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Araştırma Makalesi / Research Article

Morphometric Diversity for Rootstock Characteristics of Turkish Hazel (*Corylus colurna* L.) Populations in The Western Black Sea Region of Türkiye

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Abstract

The Turkish hazel (*Corylus colurna* L.) is native to Türkiye, where it is found only in small, scattered, and isolated populations within its natural distribution area. These remaining populations are of critical importance for conservation, for continued use as a natural reservoir, and natural selection. The trees are up to 400 years old and already well-adapted to harsh environmental conditions. In recent years, this species has drawn the attention of agriculture and forest practitioners and scientists in several countries who use this important and valuable tree species in studies of the effects of climate change. The origin and genotype of the reproductive material of this species play a key role in its adaptation to environmental conditions, and possible cultivation. The purpose of this study is to reveal the variation of genotypes selected from 13 different populations in Kastamonu and Bolu provinces in terms of rootstock characteristics. These regions are the locations where the Turkish tree hazel is most abundant. For this aim, the growth habit, vigor, number of suckers, and internode of one-year-old shoots were scored on the parent trees. A Kruskal Wallis-H test was applied to the non-parametric data to determine if there were differences among the populations for each variable and the total number of points. Then the Mann-Whitney-U test was used for differences among the groups. In addition, the phylogenetic relationship among the populations and genotypes was revealed by Cluster analysis. Among the rootstocks scored, KTU3 and KTU64 provided the highest score according to non-suckering and strong growth. It has been observed that individuals in Turkish hazelnut populations generally do not form suckers (%89.4) and show strong growth. *C. colurna* trees were observed to be individual and scattered in the population. Most of the trees are elderly and need to be protected in situ. Turkish hazel population will play a key role in production and sustainable such as to develop rootstock and variety in agriculture production, sustainable forest development, and for ecological adaptation in climate change scenarios.

Keywords: *Corylus colurna* L., filbert, sucker, genotype, rootstock

Batı Karadeniz Bölgesinde Yetişen Türk Fındığı (*Corylus colurna* L.) Popülasyonlarının Anaç Özellikleri Bakımından Morfometrik Çeşitliliği

Öz

Türk fındığı (*Corylus colurna* L.) Türkiye'ye özgü doğal bir türdür. Yayılım alanı içinde küçük, dağınık ve izole popülasyonlar bulunur. Bu popülasyonlar, koruma ve doğal rezervuar olarak sürekli kullanım alanı ve seleksiyon için kritik öneme sahiptir. Ağaçlar zorlu çevre koşullarına iyi uyum sağlamış olup 400 yaşında kadar yaşadığı tahmin edilmektedir. Son yıllarda bu tür, iklim değişikliğinin etkilerine ilişkin çalışmalarda önemli ve değerli ağaç türünü kullanan birçok ülkede tarım ve ormancılık alanında bilim adamlarının dikkatini çekmiştir. Bu orjinal genotipler çevre koşullarına adaptasyonunda ve olası üretimde önemli kilit rol oynamaktadır. Bu çalışmanın amacı, Kastamonu ve Bolu illerinde 13 farklı popülasyondan seçilen genotiplerin anaç özellikleri yönünden varyasyonunu ortaya koymaktır. Bu bölgeler Türk fındığının en yaygın bulunduğu olduğu yerlerdir. Bu amaçla, ebeveyn ağaçlarda bir yaşındaki sürgünlerin büyüme alışkanlığı, büyüme gücü, dip sürgünü sayısı ve boğum arası ölçümleri yapılmıştır. Parametrik olmayan verilere, popülasyonlar arasında her bir değişken ve toplam puan sayısı için farklılığı belirlemek için Kruskal Wallis-H testi uygulanmıştır. Daha sonra gruplar arasındaki farklılıklar için Mann-Whitney-U testi kullanılmıştır. Ayrıca popülasyonlar ve genotipler arasındaki filogenetik ilişki Cluster analizi ile ortaya konmuştur. Puanlanan anaçlar arasında en yüksek puanı Kastamonu Tunuslarda yetişen KTU3 ve KTU64 nolu bireyler almış olup dip sürgünü vermeme ve güçlü büyüme yönünden öne çıkmışlardır. Türkiye fındık popülasyonlarında bireylerin genellikle dip sürgünü oluşturmadıkları (%89.4) ve kuvvetli büyüme gösterdikleri gözlemlenmiştir. *C. colurna* ağaçlarının popülasyon içinde bireysel ve dağınık olduğu gözlenmiştir. Ağaçların çoğu yaşlıdır ve yerinde korunmaları önerilir. Türk fındığı popülasyonunun, tarımsal üretimde anaç ve çeşit geliştirmede, sürdürülebilir orman gelişimi ve iklim değişikliği senaryolarında ekolojik uyum gibi üretim ve sürdürülebilirlikte kilit rol oynayacağı söylenebilir.

Anahtar kelimeler: *Corylus colurna* L., fındık, dip sürgünü, genotip, anaç

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1. Introduction

Corylus colurna L., belonging to the Europe-Siberia flora region (Molnar, 2011), is a species native to Türkiye (İslam, 2021). Smekalova and Ushakova (2006) is stated that the Caucasus Mountains as the primary core areas for *C. colurna*. Although the Turkish hazel populations may be relatively marginal geographically, they thrive in optimal ecological conditions within the Northern Anatolian forests (Ayan et al., 2016a; Ayan et al., 2018a). The natural distribution of Turkish hazel extends to the Vâlcan Mountains in Romania and northern regions of Bosnia and Herzegovina. The species began spreading to Central Europe in the 17th century and has since grown to a limited extent in Italy, Austria, Germany, Poland, Ukraine, and Hungary. In Europe, Turkish hazel is primarily recognized as a tree species found in gardens and parks (Šeho et al., 2019). However, there is currently a growing interest in Turkish hazel as a valuable alternative tree species in Europe (Šeho et al., 2019; de Avila et al., 2021).

It has been overused because of its valuable wood (Šeho et al. 2017a). And its growth habit is characterized by scattered occurrences, with small stands, groups, isolated clusters, and occasionally individual trees, in Türkiye (Ayan et al., 2016a). This species has many useful characteristics such as high resistance to abiotic and biotic stresses, tolerance of low soil fertility, drought tolerance due to its strong root system, and tolerance of winter cold and late spring frost. Their presence has a stabilizing effect on forest stands.

Hence, the existing Turkish hazel populations hold significant importance as they serve as a crucial natural reservoir for seed collection (Šeho et al., 2019). Moreover, these trees have already demonstrated their resilience and adaptation to challenging environmental conditions (Alexandrov, 1995). In countries where this species naturally occurs, it is recommended to avoid importing the propagation material and instead focus on the plant materials within those countries (Šeho et al., 2019).

Turkish hazel is considered as a non-invasive species (Šeho et al., 2017a). Natural hybridizations with other *Corylus* species are possible, but not quite usual and İslam (2019) reported *C. avellana* don't showed good set with *C. colurna*. Erdogan and Mehlenbacher (2000) were made reciprocal cross and described clusters of 20% between *Corylus colurna* x *C. avellana* but 92% of the nuts were empty. Nut set was also least with other parent.

C. colurna can also provide different phenotypic traits such as different leaf shapes, hairs of leaf stalks and nut, husk, which complicate its identification (Šeho et al., 2017b). Non-suckering ability of tree hazel can be transferred by hybridization to other hazelnut trees (Erdogan and Mehlenbacher, 2000).

Corylus colurna differentiates from *C. avellana* clearly as its vertical habitus and high trees form. Another characteristics are hard and thick shells. From the genetic point, the Turkish hazel has

not been widely investigated. Kumar Srivastava et al. (2010) found a similar structure and divergence using phenotypic characteristics in *C. colurna*.

Arslan (2005, in Ghimessy, 1980) states that in Hungary, *C. colurna* is a valuable reserve tree species and accepted as a fast-growing species. The aforementioned factors contribute to its selection as a valuable source of rootstock (Ninic-Todorovic et al., 2012). Although it usually grows in continental climates, it can also grow in coastal areas with a humid maritime climate. The species is resistant to drought, it mostly occurs on sunny slopes, and it grows even in poor soils (Šeho et al., 2019; İslam, 2021).

This taxon is ranked as “Low Risk” category according to The International Union for Conservation of Nature (IUCN) Red List with the status "least concern" (Shaw et al., 2014). Because trees are still plentiful in the wild, and thus it is not a focus of conservation efforts. However, the genetic conservation of this species is an important consideration in the sustainable management of forests and natural reservoir. On the other hand, these populations are important genetic resources for researchers in agricultural and forest production.

C. colurna (Turkish hazel) are a commonly known plant in Turkiye (İslam, 2018). Rootstock breeding for horticultural purposes necessitates the consideration of several vital characteristics. These include the following features: non-suckering and erect habit, optimal grafting compatibility, upright growth habit to facilitate mechanized harvesting, adaptability to various soil conditions, and late bud burst to mitigate the risk of damage from spring frosts (İslam, 2019). The aim of the investigation is to identify the population diversity in the Western Black Sea region, Turkiye, where *C. colurna* is the most intensively distributed, and the most suitable rootstocks possible in these populations. For the determination of the most suitable rootstocks, the growth habit, vigor, number of suckers, and length of one-year-old shoots characteristics were taken as a basis.

2. Materials and Methods

2.1. Material

In this investigation, the rootstock characteristics of selected genotypes from 13 different populations in the Kastamonu and Bolu regions in Türkiye were studied. These regions are the locations (Table 1, Figure 1) where the Turkish hazel tree is most abundant (Šeho et al., 2019).

Figure 1. Locations of sampled natural *C. colurna* populations in Türkiye (see Table 1 for population numbers).

Tablo 1. Sampled populations and their characteristics.

Pop. Nu.	Code	Province	Population name	North to south coordinate range (N)	West to east coordinate range (E)	Elevation range (m)	Direction
1	KTS	Kastamonu	Ağlı-Tunuslar (KTU)	41.37432-41.37549	33.30548-33.31801	1180-1330	N-E-S
2	KTK	Kastamonu	Tosya-Küçüksekiler (KTS)	40.54291-40.54461	34.02225-34.02579	920-990	N
3	KMU	Kastamonu	Ağlı-Müsellimler (KMU)	41.38014-41.38326	33.29514-33.30514	1130-1220	S
4	KAK	Kastamonu	Araç-Karacık-Uçancık(KAK)	41.01543-41.02702	33.20455-33.20641	1160-1230	N-W
5	KAG	Kastamonu	Araç-Güzlük (KAG)	41.02555-41.03112	33.20554-33.21179	920-1071	N
6	BSB	Bolu	Seben (BSB)	40.27599-40.28254	31.35462-31.36323	1150-1242	N-S
7	BSA	Bolu	Pelitçik-Şabanlar (BPS)	40.61365-40.61401	31.46325-31.46375	967-1097	N-S
8	BKY	Bolu	Pelitcik-Karamankaya (BPM)	40.62403-40.63150	31.46452-31.47054	1057-1148	N-S
9	BKA	Bolu	Pelitcik-Karabozlar (BPK)	40.60789-40.61564	31.45527-31.46386	1063-1117	N-S
10	BMU	Bolu	Muratlar (BMU)	40.76069-40.77017	31.85980-31.86498	835-912	N
11	BME	Bolu	Merkeşler (BME)	40.51400-40.86699	31.47571-31.79935	920-968	S
12	BGF	Bolu	Güneyfelakettin (BGF)	40.61976-40.61978	31.43950-31.44188	1079-1101	S
13	BGA	Bolu	Güneyfelakettin-Aşağımahalle (BGA)	40.61708-40.61868	31.23381-31.44294	992-1059	S

2.2. Method

Modified Weighing Grading Method was used in rootstock selection in this investigation. Michelson et al. (1958) "Weighed Rating Method" used by us has been modified and applied. Genotypes were subjected to weighted grading according to 4 characteristics (Rootstock's habitus, Rootstock vigor, Number of suckers, Length of internode). For the scaled rating, each feature has a different degree of importance (Table 2). A scale of 1-5 was used when converting to numeric values. The minimum and maximum values of the traits in the population was found, the difference between them is divided into 5 equal parts, the desired criterion is given a value of 5, and the value of 1 for those that do not. Each value was multiplied by its relative score to determine the score for the relevant feature. The total weighted degree score was obtained by summing the scores of the features.

Table 2. Selection criteria and relative scores for rootstock

Rootstock Characteristic	Relative score
Number of suckers	50
Rootstock vigor	10
Rootstock habitus	20
Length of internode	20

2.3. Statistically analysis

In the investigation, rootstock selection was performed in 13 populations. The growth habit, vigor, number of suckers, and length of one-year-old shoots were scored on the parent trees. In terms of the measured variables, analyses were made according to the total score of the variables among both populations and rootstocks. For this aim, A Kruskal Wallis-H test was applied to the non-parametric data to determine if there were differences among the populations for each variable and the total number of points. Then the Mann-Whitney-U test was used for differences among the groups. In addition, the phylogenetic relationship among the populations and genotypes was revealed by Cluster analysis.

3. Results and Discussion

The characteristics of the 13 populations, total numbers and percent values were given in Table 3. Of a total 360 trees, 322 do not give sucker. Only three individuals form a lot suckering. 273 of the

types have upright habitus and 333 of them are strongly developing. The length of internode was found between 1.05-6.0 cm in all individuals.

Table 3. The characteristics of the populations

Characteristic	Category	Total number	%
Suckering	Non	322	89.4
	Little	23	6.4
	Middle	12	3.4
	A lot	3	0.8
Habitus	Upright	273	75.8
	Half upright	42	11.7
	Splayed	45	12.5
Vigor	Strong	333	92.5
	Middle	3	0.8
	Weak	24	6.7
Length of internode	Short	140	37.9
	Middle	159	45.2
	Long	61	16.9

The results of the cluster analysis performed for 360 rootstocks representing 13 populations are given in Figures 2 and 3. Among the rootstocks scored according to the four rootstock characters, the growth habit, vigor, number of suckers, and length of one-year-old shoots, KTU3 and KTU64 provided the highest score (Figure 2). These types show upright development and non-suckering.

In the Figure 2, Seben (BSB) and Muratlar (BMU) populations form a separate branching and are clearly separated from the others. In these two populations, 53 individuals form non-suckering (%88) and it can be stated that only 12 individuals develop strongly (20%). It can be said that the trees in these population develop splay.

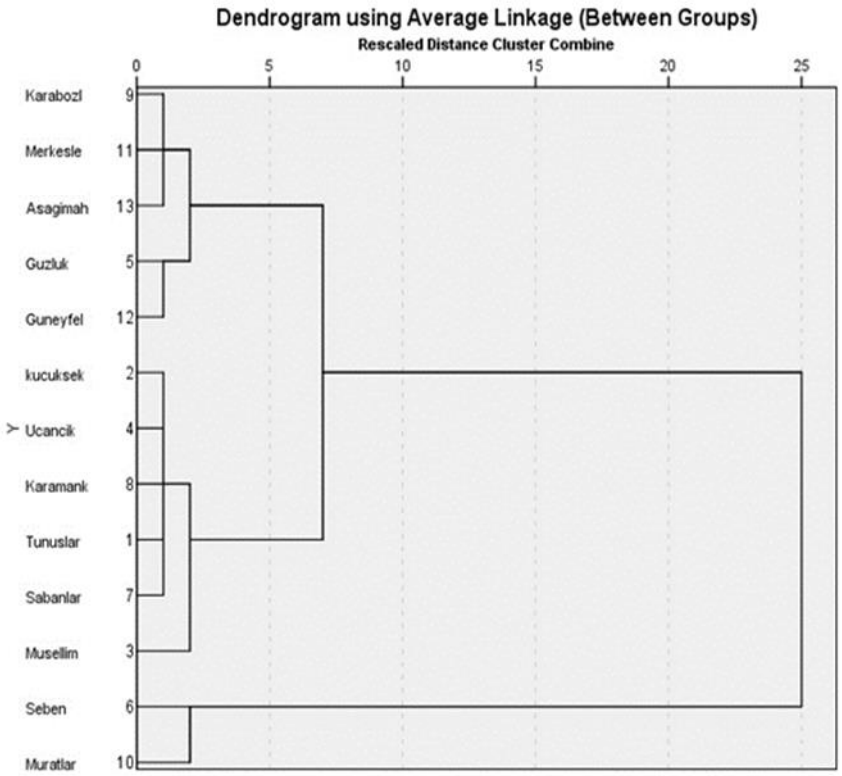

Figure 2. Cluster analysis based on the populations.

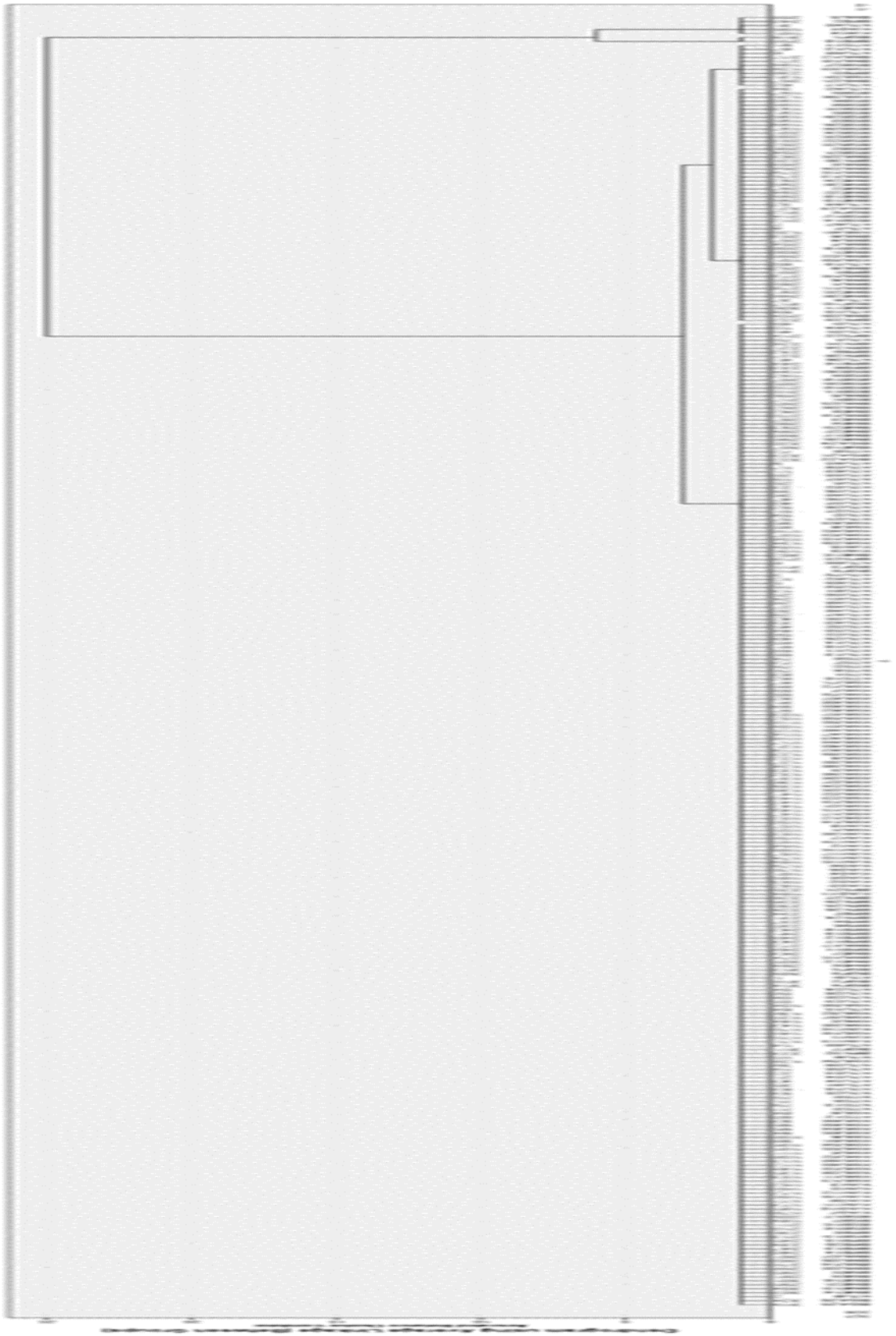

Figure 3. Cluster analysis based on the rootstock.

So far, our current knowledge regarding the genetic diversity of *C. colurna* in the remaining populations within its natural distribution area is limited. Initial studies conducted by Šeho et al. (2017) revealed distinct differences between Balkan Peninsula and Turkiye provenances. Ayan et al. (2018a) conducted research on Turkish hazel's pomological features, examining some characteristics from cluster and nut samples across four populations. In addition, some studies were made on the nut characteristics of Turkish hazelnuts (Mitrovic et al. 2001, Ayan et al., 2016b; Šeho et al., 2016 and 2019) and protein and oil contents (Ayan et al. 2018b).

It has been observed that individuals in Turkish hazelnut populations generally do not form suckers and show strong growth. The non-suckering of Turkish Hazel is noted by many researchers (Radigati et al. 1996; İslam, 2019; Farinelli et al, 2021; Rovira et al., 2022). Also, strong growth is reported (Arslan, 2005; Nikolova, 2007; Temel et al., 2017; Šeho et al., 2019; İslam, 2019). The findings obtained from the study are similar to the literature.

4. Conclusions and Recommendations

C. colurna trees were observed to be individual and scattered in the population. Most of the trees are elderly and need to be protected in situ. Conservation programs should integrate improvement. Materials that are chosen can be conserved ex-situ through the establishment of progeny or clonal archives. Seed orchards can also be established and selected materials can be preserved ex-situ as progeny or clonal archives and seed orchards.

KTU3 and KTU64 provided the highest score according to non-suckering and strong growth. The length of internode was found between 1.05-6.0 cm in all individuals.

Genetic conservation of Turkish hazel will play a key role in production and sustainable such as to develop rootstocks and varieties in agriculture production, sustainable forest development, and for ecological adaptation in climate change scenarios.

The existing information on *C. colurna* is relatively scarce, and this study aims to expand our understanding of the species and its populations, shedding light on their genetic and cultural potential as a versatile provider of various services. The tree's regular and straight stem form makes it particularly appealing from a technological standpoint. Moreover, the observed variations in nut quality offer additional value for the species, suggesting its potential in plantations and agroforestry systems. On the other hand, it paves the way for its use as rootstock in agricultural production in terms of features such as upright growth, non-suckering or with few suckers, strong or weak development. At the same time, different forms are likely to emerge by crossing with other species to achieve the desired rootstock characteristics.

Given the dispersed distribution and relatively close genetic proximity among populations, it is imperative for conservation programs to integrate enhancement strategies. This entails preserving natural populations in their original habitats (in situ conservation) while also establishing ex situ conservation methods, such as progeny or clonal archives and seed orchards, to safeguard selected materials.

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Authors' Contributions

Authors of this study contributed equally to the research and its findings.

Statement of Conflicts of Interest

The all authors declare that there are no conflicts of interest related to the study.

Statement of Research and Publication Ethics

The author affirms that this study complies to the principles of research and publication ethics.

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