TÜBİTAK

Turkish Journal of Agriculture and Forestry

http://journals.tubitak.gov.tr/agriculture/

Research Article

Turk J Agric For
(2013) 37: 575-584
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doi:10.3906/tar-1301-39

# Morphological characterization of cherry rootstock candidates selected from Samsun Province in Turkey

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**Received:** 14.01.2013 • **Accepted:** 05.03.2013 • **Published Online:** 28.08.2013 • **Printed:** 25.09.2013

**Abstract:** Sweet cherry and sour cherry production in Turkey occupies an important place in worldwide production and is still of considerable importance in terms of providing further fruit species and gene resources. In this study, 88 sweet cherry, 16 sour cherry, and 9 mahaleb types displaying potential for cultivar rootstocks were selected from wild cherry populations in Samsun Province of the Central Black Sea Region in Turkey. The morphologic characteristics of the studied genotypes were compared with the standard clone rootstocks PHL-A, MaxMa 14, Montmorency, Weiroot 158, Gisela 5, Gisela 6, and SL 64. A total of 22 morphological and phenotypic characteristics were evaluated in the selected genotypes and clonal rootstocks. The obtained data were analyzed by using principal component analysis, and 7 principal component (PC) axes accounted for 70.37% of the total cumulative variation. The first PC axis, which accounted for 22.4% of the total variation, was represented by leaf blade length, leaf blade width, petiole length, ratio of 1-year-old shoot internodes length, and 1-year-old shoot branching, while the second PC axis, which accounted for 13.55% of the variation, was represented by leaf blade ratio of length to width, 1-year-old shoot length, 1-year-old shoot thickness, and leaf blade shape. Average linkage cluster analysis was also performed, and 7 main clusters were identified. According to the diversity analysis of coefficients, the C 0032 and C 0094 genotypes were identified as being very similar, while the C 0002 and S 0012 genotypes were determined as the most distant genotypes in terms of morphology. In conclusion, the genotypes evaluated in this study may be useful for rootstock breeding programs.

**Key words:** Cherries rootstock, morphological characterization, multivariate analysis, Samsun-Turkey

## 1. Introduction

The use of standard rootstock has become a necessity in modern fruit production. Rootstock selection should be performed in order to increase plant resistance against adverse climatic and soil conditions, to broaden adaptability, and to increase fruit yield and quality, since these characteristics are as important as the control of tree size and dwarfing. Rootstocks have been used in the propagation of temperate fruits for over 2000 years. In addition to allowing convenient propagation, rootstock use also has a positive impact on plant adaptation to different environmental conditions (Webster, 1995). Rootstock breeding has been the main focus of studies aiming to increase the yield of the dwarf cherry rootstock, and also of research that has been conducted during the last 70–80 years for new varieties. The Mazzard and Mahaleb generative rootstocks have been used until the 1990s. As a result of the rootstock breeding program carried out at the East Malling Research Station in the United Kingdom during the 1920s, the F 12 / 1 clone was selected from Mazzard, and the Colt clone was selected from the *Prunus avium* × *Prunus pseudocerasus* cross. These rootstocks are still used currently today, although their use is no longer very common.

The largest breeding program of cherry rootstock clones was initiated in Germany (Giessen) in 1965. At the end of these studies, the Gisela 5 (*Prunus cerasus* × *Prunus canescens*) and Gisela 6 (*P. cerasus* × *P. canescens*), which are rootstocks of the Gisela series, provided better results compared to the other rootstocks in terms of yield and dwarf growth (Rieger, 2006). In recent years, the P-HL series, Pi-Ku series, Camil (GM 79), Damil (GM 61 / 1), Inmil (GM 9), Gisela, and M × M (MaxMa) hybrid rootstock clones have also been obtained as a result of species and interspecies crosses (Hrotko, 2008).

In Turkey, the mahaleb (*Prunus mahaleb*), wild cherry (*Prunus avium*), and sour cherry (*Prunus cerasus*) seedling rootstocks are used in cherry production. Ercisli et al. (2006) reported that 40% of the cherry production in Turkey is carried out on wild cherry seedling rootstocks,

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with 30% being mahaleb seedlings and 30% being a mix of Gisela 5, Gisela 6, and SL 64 clonal rootstocks. However, as is the case with other species used in fruit production, Turkey does not have its own native cherry clone rootstocks.

Turkey is one of the most important genetic sources for cherry in the world and provides an important source of variation for plant breeding. The aim of our study was to investigate genotypic variation among 88 sweet cherry, 16 sour cherry, and 9 mahaleb types, selected from the wild genotype cherry populations in the Samsun Province of the Central Black Sea Region that can potentially be used as rootstocks for cultivars.

## 2. Materials and methods

This study was conducted at the Black Sea Agricultural Research Institute (Karadeniz Tarımsal Araştırma Enstitüsü) in Samsun between 2007 and 2009. The germplasm used in this study was collected from 15 districts within Samsun Province (Table 1). Samsun is located at 40°50′N–41°51′N, 37°08′E–34°25′E.

A total of 88 sweet cherry, 16 sour cherry, and 9 mahaleb types, which were selected in 2007 and 2008 from wild cherry populations and which have the potential of being used as rootstocks for cultivars, constituted the materials of this study. The morphologic characteristics of the studied genotypes were compared with PHL-A, MaxMa 14, Montmorency, Weiroot 158, Gisela 5, Gisela 6, and SL 64 standard clone rootstocks. Leaves and shoots of the types grafted by budding in the observation gardens were identified by using the identification and morphological characterization criteria of UPOV (International Union for the Protection of New Varieties of Plants, Prunus Rootstocks 2002, TG / 187 / 1 - 03.03.2007). Morphological characteristics of the leaves were determined in July, while the morphological features of the shoots were determined in December. A total of 120 genotypes and cultivars, including the selected genotypes and clonal rootstocks, were evaluated according to a total of 22 morphological and phenotypic characteristics (Table 2).

Simple correlations, factor and cluster analyses, and scatter plots were prepared by using SPSS 20.0 Windows. Factor analysis was performed by using the Varimax factor rotating method. A dendrogram of the genetic similarities between the genotypes was compiled using the Ward method.

## 3. Results

The location data for the wild cherry, sour cherry, and mahaleb types were determined by using GPS. The data were transferred to a GIS database, and a distribution map was created with ArcGIS 9.2 software (Figure 1).

Principal component analysis (PCA) was used to assess the variation between cherry genotypes. The first 7 axes accounted for 70.37% of the variability among 120 types (Table 3). The 1st PC axis accounted for 22.4% of the variation, while the 2nd, 3rd, and 4th axes accounted for 13.6%, 10.4%, and 7.4%, respectively. The first axis was mainly related to leaf blade length, leaf blade width, petiole length, 1-year-old shoot internodes length, and 1-year-old shoot branching. The second axis was mainly related to leaf blade ratio of length to width, 1-year-old shoot length, 1-year-old shoot thickness, and leaf blade shape. The remaining 5 axes were related to other leaf, shoot, and plant traits (Table 3).

Table 4 provides the correlations among 22 characteristics. One characteristic, plant vigor, was positively correlated with nectary color (0.31), leaf blade width (0.30), petiole length (0.29), and leaf predominant number of nectaries (0.27), while it was negatively correlated with 1-year-old shoot branching (–0.27). One-year-old shoot thickness was positively correlated with 1-year-old shoot length (0.71). One-year-old shoot branching was negatively correlated with leaf blade length (–0.64), leaf blade width (–0.52), and petiole length (–0.68), while it was positively correlated with ratio of length of leaf blade to length of petiole (0.41). Leaf blade length (0.50), leaf blade width (0.49), and petiole length (0.41) showed positive correlation with 1-year-old shoot length of internodes.

The populations were grouped into 7 clusters by cluster analysis. The different cherry genotypes, identified based on the similarity of their morphological characteristics and their hierarchical clustering, are shown in Figure 2. These 7 groups and their 15 subgroups can be considered as distinct germplasm pools (Figure 2). The means and standard deviations of the traits for each cluster are given in Table 5. According to diversity analysis of coefficients, the C 0032 and C 0094 genotypes were very similar, while the C 0002 and S 0012 genotypes were determined as the most distant genotypes in terms of morphological variability. The major clusters can be summarized as follows: Group A consisted of 6 subgroups and includes 88 genotypes. Narrow elliptic and elliptic leaf shapes were observed in Group A. Plant vigor was observed as medium and strong, while the upper side coloration of the leaf blade was found to be light and dark green. One-year-old shoots were, on average, 123.0 cm in length and 14.8 mm in thickness, with an internodes length of 4.2 cm. There were only 2 genotypes in Groups B and C. Elliptic leaf shapes were observed in Group B, while narrow elliptic leaf shapes were observed in Group C. The upper side coloration of the leaf blades was found to be dark green in Group B, and both light and dark green in Group C. Leaf stipules were observed to be present in Group C, but absent in Group B. While 1-year-old shoots

**Table 1.** Geographical location data of the types selected from Samsun Province in Turkey (C: *P. avium*, S: *P. cerasus*, M: *P. mahaleb*).

| District | Village | Selection code | Altitude (m) |
|---|---|---|---|
| Alaçam | Alidede | C 0006 | 683 |
| | | C 0074 | 812 |
| | Kapaklı | C 0070 | 476 |
| Asarcık | Akyazı | C 0054 | 810 |
| | Ayaklıalan | C 0051 | 678 |
| | | C 0052 | 645 |
| | | C 0053 | 524 |
| | Dağcılar | C 0114 | 780 |
| | Hisariye | C 0096 | 754 |
| | | S 0022 | 779 |
| | Kesealan | C 0049 | 1013 |
| | Yeniömerli | C 0095 | 848 |
| | Yeşilköy | C 0048 | 799 |
| Ayvacık | Çökekli | M 0008 | 914 |
| | | M 0009 | 700 |
| | Esenyurt | C 0089 | 689 |
| | | C 0090 | 314 |
| | | C 0117 | 620 |
| | Sofualan | C 0116 | 691 |
| | | S 0019 | 630 |
| | Yeşilçam | C 0087 | 146 |
| | | C 0115 | 252 |
| | | S 0012 | 173 |
| Bafra | Arasdemirci | C 0067 | 623 |
| | | C 0068 | 623 |
| | Kamberli | C 0110 | 401 |
| | | C 0111 | 431 |
| | | C 0112 | 475 |
| | | C 0132 | 429 |
| | | C 0134 | 510 |
| | | C 0135 | 544 |
| Çarşamba | Eğridere | C 0059 | 332 |
| | | C 0060 | 658 |
| | | C 0061 | 632 |
| | | C 0113 | 418 |
| | | S 0015 | 168 |
| | | S 0018 | 241 |
| | Güldere | C 0106 | 274 |
| | | C 0107 | 262 |
| | Kestanepınar | C 0131 | 328 |
| Havza | Çiftlik | C 0055 | 1033 |
| | Hacıbattal | M 0004 | 534 |
| | Kirenlik | M 0002 | 705 |
| | Orhaniye | C 0057 | 866 |
| | | C 0058 | 863 |
| | Şerifali | M 0003 | 352 |
| | Yağcımahmut | S 0004 | 821 |
| Kavak | Atayurt | C 0035 | 797 |
| | Bayraklı | C 0038 | 817 |
| | Bükceğiz | C 0093 | 765 |
| | Karlı | C 0092 | 753 |
| | Kozansıkı | C 0094 | 751 |
| | Sıralı | C 0036 | 866 |
| Ladik | Budakdere | C 0100 | 1004 |
| | Cüce | C 0002 | 958 |
| | Deliahmetoğlu | C 0099 | 983 |
| | | S 0016 | 909 |
| Ladik (continued) | Derinöz | S 0013 | 815 |
| | Central district | S 0014 | 964 |
| | | S 0017 | 929 |
| | Karaaptal | C 0005 | 754 |
| | Küpecik | C 0064 | 954 |
| | Soğanlı | C 0003 | 1085 |
| | | C 0004 | 1210 |
| Ondokuz mayıs | Aydınpınar | C 0066 | 884 |
| | Çepinler | C 0065 | 247 |
| | Düzköy | S 0008 | 236 |
| Salıpazarı | Central district | C 0122 | 118 |
| | Karacaören | C 0119 | 490 |
| | | C 0120 | 337 |
| | Karaman | C 0008 | 382 |
| | Muslubey | C 0062 | 74 |
| | Taçalan | C 0010 | 534 |
| | | C 0011 | 834 |
| | Tahnal | C 0121 | 1097 |
| Samsun Central District | Çamlıyazı | S 0001 | 402 |
| | Erikli | C 0030 | 761 |
| | Kabadüz | C 0024 | 718 |
| | | C 0026 | 738 |
| | | C 0027 | 722 |
| | | C 0028 | 824 |
| | | C 0032 | 480 |
| | Sarıbıyık | S 0002 | 409 |
| | | S 0003 | 535 |
| | Taflan | C 0031 | 198 |
| | Toygar | S 0021 | 560 |
| Tekkeköy | Bakacak | C 0123 | 511 |
| | Çırakman | C 0124 | 126 |
| | Çimenli | C 0125 | 656 |
| | | C 0126 | 599 |
| | | C 0127 | 599 |
| | | C 0128 | 690 |
| | Erenköy | C 0129 | 755 |
| | Kazımkarabekir | C 0083 | 287 |
| | | C 0084 | 509 |
| | Kocamanbaşı | C 0040 | 427 |
| Vezirköprü | Çalkara | M 0006 | 332 |
| | Çalman | C 0105 | 659 |
| | | M 0007 | 681 |
| | Elaldı | C 0102 | 862 |
| | | C 0103 | 791 |
| | | C 0104 | 808 |
| | | C 0118 | 791 |
| | Central district | M 0001 | 351 |
| | | M 0005 | 351 |
| | Öğürlü | C 0014 | 735 |
| | | C 0015 | 749 |
| | | C 0019 | 726 |
| | | C 0020 | 708 |
| Yakakent | Karaaba | C 0082 | 593 |
| | | S 0011 | 685 |
| | Yeşilköy | C 0080 | 151 |
| | | C 0081 | 246 |

**Table 2.** Morphological and physiological characteristics used for the characterization of cherry types.

| |
|---|
| **Leaf** |
| LBL: Leaf blade: length (cm) |
| LBW: Leaf blade: width (cm) |
| RLW: Leaf blade: ratio of length to width |
| PL: Petiole: length (cm) |
| RLP: Leaf blade: ratio of leaf blade length to petiole length |
| LBS: Leaf blade: shape; narrow elliptic (1), elliptic (2), circular (3), ovate (4), obovate (5) |
| LBC: Leaf blade: upper side coloration; light green (1), dark green (2), red (3), reddish brown (4) |
| LBP: Leaf blade: lower side pubescence at apex, weak (3), medium (5), strong (7) |
| LAC: Young shoot: intensity of anthocyanin coloration in young leaves (during rapid growth); weak (3), medium (5), strong (7) |
| LBM: Leaf blade: margin incision; only crenate (1), both crenate and serrate (2), only serrate (3) |
| LS: Leaf: presence of stipules; absent (1), present (9) |
| LN: Leaf: presence of nectaries, absent (1), present (9) |
| LNN: Leaf: predominant number of nectaries; absent (0), 1 (1), 2 (2), more than 2 (3) |
| NC: Nectary: color; absent (0), green (1), yellow (2), red (3), violet (4) |
| **One year old shoot** |
| SL: One-year-old shoot: length (cm) |
| ST: One-year-old shoot: thickness (mm) |
| SIL: One-year-old shoot: internodes length (middle third of shoot) (cm) |
| SB: One-year-old shoot: branching (at the end of summer) |
| AAC: One-year-old shoot: anthocyanin coloration of apex; absent or very weak (1), weak (3), medium (5), strong (7), very strong (9) |
| BP: One-year-old shoot: position of vegetative bud in relation to shoot; adpressed (1), slightly held-out (2), markedly held-out (3) |
| **Plant** |
| PV: Plant: vigor; weak (3), medium (5), strong (7) |
| PH: Plant: habit; upright (1), spreading (3), drooping (5) |

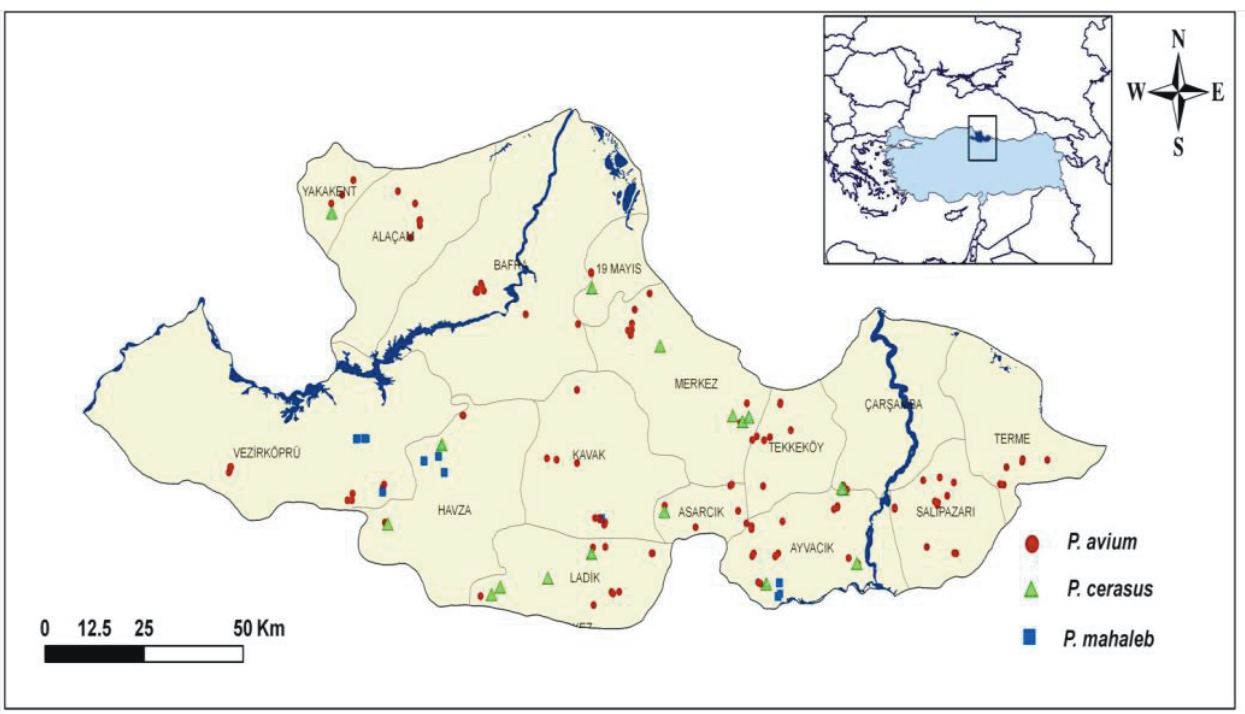


**Figure 1.** Map of the distribution of cherry (*P. avium*), sour cherry (*P. cerasus*), and mahaleb (*P. mahaleb*) genotypes in Samsun Province.

**Table 3.** Eigenvalues and proportions of variance described by the 7 principal components that correspond to Eigenvalues greater than 1.

| | PC axis | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Eigenvalues | 4.93 | 2.98 | 2.29 | 1.63 | 1.28 | 1.25 | 1.13 |
| Explained proportion of variation (%) | 22.40 | 13.55 | 10.42 | 7.40 | 5.80 | 5.67 | 5.13 |
| Cumulative proportion of variation (%) | 22.40 | 35.95 | 46.37 | 53.77 | 59.57 | 65.24 | 70.37 |
| Characteristic | Eigenvectors | | | | | | |
| Leaf blade: length | 0.88 | –0.23 | 0.02 | –0.17 | 0.02 | –0.03 | 0.13 |
| Leaf blade: width | 0.75 | 0.20 | –0.35 | –0.16 | –0.05 | 0.17 | 0.28 |
| Leaf blade: ratio of length to width | 0.38 | –0.66 | 0.48 | –0.05 | 0.12 | –0.26 | –0.17 |
| Petiole: length | 0.86 | 0.02 | –0.24 | –0.12 | 0.05 | –0.24 | –0.09 |
| Leaf: ratio of leaf blade length to petiole length | –0.42 | –0.30 | 0.50 | 0.03 | –0.05 | 0.29 | 0.26 |
| One-year-old shoot: length | 0.17 | 0.66 | 0.37 | –0.29 | 0.22 | 0.01 | –0.21 |
| One-year-old shoot: thickness | 0.32 | 0.61 | 0.14 | –0.51 | 0.28 | 0.01 | –0.09 |
| One-year-old shoot: internodes length | 0.62 | –0.01 | –0.02 | –0.14 | 0.12 | 0.11 | 0.25 |
| One-year-old shoot: branching | –0.76 | 0.17 | 0.18 | –0.11 | 0.20 | 0.18 | 0.07 |
| Leaf blade: shape | –0.27 | 0.61 | –0.50 | 0.17 | –0.15 | 0.23 | 0.19 |
| Leaf blade: upper side coloration | 0.12 | –0.27 | 0.19 | –0.27 | 0.42 | 0.27 | 0.39 |
| Leaf blade: lower side pubescence at apex | 0.33 | –0.12 | 0.01 | 0.01 | –0.45 | 0.34 | –0.01 |
| Intensity of anthocyanin coloration in young leaves | 0.37 | 0.49 | 0.60 | 0.04 | –0.32 | 0.09 | 0.06 |
| Leaf blade: margin incision | 0.46 | –0.18 | –0.23 | –0.15 | –0.47 | –0.16 | –0.10 |
| Leaf: presence of stipules | –0.02 | 0.52 | 0.37 | 0.26 | 0.07 | –0.41 | –0.15 |
| Leaf: presence of nectaries | 0.28 | 0.15 | –0.10 | 0.79 | 0.25 | 0.02 | 0.01 |
| Leaf: predominant number of nectaries | 0.58 | 0.09 | –0.02 | 0.40 | 0.28 | –0.01 | –0.04 |
| Nectary: color | 0.49 | –0.25 | 0.22 | 0.39 | 0.10 | 0.17 | 0.05 |
| One-year-old shoot: anthocyanin coloration of apex | 0.27 | 0.40 | 0.65 | 0.14 | –0.41 | 0.07 | 0.12 |
| Position of veg. bud in relation to shoot | 0.08 | –0.46 | 0.37 | 0.04 | 0.00 | 0.15 | –0.09 |
| Plant: vigor | 0.44 | 0.22 | –0.07 | 0.15 | 0.17 | 0.50 | –0.24 |
| Plant: habit | –0.01 | 0.17 | 0.08 | 0.11 | 0.02 | –0.47 | 0.71 |

**Table 4.** Correlation coefficients between some of the traits of different genotypes/clonal rootstocks.

| | LBL | LBW | RLW | PL | RLP | SL | ST | SIL | SB | LBS | LBC | LBP | LAC | LBM | LS | LN | LNN | NC | AAC | BP | PV | PH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LBL | 1.00 | | | | | | | | | | | | | | | | | | | | | |
| LBW | 0.77 | 1.00 | | | | | | | | | | | | | | | | | | | | |
| RLW | 0.52 | −0.13 | 1.00 | | | | | | | | | | | | | | | | | | | |
| PL | 0.76 | 0.66 | 0.28 | 1.00 | | | | | | | | | | | | | | | | | | |
| RLP | −0.15 | −0.31 | 0.18 | −0.70 | 1.00 | | | | | | | | | | | | | | | | | |
| SL | 0.03 | 0.10 | −0.11 | 0.11 | −0.08 | 1.00 | | | | | | | | | | | | | | | | |
| ST | 0.21 | 0.35 | −0.15 | 0.29 | −0.25 | 0.71 | 1.00 | | | | | | | | | | | | | | | |
| SIL | 0.50 | 0.49 | 0.17 | 0.41 | −0.17 | 0.09 | 0.29 | 1.00 | | | | | | | | | | | | | | |
| SB | −0.64 | −0.52 | −0.33 | −0.68 | 0.41 | 0.17 | −0.01 | −0.37 | 1.00 | | | | | | | | | | | | | |
| LBS | −0.36 | 0.19 | −0.81 | −0.17 | −0.16 | 0.05 | 0.07 | −0.16 | 0.20 | 1.00 | | | | | | | | | | | | |
| LBC | 0.22 | 0.11 | 0.22 | 0.08 | 0.14 | −0.06 | 0.04 | 0.05 | −0.01 | −0.26 | 1.00 | | | | | | | | | | | |
| LBP | 0.24 | 0.22 | 0.09 | 0.20 | −0.05 | −0.01 | −0.06 | 0.17 | −0.21 | −0.11 | 0.04 | 1.00 | | | | | | | | | | |
| LAC | 0.20 | 0.18 | 0.04 | 0.17 | −0.02 | 0.44 | 0.36 | 0.16 | −0.18 | 0.01 | 0.00 | 0.14 | 1.00 | | | | | | | | | |
| LBM | 0.42 | 0.37 | 0.17 | 0.39 | −0.13 | −0.04 | −0.01 | 0.18 | −0.44 | −0.13 | −0.14 | 0.23 | 0.02 | 1.00 | | | | | | | | |
| LS | −0.13 | −0.10 | −0.07 | −0.02 | −0.04 | 0.39 | 0.21 | −0.12 | 0.04 | 0.07 | −0.18 | −0.12 | 0.32 | −0.18 | 1.00 | | | | | | | |
| LN | 0.09 | 0.16 | −0.07 | 0.16 | −0.16 | −0.02 | −0.10 | 0.08 | −0.23 | 0.11 | −0.09 | 0.05 | 0.07 | −0.06 | 0.18 | 1.00 | | | | | | |
| LNN | 0.43 | 0.36 | 0.19 | 0.39 | −0.18 | 0.16 | 0.12 | 0.32 | −0.33 | −0.07 | 0.02 | 0.11 | 0.19 | 0.21 | 0.10 | 0.55 | 1.00 | | | | | |
| NC | 0.43 | 0.20 | 0.38 | 0.32 | 0.02 | −0.08 | −0.10 | 0.28 | −0.29 | −0.25 | 0.09 | 0.14 | 0.14 | 0.11 | −0.01 | 0.31 | 0.23 | 1.00 | | | | |
| AAC | 0.13 | 0.10 | 0.05 | 0.06 | 0.07 | 0.30 | 0.20 | 0.09 | −0.12 | −0.05 | −0.04 | 0.13 | 0.85 | −0.01 | 0.34 | 0.07 | 0.07 | 0.18 | 1.00 | | | |
| BP | 0.12 | −0.14 | 0.38 | 0.01 | 0.23 | −0.12 | −0.17 | 0.09 | −0.08 | −0.33 | 0.10 | 0.06 | 0.03 | −0.02 | −0.17 | −0.04 | 0.03 | 0.17 | 0.06 | 1.00 | | |
| PV | 0.22 | 0.30 | −0.05 | 0.29 | −0.23 | 0.22 | 0.19 | 0.25 | −0.27 | 0.07 | 0.04 | 0.13 | 0.18 | 0.06 | −0.02 | 0.20 | 0.27 | 0.31 | 0.15 | −0.04 | 1.00 | |
| PH | −0.03 | 0.00 | −0.07 | 0.03 | −0.01 | 0.05 | 0.00 | 0.10 | 0.04 | 0.08 | 0.02 | −0.09 | 0.07 | −0.04 | 0.15 | 0.06 | 0.01 | −0.01 | 0.12 | −0.10 | −0.16 | 1.00 |

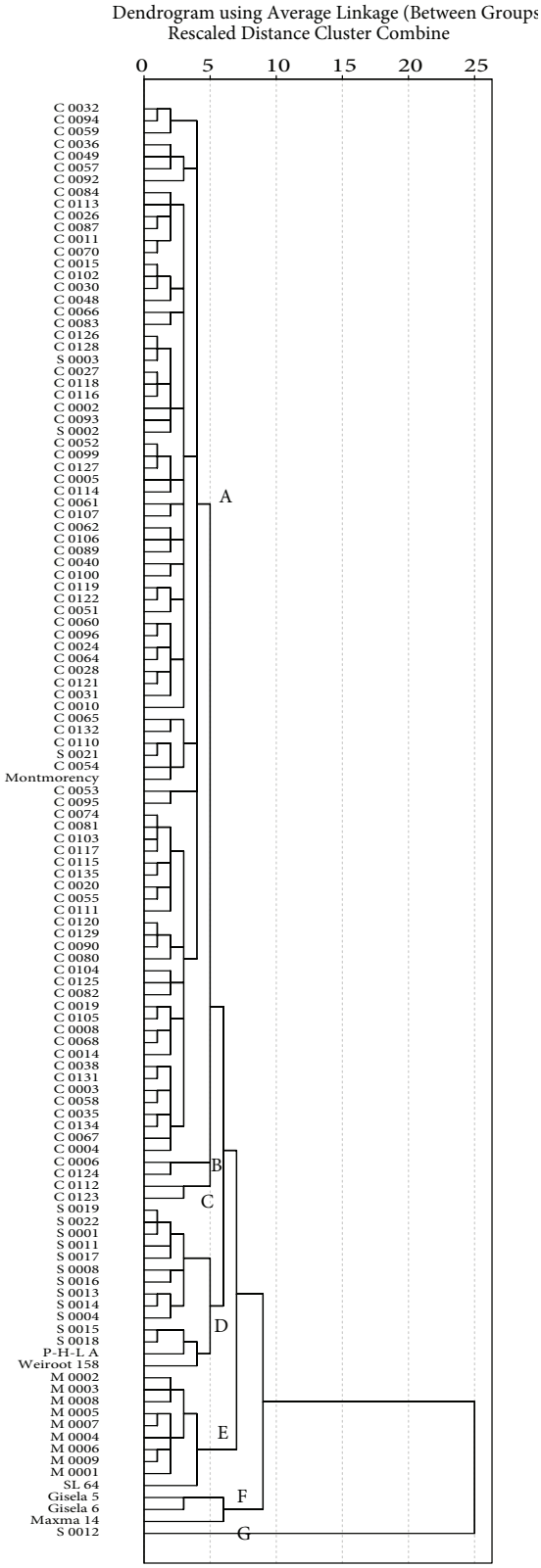


**Figure 2.** Cluster analysis for 120 genotypes and clonal rootstocks based on morphological data.

in Group B were on average 147.6 cm in length and 18.9 mm in thickness, with internodes length of 6.6 cm, 1-year-old shoots in Group C were on average 97.1 cm in length and 12.4 mm in thickness, with an internodes length of 3.5 cm. In both groups, only serrate leaf blade margin incisions were observed. Group D included 14 genotypes and consisted of 2 subgroups. Narrow elliptic and elliptic leaf shapes were observed in Group D. The upper side coloration of the leaf blade was found to be both light and dark green. One-year-old shoots were, on average, 126.4 cm in length and 14.8 mm in thickness, with an internodes length of 3.5 cm. Group E consisted of 10 genotypes. These were all mahaleb genotypes and SL 64 clonal rootstocks. Elliptic, circular, and ovate leaf shapes were observed in Group E. Intensity of anthocyanin coloration of young leaves (during rapid growth) was found to be weak. Group F included 3 clonal rootstocks (Gisela 5, Gisela 6, and MaxMa 14). The 1-year-old shoot was measured as 124.3 cm in length and 8.4 mm in thickness, with an internodes length of 2.6 cm. The number of branchings (at the end of summer) was calculated as 9.6. Plant vigor was observed as weak and medium, while plant habit was found to be upright and spreading. Group G consisted of only one genotype (S 0012). The 1-year-old shoot was measured as 134.8 cm in length and 18.4 mm in thickness, with an internodes length of 3.1 cm. The number of branchings (at the end of summer) was calculated 9.6. Unlike the other genotypes and clonal rootstocks, leaf stipules and leaf nectaries were not present in this genotype.

The high level of total variance described by the first 3 axes is shown in a 2D and 3D screen plot. Each genotype and clonal rootstock was plotted according to the score of its principal components (the cumulative proportion of variance) for each of the first 3 axes (Figure 3).

## 4. Discussion

A high level of genetic diversity was observed among the wild cherry, sour cherry, and mahaleb genotypes collected from Samsun Province in the Central Black Sea Region of Turkey. Several researchers have reported morphological variations in certain *Prunus subgenus cerasus* genotypes, such as the sweet cherry (*P. avium*), sour cherry (*P. cerasus*), and mahaleb (*P. mahaleb*) (Moghadam and Khalighi, 2006, 2007; Khadivi-Khub et al., 2008; Perez Sanchez et al., 2008; Rakonjac et al., 2010). Our results in Table 4 show that plant vigor was positively correlated with 1-year-old shoot length and 1-year-old shoot thickness. These data are in agreement with the findings of Moghadam and Khalighi (2006, 2007) with mahaleb, Hrotkó (1996) and Faust and Zagaja (1984) with sweet cherry, and Rakonjac et al. (2010), who also reported a positive correlation between the tree vigor and the tree height with 'Oblacinska' sour cherry.

**Table 5.** Mean trait values used for the identification of cherry types.

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| Leaf blade: length | 12.5 ± 1.3 | 13.2 ± 0.9 | 14.2 ± 0.4 | 10.2 ± 1.3 | 7.2 ± 0.4 | 6.9 ± 1.6 | 9.5 ± 0.1 |
| Leaf blade: width | 7.1 ± 0.8 | 8.7 ± 0.4 | 6.2 ± 0.3 | 5.4 ± 0.5 | 5.8 ± 0.6 | 4.0 ± 1.0 | 4.8 ± 0.3 |
| Leaf blade: ratio of length to width | 1.8 ± 1.2 | 1.6 ± 0.1 | 2.3 ± 0.0 | 1.9 ± 0.1 | 1.3 ± 0.1 | 1.7 ± 0.1 | 1.9 ± 0.1 |
| Petiole: length | 3.2 ± 0.5 | 3.2 ± 0.3 | 3.8 ± 1.3 | 1.9 ± 0.2 | 2.2 ± 0.3 | 1.0 ± 0.1 | 1.6 ± 0.2 |
| Leaf: ratio of leaf blade length to petiole length | 4.0 ± 0.5 | 4.2 ± 0.1 | 4.0 ± 1.5 | 5.5 ± 0.7 | 3.4 ± 0.6 | 7.3 ± 2.4 | 5.9 ± 0.5 |
| One-year-old shoot: length | 123.0 ± 39.6 | 147.6 ± 31.9 | 97.1 ± 10.8 | 126.4 ± 37.5 | 142.0 ± 25.3 | 124.3 ± 20.1 | 134.8 ± 7.8 |
| One-year-old shoot: thickness | 14.8 ± 3.4 | 18.9 ± 1.4 | 12.4 ± 2.1 | 14.8 ± 3.2 | 15.3 ± 2.9 | 8.4 ± 1.2 | 18.4 ± 5.2 |
| One-year-old shoot: internodes length | 4.2 ± 0.8 | 6.6 ± 0.6 | 3.5 ± 0.7 | 3.5 ± 0.7 | 2.5 ± 0.3 | 2.6 ± 0.3 | 3.1 ± 0.6 |
| One-year-old shoot: branching | 2.6 ± 1.7 | 3.9 ± 3.0 | 0.0 ± 0.0 | 10.6 ± 2.8 | 12.2 ± 5.6 | 9.6 ± 5.0 | 15.8 ± 0.9 |
| Leaf blade: shape | 1 - 2 | 2 | 1 | 1 - 2 | 2 - 3 - 4 | 1 - 4 | 1 |
| Leaf blade: upper side coloration | 1 - 2 | 2 | 1 - 2 | 1 - 2 | 1 - 2 | 1 - 2 | 2 |
| Leaf blade: lower side pubescence at apex | 3 - 5 - 7 | 5 | 3 | 3 | 3 | 3 - 5 | 3 |
| Young shoot: intensity of anthocyanin coloration of young leaf | 3 - 5 - 7 | 3 - 5 | 3 | 3 - 5 | 3 | 3 - 5 | 3 |
| Leaf blade: margin incisions | 1 - 2 - 3 | 3 | 3 | 1 - 2 - 3 | 1 - 2 - 3 | 1 - 3 | 3 |
| Leaf: presence of stipules | 1 - 9 | 1 | 9 | 1 - 9 | 1 - 9 | 9 | 1 |
| Leaf: presence of nectaries | 9 | 9 | 9 | 9 | 9 | 9 | 1 |
| Leaf: predominant number of nectaries | 2 - 3 | 3 | 3 | 1 - 2 - 3 | 2 - 3 | 2 - 3 | 0 |
| Nectary: color | 1 - 2 - 3 | 2 | 2 - 3 | 2 - 3 - 4 | 1 - 2 | 1 - 2 - 3 | 0 |
| One-year-old shoot: anthocyanin coloration of apex | 1 - 5 - 7 | 1 - 5 | 1 | 1 - 3 - 5 | 1 | 1 - 5 | 1 |
| One-year-old shoot: position of vegetative bud in relation to shoot | 1 - 2 - 3 | 2 | 2 - 3 | 1 - 2 - 3 | 1 - 2 | 2 - 3 | 2 |
| Plant: vigor | 5 - 7 | 5 | 3 | 3 - 5 - 7 | 3 - 5 | 3 - 5 | 3 |
| Plant: habit | 1 - 3 - 5 | 1 - 3 | 1 | 1 - 3 | 1 - 3 | 1 - 3 | 1 |

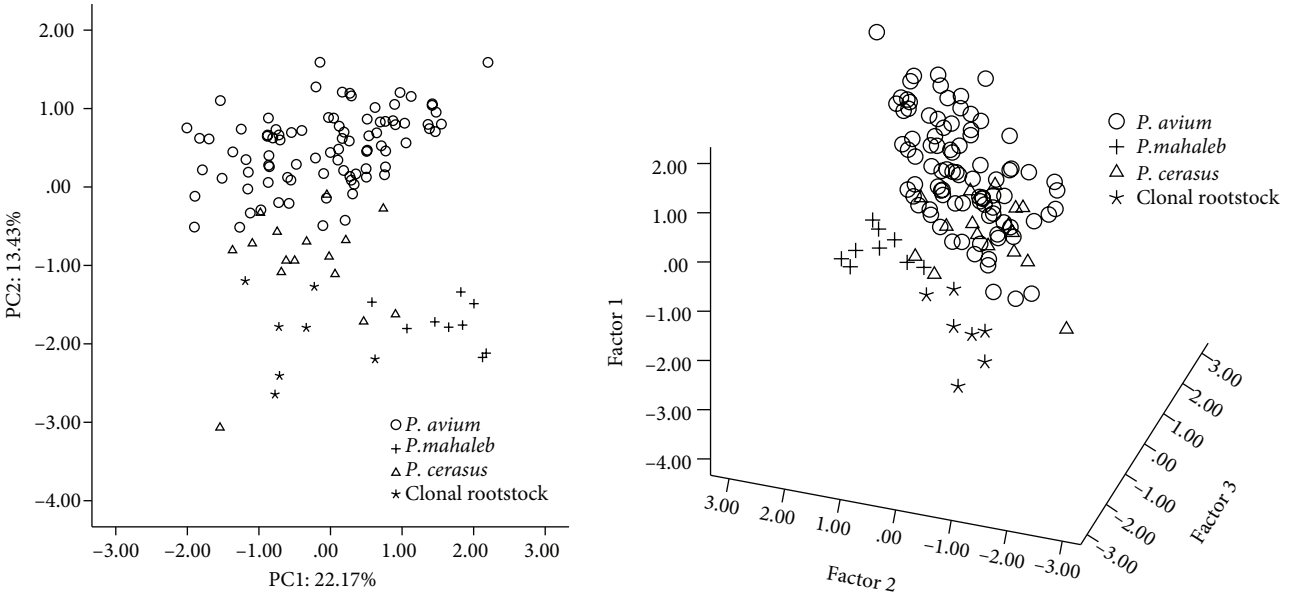


**Figure 3.** 2D and 3D scatter diagrams of the relationships among the genotypes and clonal rootstocks (based on morphological traits).

PCA was used to identify the most significant variables in the data set. PCA has been used until now to evaluate germplasm of different *Prunus* species, including peach (Perez et al., 1993; Esti et al., 1997; Wu et al., 2003; Nikolic et al., 2010), apricot (Badenes et al., 1998; Ruiz and Egea, 2008; Yılmaz et al., 2012), mahaleb (Moghadam and Khalighi, 2006, 2007), cherry plum (Horvath et al., 2008; Sedaghathoor et al., 2009; Aran et al., 2012), sour cherry (Krahl et al., 1991; Onal, 2002; Rakonjac et al., 2010), cherry (Hillig and Iezzoni, 1988; Hjalmarsson and Ortiz, 2000; Beyer et al., 2002, Rodrigues et al., 2008; Perez Sanchez et al., 2008; Lacis et al., 2009, Zamani et al., 2012), and *Prunus incana* (Nazari et al., 2012). Morphological characterization is necessary for germplasm description and classification, and statistical methods such as PCA are useful tools for screening the accessions of a collection (Cantini et al., 1999; Badenes et al., 2000). PCA allows visualization of the differences between the individuals, as well as the identification of potential groups and the relationships of the individuals between variables (Martinez-Calvo et al., 2008).

Zhang et al. (2008) observed that the relationships of individuals among different morphological traits, fruit width, leaf length, stem length, branch type, fruit color, and fruit shape were the most useful for assessing the accessions of tomentosa cherries. Nazari et al. (2012) reported that leaf area, fruit weight, petiole length to blade length ratio, fruit length to diameter ratio, and leaf serration were the most useful traits for evaluating *P. incana* accessions. Cluster analysis clearly separated *P. incana* accessions from the other *Prunus* species, and researchers were able separate *P. incana* accessions according to their geographic locations. Shahi-Gharahlar et al. (2010) reported that a dendrogram obtained from morphological traits clearly distinguished the subgenus *Cerasus* genotypes from other the genotypes. Perez Sanchez et al. (2008) suggested that a dendrogram obtained from morphological characteristics clearly showed the relationships between cultivars of sweet, sour, and duke cherries.

In conclusion, the studied genotypes were diverse and they demonstrated a large range of variations. The collection, evaluation, and characterization of the germplasm of Turkish cherries are a field of interest, and also of considerable economic and ecological importance. Such studies may show that germplasm will potentially provide rootstocks with good adaptations for different climates and soil conditions in Turkey.

**Acknowledgments**

The authors are grateful to the Scientific and Technological Research Council of Turkey (Project No.: TÜBİTAK 106O031) for financial support. Thanks are also due to Dr Fatih Seyis for his help in statistical analysis.

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