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POMOLOGICAL AND PHENOLOGICAL CHARACTERIZATION OF PROMISING WALNUT (*Juglans regia* L.) GENOTYPES FROM MALATYA, TURKEY

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Abstract. Turkey has significant walnut (*Juglans regia* L.) plantations most of which are seedling-grown trees. Eastern Anatolia region of Turkey has rich phenotypic diversity. In this study, walnut genotypes of the region were evaluated and considerable genetic variation in pomological and phenological characteristics was found in walnut genotypes which were of seedling origin. The study region was about 12 000 km^2 are between 35°54'–39°03' N latitude and 38°45'–39°08' E longitude. It is estimated that the region has 162 800 walnut trees. During our survey more than 3000 walnut genotypes were observed for several horticultural characteristics. Selections studied were carried out among these populations. Based on several horticultural characteristics, 158 genotypes were selected. Here, we report the several characteristics of 16 superior walnut genotypes of these 158 selections with promising yield and fruit characteristics. Among our selections we observed the ranges of 65–100% for terminal fruitfulness, 38–67 % for lateral fruitfulness, 1.98–3.15 fruits for terminal shoots, 1.36–2.25 fruits for lateral shoots, 12.6–17.5 g nut weight, 6.9–9.1 g kernel weight, 47.3–60.8% kernel ratio and 0.95–17.5 mm shell thickness. The most promising genotypes were 94 Mws 30, 95 Mws 78 and 97 Mws 103, and these selections will be used for further breeding efforts.

Key words walnut; *Juglans regia* L.; breeding; genetic resources; nut characteristics; pomology; Turkey

INTRODUCTION

Walnuts (*Juglans spp.*) are commercially important species because of their high quality wood, nutritious nuts and leaves of significant pharmacological value [Forde 1975]. Walnut species are found throughout the world including Southern Asia, South Eastern Europe, North, South and Central America. *Juglans regia* L., the English or Persian walnut, is the most economically important species [Davis 1982; Şen 1986;

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McGranahan and Leslie 1991]. Total world production of walnuts is between 1.1–1.4 million tons/years. Turkey ranked fourth in the world with 126 000 tons of walnut (*Juglans regia*) production [FAO 2004].

The genetic variation of native walnut populations presents many opportunities for walnut breeding [Sharma and Sharma, 2001; Orel et al. 2003; Zeneli et al. 2005]. Anatolia with various eco-geographical regions is one of the major centres for Persian walnut diversity. Native walnut populations are widely present in this region and are found as scattered individuals or groups of several trees in the borders of agricultural lands, orchards or by the rivers. Continuous seed propagation for thousands of years in Turkey has given rise to a great number of seedling walnut trees, which represent valuable walnut gene resources. The number of native trees is estimated to be over 4.5–5 million and they possess large genetic variability in yield, nut and kernel characteristics, late bud breaking, late flowering, winter hardiness, tolerance to disease [Şen 1986; Akça 2001; Ercişli 2004; Beyazit et al. 2007].

Given that Turkey has rich walnut genetic resources, several selection studies haven been carried out in Turkey. The first selection studies were conducted in the Marmara Region [Ölez 1971] and in the North Eastern Anatolia and Eastern Black Sea Region [Şen 1980]. Then, selection studies were extended to many different parts of Anatolia. From these studies, the most promising genotypes have been described with regard to several tree and fruit characteristics [Şen and Tekintaş 1992; Beyhan 1993; Aşkın and Gün 1995; Yarılgaç 1997; Küden et al. 1997; Sütyemez and Eti 2001; Akça and Ozongun 2004; Aslantaş 2006] and even some of them have been released as standard cultivars [Çelebioğlu et al. 1988]. The objective of this study was to determine fruit and tree properties of selected walnut genotypes under Malatya region.

MATERIALS AND METHODS

Plant material and experimental site. The study was carried out in the Malatya region of Turkey from 1993 to 1999 (fig. 1). The region has more than 12 000 km^2 are between 35°54'–39°03' N latitude and 38°45'–39°08' E longitude. The region has a typical continental climate with 382 mm yearly precipitation and 13.7°C average yearly temperature. Average altitude of the arable land in the region ranges 870–1800 m. This region is famous for its fruit species where apricot is the dominating fruit tree grown [Asma 2007]. In the region, there are significant mulberry and sweet cherry orchards. Walnut is also among the most important fruit species in the region. There are many walnut orchards in the region; however, it is also possible to see walnut trees planted on the borders of other fruit trees as well as home garden. These walnut trees are almost exclusively seedling-grown. It has been estimated that the region has 162 800 walnut genotypes [Anonymous 2006]. This fact give fruit researchers a great opportunity make selection.

Assessment criteria. During the first phase of the study, the selections were conducted. Only seedling-grown trees were evaluated. After the observation of numerous trees at the first phase, the initial selections were carried out in the second phase. Only 10-year-old or older trees which are free from pets and diseases were considered for

selections. The selection criteria at this stage included yield potential and nut size. Only genotypes having > 6 g nuts and >40% kernel / but ratios were selected. The positions of the selections were determined by Global Positioning System. Genotypes were coded as; year-Malatya walnut selection (Mws)-genotype number.

Fig. 1. Map showing Turkey and surveyed area (A). A Europe map and Turkey's location is presented in panel B

Rys. 1. Mapa Turcji i badanego obszaru (A). Mapa Europy i położenie Turcji przedstawia panel B

At the initial selection, 158 genotypes were selected and included in the further studies. Several characteristics were determined in the selected genotypes when they were on their sampling sites. The age and yield potential of the trees were determined from the growers/owners of the trees. To determine the terminal and lateral fruitfulness, four regions (east, west, north and south) of the trees were sampled. In each region a total of four shoots, two of which were lateral and the other two were terminal, were selected. Therefore, in each three a total of 8 lateral and 8 terminal shoots were selected. Lateral and terminal fruitfulness were calculated as fruitful shoots / total shoots and expressed in percentages. The yield of the trees were assigned onto three categories; low (< 50 kg nut / tree), medium (50–100 kg nut / tree) and high (> 100 kg nut / tree) yielding genotypes. Phenological traits (bud break, flowering habit, ripening time, the nuts number in each terminal and lateral cluster, terminal and lateral fruitfulness (%) were determined by visiting the tree by weekly during April and September. The nut characteristics (nut and kernel weight, kernel/nut weight ratio (%), shell thickness, fruit shape, shell and kernel colour, station of kernel removal) were determined from 20 randomly chosen nuts. The observations/measurements were conducted during two successive years.

Data analysis. The results were analysed statistically by the one way analysis of variance (ANOVA) and separated by Least significant difference (LSD) using SAS [SAS 1990] for each trait measured. The 158 walnut genotypes were evaluated using a weighted-rankit method according to ranges presented in Şen [1980]. After the analysis of the two-year data, 16 superior genotypes were selected.

RESULTS AND DISCUSSION

The origins of the 16 promising genotypes were presented in Table 1. Most of the promising genotypes were centred on a 40 km^2 area with the altitude of 1016–1679 m. Several tree characteristics such as tree height, trunk diameter and height were recorded. However, these values were not presented as they were found to be associated with tree age [Fady et al., 2003].

Tree, flower and yield characteristics of 16 walnut selections are presented in Table 2. The age of the selected genotypes was estimated to range between 35–95 years old. Yield capacity is an important characteristic for economic walnut production as other fruits. Walnut productivity depends on flowering time and habit, number of fruit on terminal and lateral shoots, lateral and terminal fruitfulness, nut and kernel weight, and nut/kernel ratio [Forde 1975; McGranahan and Leslie 1991; Aslantaş 2006]. Out of 16 genotypes, five were found to be medium yielding while the rest of the genotypes had high yield.

Date of bud break in selected types usually varied from April 2 to April 28 (tab. 2). All of the genotypes were determined as early and medium leafing. In this region, chance of having a late spring frost is still likely until the end of April. However, none of the genotypes were damaged from the low temperature (up to -25ºC) during the winter time. The harvest date of selected trees varied from the medium September to the early of October. Our results regarding the bud break and harvest dates were compara-

Table 1. Origin of walnut genotypes selected from Eastern Anatolia Region, Turkey
Tabela 1. Pochodzenie genotypów orzecha wyselekcjonowanych w regionie wschodniej Anatolii w Turcji

Genotype Genotyp	Altitude Wysokość m	Latitude Szerokość	Longitude Długość
93 Mws 06	1475	38°46’ N	37°53’ E
94 Mws 20	1643	38°39’ N	37°52’ E
94 Mws 21	1643	38°39’ N	37°52’ E
94 Mws 24	1635	38°39’ N	37°52 E
94 Mws 29	1622	38°39’ N	37°51’ E
94 Mws 30	1679	39°00’ N	37°54’ E
94 Mws 37	1674	39°00’ N	37°54’ E
94 Mws 45	1478	38°39’ N	37°51’ E
94 Mws 58	1475	38°39’ N	37°51’ E
95 Mws 72	1475	38°39’ N	37°51’ E
95 Mws 78	1470	38°46’ N	37°53’ E
96 Mws 92	1468	38°46’ N	37°53’ E
97 Mws 103	1474	38°46’ N	37°53’ E
97 Mws 118	1016	38°32’ N	37°20’ E
98 Mws 133	1025	38°32’ N	37°20’ E
98 Mws 151	1235	38°33’ N	37°25’ E

ble to those of previously published from Turkey [Yarılgaç et al. 2001; Balcı et al. 2001; Akça and Ozongun 2004] and can be considered as highly variable traits. Solar et al. [2002] investigated several horticultural characteristics of 840 walnut trees of Slovenia and found that the most variable trait was bud break time.

The flowering habits in the selected genotypes were determined as different (tab. 2). There were eleven genotypes protandrous, tree genotypes protogynous and two genotypes homogameous among the selected individuals. Protandrous is genetically dominant and this habit is the most common. The differences may be owing to ecological condition effects on dichogamy [Şen 1986; Germain, 1990].

The ratio of terminal fruitfulness of selected types ranged 65% (93 Mws 29 and 94 Mws 45) and 100% (94 Mws 30) (tab. 2). The ratio of lateral fruitfulness ranged between 35% and 67% in the selected types. 94 Mws 30 and 96 Mws 92 types produced the highest rate of lateral fruits 67% and 65%, respectively. The ratio of lateral fruitfulness in all selected genotypes (94 Mws 20 and 94 Mws 37 types except) were higher than 40%. Average fruit number changed between 3.15 (94 Mws 30) and 1.98 (94 Mws 29) on terminal shoots, and between 2.25 (94 Mws 30) and 1.33 (97 Mws 103) on lateral shoots. Our findings were in agreement with those of previously published which were conducted in Turkey [Akça 1994; Balcı et al. 2001; Akça and Ozongun 2004; Aslantaş 2006]. A high ratio of fruitfulness lateral buds is not common in old European and American cultivars, but a new walnut cultivars are mostly laterally fruitfulness. For instance, some of the cultivars which are laterally fruitfulness include 'Chandler', 'Vina' and 'Sunland' ranged from 80% to 87% [Hendricks et al. 1985; Akça and Ozolgun 2004].

Nut characteristics of 16 walnut selections are presented in Table 3. The average nut weight changed between 17.5 and 12.6 g. The highest value showed 94 Mws 29 (17.5 g) followed by 94 Mws 20 (16.7 g) and '94 Mws 20' genotypes (16.65 g). Kernel weight varied from 9.1 g (97 Mws 103) to 6.9 g (94 Mws 37). Kernel/nut ratio ranged from 60.8% (94 Mws 30) to 46.9% (94 Mws 29), and were higher than 50% in 8 of 16 selected genotypes. In selections, nut weight and kernel weight were higher than found in selected types by other researchers in Turkey [Yarılgaç et al. 2001; Balcı et al. 2001; Aslantaş 2006]. These traits were also found to be highly variables for 229 seedling trees growing naturally in India [Sharma and Sharma 2001].

Shell thickness varied between 0.95 mm (97 Mws 118) to 2.05 mm (94 Mws 45). Promising walnut types should have a shell thickness of between 0.7 and 1.5 mm [Zhadan and Strukov 1977]. Fruit shape was determined as round and ovate, kernel colour was light yellow and yellow. Kernel removal was easy in the majority of the selected genotypes. All of selected genotypes cropped regularly in every year. The ideal nut should have a clean, strong, thin shell, a tight seal and weight between 12 and 18 g. The kernel should be easily removable from the shell, uniformly light in colour, clean, and weight 6–10 g or at least 50% of entire nut weight. Nut and kernel quality is strongly affected by genotype, environment and their interaction [McGranahan and Leslie 1991; Akça and Ozongun 2004].

The results were analysed by using least significant difference (LSD). It was determined the difference in level of $p < 0.05$ in between properties that are measurable variables.

Table 2. Tree, flower, yield and plant characteristics of walnut genotypes selected from Eastern Anatolia Region, Turkey
Tabela 2. Cechy drzew, kwiatów, plonu genotypów orzecha wyselekcjonowanych w regionie wschodniej Anatolii w Turcji

Genotype Genotyp	Average age (estimated year) Średni wiek (szacowany rok)	Yield Plon	Bud break* Pękanie pąków *	Harvest* Zbiór*	Flowering habit Pokrój kwitnienia	Terminal fruitfulness Owocowanie na pędach szczytowych	Lateral fruitfulness Owocowanie na pędach bocznych	Average fruit number terminal shoots Średnia liczba owoców na pędach szczytowych	Average fruit number lateral shoots Średnia liczba owoców na pędach bocznych
93 Mws 06	55–60	Medium	Apr I	Sep III	Protodandrous	75 ± 3.6 e	43 ± 3.6 ef	2.18±0.1 fgh	1.53±0.1 gh
94 Mws 20	50–55	Medium	Apr II	Sep IV	Protodandrous	73 ± 3.1 ef	38 ± 2.0 fg	2.36±0.1 ef	1.88±0.1 d
94 Mws 21	45–50	High	Apr II	Sep IV	Protodandrous	88 ± 2.0 bcd	54 ± 4.3 bc	2.55±0.1 de	2.03±0.1 bc
94 Mws 24	90–95	High	Apr II	Sep IV	Protodandrous	90 ± 3.3 bcd	52 ± 4.3 bcd	2.81±0.1bc	1.96±0.1 cd
94 Mws 29	40–45	Medium	Apr III	Oct I	Protodandrous	65 ± 4.3 f	47 ± 3.6 cde	1.98±0.1 h	1.42±0.1 ij
94 Mws 30	35–40	High	Apr III	Sep IV	Protodandrous	100 ± 4.5 a	67 ± 2.6 a	3.15±0.1 a	2.25±0.1 a
94 Mws 37	40–45	High	Apr II	Sep III	Protodandrous	92 ± 3.9 a-d	35 ± 2.2 g	2.64±0.1 cd	1.66±0.1ef
94 Mws 45	60–65	Medium	Apr II	Sep III	Protogynous	65 ± 4.4 f	44 ± 2.4 def	2.05±0.1 h	1.36±0.1 ij
94 Mws 58	80–85	High	Apr II	Sep IV	Homogamous	85 ± 4.6 d	55 ± 3.3 bc	2.10±0.1 gh	1.59±0.1 gf
95 Mws 72	80–85	High	Apr II	Sep IV	Protodandrous	90 ± 5.2 bcd	52 ± 3.6 bcd	2.82±0.1 bc	2.01±0.1 c
95 Mws 78	55–60	High	Apr I	Sep IV	Protogynous	92 ± 3.0 a-d	45 ± 3.4 def	2.70±0.3 bcd	1.74±0.1 e
96 Mws 92	45–50	High	Apr I	Sep III	Protodandrous	95 ± 4.4 abc	65 ± 2.6 a	2.90±0.2 b	2.12±0.1 b
97 Mws 103	60–65	High	Apr II	Sep IV	Protodandrous	86 ± 5.1 cd	48 ± 2.8 cde	2.52±0.1 de	1.33±0.1 j
97 Mws 118	85–90	High	Apr I	Sep IV	Protogynous	94 ± 5.5 a-d	54 ± 3.1 bc	2.66±0.2 cd	1.56±0.1 g
98 Mws 133	40–45	High	Apr I	Sep IV	Homogamous	96 ± 4.1 ab	57 ± 2.2 b	2.81±0.1 bc	1.69±0.1 e
98 Mws 151	35–40	Medium	Apr I	Sep III	Protodandrous	73 ± 4.7 ef	42 ± 3.9 efg	2.26±0.1 fg	1.44±0.1 hi
$LSD_{0.05}$						12.25	9.54	0.23	0.21

* I, II, III, IV – monthly quarter – kwartał

Table 3. Pomological characteristics of walnut genotypes selected from Eastern Anatolia Region, Turkey
Tabela 3. Pomologiczne cechy genotypów orzecha wyselekcjonowanych w regionie wschodniej Anatolii w Turcji

Genotype Genotyp	Nut weight Masa orzecha (g)	Kernel weight Masa jądra (g)	Kernel ± nut weight ratio Stosunek masy jądro ± orzech (%)	Shell thickness Grubość skorupy (mm)	Fruit shape Kształt owocu	Shell colour Barwa skorupy	Kernel colour Barwa jądra	Kernel removal Usunięcie jądra
93 Mws 06	15.4 ± 0.6 c-f	7.8 ± 0.4 b-e	50.7 ± 0.8 def	0.98 ± 0.1 h	round	dark	light yellow	easy
94 Mws 20	16.6 ± 0.7 abc	8.1 ± 0.3 bcd	48.8 ± 0.7 fgh	1.85 ± 0.1 b	round	dark	yellow	easy
94 Mws 21	15.1 ± 0.8 d-g	7.5 ± 0.3 cde	49.7 ± 0.9 efg	1.30 ± 0.1 f	round	light	yellow	easy
94 Mws 24	14.6 ± 0.6 efg	7.1 ± 0.3 de	48.6 ± 0.6 fgh	1.53 ± 0.1 de	round	dark	yellow	easy
94 Mws 29	17.5 ± 0.6 a	8.2 ± 0.3 abc	46.9 ± 0.5 h	1.45 ± 0.1 e	round	dark	light yellow	medium
94 Mws 30	14.3 ± 0.5 fgh	8.7 ± 0.2 ab	60.8 ± 0.6 a	1.65 ± 0.1 c	round	dark	light yellow	easy
94 Mws 37	13.1 ± 0.4 hij	6.9 ± 0.2 e	52.7 ± 0.5 cd	1.10 ± 0.1 g	ovate	dark	light yellow	easy
94 Mws 45	16.7 ± 0.4 ab	7.9 ± 0.3 b-e	47.3 ± 0.6 gh	2.05 ± 0.1 a	round	dark	yellow	medium
94 Mws 58	16.0 ± 0.5 bcd	7.7 ± 0.3 b-e	48.1 ± 0.9 gh	1.55 ± 0.1 cde	ovate	light	yellow	easy
95 Mws 72	13.3 ± 0.5 hij	7.1 ± 0.2 de	53.4 ± 0.5 c	1.60 ± 0.1 cd	round	light	light yellow	easy
95 Mws 78	12.6 ± 0.4 j	7.2 ± 0.1 cde	57.1 ± 0.3 b	1.30 ± 0.1 f	round	dark	yellow	easy
96 Mws 92	15.7 ± 0.7 b-e	8.1 ± 0.4 bcd	51.6 ± 0.6 cde	1.45 ± 0.1 e	ovate	light	yellow	medium
97 Mws 103	15.3 ± 0.6 def	9.1 ± 0.2 a	59.5 ± 0.5 a	1.05 ± 0.1 gh	ovate	dark	yellow	easy
97 Mws 118	13.9 ± 0.4 ghi	7.8 ± 0.2 b-e	56.1 ± 0.3 b	0.95 ± 0.1 h	ovate	light	yellow	easy
98 Mws 133	12.7 ± 0.6 ij	7.2 ± 0.3 cde	56.7 ± 0.9 b	1.23 ± 0.1 f	round	light	yellow	medium
98 Mws 151	15.3 ± 0.6 def	7.6 ± 0.3 cde	49.7 ± 0.5 efg	1.85 ± 0.1 b	round	dark	yellow	medium
$LSD_{0.05}$	1.29	0.96	3.52	0.19				

round – okrągły, ovate – owalny, dark – ciemny, light – jasny, light yellow – jasnożółty, yellow – żółty, easy – łatwe, medium – średnie

Given the high value of the seedling grown walnut trees as genetic resources several attempts were taken to characterization revealing their breeding values [Dangl et al., 2005; Potter et al., 2002; Sharma and Sharma 2001; Solar et al., 2001]. Kafkas et al. [2005] studied the relationship among the 21 walnut genotypes by amplified fragment length polymorphism and selective amplification of microsatellite polymorphic loci techniques and significant genotypic variation among the genotypes potentially useful for breeding studies. They concluded that their molecular variation patterns coincided with those of horticultural traits. Similar conclusions were made by Potter et al. [2002]. Therefore, although or genotypes were not characterized by molecular markers, it is likely that their high level of horticultural variation is reflected by high level of molecular variation.

CONCLUSION

The selection study presented here was conducted on Malatya region which had rich walnut population. To our knowledge, the region has been screened first time for these walnut genotypes. We presented several characteristics of 16 superior genotypes in terms of yield, nut quality and tree characteristics. The weighted-ranking indicated that the most promising genotypes are 94 Mws 30, 95 Mws 78 and 97 Mws 103. These genotypes will be utilized in cross breeding studies. They are also available for walnut researchers as bud wood.

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POMOLOGICZNA I FENOLOGICZNA CHARAKTERYSTYKA OBIECUJĄCYCH GENOTYPÓW ORZECHA WŁOSKIEGO (*Juglans regia* L.) Z MALATYA W TURCJI

Streszczenie. Turcja posiada znaczące plantacje orzecha (*Juglans regia* L.), których drzewa w większości pochodzą z siewek. Region Anatolia w Turcji odznacza się bogatą różnorodnością fenotypową. W niniejszym badaniu oceniono genotypy orzecha oraz stwierdzono znaczą różnorodność genetyczną w cechach pomologicznych i fenologicznych genotypów orzecha, które pochodziły z siewek. Badany region ma obszar około 12 000 km^2 i znajduję się między szerokością geograficzną 35°54'–39°03' N a długością 38°45'–39°08' E. Szacuje się, że obszar ten ma około 162 800 drzew orzecha. Podczas niniejszego badania obserwacji poddano ponad 3000 genotypów orzecha pod kątem kilku cech ogrodniczych. Między tymi populacjami przeprowadzono badania selekcyjne. Na podstawie kilku cech ogrodniczych wybrano 158 genotypów. Opisujemy wybrane cechy 16 najlepszych genotypów orzech z tych 158 selekcji o obiecujących cechach plonu i owoców. Pośród selekcji zaobserwowano 65–100% owocowania na pędach szczytowych, 38–67 % owocowania na pędach bocznych, 1,98–3,15 owoców na szczytowych pędach, 1,36–2,25 owoców na bocznych pędach, masę orzecha 12,6–17,5 g, masę jądra 6,9–9,1 g, 47,3–60,8% jąder oraz grubość skorupy 0,95–17,5 mm. Do najbardziej obiecujących genotypów należały 94 Mws 30, 95 Mws 78 and 97 Mws 103 i one będą używane w dalszych próbach hodowlanych.

Słowa kluczowe: hodowla; zasoby genetyczne; cechy orzecha; pomologia

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