distinctive and visible since the number of the veins is 10 on the half. The shell is 1.31 mm in thickness while the pellicle in 0.11 mm.

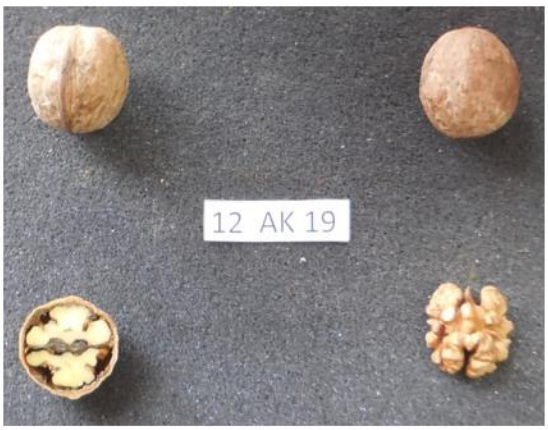


Nut shape	
In longitudinal section through suture	Circular
In lateral view	Circular
In cross section	Oblate
Shape of base in lateral view	Oblate
Shape of apex in lateral view (exc. Tip)	Obtuse
Length of tip	Long
Extent of pad around suture	Upper 2/3
Prominence of pad on suture	Strong
Width of pad on suture in lateral view	Medium
Shell color	
L*	56.02
a*	8.20
b*	24.01

Altitude (m)	1540
Coordinates	38° 51' 5.9" N-40° 22' 17.9" E
Shell dimension	
Nut diameter/width (mm)	29.90
Nut height (mm)	28.67
Nut length (mm)	44.42
Nut length index (%)	1.52
Shell smoothness	6
Weight (g)	
Inshell weight (g)	9.72
Kernel weight (g)	5.12
Kernel percentage (%)	52.64
Thickness (mm)	
Shell	1.31
Pellicle	0.11
Pellicle color	
L*	58.07
a*	6.41
b*	29.25
Pellicle veins	10

Fig. 3. *Nut and kernel properties 12AK12 walnut genotypes*

The tree of 12AK19 genotype is located at the elevation of 1480 m (Fig. 4). Nut shape of the genotype is circular/oblate with a very smooth surface. Inshell and kernel weight is 10.76 and 6.11 g with a kernel percentage of 56.77%. The shell has a lighter yellow color (L* 58.41, b* 20.05) compared to kernel color (L* 51.80, b* 29.84). Veins on the kernel are distinctive and visible since the number of the veins is 9 on the half. The shell is 1.46 mm in thickness while the pellicle in 0.09 mm.



Nut shape	
In longitudinal section through suture	Circular
In lateral view	Oblate
In cross section	Oblate
Shape of base in lateral view	Oblate
Shape of apex in lateral view (exc. Tip)	Rounded
Length of tip	Medium
Extent of pad around suture	Upper 2/3
Prominence of pad on suture	Medium
Width of pad on suture in lateral view	Medium
Shell color	
L*	58.41
a*	6.52
b*	20.05

Altitude (m)	1480
Coordinates	38° 51' 22.1" N - 40° 22' 43.5" E
Shell dimension	31.25
Nut diameter/width (mm)	31.34
Nut height (mm)	34.98
Nut length (mm)	1.11
Nut length index (%)	
Shell smoothness	3
Weight (g)	
Inshell weight (g)	10.76
Kernel weight (g)	6.11
Kernel percentage (%)	56.77
Thickness (mm)	
Shell	1.46
Pellicle	0.09
Pellicle color	
L*	51.80
a*	7.44
b*	29.84
Pellicle veins	9

Fig. 4. *Nut and kernel properties 12AK19 walnut genotypes*

The tree of 12AK22 genotype is located at the elevation of 1480 m (Fig. 5). Nut shape of the genotype is circular/elliptic with a very smooth surface. Inshell and kernel weight is 9.86 and 5.48 g with a kernel percentage of 55.50%. The shell has a lighter yellow color (L* 63.00, b* 20.24) compared to kernel color (L* 62.56, b* 30.78). Veins on the kernel are not distinctive and seen seamless since the number of the veins is only 4. The shell is 1.51 mm in thickness while the pellicle in 0.25 mm.

Nut shape	
In longitudinal section through suture	Circular
In lateral view	Circular
In cross section	Elliptic
Shape of base in lateral view	Oblate
Shape of apex in lateral view (exc. Tip)	Rounded
Length of tip	Absent
Extent of pad around suture	Upper 2/3
Prominence of pad on suture	Weak
Width of pad on suture in lateral view	Narrow
Shell color	
L*	63.00
a*	6.54
b*	20.24

Altitude (m)	1480
Coordinates	38° 51' 22" N - 40° 22' 45.7 "E
Shell dimension	
Nut diameter/width (mm)	29.47
Nut height (mm)	30.39
Nut length (mm)	35.09
Nut length index (%)	1.17
Shell smoothness	3
Weight (g)	
Inshell weight (g)	9.86
Kernel weight (g)	5.48
Kernel percentage (%)	55.50
Thickness (mm)	
Shell	1.51
Pellicle	0.25
Pellicle color	
L*	62.56
a*	6.55
b*	30.78
Pellicle veins	4

Fig. 5. *Nut and kernel properties 12AK22 walnut genotypes*

The tree of 12YE26 genotype is located at the elevation of 1794 m (Fig. 6). Nut shape of the genotype is circular/oblate with a very smooth surface. Inshell and kernel weight is 10.77 and 5.28 g with a kernel percentage of 48.88%. The color of both shell and kernel are almost identical (b* 26.03 and 25.02) while the shell has a brighter yellow color (L* 60.03) than the kernel does (L* 47.06). Veins on the kernel are mildly distinctive and since the number of the veins is only 6. The shell is 1.75 mm in thickness while the pellicle in 0.15 mm.

Nut shape	
In longitudinal section through suture	Circular
In lateral view	Oblate
In cross section	Circular
Shape of base in lateral view	Oblate
Shape of apex in lateral view (exc. Tip)	Rounded
Length of tip	Absent
Extent of pad around suture	Whole
Prominence of pad on suture	Weak
Width of pad on suture in lateral view	Narrow
Shell color	
L*	60.03
a*	8.76
b*	26.03

Altitude (m)	1794
Coordinates	38° 51' 59.9" N - 40° 19' 29.6" E
Shell dimension	
Nut diameter/width (mm)	29.52
Nut height (mm)	31.32
Nut length (mm)	34.21
Nut length index (%)	1.12
Shell smoothness	3
Weight (g)	
Inshell weight (g)	10.77
Kernel weight (g)	5.28
Kernel percentage (%)	48.88
Thickness (mm)	
Shell	1.75
Pellicle	0.15
Pellicle color	
L*	47.06
a*	10.54
b*	25.02
Pellicle veins	6

Fig. 6. *Nut and kernel properties 12YE26 walnut genotypes*

The genotypes generally have a mild or almost smooth shell surface (Table 1). The smoothness on shell surface is an important walnut shell characteristic which is greatly valued by consumers. Shell smoothness is also a prime trait in the walnut processing industry since kernels with smooth shells can be extracted from accessions easier than kernels with rough shells [15].

Table 1. *Some valued nut and kernel properties of the walnut genotypes*

Genotypes	Shell smooth.	Shell color (b*)	Shell color (L*)	Inshell weight (g)	Kernel weight (g)	Kernel %	Pellicle color (b*)	Pellicle color (L*)	Pellicle veins
12AK01	5	30.78	56.60	15.80	6.80	44.20	28.39	52.21	10
12AK12	6	29.84	56.02	9.72	5.12	52.64	29.25	58.07	10
12AK19	3	29.25	58.41	10.76	6.11	56.77	29.84	51.80	9
12AK22	3	28.39	63.00	9.86	5.48	55.50	30.78	62.56	4
12YE26	3	25.02	60.03	10.77	5.28	48.88	25.02	47.06	6
Mean	*4*	*28.66*	*58.81*	*11.38*	*5.76*	*51.60*	*28.66*	*54.34*	*7.80*

Shells of the genotypes mostly have a light-yellow color while 12YE26 stands out with the lightest yellow color among them (Table 1). The yellow color brightness on shells ranges from 56.02 to 63.00 among genotypes (Table 1). Brightest yellow color is seen in 12AK22 whereas the darkest in 12AK12. Inshell weight varies 9.72 g to 15.80 g with an average of 11.38 g (Table 1). 12AK01 distinguishes itself from others with a very high inshell weight and eventually size. Simsek et al. [13] reported a similar inshell weight of 10.88-15.35 g for walnut 12 germplasms selected in Bingol. In another study involving 17 promising walnut genotypes from Bingol province, the inshell weights reported to in the range of 9.98 – 13.10 g.

Kernel weight is found the range of 5.12 and 6.80 g with a mean of 5.76 g (Table 1). 12AK01 has the heaviest kernel followed by 12AK19. We found the average kernel weight 5.76 g which falls in the range of 5.05 – 6.76 g reported by Muradoglu et al. [12] and 5.56 to 8.36 g reported by Simsek et al. [13] in Bingol. A walnut fruit and kernel can weigh as much as 27 and 13 g (cv. Sutyemez 1) [16]. Walnut and kernel weight/size is a genetical characteristic that may be affected by climate and growing conditions but unaffected by tree ages [17, 18].

Kernel percentage for 12AK01 and 12YE26 is under 50% whereas for 12AK12, 12Ak19 and 12AK22 above 50% (Table 1). The highest kernel percentage is displayed by 12AK22 followed by 12AK22 and 12AK12. The kernel percentage ranges from 48.88 to 56.77%. A similar value of 43.29 – 54.54 % for kernel percentage was reported by Muradoglu et al. [12]. A high kernel percentage is sought-after trait for walnut cultivars however an excessive percentage may not be desired since it may be sign of a thin sell with poor strength [19, 20].

Yellow color value on the pellicle varies from 25.02 to 30.78 (Table 1). 12YE26 genotype steps fort for the lightest yellowed color. Yellow brightness ranges from 47.06 to 62.56 among genotypes. Brightest yellowed-pellicle is observed in 12AK22. 12AK01, 12AK12 and 12AK19 genotypes have visible veins on the pellicle while 12YE26 mildly visible and 12AK22 nearly invisible. The trait of kernel removal and light-colored kernel has been used select promising for walnut breeding studies [21-23].

Conventional hybrid breeding techniques for walnuts are arduous and take a long time, thus selections are more convenient and take a short time [15]. The process of selecting the best types of walnut primarily starts with choosing high quality nuts that should have a smooth, clean, strong, thin and tight sealed shell, weigh between 12-18 g [20]. The kernel should be shelled easily, uniformly light in color, clean [15], have no or faint veins on the pellicle, and weigh 6 to 10 g. The kernel percentage should be around or over 50% [24]. Thick walnut shell may not be desired since it may exhibit a loose seal at the suture, which allows insects to penetrate into the shell [20]. On the other hand, shell with loose seal can break easily, which is an important trait for the walnut processing industry. It is

necessary keep in mind that elevation has a positive effect on walnut quality. Walnut nuts at an elevation of over 1500 m along with less rainfall have been reported be generally high-grade in quality over those at lower elevation with a heavy rainfall [25, 26].

CONCLUSION

The promising genotypes were selected from 2 districts of Bingol province with having harsh climatic conditions and an elevation of over 1400 m. The two districts are a rich source of walnut germplasm. Fruit were harvested from trees to which a special care was not been given. Therefore, the results presented in this work may be used to walnut breeding studies for especially obtaining cold-tolerant and/or growing high altitudes with bearing in mind that a desired walnut fruit that would have a kernel that may be easily separated from the shell, light in color, clean, vein free, plump, and weighs around 50% of the inshell weight [18, 20].

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