Research Article

Morphological Characterization of Cherry Rootstock Candidates Selected from Central and East Black Sea Regions in Turkey

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The use of rootstocks particularly for sweet cherry cultivars is of great importance for successful and sustainable production. Choosing the right cherry rootstocks is just as important as choosing the right cultivar. In this study, 110 sweet cherry, 30 sour cherry, and 41 mahaleb types displaying rootstock potential for sweet cherry cultivars were selected from Central and East Black Sea Regions in Turkey. The morphologic characteristics of the studied genotypes were compared with the standard clonal rootstocks PHL-A, MaxMa14, Montmorency, Weirroot 158, Gisela 5, Gisela 6, and SL 64. A total of 42 morphological UPOV characteristics were evaluated in the selected genotypes and clonal rootstocks. The obtained data were analyzed by using principal component analysis and it revealed that eigenvalues of the first 3 components were able to represent 36.43% of total variance. The most significant positive correlations of the plant vigor were determined with leaf blade length and petiole thickness. According to the diversity analysis of coefficients, the 05 C 002 and 08 C 039 genotypes were identified as being similar (6.66), while the 05 C 002 and 55 S 012 genotypes were determined as the most distant genotypes (325.84) in terms of morphology.

1. Introduction

Turkey produces 438,550 tons of sweet cherries and 182,234 tons of sour cherries annually playing an important role in world sweet and sour cherry production. According to recent statistics, Turkey takes the first place in both sweet cherry production and export [1]. In Turkey, the mahaleb (Prunus mahaleb), wild sweet cherry (Prunus avium), and wild sour cherry (Prunus cerasus) seedlings are widely used as rootstocks for both sweet and sour cherry cultivars. Ercisli et al. [2] reported that 40% of the sweet cherry production in Turkey is carried out with wild sweet cherry seedlings, 30% with mahaleb seedlings, and 30% with Gisela 5, Gisela 6, and SL 64 clone rootstocks. Sweet cherry scion cultivars have been selected over millennia for many reasons, while rootstocks have only recently received attention. Unlike scion cultivar development, evaluation of rootstock programs may require at least 10 years to be completed. However, improved new technologies have provided significant improvements in evaluation.

Genetic diversity (variation within species) is vital for the evolution of agricultural species and their adaptation to particular environments through a mixture of natural and human selection. In crop agriculture, for some species, this selection has led to the development of many thousands of “landraces” or “farmers” varieties. In addition to
domesticated plants, wild species are important nutritionally and culturally to many people [3]. Germplasms collection and characterization are essential stages for breeding programs. Germplasms collection and characterization are generally performed by describing morphological characteristics. The international criteria of the International Union for the Protection of New Varieties of Plants (UPOV) and the International Plant Genetic Resources Institute (IPGRI) were created in order to remove unclear situation and to enable researchers to use common descriptive characteristics. The data from morphological traits were evaluated statistically by using principle component analysis (PCA), correlation, and morphological distance index.

Turkey is one of the most important genetic sources for cherries in the world and provides an important source of variation for plant breeding. However, as is the case with other species used in fruit production, our country does not have its own native cherry clonal rootstocks.

The aim of our study was to investigate genotypic variation among 110 sweet cherry, 30 sour cherry, and 41 mahaleb types selected among wild cherry populations in Central and East Black Sea Regions in Turkey that can potentially be used as rootstocks for cultivars in future.

2. Materials and Methods

With an initial extensive survey studies, a total of 459 wild accessions were collected from Central and East Black Sea Regions in Turkey and were preserved at the Black Sea Agricultural Research Institute located in Samsun province during 2006–2009. The survey studies were conducted at Amasya, Artvin, Giresun, Gümüşhane, Ordu, Rize, Samsun, Tokat, and Trabzon provinces of Black Sea region. Selected wild genotypes (P. avium, P. cerasus, P. and mahaleb) were grafted by budding in the observation gardens. All types were identified using morphological characterization criteria of to UPOV (International Union for the Protection of New Varieties of Plants, Prunus Rootstocks 2002, TG/187/1-03.03.2007). Among 459 genotypes, we selected a total of 181 promising genotypes consist of 110 sweet cherry, 30 sour cherry, and 41 mahaleb and they were used for further analyses (Table 1). The morphologic characteristics of the studied genotypes were compared with PHL-A, MaxMa 14, Montmorency, Weirout 158, Gisela 5, Gisela 6, and SL 64 worldwide reference clonal rootstocks. Morphological characteristics of the leaves were determined in July, while the morphological features of the shoots were determined in December. A total of 188 genotypes, including the selected genotypes and clonal rootstocks, were evaluated according to a total of 42 morphological and phenotypic characteristics (Table 2). Simple correlations, factor and cluster analyses, and scatter plots were prepared by using SPSS (version 20.0 for 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. The location data of selected genotypes was determined using GPS in the project area. These data were transferred in the GIS database and the distribution map was created using ArcGIS 9.2 software (Figure 1).

| Accession | Collection area (province-district) | Altitude (m) |
|-----------|------------------------------------|--------------|
| 05 C 002  | Amasya-Merkez                      | 1002         |
| 05 C 003  | Amasya-Taşova                      | 640          |
| 05 C 004  | Amasya-Taşova                      | 640          |
| 05 C 005  | Amasya-Gümüşhacıköy                | 821          |
| 05 C 006  | Amasya-Gümüşhacıköy                | 826          |
| 05 C 007  | Amasya-Gümüşhacıköy                | 875          |
| 05 C 009  | Amasya-Gümüşhacıköy                | 956          |
| 05 M 001  | Amasya-Merkez                      | 449          |
| 05 M 006  | Amasya-Merkez                      | 846          |
| 05 M 007  | Amasya-Taşova                      | 1002         |
| 05 M 008  | Amasya-Taşova                      | 767          |
| 05 M 009  | Amasya-Taşova                      | 430          |
| 05 M 010  | Amasya-Taşova                      | 430          |
| 08 C 001  | Artvin-Yusufeli                    | 1554         |
| 08 C 005  | Artvin-Yusufeli                    | 1409         |
| 08 C 007  | Artvin-Yusufeli                    | 1445         |
| 08 C 008  | Artvin-Yusufeli                    | 1411         |
| 08 C 017  | Artvin-Şavşat                      | 1674         |
| 08 C 018  | Artvin-Şavşat                      | 1974         |
| 08 C 022  | Artvin-Şavşat                      | 1821         |
| 08 C 028  | Artvin-Şavşat                      | 1622         |
| 08 C 033  | Artvin-Borçka                      | 475          |
| 08 C 037  | Artvin-Yusufeli                    | 1488         |
| 08 C 039  | Artvin-Yusufeli                    | 1448         |
| 08 C 044  | Artvin-Yusufeli                    | 1499         |
| 08 C 045  | Artvin-Yusufeli                    | 1567         |
| 08 C 046  | Artvin-Yusufeli                    | 884          |
| 08 C 053  | Artvin-Merkez                      | 977          |
| 08 C 056  | Artvin-Yusufeli                    | 1084         |
| 08 C 057  | Artvin-Yusufeli                    | 1565         |
| 08 S 002  | Artvin-Yusufeli                    | 1560         |
| 08 S 003  | Artvin-Yusufeli                    | 675          |
| 08 S 005  | Artvin-Yusufeli                    | 1502         |
| 28 C 002  | Giresun-Çanakçı                     | 427          |
| 28 C 005  | Giresun-Tirebolu                    | 53           |
| 28 C 007  | Giresun-Dereli                      | 1014         |
| 28 C 015  | Giresun-Yağlıdere                   | 256          |
| 28 C 016  | Giresun-Yağlıdere                   | 68           |
| 28 C 020  | Giresun-Bulancak                    | 717          |
| 28 S 001  | Giresun-Çanakçı                     | 417          |
| 28 S 002  | Giresun-Sebinkarahisar              | 1247         |
| 28 S 003  | Giresun-Şebinkarahisar              | 1121         |
| 28 M 001  | Giresun-Sebinkarahisar              | 1450         |
| 28 M 003  | Giresun-Aluçra                      | 1464         |
| Accession | Collection area (province-district) | Altitude (m) |
|-----------|------------------------------------|--------------|
| 28 M 005  | Giresun-Şebinkarahisar               | 1270         |
| 28 CA 001 | Giresun-Şebinkarahisar               | 1270         |
| 28 CA 002 | Giresun-Şebinkarahisar               | 1217         |
| 29 C 001  | Gümüşhane-Merkez                     | 1199         |
| 29 C 003  | Gümüşhane-Torul                       | 1455         |
| 29 C 004  | Gümüşhane-Kürtün                      | 1276         |
| 29 C 005  | Gümüşhane-Kürtün                      | 1109         |
| 29 C 006  | Gümüşhane-Torul                       | 1065         |
| 29 S 001  | Gümüşhane-Merkez                      | 1287         |
| 29 S 003  | Gümüşhane-Köse                        | 1654         |
| 29 S 004  | Gümüşhane-Şiran                       | 1395         |
| 29 S 005  | Gümüşhane-Torul                       | 1043         |
| 29 M 001  | Gümüşhane-Merkez                      | 1281         |
| 29 M 004  | Gümüşhane-Şiran                       | 1229         |
| 29 M 006  | Gümüşhane-Torul                       | 1363         |
| 29 CA 001 | Gümüşhane-Kelkit                      | 1464         |
| 29 CA 002 | Gümüşhane-Kelkit                      | 1578         |
| 29 CA 003 | Gümüşhane-Kelkit                      | 1710         |
| 29 CA 004 | Gümüşhane-Şiran                       | 1329         |
| 52 C 004  | Ordu-Aybastı                          | 771          |
| 52 C 005  | Ordu-Kabataş                          | 623          |
| 52 C 007  | Ordu-Mesudiye                         | 1203         |
| 52 C 008  | Ordu-Gölköy                           | 919          |
| 52 C 009  | Ordu-Kabadüz                           | 189          |
| 52 C 011  | Ordu-Fatsa                            | 610          |
| 52 C 013  | Ordu-Korgân                           | 1525         |
| 52 C 014  | Ordu-Korgân                           | 1162         |
| 52 C 015  | Ordu-Kumru                            | 579          |
| 52 C 019  | Ordu-Kumru                            | 730          |
| 52 C 026  | Ordu-Kabataş                           | 613          |
| 52 C 029  | Ordu-Çamaş                             | 155          |
| 52 C 030  | Ordu-Çamaş                             | 474          |
| 52 C 031  | Ordu-Çatalpınar                        | 359          |
| 52 C 035  | Ordu-Çatalpınar                        | 640          |
| 52 C 038  | Ordu-Mesudiye                         | 1289         |
| 52 C 039  | Ordu-Mesudiye                         | 1072         |
| 52 C 042  | Ordu-Gölköy                           | 829          |
| 52 C 046  | Ordu-Gürgentepe                        | 1015         |
| 52 C 050  | Ordu-Gürgentepe                        | 1021         |
| 52 C 054  | Ordu-Ulubey                           | 513          |
| 52 C 056  | Ordu-Merkez                           | 219          |
| 52 C 061  | Ordu-Kabadüz                           | 406          |
| 52 C 063  | Ordu-Gülyali                           | 195          |
| 52 C 065  | Ordu-Gülyali                           | 357          |
| 52 C 071  | Ordu-Merkez                           | 524          |
| 52 C 073  | Ordu-Perşembe                          | 229          |

| Accession | Collection area (province-district) | Altitude (m) |
|-----------|------------------------------------|--------------|
| 52 C 074  | Ordu-Perşembe                        | 110          |
| 52 C 075  | Ordu-Perşembe                        | 297          |
| 52 C 077  | Ordu-Ünye                             | 374          |
| 52 C 081  | Ordu-Çayıbaş                         | 536          |
| 52 C 087  | Ordu-İkizce                           | 341          |
| 52 C 090  | Ordu-Akkuş                            | 1097         |
| 52 C 091  | Ordu-Akkuş                            | 1198         |
| 52 C 093  | Ordu-Akkuş                            | 965          |
| 52 C 096  | Ordu-Fatsa                            | 331          |
| 52 C 100  | Ordu-Ünye                             | 354          |
| 52 S 001  | Ordu-Kabataş                          | 450          |
| 52 S 002  | Ordu-Camaş                            | 329          |
| 52 S 003  | Ordu-Mesudiye                         | 1138         |
| 52 S 004  | Ordu-Mesudiye                         | 1302         |
| 52 S 005  | Ordu-Mesudiye                         | 1133         |
| 52 S 006  | Ordu-Perşembe                         | 0           |
| 52 S 007  | Ordu-Çayıbaş                          | 430          |
| 52 S 008  | Ordu-Akkuş                            | 1102         |
| 52 M 001  | Ordu-Kabataş                          | 503          |
| 52 M 003  | Ordu-Mesudiye                         | 1350         |
| 52 M 005  | Ordu-Merkez                           | 376          |
| 52 M 006  | Ordu-Akkuş                            | 1258         |
| 52 M 007  | Ordu-Akkuş                            | 1125         |
| 52 M 008  | Ordu-Akkuş                            | 1223         |
| 52 M 009  | Ordu-Akkuş                            | 1064         |
| 53 C 001  | Rize-İkizdere                         | 780          |
| 53 C 002  | Rize-İkizdere                         | 968          |
| 53 C 005  | Rize-İkizdere                         | 838          |
| 53 C 006  | Rize-İkizdere                         | 701          |
| 53 C 008  | Rize-Güneyşu                          | 518          |
| 53 C 009  | Rize-Çayeli                           | 798          |
| 53 S 001  | Rize-Çamlıhemsin                      | 1315         |
| 55 C 002  | Samsun-Ladik                          | 958          |
| 55 C 005  | Samsun-Ladik                          | 754          |
| 55 C 015  | Samsun-Vezirköprü                      | 749          |
| 55 C 027  | Samsun-Merkez                         | 722          |
| 55 C 040  | Samsun-Termee                         | 427          |
| 55 C 049  | Samsun-Asarcık                        | 1013         |
| 55 C 054  | Samsun-Asarcık                        | 810          |
| 55 C 055  | Samsun-Havza                          | 1033         |
| 55 C 060  | Samsun-Çarşamba                       | 658          |
| 55 C 065  | Samsun-Ondokuzmayis                   | 247          |
| 55 C 067  | Samsun-Bafra                          | 623          |
| 55 C 072  | Samsun-Alaçam                         | 683          |
| 55 C 080  | Samsun-Yakakent                       | 151          |
| 55 C 081  | Samsun-Yakakent                       | 246          |
| Accession | Collection area (province-district) | Altitude (m) |
|-----------|------------------------------------|--------------|
| 55 C 083  | Samsun-Terme                        | 287          |
| 55 C 092  | Samsun-Kavak                        | 753          |
| 55 C 093  | Samsun-Kavak                        | 765          |
| 55 C 105  | Samsun-Vezirköprü                  | 592          |
| 55 C 111  | Samsun-Bafra                       | 431          |
| 55 C 116  | Samsun-Ayvacık                      | 691          |
| 55 C 121  | Samsun-Salıpazarı                  | 1097         |
| 55 C 124  | Samsun-Çarsamba                    | 126          |
| 55 C 131  | Samsun-Çarsamba                    | 328          |
| 55 C 134  | Samsun-Bafra                       | 510          |
| 55 S 004  | Samsun-Havza                       | 821          |
| 55 S 008  | Samsun-Ondokuzmayıs                | 236          |
| 55 S 01   | Samsun-Yakakent                    | 685          |
| 55 S 02   | Samsun-Ayvacık                      | 173          |
| 55 S 05   | Samsun-Çarsamba                    | 168          |
| 55 S 06   | Samsun-Ladık                       | 909          |
| 55 S 09   | Samsun-Ayvacık                      | 630          |
| 55 S 21   | Samsun-Merkez                      | 560          |
| 55 S 22   | Samsun-Asarcık                     | 779          |
| 55 M 01   | Samsun-Vezirköprü                  | 351          |
| 55 M 03   | Samsun-Havza                       | 352          |
| 55 M 05   | Samsun-Vezirköprü                  | 351          |
| 55 M 06   | Samsun-Vezirköprü                  | 332          |
| 55 M 09   | Samsun-Ayvacık                      | 700          |
| 60 C 01   | Tokat-Resadiye                     | 1152         |
| 60 C 05   | Tokat-Pazar                         | 1180         |
| 60 M 01   | Tokat-Merkez                       | 655          |
| 60 M 02   | Tokat-Merkez                       | 673          |
| 60 M 05   | Tokat-Almus                        | 1074         |
| 60 M 08   | Tokat-Almus                        | 1004         |
| 60 M 00   | Tokat-Almus                        | 1004         |
| 60 M 014  | Tokat-Almus                        | 805          |
| 60 M 015  | Tokat-Almus                        | 796          |
| 60 M 016  | Tokat-Almus                        | 802          |
| 60 M 017  | Tokat-Almus                        | 789          |
| 60 M 019  | Tokat-Almus                        | 817          |
| 60 M 028  | Tokat-Niksar                       | 710          |
| 60 M 030  | Tokat-Niksar                       | 672          |
| 60 M 031  | Tokat-Merkez                       | 676          |
| 60 M 033  | Tokat-Merkez                       | 834          |
| 60 M 036  | Tokat-Pazar                        | 1013         |
| 60 M 037  | Tokat-Pazar                        | 1044         |
| 60 M 044  | Tokat-Merkez                       | 783          |
| 61 C 02   | Trabzon-Arkılı                     | 215          |
| 61 C 015  | Trabzon-Maçka                     | 992          |
| 61 C 017  | Trabzon-Akçaabat                   | 1714         |

### 3. Results and Discussion

Great genetic diversity was observed among the wild sweet cherry, sour cherry, and mahaleb genotypes collected from Central and East Black Sea Region of Turkey. Several researchers have reported the morphological variation between some *Prunus subgenus cerasus* genotypes such as for sweet cherry (*P. avium*), sour cherry (*P. cerasus*), and mahaleb (*P. mahaleb*) [4–7].

The morphological traits assessed showed a wide variation. Differences among cherries genotypes based on similarity of morphological characters are shown in Figure 2 using the hierarchical clustering. Unweighted pair group method with arithmetic mean cluster analysis revealed distance indexes between 6.66 and 325.84. A total of 188 genotypes including the selected genotypes and clonal rootstocks were examined for morphological distance. The closest sweet cherry rootstock candidates were 52 C 071 and 52 C 079 (12.79), while the most distant were 05 C 002 and 08 C 039 (184.29). The closest sour cherries were 53 S 001 and 61 S 001 (8.75), while the most distant were 08 S 002 and 55 S 021 (44.38). The closest mahalebs were 28 M 001 and 55 M 005 (6.66), while the most distant were 05 M 001 and 52 M 007 (72.14). The most distant genotypes among species were 05 C 002 and 55 S 012 (325.84). According to the analysis of the morphological index, all of the genotypes were distinguishable from one another. The dendrogram had eight main groups, which had twelve subgroups. The first group consisted of four subgroups and included one hundred seventy five genotypes and Gisela 5, Gisela 6, and Maxma 14 clonal rootstocks. The second group consisted of 08 C 056 genotype and PHL-A, Weirroot 158, and Montmorency clonal rootstocks. Other six groups consisted of only one genotype/clonal rootstock, respectively, 61 C 017, 28 C 005, 52 M 001, 08 C 039, SL 64, and 55 S 012.

Correlations between pomological traits were observed, but these data are not given in the tables in this paper. A characteristic such as plant vigor was positively correlated with leaf blade length (0.38), petiole length (0.34), and petiole thickness (0.36). One-year-old length of internodes was positively correlated with leaf blade length (0.60), petiole length (0.58), and petiole thickness (0.56), while it was negatively correlated with leaf shape (−0.40). One-year-old branching (at the end of summer) was negatively correlated with leaf blade length (−0.57), petiole length (−0.58), petiole thickness (−0.53), and one-year-old length of internodes...
| Table 2: Morphological characteristics used for the characterization of cherry types. |
|---------------------------------------------------------------|
| **Plant**<br>Vigor PV | Weak (3), medium (5), strong (7)<br>Habit PH | Upright (1), spreading (3), drooping (5)<br>Branching PB | Weak (3), medium (5), strong (7)<br><br>**One-year-old shoot**<br>Thickness ST | Thin (3), medium (5), thick (7)<br>Length SL | (cm)<br>Length of internodes SIL | Short (3), medium (5), long (7)<br>First branch height FBH | (cm)<br>Branch angle BA | (°)<br>Pubescence (upper third) SP | Absent (1), present (9)<br>Number of lenticels SLN | Few (3), medium (5), many (7)<br>Anth. coloration of apex SA | Absent or very weak (1), weak (3), medium (5), strong (7), very strong (9)<br><br>**Position of vegetative bud**<br>Position of vegetative bud SBP | Adpressed (1), slightly held out (2), markedly held out (3)<br>Size of vegetative bud SBS | Small (3), medium (5), large (7)<br>Shape of apex of vegetative bud BAS | Acute (1), obtuse (2), rounded (3)<br>Size of vegetative bud support BSS | Small (3), medium (5), large (7)<br>Branching (at the end of summer) SB | Number of branching<br><br>**Intensity of anthocyanin coloration of young leaf**<br>Intensity of anthocyanin coloration of young leaf LAI | Weak (3), medium (5), strong (7)<br><br>**Leaf**<br>Length LL | (cm)<br>Width LW | (cm)<br>Ratio length/width RLW | Very small (1), small (3), medium (5), large (7), very large (9)<br>Shape LS | Narrow elliptic (1), elliptic (2), circular (3), ovate (4), obovate (5)<br>Angle of apex (excluding tip) LAA | Acute (1), right-angled (2), obtuse (3)<br>Length of tip LTL | Short (3), medium (5), long (7)<br>Shape of base LBS | Acute (1), obtuse (2), truncate (3)<br>Color of upper side LUC | light green (1), dark green (2), red (3), reddish brown (4)<br>Glossiness of upper side LUG | Weak (3), medium (5), strong (7)<br>Pubescence of lower side at apex LLP | Weak (3), medium (5), strong (7)<br>Incisions of margin LMI | Only crenate (1), both crenate and serrate (2), only serrate (3)<br>Depth of incisions of margin LMID | Shallow (3), medium (5), deep (7)<br>Petiole length PL | Short (3), medium (5), long (7)<br>Petiole presence of pubescence PUP | Absent (1), present (9)<br>Petiole intensity of pubescence PUPI | Weak (3), medium (5), strong (7)<br>Petiole depth of groove PGD | Shallow (3), medium (5), deep (7)<br>Petiole thickness PT | (cm)<br>Ratio length of leaf/petiole RLPL | small (3), medium (5), large (7)<br>Presence of stipules LSP | Absent (1), present (9)<br>Stipule length STL | Short (3), medium (5), long (7)<br>Presence of nectaries LN | Absent (1), present (9)<br>Predominant number of nectaries LNN | One (1), two (2), more than two (3)<br><br>**Position of nectaries**<br>Position of nectaries LNP | predominantly on base of blade (1), equally distributed on base of blade and petiole (2), predominantly on petiole (3)<br><br><br>Nectary color NC | Gren (1), yellow (2), red (3), violet (4)<br><br>Nectary shape NS | Round (1), reniform (2)
| Characters                                      | Eigen vectors | PC axis |
|-----------------------------------------------|---------------|---------|
| Leaf blade: shape                              | \(-0.69\)     | 1       |
| Leaf blade: angle of apex                      | \(-0.36\)     | 2       |
| Leaf blade: length of tip                      | \(0.47\)      | 3       |
| Leaf blade: shape of base                      | \(-0.28\)     | 4       |
| Leaf blade: color of upper side                | \(0.24\)      | 5       |
| Leaf blade: glossiness of upper side           | \(-0.23\)     | 6       |
| Leaf blade: pubescence of lower side at apex   | \(0.36\)      | 7       |
| Young shoot intensity of anth. coloration      | \(0.49\)      | 8       |
| Leaf blade: incisions of margin                | \(0.48\)      | 9       |
| Leaf blade: depth of incisions of margin       | \(0.42\)      | 10      |
| Leaf: presence of stipules                     | \(-0.05\)     | 11      |
| Petiole: presence of pubescence of upper side | \(-0.03\)     | 12      |
| Petiole: intensity of pubescence of upper side| \(0.16\)      | 13      |
| Petiole: depth of Groove                       | \(0.54\)      |         |
| Leaf: presence of nectaries                    | \(0.09\)      |         |
| Leaf: predominant number of nectaries          | \(0.53\)      |         |
| Leaf: position of nectaries                    | \(0.26\)      |         |
| Nectary: color                                 | \(0.67\)      |         |
| Nectary: shape                                 | \(0.15\)      |         |
| Leaf blade: length                             | \(0.91\)      |         |
| Leaf blade: width                              | \(0.68\)      |         |
| Leaf blade: ratio length/width                 | \(0.71\)      |         |
| Petiole: length                               | \(0.73\)      |         |
| Petiole: ratio length of leaf blade/length of petiole | \(0.07\) |         |
| Petiole: thickness                             | \(0.84\)      |         |
| Stipule: length                                | \(0.50\)      |         |
| Plant: vigor                                  | \(0.43\)      |         |
| Plant: habit                                  | \(-0.15\)     |         |
| Plant: branching                              | \(-0.16\)     |         |
| Pubescence of shoot                            | \(-0.11\)     |         |
| Anthocyanin coloration of apex                 | \(0.53\)      |         |
| One-year-old shoot: pos. of veg. bud in relation to shoot | \(0.21\) |         |
| One-year-old shoot: size of vegetative bud     | \(0.08\)      |         |
| One-year-old shoot: shape of apex of vegetative bud | \(0.01\) |         |

**Table 3:** Eigenvalues and proportions of variance described by the 13 principal components that correspond to eigenvalues greater than 1.
Table 3: Continued.

| PC axis          | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 |
|------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|
| One-year-old shoot: size of vegetative bud support | 0.17 | −0.32 | −0.16 | 0.31 | −0.10 | −0.04 | 0.20 | 0.25 | 0.19 | 0.15 | 0.14 | **0.38** | −0.08 |
| One-year-old shoot: length                          | −0.09 | 0.08 | 0.43 | **0.68** | 0.21 | 0.04 | −0.04 | −0.04 | 0.06 | −0.07 | 0.08 | −0.01 | 0.22 |
| One-year-old shoot: thickness                        | −0.10 | 0.27 | 0.24 | **0.75** | 0.05 | −0.04 | −0.18 | −0.01 | 0.21 | 0.04 | 0.08 | −0.05 | −0.02 |
| One-year-old shoot: length of internode              | **0.70** | 0.27 | −0.09 | 0.07 | −0.09 | 0.19 | 0.05 | 0.20 | −0.07 | 0.18 | −0.14 | 0.10 | 0.03 |
| One-year-old shoot: number of lenticels              | 0.12 | 0.11 | −0.04 | −0.55 | 0.21 | −0.20 | −0.25 | 0.03 | 0.08 | 0.31 | 0.27 | −0.09 | −0.15 |
| One-year-old shoot: branching                        | −**0.66** | −0.24 | 0.04 | 0.39 | 0.32 | −0.09 | −0.06 | 0.10 | −0.03 | −0.06 | 0.10 | −0.04 | 0.05 |
| First branch height                                  | **0.56** | 0.32 | 0.18 | 0.27 | 0.01 | −0.02 | 0.02 | 0.22 | −0.21 | 0.16 | −0.19 | 0.00 | −0.18 |
| Branch angle                                          | −0.20 | 0.14 | 0.17 | **0.61** | 0.20 | −0.14 | 0.04 | 0.30 | −0.31 | 0.13 | −0.07 | −0.04 | −0.16 |

Figure 1: Map of the distribution for genotypes in Central and East Black Sea Regions in Turkey.

Figure 2: Cluster analysis for 188 genotypes/clonal rootstocks based on morphological data.

Information regarding the associations and correlations between different plant characteristics are valuable for breeding programs.

Principal component analysis (PCA) was used to examine the variation of cherries genotypes/clonal rootstocks. Morphological characterization is necessary for the description and classification of germplasm and statistical methods like principal components analysis are useful tools for screening the accessions of a collection [8, 9]. It allows for visualization of the differences among the individuals, identification of possible groups, and relationships among individuals and variables [10]. The first thirteen axes accounted for 72.38% of the variability among 188 accessions (Table 3). The first PC axis accounted for 8.13% of the variation, whereas the second, third, and fourth axes accounted for 3.81%, 3.36%, and 2.75%, respectively. The first axis was mainly related to leaf blade length (0.91), petiole: thickness (0.84), petiole length (0.73), leaf blade: ratio length/width (0.71), and one-year-old shoot: length of internodes (0.70). The second axis was concerned with leaf: ratio length of leaf blade/length of petiole (−0.76). The third axis was mainly concerned with leaf: presence of stipules (0.87), petiole: presence of pubescence of upper side (0.87), and petiole: intensity of pubescence of upper side (0.79). The remaining ten axes were related to other leaf, shoot, and plant traits (Table 3).

The populations were grouped into seventeen clusters by cluster analysis. These are composed of six groups and eleven single genotypes. The different cherry genotypes identified based on the similarity of their morphological characteristics and their hierarchical clustering are shown in Figure 2. These seventeen groups can be considered as distinct germplasm pools (Figure 2). According to diversity analysis of coefficients, the 28 M 0001 and 55 M 0005 genotypes were found to be very similar (6.66), while the 05 C 0002 and 55 S 0012 genotypes were determined as the most distant...
genotypes (325.84) in terms of morphological variability. Shahi-Gharahlar et al. [11] reported that dendrogram obtained from morphological traits clearly distinguished the Cerasus subgenus genotypes from the other genotypes. Pérez-Sánchez et al. [4] suggested that a dendrogram obtained from morphological characteristics clearly showed the relationships between cultivars of sweet, sour, and duke cherries.

The high total variance explained by the first three axes was shown in a 2D and 3D screen plot; each genotype/clonal rootstock was plotted based on its principal components score (the cumulative proportion of variance) for each of the first three axes (Figure 3).

4. Conclusions

As a result, it can be said that the studied genotypes are diverse and display great variations. The collection, evaluation, and characterization of Turkish cherries germplasm are a field of interest and are of economical and ecological importance. This provides rootstocks with good adaptations to diverse climatic and soil conditions of Turkey. The results may serve as a significant reference for the comparison of genetic resources, the characterization of cherry genotypes, and the cherry rootstock breeding programs to select the best parents with the highest variation. In conclusion, the genotypes evaluated in this study may be useful for both breeders and rootstock breeding programs.

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References

[1] Food and Agricultural Organization (FAO), February 2013, http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567.

[2] S. Erçisli, A. Esitken, E. Orhan, and O. Özdemir, “Rootstocks used for temperate fruit trees in Turkey: an overview,” Sodininkyste ir Darzininkyste, vol. 25, pp. 27–33, 2006.

[3] E. Cromwell, “Agricultural, biodiversity and livelihood: issue and entry point: final report,” April 1999, http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8286.pdf.

[4] R. Pérez-Sánchez, M. A. Gómez-Sánchez, and R. Morales-Corts, “Agromorphological characterization of traditional Spanish sweet cherry (Prunus avium L.), sour cherry (Prunus cerasus L.) and duke cherry (Prunus × goudouinii Rehd.) cultivars,” Spanish Journal of Agricultural Research, vol. 6, no. 1, pp. 42–55, 2008.

[5] A. Khadivi-Khub, Z. Zamani, and N. Bouzari, “Evaluation of genetic diversity in some Iranian and foreign sweet cherry cultivars by using RAPD molecular markers and morphological traits,” Horticulture Environment and Biotechnology, vol. 49, no. 3, pp. 188–196, 2008.
[6] E. G. Moghadam and A. Khalighi, "Relationship between vigor of Iranian Prunus mahaleb L. selected dwarf rootstocks and some morphological characters," *Scientia Horticulturae*, vol. 111, no. 3, pp. 209–212, 2007.

[7] V. Rakonjac, M. F. Akšić, D. Nikolić, D. Milatović, and S. Čolić, "Morphological characterization of "Oblačinska" sour cherry by multivariate analysis," *Scientia Horticulturae*, vol. 125, no. 4, pp. 679–684, 2010.

[8] C. Cantini, A. Cimato, and G. Sani, "Morphological evaluation of olive germplasm present in Tuscany region," *Euphytica*, vol. 109, no. 3, pp. 173–181, 1999.

[9] M. L. Badenes, J. Martínez-Calvo, and G. Llacer, "Analysis of a germplasm collection of loquat (Eriobotrya japonica Lindl.)," *Euphytica*, vol. 114, no. 3, pp. 187–194, 2000.

[10] J. Martínez-Calvo, A. D. Gisbert, M. C. Alamar et al., "Study of a germplasm collection of loquat (Eriobotrya japonica Lindl.) by multivariate analysis," *Genetic Resources and Crop Evolution*, vol. 55, no. 5, pp. 695–703, 2008.

[11] A. Shahi-Gharahlar, Z. Zamani, M. R. Fatahi, and N. Bouzari, "Assessment of morphological variation between some Iranian wild Cerasus sub-genus genotypes," *Horticulture Environment and Biotechnology*, vol. 51, pp. 308–318, 2010.