UDC 575.630
https://doi.org/10.2298/GENSR2201131K
*Original scientific article*

# GENETIC DIVERSITY OF WHITE MULBERRY (*Morus alba* L.) ACCESSIONS SELECTED FROM NORTH EASTERN TURKEY

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Keskin S., Y. Akca, S. Ercisli (2022). *Genetic diversity of white mulberry (Morus alba L.) accessions selected from north eastern Turkey.* - Genetika, Vol 54, No.1, 131-145.
This study was carried out between 2011-2013 years, on the mulberry population of Gümüşhane province and aimed to select promising white mulberry (*Morus alba*) genotypes according to main mulberry breeding criteria. Fruit samples were taken from 62 white mulberry genotypes in the first year and 54 in the second year. In fruit samples of selected promising white mulberry genotypes pomological and technological traits were investigated. Results indicated high diversity among selected genotypes for most of the pomological and technological traits. The average fruit weight ranged from 1.41 g (KU18) to 5.47 g (GUM23); Soluble Solid Content (SSC) from 10.07% (TO23) to 26.60% (GUM20); taste and aroma scores from 2.56 (GUM1) to 10.00 (TO29); fruit juice yield from 47.70% (GUM 20) to 92.44% (TO26); dried fruit yield from 11.99% (TO31) to 30.93% (TO23); fruit diameter from 11.25 mm (TO5) to 18.23 mm (KU7); fruit length from 17.84 mm (KU21) to 33.95 mm (KU7); stalk length from 4.41mm (GUM17) to 16.10 mm (GUM20), respectively. After assessment at the end of the study, 9 genotypes were found suitable for table consumption, 10 genotypes for molasses processing and 13 genotypes for drying.
*Keywords*: Mulberry (*Morus alba*), Fruit traits, Genetic resources, Selection.

## INTRODUCTION

Mulberry belongs to the genus *Morus*, family Moraceae and main species within the genus *Morus*, family main species within genus are *Morus alba* L., *Morus nigra* L., *Morus rubra* L.,

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*Morus austarlis*, *Morus latifolia*, *Morus multicaulis*, *Morus ihou*, *Morus kagayamaae* and *Morus bombycis* (EYDURAN *et al*., 2015). They have small to medium-sized trees with edible attractive fruits. Among mulberry species, *Morus alba* L. (white mulberry), *Morus nigra* L. (black mulberry) and *Morus rubra* L. (red mulberry) have gained more importance for fruit production (SKENDER *et al*., 2019).

Mulberries are native to temperate areas of Asia and North America and several species are cultivated for their fruits and as ornamentals. There are great differences among *Morus* species in terms of plant and fruit characteristics and also growing techniques because they are grown from mild temperature including Turkey, Azerbaijan, Bosnia & Herzegovina, to tropics including Indonesia, Africa, Taiwan, South America, etc. (ERCISLI and ORHAN, 2007; GECER *et al*., 2016).

Turkey is accepted as one of the leading mulberry producers in the world and it is one of the original centers of mulberries. It is the among main fruit species in Turkey and is mostly processed into several unique products (ERCISLI and ORHAN, 2008; ERCISLI *et al*., 2010). Due to better fruit organoleptic characteristics, easier propagation, high processing capacity, etc. *Morus alba* dominates mulberry production not only in Turkey but also in the Caucasian region. Balkan countries and also Asia countries including Iran, Afghanistan, Uzbekistan etc. approximately 95.0% of mulberry trees are belongs to *Morus alba* L. (ORHAN, 2009; SKANDER *et al*., 2019). Throughout Asia, but particularly in near and central Asia and in the Near East, a few mulberry orchards also exist and mulberries are highly appreciated for its delicious fruit, which is consumed fresh, or in the form of juice or conserved for centuries.

In Turkey, *Morus alba* is processed into very special local products called as 'pestil' and 'köme', well known as traditional Turkish foods, with honey, walnut, hazelnut, and flour mixture. Although they have been produced for the last few decades on an industrial scale, the production methods and properties of the products are not standardized yet (KAFKAS *et al*., 2008).

Mulberry trees, in general, found semi-wild conditions as solitary trees in mulberry producer countries and mulberry breeding studies mostly conducted on selection breeding these semi-wild genotypes aimed to obtain higher yielded genotypes with bigger fruits (ZHENG *et al*., 1988; ORHAN, 2009; AYDIN *et al*., 2016; BALIK *et al*., 2019). In Turkey, the first mulberry selection studies were started in 1996 (LALE and OZCAGIRAN, 1996) in the Aegean region and continued in the different agro-climatic regions in the country (ASLAN, 1998; YILMAZ *et al*., 2012).

Gümüşhane is the pioneer region for 'pestil' and 'köme' processing and 'pestil' and 'köme' have been registered and attained Geographical Registration Certificates from the Turkish Patent Institute with their unique production methods and properties, among many similar products in the world markets (YILDIZ, 2013).

In this study, a selection breeding was conducted in Gumushane province on semi wild-grown mulberry trees and some pomological and technological characteristics of selected genotypes were determined. The selected genotypes will be registered as new mulberry cultivars in Turkey in near future.

## MATERIAL AND METHODS

*Plant material*

This study was conducted between 2011 and 2013 yearson semi wild mulberry genotypes naturally found Gumushane province and Kürtün and Torul districts belonging to Gumushane province. Each plant (tree) is accepted as a genotype.

*Climatic conditions of the research area*

The climatic data related to 2011 to 2013 are shown in Table 1. The lowest temperature in Gumushane province was -13.2°C in 2011 -19.7°C in 2012 and -15.4°C in 2013, respectively. The research area has been received more precipitation in April in both 2011 and 2012 and in May in 2013.

*Table 1. Climatic data of Gumushane province in 201, 2012 and 2013 years*

| Climatic data | Years | January | February | March | April | May | June | July | August | September | October | November | December | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monthly average temperature (°C) | 2011 | 0.3 | 0.6 | 3.6 | 8.3 | 12.5 | 16.6 | 21.7 | 19.8 | 16.3 | 10.6 | 0.7 | 0.8 | 9.2 |
| | 2012 | 1.5 | 3.8 | 0.2 | 11.1 | 14.5 | 18.6 | 20.8 | 20.2 | 17.9 | 13.2 | 7.5 | 1.9 | 10.0 |
| | 2013 | 0.9 | 2.7 | 5.4 | 10.3 | 15.8 | 17.7 | 18.7 | 19.7 | 15.3 | 9.4 | 6.6 | 3.8 | 9.7 |
| Monthly maximum temperature (°C) | 2011 | 10.2 | 11.1 | 17.0 | 23.0 | 30.0 | 30.0 | 39.7 | 38.7 | 30.9 | 29.3 | 13.8 | 14.3 | 24.0 |
| | 2012 | 8.8 | 8.9 | 14.2 | 24.0 | 27.0 | 33.7 | 38.3 | 37.0 | 32.6 | 31.2 | 21.1 | 15.5 | 24.4 |
| | 2013 | 10.3 | 14.2 | 20.9 | 26.3 | 29.7 | 35.0 | 31.6 | 35.6 | 32.8 | 27.6 | 19.9 | 8.4 | 24.4 |
| Monthly minimum temperature (°C) | 2011 | 8.4 | 13.2 | 8.5 | 4.4 | 1.1 | 7.1 | 8.5 | 9.8 | 0.0 | 1.3 | 11.4 | 8.7 | 2.5 |
| | 2012 | 17.0 | 19.7 | 12.3 | 0.5 | 5.3 | 8.3 | 7.1 | 8.7 | 6.1 | 2.7 | 2.3 | 7.8 | 1.8 |
| | 2013 | 15.4 | 5.0 | 9.0 | 0.1 | 5.5 | 5.9 | 7.3 | 7.6 | 4.7 | 0.8 | 2.4 | 14.4 | 1.3 |
| Monthly minimum temperature <0.1°C) | 2011 | 24 | 22 | 21 | 5 | 0 | 0 | 0 | 0 | 0 | 1 | 20 | 27 | 10 |
| | 2012 | 27 | 28 | 26 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 16 | 8.6 |
| | 2013 | 23 | 22 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 7 | 31 | 8.8 |
| Monthly total precipatition (mm) | 2011 | 7.6 | 11.8 | 29.8 | 100.2 | 51.8 | 67.6 | 11.2 | 23.0 | 10.2 | 26.8 | 9.2 | 2.8 | 29.3 |
| | 2012 | 33.0 | 29.4 | 15.4 | 64.2 | 17.0 | 48.8 | 3.6 | 1.4 | 0.6 | 27.6 | 19.2 | 50.4 | 25.9 |
| | 2013 | 34.4 | 46.8 | 51.2 | 44.2 | 15.2 | 2.0 | 1.0 | 0.2 | 8.2 | 1.2 | 16.6 | 8.4 | 19.1 |
| Monthly average relative humidity (%) | 2011 | 63.7 | 68.9 | 58.9 | 65.0 | 65.3 | 62.3 | 55.6 | 57.7 | 58.3 | 59.0 | 66.6 | 58.6 | 61.7 |
| | 2012 | 68.0 | 63.7 | 60.5 | 53.5 | 65.5 | 57.5 | 53.2 | 57.8 | 51.4 | 59.9 | 69.6 | 69.5 | 60.8 |
| | 2013 | 66.9 | 64.3 | 55.6 | 56.5 | 51.5 | 59.2 | 55.1 | 53.0 | 57.4 | 54.4 | 64.4 | 66.8 | 58.7 |

*Selection*

The pre-selection was done on 25.00 white mulberry genotypes naturally grown in Gumushane province. In the pre-selection study, to select promising genotypes high yield, high fruit weight, free of pest and diseases in natural condition has been considered. In 2011 and 2012 year a total of 106 promising genotypes were selected among 25.000 plants according to the above pre-selection criteria. As the fruit maturing period is long for mulberry trees, determining the yield for each tree is not possible by weighing. For this reason, the yield was evaluated by comparing the trees in the same area and under the same climate conditions (ERDOGAN, 2003).

*Pomological and technological properties*

Fruit weight (g), fruit length (mm), fruit width (mm), and fruit stalk length (mm) of genotypes have been determined by digital balance and caliper by using 30 fruits. Fruit juice yield was determined by pressing 100 g fruit and weighing obtained juice. Dry fruit yield was determined by drying 100 g fresh fruit at 65°C in an oven and weighing total dry weight. The color of dried fruits has been measured on 10 dried fruits with chromometer as L* value (lightness) (100: White, 0: Black), a* (+ denotes redness, - denotes greenness), b* (+ denotes yellowness, - denotes blueness) (Minolta CR400). Fruit taste and aroma have been determined by 5 panelists. The pH of fruit juice was determined by pH meter (InoLab, Level 1, Germany) and total acidity was determined by titration with 0.1 N NaOH and expressed as malic acid. Total sugar analysis was done with "RQflex plus 10" (MERCK, Germany) device (ORHAN, 2009).

Total N determined by micro Kjeldahl method and P, K, Ca, Mg, Fe, Mn, Zn and Cu content has been determined with ICP OES spectrophotometer (Perkin Elmer, Optima 2100 DV, ICP/OES, Shelton, CT 064844794, USA) after wet digestion process with $HNO_3$: $H_2O_2$ (2:3) (MERTENS, 2005).

*Classification of genotypes for use areas*

White mulberry (*Morus alba* L.) genotypes are classified as fresh (Table), molasses and drying because white mulberries in the market sell as fresh, dry, or processed form (molasses). For the modified weighted ranked method, yield, fruit weight dried fruit color, the dry yield has been considered for dried mulberries. For table mulberries, yield, fruit weight, soluble solid content (SSC), taste and aroma has been considered and for molasses genotypes, yield, taste, aroma, fruit juice yield and SSC has been considered

*Modified weighted ranked score*

For the modified weighted ranked score, the differences between maximum and minimum values of traits were determined and genotypes were classified (ORHAN, 2009). The selection criteria, relative score, classes and class scores are shown in Table 2.

*Table 2. Selection criteria, relative score, classes and class scores*

| Use area | Characteristics | Relative score(%) | Classes | Class scores |
|---|---|---|---|---|
| Table | | 30 | High | 10 |
| Drying | Yield | 30 | Medium | 6 |
| Mollasses | | 30 | Low | 2 |
| | | | Very big | 10 |
| Table | Fruit weight | 30 | Big | 7 |
| Drying | | 10 | Medium | 5 |
| | | | Small | 2 |
| Table | | 25 | High | 10 |
| Drying | SSC | - | Medium | 6 |
| Mollasses | | 20 | Low | 2 |
| Table | | 15 | High | 10 |
| Drying | Taste and aroma | - | Medium | 6 |
| Mollasses | | 20 | Low | 2 |
| Table | | - | High | 10 |
| Drying | | 40 | Medium | 6 |
| Mollasses | Dry yield | - | Low | 2 |
| Table | | - | Light | 10 |
| Drying | | 20 | Medium | 6 |
| Mollasses | Dry fruit color | - | Dark | 2 |
| Table | | 15 | High | 10 |
| Drying | | - | Medium | 6 |
| Mollasses | Fruit juice yield | 20 | Low | 2 |

## RESULTS AND DISCUSSION

Fruit weight varied from 1.41 g (KU18) to 4.24 g (TO27) in 2011 and according to fruit weight 11 genotypes had very big fruits, 15 genotypes big, 28 genotypes had medium and 8 genotypes had small fruits (Table 3). In the second year of study (2012) fruit weights were found between 1.92 g (GM27) and 5.47 g (GUM23) and 8 genotypes had very big fruits, 18 genotypes had big fruit, 53 genotypes had medium and 11 genotypes had small fruits (Table 4). The fruit weight of promising genotypes was found between 1.92 g (GUM27) and 5.27 g (KU7) (Table 4). Three genotypes had very big fruits, 3 genotypes had big fruits, 15 genotypes had medium-size fruits and 3 genotypes had small fruits (Table 4). One of the most important breeding criteria for mulberries is bigger and more attractive fruits (ALJANE and SDIRI, 2016). Previous studies indicated diverse fruit weights from different countries ranged from 0.56 g to 6.25 g (BOUBAYA *et al*., 2009; ORHAN and ERCISLI, 2010; JALIKOP *et al*., 2011; YILMAZ *et al*., 2012; ALJANE and SDIRI, 2016; HOSSEINI *et al*., 2018). In our study, the genotypes KU40 and KU7 had fruit weights over 5 g. Moreover, selected genotypes in this study, in general, had higher fruit weight than studies completed in particular in Turkey. The fruit width and fruit length were found between 11.25 mm (TO5)-17.37 mm (TO27) and 17.84 (KU21)- 28.77 mm (TO20) on 62 mulberry genotypes in the 2011 year (Table 4). In the 2012 year, fruit width and length were

ranged from 11.85 mm (GUM26) to 18.23 mm (KU7) and 19.28 mm (GUM27) to 33.95 mm (KU7) respectively (Table 5). The promising genotypes selected at the and of the study had fruit width and length 15.24 mm (TO7)-18.23 mm (KU7) and 19.28 mm (GUM27) and 33.95 mm (KU7) (Table 6). ERDOGAN and CAKMAKCI (2006) reported fruit width and length between 10.4 mm (T-2)-12.9 mm (T-1) and 19.1 mm (T-4)-28.2 mm (T-5). ORHAN (2009) found that fruit width and length of selected white mulberry genotypes were between 9.97-17.36 mm and 19.75-31.03 mm.

*Table 3. Fruit characteristics of white mulberry genotypes selected in the 2011 year*

| Fruit characteristics | Classes | | The number of genotypes | Fruit characteristics | Classes | | The number of genotypes |
|---|---|---|---|---|---|---|---|
| Fruit weight (g) | Very big | 4.24-3.53 | 11 | Dry yield (%) | High | 30.93-24.62 | 3 |
| | Big | 3.52-2.82 | 15 | | Medium | 24.61-18.31 | 34 |
| | Medium | 2.81-2.11 | 27 | | Low | 18.30-11.99 | 24 |
| | Small | 2.10-1.41 | 9 | | | | |
| SSC (%) | High | 26.20-20.82 | 4 | Fruit color (L) of dried fruits | High | 49.65-40.70 | 15 |
| | Medium | 20.81-15.43 | 28 | | Medium | 40.69-31.76 | 30 |
| | Low | 15.42-10.07 | 30 | | Low | 31.75-22.81 | 16 |
| Fruit taste and aroma | High | 9.33-7.09 | 22 | Fruit juice yield (%) | High | 92.44-80.37 | 11 |
| | Medium | 7.08-4.84 | 31 | | Medium | 80.36-68.30 | 32 |
| | Low | 4.83-2.60 | 9 | | Low | 68.29-56.23 | 18 |

Fruit stalk lengths were 5.49 (KU6)-13.17 mm (KU3) in the 2011 year and 4.41mm (GUM17)-16.10 mm (GUM20) in the 2012 year. The promising genotypes selected at the end of the study had fruit stalk length 4.41 mm (KU17) and 12.14 mm (GUM22) respectively (Table 5). Previously fruit stalk length was reported between 4.02 mm and 12.75 mm according to years and genotypes (ORHAN, 2009)

SSC content varied from 10.07% (TO23) to 26.20% (TO31) in 2011 and 14.20% (TO39)- 26.60% (GUM20) in 2012 (Table 3). The promising genotypes selected at the end of the study had fruit SSC content between 14.80% (TO29) and 24.40% (KU17), respectively (Table 4). In terms of SSC content, 7 promising genotypes had high, 16 genotypes had medium and 3 genotypes had low SSC content (Table 4). ORHAN (2009) reported SSC content between 13.2-23.1%. LALE and OZCAGIRAN (1996) found the average SSC content in white mulberries grown in the western part of Turkey as 22.00%. In the northern part of Turkey, SSC content was reported between 15.3-23.8% among white mulberries (ISLAM *et al*., 2003). In the eastern part

of Turkey including Malatya, Elazığ, Erzincan and Tunceli provinces a selection of studies conducted on white mulberries and SSC content was found to be 21.60-30.80% among selected promising genotypes (ASLAN, 1998). In Japan, SSC content was reported between 6.60-20.80% among 260 mulberry genetic resources (MACHII *et al*., 2001). Previous studies are also indicated that biochemical content of different horticulture plants is cultivar/genotype dependent (ERCISLI *et al*., 2003; ZIA-UL-HAQ *et al*., 2013; BOLAT *et al*., 2014; GECER *et al*., 2020; KIRAN *et al*., 2020; BOLARIC *et al*., 2021; GRYGORIEVA *et al*., 2021).

The fruit juice yield is another important parameter for mulberry breeding for processing. In our study, fruit juice yield was found to be between 56.24% (KU7)-92.44% (TO26) in 2011. Considering classification of genotypes for fruit juice yield, 1 genotype had high, 32 genotypes had medium and 18 genotypes had low fruit juice yield (Table 3). In the 2012 year, these values were between 47.70% (TO20)-81.87% (GUM17), respectively. In 2012, 29 genotypes had high, 52 genotypes had medium and 9 genotypes had low fruit juice content (Table 4). The promising genotypes selected at the end of the study had fruit juice content between 57.23% (TO16) and 76.70% (GUM27) (Table 4). According to results, 13 genotypes had high, 11 genotypes had medium and 2 genotypes had low fruit juice content. ORHAN (2009) reported this value between 30.09-75.08% and ERDOGAN (2003) reported 58.21-66.63% among white mulberry genotypes. We found a higher fruit juice yield than ORHAN (2009) and ERDOGAN (2003).

*Table 4. Fruit characteristics of white mulberry genotypes selected in the 2012 year*

| Fruit characteristics | Classes | | The number of genotypes | Fruit characteristics | Classes | | The number of genotypes |
|---|---|---|---|---|---|---|---|
| Fruit weight (g) | Very big | 5.47-4.58 | 8 | Dry yield (%) | High | 27.06-22.80 | 19 |
| | Big | 4.57-3.70 | 18 | | Medium | 22.79-18.55 | 54 |
| | Medium | 3.69-2.81 | 53 | | Low | 18.54-14.29 | 17 |
| | Small | 2.80-1.92 | 11 | | | | |
| SSC (%) | High | 26.60-22.47 | 11 | Fruit color (L) of dried fruits | High | 52.05-42.96 | 15 |
| | Medium | 22.46-18.33 | 51 | | Medium | 42.95-33.88 | 39 |
| | Low | 18.32-14.20 | 28 | | Low | 33.87-24.79 | 36 |
| Fruit taste and aroma | High | 10.00-7.52 | 10 | Fruit juice yield (%) | High | 81.87-70.48 | 29 |
| | Medium | 7.51-5.04 | 44 | | Medium | 70.47-59.09 | 52 |
| | Low | 5.03-2.56 | 36 | | Low | 59.08-47.70 | 9 |

The dry fruit yield of genotypes was between 11.99 (TO31) and 30.93% (TO23) in 2011 and most of the genotypes placed medium-dry fruit yield group. Three genotypes had high, 34 had medium and 24 genotypes had low dry fruit yield (Table 3). In 2012, dry fruit yield ranged from 14.29% (KU10) to 27.06% (KU33), respectively. Parallel to the first year, the majority of

genotypes placed medium-dry fruit yield group and 19 genotypes within high, 54 genotypes had medium and 17 genotypes within low dry fruit yield group (Table 3). The promising genotypes selected at the end of the study had dry fruit yields between 19.26% (TO7) and 25.56% (TO16), respectively (Table 4). Dry fruit yield is an important breeding criterion for dried mulberries. In our study, approximately 50% of genotypes placed high dry fruit yield group and 14 genotypes placed medium group. ORHAN (2009) found dry fruit yield between 20.96-38.16% among mulberry selections in Turkey. ERDOGAN (2003) also reported dry fruit yield between 28.83-38.97% among 24 mulberry selections in Turkey.

Sensory analysis (taste and aroma) degustation panel evaluated mulberry samples and in the 201 year sensory scores varied from 2.60 (GUM1) to 9.33 (TO29). The results indicated that 22 genotypes had high, 31 genotypes had medium and 9 genotypes had low sensory scores (Table 2). In the 2012 year these values were between 2.56 (GUM1) and 10.00 (TO29) and 10 genotypes had high, 44 genotypes had medium and 36 genotypes had low sensory scores (Table 3). The promising genotypes selected at the end of the study had sensory scores between 2.56 (GUM1) and 10.00 (TO29) (Table 4) and 3 genotypes had high, 15 genotypes had medium and 8 genotypes had low sensory scores (Table 4). ORHAN (2009) reported taste and aroma scores among mulberry genotypes between 6.2-7.8 and 4.2-7.3, respectively. ERDOGAN (2003) also reported taste and aroma scores of 6.8-8.7 and 5.2-8.5, respectively. The differences between our and above studies could be results of different genotypes used and also different climatic and soil conditions of studied areas may have affected these differences.

In the 2011 year, fresh and dried fruit L color indices varied from 17.76 (KU19) and 72.95 (TO20) and 22.81 (TO3) and 49.65 (TO34), respectively (Table 3). In terms of dry fruit color classification, 15 genotypes placed high, 30 genotypes placed medium and 16 genotypes placed low group. In the 2012 year fresh fruit L values were between 28.16 (KU30) and 73.66 (TO39) and dried fruits L values ranged from 24.79 (KU28) and 52.05 (TO16) (Table 3). In general, in terms of dried fruit color classification, the majority placed medium or low group and 15 genotypes placed high group (Table 4).

Fruit juice pH values of genotypes were found between 5.12 (TO13) and 6.91 (KU13) in the first year and 5.67 (TO16) and 6.70 (KU6) in the second year. The promising genotypes selected at the end of the study had fruit juice pH values between 5.67 (TO16) and 6.59 (KU27) (Table 4). YILMAZ *et al*. (2012), reported pH values of a large number of mulberry genotypes between 2.19 (Kemaliye karadut 9) and 5.86 (Mersin mor dut), ORHAN (2009) revealed pH values between 3.30 and 5.89 among mulberry genotypes. BURGUT and TUREMIS (2006) reported pH from 2.29 to 6.21 in mulberry genotypes. CAM (2000) found this value from 5.6 to 7.4 and ERDOGAN (2003) reported pH in mulberry genotypes 3.64-6.05. Our results related to pH are in good agreement with the above results.

Total acidity varied from 0.02% (TO26, TO28) to 0.11% (KU1) in 2011 and 0.02% (TO20, TO26 and TO32) to 0.08 (KU10) in 2012. The promising genotypes selected at the end of the study had total acidity 0.02% (TO26) to 0.07 (KU8), respectively (Table 4). YILMAZ *et al*. (2012) was found acidity between 0.06% (Angut 9)-1.62% (Gümüşhacı karadut 8) among mulberry genotypes. ORHAN (2009) reported that acidity was between 0.16-1.33%. BURGUT and TUREMIS (2006) reported it 0.04-1.31%.

Total sugar content was found between 213 mg/100 ml (TO17) and 641 mg/100 ml (TO22) in the 2011 year and 124-542 mg/100 ml (GUM8 and TO22 genotypes) in the 2012 year, respectively. The promising genotypes selected at the end of the study had total sugar between 162 mg/100 ml (GUM26) and 438 mg/100 ml (TO18) (Table 5). DHARMANDA (2004) indicated that mulberry fruit include 85-88% water, 7.8-9.2% carbohydrate (glucose and fructose), 0.4-1.5% protein, 0.4-0.5 oil (linoleic, stearic and oleic acids), 1.1-1.9% free acid (malic acid), 0.9-1.4 fiber and 0.7-0.9% minerals. Previously reducing sugar content of mulberry fruits was found between 8.76-14.06% (ORHAN, 2009), 8.73-12.30% (CAM, 2000). BAKKALBASI *et al*. (2004) reported that dried mulberries had total sugar between 72.71-80.23%.

*Table 5. Fruit characteristics of promising mulberry genotypes*

| | Fruit weight (g) | Fruit width (mm) | Fruit length (mm) | SSC (%) | Fruit juice yield (%) | Dry yield (%) | Stalk length (mm) | pH | Total acidity (%) | Total sugar (mg/l) | Total weighted ranked score (2011+2012)/2 | Total weighted ranked score (2012) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KU8<br>Drying | 2.97 | 15.50 | 24.84 | 20.60 | 65.64 | 24.76 | 7.79 | 5.79 | 0.07 | 228 | 830 | 950 |
| KU16<br>Drying | 3.94 | 15.98 | 28.28 | 20.80 | 65.70 | 23.11 | 6.60 | 6.36 | 0.04 | 209 | 840 | 890 |
| KU17<br>Table<br>Drying<br>Molasses | 3.41 | 15.78 | 26.18 | 24.40 | 70.84 | 22.94 | 4.41 | 6.56 | 0.04 | 308 | 740<br>790<br>820 | 790<br>870<br>920 |
| TO9<br>Table,<br>Drying | 3.05 | 15.45 | 25.92 | 24.00 | 58.73 | 24.33 | 10.65 | 5.76 | 0.04 | 401 | 690<br>750 | 790<br>870 |
| TO14<br>Drying | 4.12 | 16.89 | 27.12 | 18.00 | 68.00 | 20.24 | 8.02 | 6.00 | 0.04 | 236 | 705 | 810 |
| GUM1<br>Drying | 2.91 | 14.89 | 26.22 | 17.80 | 63.30 | 23.98 | 10.59 | 6.01 | 0.03 | 217 | 870 | 870 |
| TO16<br>Table,<br>Drying | 3.02 | 15.46 | 26.15 | 22.60 | 57.24 | 25.56 | 9.53 | 5.67 | 0.04 | 260 | 770<br>750 | 850<br>870 |
| TO18<br>Drying | 3.23 | 15.43 | 26.26 | 24.20 | 62.43 | 23.92 | 7.72 | 6.24 | 0.03 | 438 | 720 | 830 |
| TO21<br>Drying | 4.04 | 16.60 | 26.58 | 22.00 | 61.75 | 24.83 | 10.82 | 5.92 | 0.03 | 277 | 785 | 890 |
| TO26<br>Table<br>Drying | 3.61 | 15.77 | 27.59 | 22.80 | 60.64 | 24.27 | 6.75 | 6.11 | 0.02 | 240 | 770<br>800 | 790<br>870 |
| KU9<br>Molasses | 3.25 | 15.69 | 26.61 | 21.00 | 70.48 | 23.17 | 10.83 | 5.80 | 0.07 | 258 | 720 | 840 |
| TO7<br>Molasses | 2.88 | 15.24 | 23.97 | 19.00 | 71.63 | 19.26 | 9.67 | 6.25 | 0.03 | 373 | 860 | 920 |
| TO29<br>Molasses | 3.57 | 16.03 | 27.14 | 14.80 | 73.84 | 19.40 | 7.43 | 6.32 | 0.03 | 232 | 880 | 840 |

| | Fruit weight (g) | Fruit width (mm) | Fruit length (mm) | SSC (%) | Fruit juice yield (%) | Dry yield (%) | Stalk length (mm) | pH | Total acidity (%) | Total sugar (mg/l) | Total weighted ranked score (2011+2012)/2 | Total weighted ranked score (2012) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KU39 Molasses | 2.71 | 14.94 | 24.35 | 20.60 | 71.01 | 20.80 | 10.32 | 6.19 | 0.06 | 301 | 840 | 840 |
| GUM6 Molasses | 3.62 | 14.56 | 26.11 | 21.80 | 72.03 | 20.98 | 6.34 | 6.01 | 0.04 | 189 | 920 | 920 |
| GUM9 Molasses | 3.20 | 14.05 | 22.87 | 20.40 | 72.16 | 20.91 | 6.55 | 6.26 | 0.03 | 255 | 840 | 840 |
| GUM12 Molasses | 2.92 | 13.97 | 22.55 | 21.80 | 73.17 | 21.64 | 6.69 | 6.13 | 0.05 | 210 | 920 | 920 |
| GUM13 Molasses | 3.54 | 14.19 | 26.01 | 21.60 | 75.00 | 21.29 | 8.04 | 5.97 | 0.05 | 238 | 840 | 840 |
| GUM22 Molasses | 3.60 | 14.61 | 26.18 | 20.00 | 72.15 | 20.61 | 12.14 | 6.14 | 0.04 | 237 | 840 | 840 |
| GUM26 Molasses | 1.97 | 11.85 | 19.85 | 19.80 | 74.27 | 23.12 | 9.19 | 6.03 | 0.05 | 162 | 840 | 840 |
| GUM27 Molasses | 1.92 | 11.88 | 19.28 | 21.40 | 76.70 | 20.10 | 6.73 | 6.27 | 0.05 | 231 | 920 | 920 |
| GUM11 Table Molasses | 3.09 | 13.67 | 24.10 | 23.80 | 72.33 | 21.33 | 7.27 | 5.90 | 0.06 | 291 | 790 920 | 790 920 |
| KU34 Table | 4.80 | 15.11 | 30.81 | 19.20 | 66.70 | 21.14 | 10.80 | 6.11 | 0.03 | 204 | 840 | 840 |
| KU40 Table | 5.13 | 17.08 | 30.69 | 19.40 | 68.32 | 20.68 | 6.93 | 5.72 | 0.04 | 216 | 780 | 780 |
| KU7 Table | 5.27 | 18.23 | 33.95 | 18.40 | 68.25 | 20.24 | 5.72 | 6.16 | 0.06 | 200 | 715 | 840 |
| KU27 Table | 2.96 | 15.44 | 24.18 | 23.60 | 67.16 | 24.81 | 9.32 | 6.59 | 0.03 | 366 | 750 | 790 |
| Mean | 3.41 | 15.17 | 25.92 | 20.92 | 68.44 | 22.21 | 8.34 | 6.09 | 0.04 | 261 | | |

The macro and microelement content of genotypes are shown in Table 6. N content of genotypes were between 0.470 (TO18)-1.440% (TO20), P content 0.12 (KU5)-0.35% (KU33), K content 0.77-2.06% (TO20 and KU20), Ca content 0.13-0.59 (KU and TO6), Na content 0.011-0.10 (GUM20, GUM21, GUM22 and GUM23 and TO25) and Mg content 0.05-0.159 (KU5 and GUM5) and S content 0.035-0.280 (GUM6-KU29) respectively. Cu, Fe, Mn and Zn content were found between 1.62-7.69 ppm (KU6-TO25), 6.03-149 ppm (TO4-GUM5), 2.78-17.78 ppm (GUM26-TO32) and 6.11-41.80 ppm (GUM16-TO6), respectively. Fe, Mg, Ca, K, Cu, Zn, Mn, Na and P content of 3 white mulberries sampled from Coruh valley in Turkey were 0.3-0.7 mg/100 g, 19-20 mg/100 g, 159-510 mg/100 g, 45-49 mg/ 100 g, 0.2-0.4 mg/100 g, 0.4-2.0 mg/100 g, 2-2 mg/100 g, 3-4 mg/100 g and 4101-7483 mg/100 g, respectively (GUNGOR and SENGUL, 2008), ERCISLI and ORHAN (2007) reported average N % 0.75, P 247 mg/100 g, K 1668 mg/100 g, Ca 152 mg/100 g, Mg 106 mg/100 g, Na 60 mg/100 g, Fe 4.2 mg/100 g, Cu 0.5 mg/100 g, Mn 3.8 mg/100 g and Zn 2.8 mg/100 g in *Morus alba*. Our macro and microelement content are similar to the above studies.

*Table 6. Macro and microelement content of mulberry fruits*

| | Macroelements (%) | | | | | | | Microelements (ppm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Genotypes | N | P | K | Ca | Na | Mg | S | Cu | Fe | Mn | Zn |
| KU7 | 1.13 | 0.25 | 1.72 | 0.25 | 0.08 | 0.09 | 0.20 | 3.45 | 43.90 | 6.58 | 11.98 |
| KU8 | 1.04 | 0.23 | 1.39 | 0.24 | 0.07 | 0.09 | 0.18 | 4.27 | 50.17 | 6.18 | 12.51 |
| KU9 | 1.12 | 0.24 | 1.14 | 0.31 | 0.07 | 0.10 | 0.19 | 3.53 | 41.91 | 8.07 | 12.04 |
| KU16 | 0.74 | 0.19 | 1.16 | 0.18 | 0.07 | 0.07 | 0.12 | 2.78 | 38.04 | 5.36 | 6.18 |
| KU17 | 0.70 | 0.20 | 1.23 | 0.18 | 0.07 | 0.06 | 0.18 | 2.40 | 37.78 | 4.29 | 6.71 |
| KU27 | 0.84 | 0.27 | 1.49 | 0.28 | 0.09 | 0.09 | 0.17 | 3.59 | 42.19 | 9.29 | 13.48 |
| KU34 | 1.05 | 0.28 | 1.45 | 0.31 | 0.08 | 0.11 | 0.18 | 2.68 | 46.24 | 10.9 | 13.52 |
| KU39 | 0.81 | 0.25 | 1.55 | 0.23 | 0.07 | 0.08 | 0.2 | 3.48 | 27.69 | 5.44 | 12.98 |
| KU40 | 1.41 | 0.25 | 1.33 | 0.26 | 0.08 | 0.08 | 0.16 | 3.86 | 28.56 | 7.27 | 12.49 |
| TO7 | 1.09 | 0.26 | 1.47 | 0.42 | 0.07 | 0.11 | 0.16 | 4.95 | 63.57 | 11.21 | 19.13 |
| TO9 | 0.63 | 0.19 | 0.91 | 0.16 | 0.04 | 0.07 | 0.15 | 2.77 | 17.99 | 5.15 | 14.75 |
| TO14 | 1.15 | 0.28 | 1.57 | 0.25 | 0.08 | 0.10 | 0.14 | 4.02 | 35.35 | 7.56 | 15.36 |
| TO16 | 0.56 | 0.28 | 1.75 | 0.35 | 0.09 | 0.11 | 0.11 | 3.12 | 48.84 | 4.93 | 15.23 |
| TO18 | 0.47 | 0.20 | 1.11 | 0.33 | 0.07 | 0.08 | 0.10 | 4.57 | 60.74 | 6.72 | 11.51 |
| TO21 | 0.80 | 0.23 | 1.22 | 0.27 | 0.07 | 0.08 | 0.15 | 3.11 | 43.85 | 6.13 | 36.8 |
| TO26 | 0.59 | 0.17 | 0.94 | 0.26 | 0.06 | 0.07 | 0.09 | 3.31 | 35.45 | 5.17 | 22.41 |
| TO29 | 0.84 | 0.22 | 1.21 | 0.35 | 0.07 | 0.09 | 0.12 | 4.04 | 54.03 | 6.49 | 30.87 |
| GUM6 | 0.78 | 0.16 | 0.81 | 0.33 | 0.01 | 0.09 | 0.04 | 2.81 | 48.61 | 4.24 | 13.24 |
| GUM8 | 0.78 | 0.16 | 1.18 | 0.36 | 0.01 | 0.12 | 0.05 | 2.97 | 55.09 | 5.72 | 8.59 |
| GUM9 | 0.85 | 0.14 | 1.02 | 0.27 | 0.02 | 0.10 | 0.04 | 3.17 | 29.82 | 3.89 | 7.59 |
| GUM11 | 0.80 | 0.17 | 0.99 | 0.33 | 0.01 | 0.09 | 0.05 | 3.62 | 31.90 | 5.66 | 8.06 |
| GUM12 | 0.63 | 0.17 | 0.94 | 0.29 | 0.01 | 0.09 | 0.04 | 4.04 | 42.48 | 4.78 | 6.53 |
| GUM13 | 0.77 | 0.17 | 0.94 | 0.35 | 0.01 | 0.11 | 0.04 | 6.92 | 49.54 | 5.44 | 12.75 |
| GUM22 | 0.95 | 0.18 | 0.95 | 0.33 | 0.01 | 0.09 | 0.05 | 5.93 | 61.43 | 5.97 | 20.70 |
| GUM26 | 0.70 | 0.15 | 1.19 | 0.19 | 0.02 | 0.10 | 0.04 | 3.64 | 32.23 | 2.78 | 8.14 |
| GUM27 | 0.77 | 0.18 | 1.19 | 0.21 | 0.01 | 0.10 | 0.05 | 4.16 | 38.85 | 3.58 | 17.63 |

## CONCLUSION

We found a great variation among mulberry genotypes for most of the morphological and biochemical characteristics. The fruit weight of selected genotypes was found close to national or international mulberry selections or cultivars. However, fruit juice yield and SSC content were found higher than national or international mulberry selections or cultivars. In Turkey, to obtain a better quality of traditional mulberry products such as ‘kome’, ‘pestil’ and ‘pekmez’ fruit juice yield and SSC are more important. Our selections had high fruit juice yield and SSC content indicating the importance to use of them to obtain high-quality ‘kome’, ‘pestil’ and ‘pekmez’. At the end of the study, 9 genotypes were selected as fresh (table) production, 10 genotypes were found suitable for drying and 13 genotypes were found suitable for molasses production. KU17 genotypes were found suitable for fresh production, drying and also molasses production. GUM11 for suitable for molasses and table production, TO9, TO16 and TO26 were

found suitable for table production and drying. The multiplication of selected genotypes in mulberry growing projects in rural areas in order to diversify the economic activities will contribute to the development of the agriculture-based industry. The absence of standard mulberry cultivars in Turkey makes it impossible for growers to benefit from certified saplings. In this context, new standard mulberry cultivars will be introduced to Turkey with the completion of the selection 2 stages and registration study.

Received, August 04th, 2020
Accepted September 10th, 2021

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# GENETIČKA RAZNOVRSNOST UZORAKA BELOG DUDA (*Morus alba* L.) IZABRANIH IZ SEVEROISTOČNE TURSKE

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Izvod

Ovo istraživanje je sprovedeno u periodu 2011-2013. godine na populaciji duda provincije Gumušane i imalo je za cilj odabir perspektivnih genotipova belog duda (*Morus alba*) prema kriterijumima značajnim za oplemenjivanja duda. Uzimani su uzorci plodova sa 62 genotipa belog duda u prvoj godini i sa 54 genotipa u drugoj godini. U uzorcima plodova odabranih perspektivnih genotipova belog duda ispitivane su pomološke i tehnološke osobine. Rezultati su ukazali na visok diverzitet među odabranim genotipovima za većinu pomoloških i tehnoloških osobina. Prosečna masa ploda se kretala od 1,41 g (KU18) do 5,47 g (GUM23); Rastvorljivi čvrsti sadržaj (SSC) od 10,07% (TO23) do 26,60% (GUM20); ocene ukusa i arome od 2,56 (GUM1) do 10,00 (TO29); prinos voćnog soka od 47,70% (GUM 20) do 92,44% (TO26); prinos sušenog voća od 11,99% (TO31) do 30,93% (TO23); prečnik ploda od 11,25 mm (TO5) do 18,23 mm (KU7); dužina ploda od 17,84 mm (KU21) do 33,95 mm (KU7); dužina stabljike od 4,41 mm (GUM17) do 16,10 mm (GUM20), respektivno. Nakon procene na kraju studije, izdvojeno je 9 genotipova pogodnih za konzumaciju, 10 genotipova za preradu melase i 13 genotipova za sušenje.

Primljeno 06.VI.2020.
Odobreno 10.IX. 2021.