Eurasian Journal of Forest Science

Volume 11 Issue 3 October 2023

ISSN: 2147-7493

Eurasian Journal of Forest Science

ISSN: 2147 - 7493

Cover Page
Centennial of Republic of Türkiye 2023

Contact
H. Barış TECİMEN

Istanbul University-Cerrahpasa, Faculty of Forestry, Soil Science and Ecology Dept. İstanbul, Turkey

hbarist@gmail.com

Journal Web Page

http://dergipark.org.tr/tr/pub/ejejfs

https://dergipark.org.tr/en/pub/ejejfs

Eurasian Journal of Forest Science

Eurasian Journal of Forest Science is published 3 times per year in the electronic media.

This journal provides immediate open access to its content on the principle that making research freely available to the public supports a greater global exchange of knowledge.

In submitting the manuscript, the authors certify that:

They are authorized by their coauthors to enter into these arrangements. The work described has not been published before (except in the form of an abstract or as part of a published lecture, review or thesis), that it is not under consideration for publication elsewhere, that its publication has been approved by all the authors and by the responsible authorities tacitly or explicitly of the institutes where the work has been carried out. They secure the right to reproduce any material that has already been published or copyrighted elsewhere.

The names and email addresses entered in this journal site will be used exclusively for the stated purposes of this journal and will not be made available for any other purpose or to any other party. The conditions are granted by the editorial management of the journal within our privacy principals.

Eurasian Journal of Forest Science is a member of ULAKBIM DergiPark and is listed in the TR-DİZİN of TUBITAK and indexed in Index Copernicus.

ISSN: 2147 - 7493

Issue 11, Number 3, 2023

Eurasian Journal of Forest Science **Editorial Board**

Contents

Articles	Pages
1. Aesthetic and ecological characteristics of Prunus Taxa in landscape design: A Study in eastern and southeastern provinces of Türkiye	
Basri MUTLU Şevket ALP	116-136
2. Evaluating the strength properties of standing trees through fractometry	
Abdullah BERAM	137-150

Eurasian Journal of Forest Science

2023 11(3): 116-136

https://dergipark.org.tr/en/pub/ejejfs

Aesthetic and ecological characteristics of Prunus Taxa in landscape design: A Study in eastern and southeastern provinces of Türkiye

Basri MUTLU[1,*], Şevket ALP[2]

[1,*)] *Malatya Forest Enterprise Directory, 44320, Malatya, Türkiye*
[2)] *Van Yüzüncü Yıl University Faculty of Architecture and Design, Department of Landscape Design, Van, Türkiye*

Corresponding author: basrimutlu@ogm.gov.tr

Abstract
Plants play a crucial role in landscape design and are at the heart of landscape design. Climate change's purposeful plant choices could improve landscape design. In this study, it is tackeled using some native Subgen *Amygdalus* taxa in the landscape to make the natural environment flexible against global climate change, as some species are indispensable elements of plant breeders and gardens, which have adapted to the arid habitat and Türkiye is among the gene centers. The research was carried out in rural areas, afforestation areas and gardens in the provinces of Adıyaman, Hakkâri, Malatya, Şanlıurfa and Van and detected taxa were recorded on form through on-site observation, photographing and collected in accordance with the herbarium technique later to identify according to Browicz (1972) and Yazbek (2010). After field studies, the aesthetic and ecological characteristics of each of Subgenus *Amygdalus* were evaluated based on plant design. In the course of study fields, it was determined that *P. dulcis*, *P. orientalis* and *P. arabica* are used in afforestation and erosion control areas, *P. dulcis* in almond orchard plant, *P. arabica*, *P. orientalis* and *P. spinosisima* are used as hedge plants, and some taxa are used as rootstock and and they grow in different ecological areas with outstanding visual effect. In this study, it is aimed to determine Subgen *Amygdalus* growing naturally in study area, their aesthectic and ecologic features and the roles they can undertake in the landscape against climate crisis and to be introduced.

Keywords: Landscape design, Natural Plants, Biodiversity, Prunus subgen Amygdalus

Introduction

Due to the increasing environmental problems with global climate change, the issue of making the cities and landscapes of the future more resilient gain importance day by day. However, also in order to create an urban landscape that is adaptable to environmental effects, it is extremely important to prefer native species that can resist adverse environmental conditions throughout the city and can easily adapt to the environment in plant applications (Erduran and Günal, 2012). Because the use of local native species offers various advantages in terms of ecological, functional and economic aspects in the creation, protection and improvement of natural environments in and outside the city. Some of this advantages are following;

- Provide natural habitat for birds and wildlife,
- Sustain populations of pollinators and attract a variety of other beneficial insects,
- Control storm runoff and erosion,

- Develop a strong relationship with soil fungi and other native microorganisms,
- Sustain a spiritual, recreational, educational, and cultural heritage,
- Supporting local ecosystems,
- Improve the resilience of an ecosystem,
- Provide sustainbility,
- Contribute to essential environmental services and improve environmental quality,
- Contribute to rural-urban connectivity,
- Reduces the pressure of urban structures on natural habitats.

All these advantages are an effective strategy to protect local biodiversity, use water resources more efficiently and support natural habitats.

When it comes to climatical assessments, the first thing to consider is the use of natural species. Increasing water demand, especially against drought caused by climate change; dictates the use of natural plants that are compatible with environmental conditions and resistant to natural events in landscape designs (Atabeyoğlu and Bilge, 2019; Çimen and Ulus, 2020). Although natural species are so important, applications for the selection of suitable plants in both urban green space arrangements and private areas are not sufficiently carried out in Türkiye. One of the important reasons for this situation is that the intense demand for exotic species in urban and rural landscapes restricts the effective use of natural plant species, and the other is that it does not cope with the negative effects of drought and drought-resistant plants and it is the lack of knowledge and awareness about climate change, drought (Dilaver 2014).

On the other hand, in landscape arrangements, selection of plant species is so important. Because each plant has a different features that are great importance and used in design and to fulfill ecological/engineering, architectural and aesthetic functions in the landscape. These features are; size, form, strength and opacity in architecture; improving air and water quality, providing erosion control and impact on climate in ecology/engineering and size, form (shape), color and texture in aesthetic (Booth, 1996). Along with the principles of design, the these characteristics of plants should also be taken into account. For a successful functions undertake in the design, it is important to know each plant that makes up the composition well and to highlight its effective properties (Robinson, 2004).

In terms of all these features, there are suitable plant materials that can be used in rural landscape studies as a response to the climate crisis in Türkiye's flora. One of these plant materials is "*Prunus* subgen *Amygdalus* L." genus.

This genus encompasses a little range of species high ornamental, but also ecological values. Thanks to these features, much of them offers an alternative to conventional landscapes when being independently grown or blending with ornamentals into existing yards and gardens into aesthetically pleasing designs. However, only a limited range of species finds common use as landscaping plants. As an example, *P. dulcis* is traditionally cultivated for its fruit, while *P. orientalis* has been employed for erosion control in Türkiye. Additionally, certain species within this genus possess medicinal value.

One of the main reasons for researching taxa of this genus is that Türkiye is among the gene centers, and the other is that high ornamental and ecological values offer potential for both urban and rural sustainable landscapes. However, presently they occupy a very specific and limited space in the landscape and ornamental plants industry. Becuse, most of the research on this genus is genetics, breeding, anatomy and palynology, and the ethnobotanical characteristics and studies aimed at

benefiting more from their fruits. As there is very limited available data about them in landscape and ornamental plants industry, it is necessary to reveal the possibility of using these taxa by studying their ecological demands and visual characteristics both in the adaptation process to climate change and sustainable gardening practices.

The primary objective of this paper is to assess the current utilization of Subgen *Amygdalus* within the study area, focusing on its aesthetic and ecological characteristics. Furthermore, this study aims to identify the potential roles that these native species can fulfill within the landscape. Ultimately, the research aims to propose the use of these native species as a means to enhance the resilience of urban landscapes in the face of the climate crisis while simultaneously contributing to their visual appeal and fragrance.

Material and Methods

The main material of this study is *Prunus* L. subgenus *Amygdalus* L. which are naturally distributed in eastern Türkiye (Table 1) and (Fig. 1).

Table 1. Collection localities of Subgenus *Amygdalus* taxa

The name of taxa	Endanger status	Endemism	Localities	Ecological features of locatiliies
Prunus dulcis (Mill.) D.A. Webb			Adıyaman, Hakkari, Malatya, Sanliurfa, Van	Orchards, Cultivated and Afforestation areas
P. fenzliana Fritsch	DD		Hakkari (Esendere)	Creek slope, Steppe
P. trichamygdalus (Hand.-Mazz.) var. *trichamygdalus*			Adıyaman (Nemrut Mountain) Between Hakkari-Yüksekova	Sloping hillsides
P. trichamygdalus (Hand.-Mazz.) var. *elongata*	NT	+	Hakkari (Between Hakkari-Yüksekova)	Sloping hillsides
P. orientalis (Lam) Redh.	DD		Adıyaman, Elazığ, Malatya	Sloping hillsides, Steppe
P. kotschyi (Boiss. & Hohen.) Nab.	VU		Hakkari (Between Yüksekova-Esendere)	Sloping hillsides, Openings in Oak Forest
P. carduchorum Bornm.			Hakkari (Between Yüksekova and Şemdinli, Derecik Umurlu)	Steppe, Sloping hillsides
P. arabica var. *arabica* (Olivier) Meikle.	NT		Adıyaman (Kahta and Tut) Hakkari (Çukurca)	Steppe, Sloping hillsides, Openings in Oak Forest
P. lycioides (Spach) Schneider			Adıyaman (Nemrut mountain), Malatya (Beydağı)	Rocky slopes
P. spinosisima (Bunge) Franch.			Şanlıurfa	Steppe

Subgenus *Amygdalus* is a small group within *Prunus*, containing approximately 24 species, which is tree or shrub with spreading or upright crown. Branches thornless or thorny; Leaves glabrous or pubescent; petioles sessile to 30 mm long; blades color variable, shape variable, margin usually toothed; Inflorescences usually fascicled on short shoots; petals color variable base mostly tapering, apex usually notched, stamens 10 – 35; style length relative to stamens is variable. Fruits usually with short pedicels, glabrous or pubescent; drupes usually green, sometimes reddish on exposed side (Yazbek, 2010).

Subgenus *Amygdalus* is the earliest deciduous fruit and nut tree to bloom in spring. With the stone fruits, the beauty of flowers and decorative leaves and they perform multiple functions, such as for food, flavor,

and ornamental appearance in landscape. Also, they receive a great deal of attention, especially from plant breeders and horticulturists, usually to assess the potential for their use in cultivar improvement (Socias and Felipe, 1987; Socias I Company 1998; Gradziel et al., 2001).

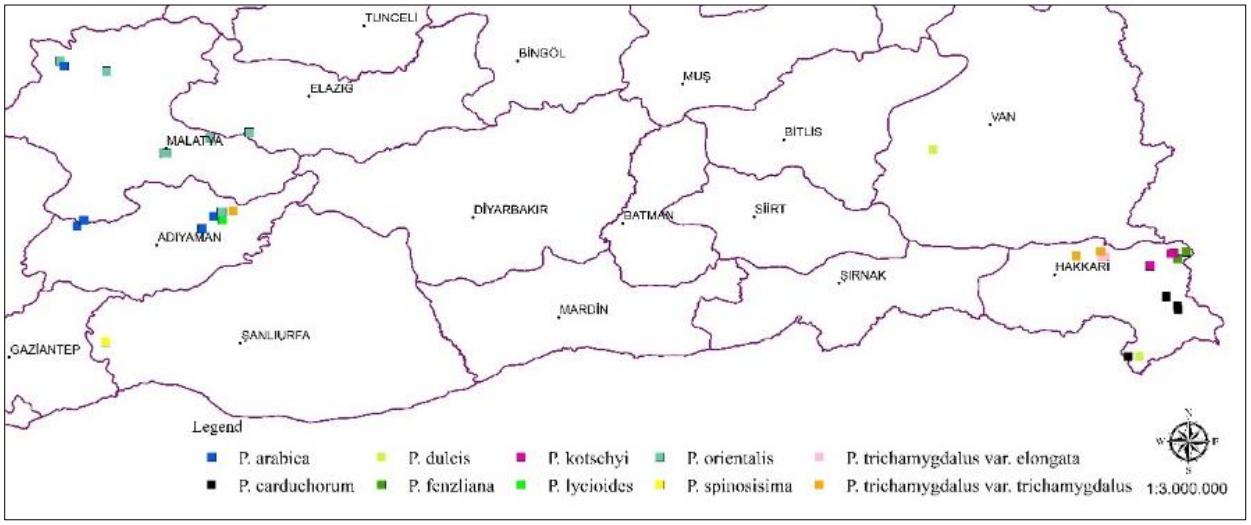


Figure 1. The map where Subgenus *Amygdalus* were collected in study

The majority are distributed in Iran and eastern Türkiye with a few in southeastern Europe, the Mediterranean region, and east into Mongolia and western China, a distribution pattern referred to as the Irano-Turanian distribution (Browicz 1989). Members of subg. *Amygdalus* are deciduous shrubs or small trees that are important components of northern temperate forests in Asia and Europe, mostly occurring in mountainous areas, often between 1,000 and 2,500 m in elevation. They occur in a variety of environments, but mainly in relatively dry habitats, and sometimes in deserts [e.g., *P. arabica* (Oliv.) Meikle]. Those in Türkiye grow at the marginal areas, poor, rocky and stony, and calcareous soils (Kaşka et al., 1999).

The study areas are characterized by a continental type of climate with very cold winters and hot summers. However, the southeast experiences a steppe climate with very hot summers, severe aridity and winters hardly experience frost but severe dry winds dominate the summer season. The precipitation in the form of snow is a regular feature in winter, and rains are common in spring and autumn. The elevation decreases from east to west and southwest. The average annual temperature increases from east to west and southwest, but the average annual precipitation decreases. The area of saline and degraded soils in the region is increasing. The factors responsible for this are over-irrigation practices, and salt accumulation due to evaporation (Öztürk et al, 2008).
The harsh climatic conditions in the region result in higher mechanical than chemical weathering of parent material, as such soils are pebbly in nature. Main soil types within the area are: alluvial, colluvial, chestnut, brown, regosols, basaltic, organic, and arid soils (Öztürk et al, 2004; Öztürk et al, 2006).

Methods

In the study, on-site observation, measurement and photography methods were used in the field studies based on Flora of Turkey and Systematics Of Prunus Subgenus Amygdalus Monograph And Phylogeny (Yazbek, 2010) records. During field studies, the one hand while determined the locations of the Subgenus *Amygdalus* samples via GPS to obtain digital map, the other hand samples were collected in accordance with the herbarium technique to identify according to Browicz (1972) and Yazbek (2010). Also, some features of each taxa such as form/habitus, leaves, flowers and fruits color, texture and

habitat were noted on form through on-site observation and they have been photographed to evaluate view of seasonal throughout year.

In the obtained data analysis phase, endemism, endangered status and noted and photographed the aesthetic and ecological characteristics of each of Subgenus *Amygdalus* were evaluated based on the principles and elements of plant design (Table) 2 and the roles these taxa can play in design are explained.

Table 2. Basic principles of plant design (Both, 1996; Robinson, 2004; Korkut et al., 2010).

Aesthetic		**Functional**
Principles of Visual Composition	Visual Properties	Design principles
Harmony and Contrast	Form	Visual control (Light, Screning, Emphasis)
Balance	Line	Motoin control (Orientation, Circulation)
Emphasis and Accent	Texture	Physical Environment control (Climate, Noise, Air pollution, Erosion)
Sequence	Color	Space Creation
Scale		
Movement and Viewing Angles		

Results

Each of 10 subg. *Amygdalus* taxa that grow naturally under different ecological condition has different traits with extraordinary flower color, fruit and decorative leaves, form and texture. When these taxa are considered separately; ***P. dulcis*;** Trees up to 8-12 m tall, with spreading crown. Bark is braun, young shot is green and tornless. Leaf blades is green, ovate-lanceolate or elliptic, when mature, it is glabrous and leathery. Drupes green, surface densely pubescent; mesocarp splits at maturity, seed is sweet or bitter (Table 3 and Fig. 2).

Table 3. Morphological features of *Prunus dulcis*

Inflorescence	**Pedicel (mm)**	**Flower Diam. (mm)**	**Flowering**	**Leaf (mm)**	**Petioles (mm)**	**Fruit (mm)**	**Fruting**
Fascicled or 1-2	10 - 50	30 - 50	March - April	20-120 x 25-30	10 – 35	40-50 x 30	Aug - Sept

Figure 2. Stands, habitat, form, flower, leaf, fruit and stone of *P. dulcis*

Habitat and Distribution: In oak and cedar forest, in abandoned orchards or orchard borders, open shrub lands and among rocks where sheltered, on dry slopes, with limestone and metamorphic rocks. Native and naturalized. Growing at elevations between 150 – 2000 m (Yazbek, 2010).

It spreads to S.W. and C. Asia, and in addition cultivated in S. Europe (Yazbek, 2010). In Türkiye, every region except the coastal parts of the Eastern Black Sea and very high plateaus (Küden, 2016).

Landscape function: It is a famous tree with the white-pink flowers, a very strong fragrance during early spring bloosom and economically valuable and edible fruit that are a good food source.

Whereas nowadays it is cultivated as a fruit tree in temperate regions all over the world and Türkiye (Fig. 3), in England it is never likely to be valued in gardens for good eatable nuts and it is for its beauty of flower alone that it is cultivated (Url 1). However, being exposed to spring late freezes, unlike usually cultivated for its fruit, it is planted as a border plant in gardens (Fig. 4) and for afforestation in barren areas in Central Anatolia or rainfed areas (Kaşka et al., 1999; Küden and Küden, 2000). Also it was used in aveneu in German (Fig. 5), (Url 3).

Figure 3. *P. dulcis* in cultivated for fruit in Malatya

Figure 4. *P. dulcis* in gardens in Derecik (Hakkâri) and as a border plant in Golbasi (Adıyaman)

Figure 5. *P. dulcis* in cultural landscape in Germany

Its beauty of flowers makes a stunning specimen for garden or park in spring exploding into masses of white flowers. So it is often naturalized as an ornamental tree in gardens in the north of the Mediterranean region (Url-2).

Needs optimum temperature 24 °C, is better in full sun and generally grows light, fertile, deep and well-drained soils in a wide variety of from sandy to clay soils and pH is 6.5 (Verma and et al., 2010).

***P. fenzliana*;** Shrubs or small tree up to 2 (4) m tall, with divaricate branches. Bark is grey, shots is subspinescent, one year old twigs green, reddish on exposed side, older twigs grey pealing to shown brown, glabrous; Leaf is green and leathery. Inflorescences solitary, fascicled on short shoots; petals pink; drupe greenish with yellowish pubescence (Browizch, 1989; Yazbek, 2010), (Table 4 and Fig. 6).

Table 4. Morphological features of *Prunus fenzliana*

Inflorescence	Pedicel (mm)	Flower Diam. (mm)	Flowering	Leaf (mm)	Leaf petioles (mm)	Fruit (mm)	Fruting
solitary, fascicled	-	15 x 20	March - April	80 x 20	10 - 15	25 x 15	Aug - Sept

Figure 6. Flower, leaf and fruit, form and stone of *P. fenzliana* in Hakkâri

Habitat and Distribution: In forests and shrub lands, mostly on rocky slopes and cliffs, and frequently in ravine. Growing at elevations between 1400 – 3500 m (Yazbek, 2010).

It is distributed in Armenia, the western regions of Azerbaijan and Northwest Iran (Kester and Asay, 1975; Ladizinsky, 1999), Turkmenistan (Yazbek, 2010) and Türkiye. Distrubition in Türkiye is Erzurum, Kars and Hakkâri provinces.

Landscape function: This taxa is not used in landscape or in cultivated area in Türkiye. But it belongs to the primary gene pool of *P. dulcis* and the secondary gene pool of peach (*P. persica*). So it has the

potential for use as a gene donor for crop improvement (Url-4) and it is used as a rootstock in almond breeding for late blooming to be easily hybridized (Graselly, 1976, Ladizinsky, 1999).

Thrives in a well-drained moisture-retentive loamy soil (Bean, 1981; Huxley, 1992). Prefers some lime in the soil but is likely to become chlorotic if too much lime is present (Chitdendon, 1951). Succeeds in sun or partial shade though it fruits better in a sunny position (Bean, 1981; Huxley, 1992). Most members of this genus are shallow-rooted and produce suckers if the roots are damaged (Bown, 1995). The plants tolerate temperatures down to -18°C (Url-5).

***P. trichamygdalus*;** Shrubs 2-3 m tall, with spreading crown. Bark is braun, branches thornless; one year old twigs greenish, glabrous or pubescent; older twigs brown to grey-brown, leaf blade is green, elliptic, rarely lanceolate or oblanceolate, abaxially sparsely pubescent, adaxially glabrousis and subleathery, petals pink, drupes green, surface short velutinous (Yazbek, 2010), (Table 5 and Fig. 7 and 8). Has two variety and var. *elongata* is endemic.

Table 5. Morphological features of *P. trichamygdalus*

Inflorescence	**Pedicel (mm)**	**Flower Diam. (mm)**	**Flowering**	**Leaf (mm)**	**Petioles (mm)**	**Fruit (mm)**	**Fruting**
Solitary or Fascicled	5	30 - 50	April	40-45 x 10-15	5 - 10	21 x 15 / 25-27 x 15-18	June - Aug

Figure 7. Habitat, form, flower, leaf and stone of *P. trichamygdalus* var. *trichamygdalus*

Figure 8. Habitat, form, flower, leaf fruit and stone of *P. trichamygdalus* var. *elongata*

Habitat and Distribution: On limestone and igneous soils, on cliffs and rocky places, particularly along gorges. Growing at elevations between 950-2500 m (Yazbek, 2010).

Distribution is Eastern Anatolia in Türkiye, and nearby areas of Iran. In Türkiye, Adıyaman, Malatya, Bitlis, Elazig, Erzincan, Hakkâri province (Yazbek, 2010).

Landscape function: This taxa, too, is not used in landscape in Türkiye. However, sweet form of *P. trichamygdalus* is cultivated in Diyarbakır - Eğil (Meydan, 2019). Crops need full sun, plant requires deep and well-drained soil.

***P. orientalis*;** Shrubs 0.5 - 3 m tall, with erect or spreading crown, Bark brown or grey. Branches thorny; one year old twigs white tomentose, older twigs grey - brown, pubescent, glabrous or glabrescent; Leaves blade silvery white because of the pubescence, elliptic, lanceolate, and less often obovate, oblanceolate or spathulate, when young or mature abaxially and adaxially white tomentose. Petals pink to pale pink, drupe silvery white because of pubescence and surface densely silvery-white tomentose; mesocarp splitting at maturity (Table 6 and Fig. 9).

Table 6. Morphological features of *P. orientalis*

Inflorescence	Pedicel (mm)	Flower Diam. (mm)	Flowering	Leaf (mm)	Petioles (mm)	Fruit (mm)	Fruting
Solitary	1-3	12-16	March	20-44 x 15 -21	5 - 8	15-25 x 10-15	Aug - Sept

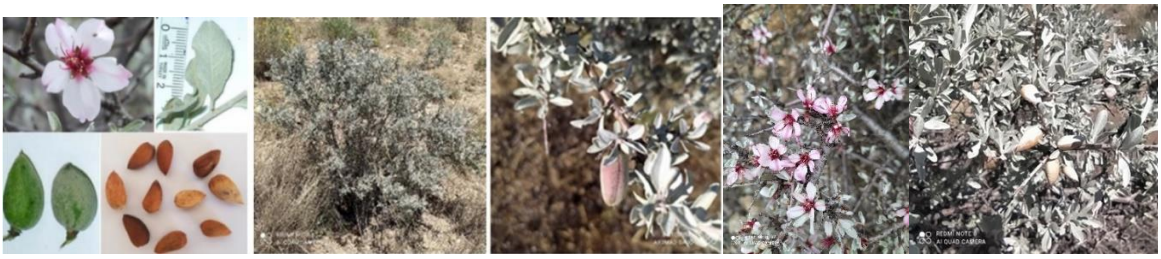


Figure 9. Habitat, form, flower, leaf and fruit of *P. orientalis*

Habitat and Distribution: Common in open grazed oak forest, open sunny niches, on rocky limestone sloppy hillsides, also on dry silt and on steep river stream banks. Growing at elevations between 500 - 2000 m., but most frequently between 800 and 1200 m altitudes (Browicz 1972), (Yazbek, 2010). In Anatolia, it generally spreads in arid, calcareous and stony areas. The annual rainfall in the areas where it grows is between 250 mm and 450 mm (Grasselly, 1976).

Its distrubutions is in the mountains of Iraq, the Syrian desert, Lebanon and western Iran to the interior of Türkiye (Kester and Asay, 1975). It has a wide distribution area over central, southern and eastern Anatolia in Türkiye (Browicz 1989), in the provinces of Adıyaman, Ankara, Antalya, Bitlis, Çankırı, Elazığ, Erzincan, İçel, Kayseri, Kahramanmaraş, Konya, Malatya, Mardin, Niğde, Şırnak and Uşak.

Landscape function: Although it is almost never used in parks and garden in Türkiye as a ornemental plant, it has been used to control soil erosion and to stabilize water flows in arid and semi-arid areas in Iran and as a rootstock in semi-desert areas (Mortazavi, 1986, Madam et al., 2011). It was also used in afforestation area to control soil erosion in Kuluncak district of Malatya province and it has been using as a border plant around vineyards and pistacio orchards in Adıyaman and Şanlıurfa provinces (Fig. 10). And it is among the recommended species for green belt and wind screen in areas close to the water source and the road in Konya (Uysal et al., 2016).

P. kotschyi; Multi-stemmed dense shrubs up to 1.2 m tall, with spreading crown. Bark is brown-grey, Branches somehow thorny; young shoots whitish pubescent, later glabrous. blade green but looks grayish because of pubescence, lanceolate, oblong-lanceolate, rarely slightly oblanceolate, when young or mature densely yellowish grey-tomentose or floccose on both surfaces. Petals pink; drupes green but looks grey because of pubescence (Table 7 and Fig. 11).

Figure 10. *P.orientalis* in erosion control areas and hedge plant at fields edge

Grows in clay loam structure and especially in soils with high lime content and high pH value. Since it is a typical plant of sunny southern aspects, it has a high demand for light.

Table 7. Morphological features of *P. kotschyi*

Inflorescence	Pedicel (mm)	Flower Diam. (mm)	Flowering	Leaf (mm)	Petioles (mm)	Fruit (mm)	Fruting
usually fascicled in pairs	1 - 5	15 - 20	April - May	40x 15	1 - 2	25 x 17 x 14	June - July

Figure 11. Habitat, form, flower, leaf and fruit of *P. kotschyi*

Habitat and Distribution: Oak forest and woodlands, growing on rocks on limestone slopes and mountain ridges, at the upper edges of the Oak and Pistacia steppe forest zone, growing at elevations between 1400 – 2450 m.

It is restricted to a small area in northern Iraq, eastern Iran and south-east Türkiye (Socias et all, 2017). It shows a narrow distribution within the Siirt and Hakkâri provinces in Türkiye.

Landscape function: It draws attention with stunning pink flowers blossing in late spring and yellowish pubescent leaf and shots but it is almost never to be used anywhere in Türkiye. It grows in light and medium textured soil and needs full sunlight.

P. carduchorum; Multi-stemmed dense shrubs 0.5– 1.2 m tall, with spreading crown. Bark brown or grey-brown. Branches thornless, but very rigid, leaf blade green, linear-lanceolate, less often lanceolate, or rarely oblanceolate, when young abaxially and adaxially pubescent, when mature, glabrous or pubescent on both surfaces. petals pink, drupe green, surface with velutinous-grey pubescence (Table 8 and Fig. 12).

Table 8. Morphological features of *P. carduchorum*

Inflorescence	Pedicel (mm)	Flower Diam. (mm)	Flowering	Leaf (mm)	Petioles (mm)	Fruit (mm)	Fruting
Solitary	1 - 2	1-1.5	April - May	6,5 x 7	1 - 2	20-23 x 16 x 12	June - July

Figure 12. Habitat, form, flower, leaf and fruit of *P. carduchorum*

Habitat and Distribution: On rocky slopes with limestone or metamorphic rocks, in Astragalus zones or open degraded forest. Growing at elevations between 1500 - 3000 m.

N. Syria, N. Iraq, N.W. Iran and E. Türkiye. It shows a narrow distribution within the provinces of Hakkâri in Türkiye (Yazbek, 2010).

Landscape function: Although it is one of the most beautiful indigenous delicate shrub with pink flowers, it is used nowhere in Türkiye like *P. kotscyi*. Grows in almost any soil except wet; full sun, adaptable to many soil conditions.

***P. arabica*;** Broomlike shrub 0.75 - 2 m tall, with upright (ascending) crown, Bark brown. Branches angled and thornless; twigs green, glabrous. Leaf blade green, narrow-lanceolate, narrow-elliptic to linear, sometimes narrow-oblanceolate, abaxial surface sparsely pubescent on midvein, adaxial surface glabrous, petals white, pale pink, or pink, as drupe matures surface glabrescent (Yazbek, 2010), (Table 9 and Fig. 13).

Table 9. Morphological features of *P. arabica*

Inflorescence	Pedicel (mm)	Flower Diam. (mm)	Flowering	Leaf (mm)	Petioles (mm)	Fruit (mm)	Fruting
Soliter	1-3	15-18	March - April	29 x 7	6	14-20x8-13x10	May - June

Figure 13. Habitat, form, flower, leaf and fruit of *P. arabica*

Habitat and Distribution: In arid and semi arid regions, on limestone and volcanic rocky slopes, mountains and savannas; often along riversides, and gorges, dry gullies and ravines, open degraded forest and on eroded slopes (Fig. 14). Growing at elevations between 500 - 2700 m (Yazbek, 2010).

Figure 14. *P. arabica* on eroded slopes in Hakkâri

Lebanon, Syria, S. Türkiye, N. Jordan, N. Iraq, E. Iran (Yazbek, 2010). It spreads within the provinces of Adıyaman, Gaziantep, Maraş, Urfa, Mardin, Siirt and Hakkâri in the southeast region in Türkiye.

Landscape function: It draws attention with stiff, long, permanently green, glabrous, angled branches and often leafless. These features can create a stunning display for any garden and parks and can make the landscape more interesting. But it is only grown as a hedge plant in the vineyard and field edges around Maraş (Yaltırık, 1971). Grows light (sandy) and heavy (clay) on dry or moist soils, although it is shade tolerant, it needs full sunlight.

***P. lycioides*;** Very dense shrub 0.6-1.2 m tall, with spreading crown. Bark grey. Branches very thorny, leaf blade green, linear, linear-lanceolate, or linear-oblanceolate, abaxial surface glabrous, rarely sparsely pubescent on midvein, adaxial surface glabrous. Petals pink to deep pink, fruit surface is glabrescent; mesocarp splitting at maturity (Yazbek, 2010), (Table 10 and Fig. 15).

Table 10. Morphological features of *P. lycioides*

Inflorescence	Pedicel (mm)	Flower Diam. (mm)	Flowering	Leaf (mm)	Petioles (mm)	Fruit (mm)	Fruting
Fascicled	0 - 1,5	10	Late Jan - Early May	13.5-20.2 x 5.1-7	1 - 3	10-15 x 10-12	Late Mar-Mid July

Figure 15. Habitat, form, flower, leaf and fruit of *P. lycioides*

Habitat and Distribution: In dry and semiarid areas, on limestone, clay, gravelly, rocky slopes and hillsides. Sometimes near rivers. Growing at broad elevation ranges of between 450 - 2200 m.

Widely spreads throughout Iran and Türkiye, with few records in N. Syria. Its distribution area in Türkiye is Southern Anatolia.

Landscape function: It has an outstanding flowers and dense thorny, however, it is never used in parks and garden in Türkiye, either. But in Central and West Asia where it distributed plays an important role in preventing and controlling soil erosion (Cavalloro and et al, 2020).

Although it is shade-tolerant, it needs full sunlight and grows loam or loamy clay soils.

***P. spinosissima*;** Shrubs (0.5) 1 - 2 m tall, with spreading crown. Bark grey, branches very thorny, petals pink to deep pink, leaf blade green, spathulate, obovate, elliptic or lanceolate. Drupes reddish from one side and green from the other, pubescent (Table 11 and Fig. 16). Seeds are a little bitter but can edible in fresh. It is morphologically similar to *P. lycioides*.

Table 11. Morphological features of *P. spinossisima*

Inflorescence	Pedicel (mm)	Flower Diam. (mm)	Flowering	Leaf (mm)	Petioles (mm)	Fruit (mm)	Fruting
Fascicled	1	-	Late Feb Late Apr	18- 29 x 8	5-7	15 x 9 x 8-10	Early May Mid Aug

Figure 16. Habitat, form, flower, leaf and fruit of *P. spinossisima*

Habitat and Distribution: In semi arid regions, on clay, limestone and volcanic rocky mountain slopes. Growing at elevations between 700 – 1900 m.

Its distribution; Afghanistan, Eastern Iran, Tacikistan South Turkmenistan and Türkiye. Its distribution area in Türkiye is Southern Anatolia (Browicz ve Zohary, 1996).

Landscape function: It has an attractive and fragrant flowers blooming and attracting birds, butterflies, and pollinators in late spring and it grows naturally or is grown as a edge plant of pistachio orchards in the Southeastern Anatolia region. It grows primarily in the temperate biome.

Discussion

According to the results obtained in the research, *P. dulcis* and *P. orientalis* are used currently in afforestation and erosion control areas in Türkiye. *P. dulcis* also is used in the (commercial) orchard and as a (naturalized) ornamental plant (in garden/in aveneu), *P. arabica*, *P. orientalis* and *P. spinosissima* are used as hedge plants and all taxa but *P. kotschyi* and *P. carduchorum* are used as a rootstock. But each Subgen *Amygdalus* taxa in study area have a various ecological/engineering, architectural and aesthetic features (Table 12).

Table 12. Aesthetic, architectural and ecologic features of subgen *amygdalus*

Taxa Name	Aesthetic				Architectural			Ecological			
	Texture	Form (Shape)	Scale	Color	Form	Height (m)	Spread (m)	Resistance to drought	Desire Temparature	Resistance to Coldness	Light
P. dulcis	F/M	Sp	H	H	T	4-12	2,5-6	M	H	M	FS
P. fenzliana	F/M	Sp	M	H	T/Sh	2-4	1-2	M/H	M	H	S/PSh
P. trichamygdalus	F/M	Sp	M	H	T/Sh	2-3	1-3	H	M	M	S/PSh
P. kotschyi	M	Sp	L	H	Sh	0.5-1.2	0.5-1	M	L	H	S
P. carduchorum	F	Sp	L	H	Sh	0.5-1.2	0.5-1	H	L	M	S/PSh
P. arabica	F/M	U	M	H	Sh	0.75-2	0.5-1	H	L	M	S/PSh
P. orientalis	M	Sp	M	H	Sh	1-3	0.5-2	H	L	H	S
P. lycioides	M	Sp	L	H	Sh	0.6-1.2	0.5-1	H	L	M	S/PSh
P. spinosissima	M	Sp	M	H	Sh	(0.5) 1-2	0.5-1.5	H	L	M	S/PSh

F; Fine, FS; Full Sun, H; High, I; Irregular L; Low, M; Medium, PSh; Partly Shade, S; Sun, Sh: Shrub, Sp; Spreading, T; Tree, U; Uprigt

According to table 12, Subgen. *Amygdalus* taxa are tree or shrub that have not only aesthetic features, but also ecological features is valuable. With these traits including from white to (deep)pink flowers blooming in spring that has strong fragrance that some has, edible fuit or nuts, resistance to drought and many pests and diseases and being rootstock, they can play an important rol in landscape (Table 13).

When each of Subgen *Amygdalus* is evaluated separately in table 13;

'***P. dulcis***' is suitable for home gardens, shopping centre precincts and urban parks. Can be planted at the garden edge away of swimming pools or close walls and paving and at street, but should be considered that fruit drop may be a minor nuisance in pedestrian and paved areas. Should not be planted near nature reserves, creeks or watercourses. The other hand, despite a fully deciduous species and losing all its leaves in winter, when it reaches full maturity, it can be considered a perfect shading tree in summer and to enjoy sun in winter. The bright leaves turning yellow in autumn can add interest to landscape, Nevertheless, in order to optimize the tree's aesthetic potential, it is recommended to place it in a sunny location with evergreen trees as a backdrop.

As well as because of the distribution of *P. dulcis* in Asian mountain systems with high erosion rates and native and naturalized in abandoned orchards or orchard borders, it is reasonably drought-resistant and resistant to many pests and diseases. While these traits make it a great low-maintenance tree for garden, park and rural areas, its adventitious roots are suitable to increase the stability of slopes and mitigate erosion on dry slopes (Kaşka et al., 1999). It has high potential both for food forests and for bird parks such as *Nycticorax nycticorax* Linne (Durmuş, 2008). Also, it produces good nectar which attracts bees (*Anthophora plumipes* Pallas ve *A. orientalis* Morawitz) and insects (Grace, 2010). Also, *P. dulcis* can act as a safety barrier to prevent land abandonment, to control forest fires and to mitigate the consequences of climate change on lands at risk of climate change other than horticulture due to playing an important role in the agricultural economy. But as the phenological stages is affected by insufficient chill accumulation, heat waves, drought, irregular rainfall, and spring frost and orchards

sustainability is susceptible to climate conditions (Guillamón et al, 2022; Thomas, 2019; Alonso et al, 2005).

Table 13. Use of subgen *amygdalus* taxa in landscape architecture

	Aesthetic			Architectural				Functional								
Taxa Name	Evergreen/Dedicou	Seasonal interest	Color/Feature	Creating Space	Screening	Privacy	Climate control	Noise Control	Erosion Control	Traffic Control	Wildlife	Rock Garden	Roof-terace Garden	Rootstock	Agroforestery	Waterside
P. dulcis	D	Spring-Summer, Fall	fragrant white or pink flowers, yellowy orange fall color	L Sh	W/S	X	X	X	X	X	X			X	X	
P. fenzliana	D	Spring-Summer, Fall	pink flowers	L	W/S	X	X	X	X	X	X			X	X	X
P. trichamygdalus	D	Spring-Summer, Fall	White or pink flowers	L	W/S	X	X	X	X	X	X			X	X	
P. kotschyi	D	Spring-Summer-Fall	pink flowers yellowish grey-tomentose or floccose foliage, fruit	E	W			X	X		X		X			X
P. carduchorum	D	Spring - Summer	Pink flowers, Fine texture	E	W			X	X		X		X			
P. arabica	D	All Season	white, pale pink, or pink flowers evergreen shoots	E	W/S			X	X		X	X		X	X	
P. orientalis	D	Spring - Summer-Fall	White or pink flowers, Silvery-green foliage	E	W/S			X	X		X	X		X	X	
P. lycioides	D	Spring - Summer	Pink-deep pink flowers	E	W			X	X		X	X	X	X		
P. spinosissima	D	Spring - Summer	Pink-deep pink flowers	E	W/S			X	X		X			X		

E; Enclosure, L; Limitation, S; Sun, Sh; Shading, W; wind.

‘***P. fenzliana’*** with small-sized fruit and pink flowers blooming in late spring and being small tree stands out. Its masses of white flowers that provide ample colour and attract a host of insects and birds and its resistantance of reasonably coldness and to many pests and diseases and low-maintenance is to make it a invaluable wonderful landscape subject.

By and large since this taxa can be a popular choice for small garden and parks and also for narrow spaces or in border. Because it is a deciduous tree, its open and airy structure creates light shade underneath the canopy and can be used a small shading tree/shrub at the garden edge in summer. This species has a non-aggressive root system so, it is safe to plant alongside paving or retaining walls. In the other with its fine texture it can be used as a soliter or in groups in gardens, parks or sandy cliffs. As it is adaptation to moist soil, though it might need watering in arid regions, but may be a preferred option for the colonization of in colder regions. It is an ideal replacement for the exotic *Prunus* taxa espicially colder regions. Though fruit and sweet or slightly bitter seed are edible as raw or cooked, if the seed is too bitter, this plant are mildly toxic to humans. Plants in this genus are notably susceptible to honey fungus (Huxley, 1992). As low humidity and high temperatures protect it from fungal diseases, climate change may affect it positively.

‘***P. trichamygdalus***’ with medium-sized fruit and attractive whitish-pink flowers blooming on short shoots before emerging leaves in mid spring can be cultivated in gardens for its beauty of flower alone. It is an ideal replacement for the exotic *Prunus* shrubs espicially drought areas.

Due to its open, airy structure it is suitable to create light shade underneath its canopy in summer like *P. fenzliana*. It is ideal for hedges and for over lawns and rock gardens as a soliter or in groups. It is qualified for edge of walls at the garden due to the small size or to create a wall effect in a line for separating areas. Also its leathery leaves turning yellow in autumn add interest to landscape. As growing up particularly along gorges, it has a high capacity to tolerate drought and cold conditions, so it provides posibility to increase the stability of slopes and mitigate erosion on dry slopes and it can be planted in wastelands. As medium-sized fruit and non-bitter forms of *P. trichamygdalus* is cultivated in orchard, it can be a potential for food forests because the phenological stages may not be affected so much adverse conditions. Moreover since providing likely food and habitat for wildlife and can be suitable and for bird parks.

P. orientalis with white tomentose leaves and fruits throughout the vegetation season and pinkish blooming in mid spring before leaves emerge is to stand out. Also, that its flowers show very high frost resistance (Grasselly, 1976), needing too low-watering and its resistance to salt and drought-tolerant makes it a perfect shrub. Therefore, it can be alternative to exotic shrubs needing watering. It is qualifed as a snow and wind curtains or hedge plant due to thorny dense form and for xeriscape design. It can be pruned formal shapes to create backgrounds in flowerbed or to contrast. Also it has been using to control soil erosion and to stabilize water flows in arid and semi-arid areas and as a a rootstock.

Since *P. orientalis* seeds are a little bitter but can edible in fresh, its fruits can help to feed wildlife living in rural and urban areas and flowers provide important benefits for bees it can be suitable potential both for agroforstery and for bird parks.

‘***P. kotschyi***’ can preferred as an ornamental plant with small yellowish pubescent fruit, foliage and outstanding pink flowers in parks and gardens in cold city to create positive effects on the urban landscape, because it tolerance to abiotic stresses such as drought, low winter temperature, snowfall and frost. It can provides a beautiful background with its flowers, to define and separate spaces or to form a

low hedge or to control car light in narrow refuge due to its thorny, dense low stem. It can be used for decorative purposes in a groups or solitery in parks or in roof-terrace gardens. It is ideal to use in mountain steppes to mitigate erosion or to establish green belt along roads. Morover it can be used in cut floristry and be pruned to shape if need. Seeds are bitter and not edible but fruit and nectar are good source for wildlife. Since providing food and habitat for wildlife, it can be as an insect and bird-attracting garden subject. It can be an excellent alternative to the exotic *Chaenomeles japonica*.

'***P. carduchorum***' explosion of pink flowers in mid spring can provides a stunning display for any garden and parks and it can be an excellent substitute for against the exotic plants or alternative to *Chaenomeles japonica*.

It can play an active role in in the resilient of urban landscape, for it is reasonably drought-resistant and is resistant to many pests and diseases and need low maintanence. Since it often grows on roadsides slope and shallow soils, it can be tolerant of exhaust gas emissions and be used roadside planting and in urban open areas or to create green belts along roads in city or mountain steppes. Also, often growing under the quercus canopy as well, it can be an excellent choice for creating a kind of mini-forest in the gardens and parks. Due to its non-aggressive root system, it is safe to plant next to sidewalks or retaining walls as a ornamental plant. It can be partly pruned for hedge. Seeds are bitter and not edible but nectar attracts bees and insects who pollinate its flower. Fresh fruit attracts small mammals. So it provides wildlife habitats and can be used in insect and bird-attracting garden.

'***P. arabica***' with white or pale pink blooming during early spring and attractive green twigs can play a special rol in landscape to create stuning space. For exmple its upright form and green dense twigs make it an outstanding screening shrub and an effective hedge or a focus plant. It is qualifed as a snow and wind curtains or hedge plant due to thorny dense form or for xeriscape design. When espicially it is used as an ornamental plant in stony or rocky backgrounds in arid areas in continental climate, it can be succed interesting landscape.

As it shows great tolerance to abiotic stresses such as drought, salinity, low soil fertility and low winter temperatures, it can be used for afforestation along with *Pinus brutia* (Yaltırık, 1971), and can plays a valuable role to combat desertification, to stop dunes, to control soil erosion and to stabilize water bodies in arid and semi-arid mountains. Also it is suitable candidate for green belts of cities especially on infertile soils in arid and semi-arid areas (Mozaffarian, 2005). It capables of providing favorable conditions and microclimate for other species by coping with unfavorable conditions in rock debris and slopes. It can be used in road slope and it can good substitute for exotic plants or maybe for *Spartium junceum* L.
Although *P. arabica* fruit is not an economically important plant, is eaten by local people in some places and sold in the market (Meikle 1966; Browicz and Zielinski 1984). Even it is not suitable for food forests, it can be cultivated for multi purposes including food and habitat for wildlife and an insect and bird-attracting garden subject. On the other hand, seeds and seedlings may present an important genetic resource to be used in breeding programs to generate new cultivars and rootstocks that are more adapted to climate change.

'***P. lycioides***' can be one of favourite shrubs with an attractive flowers in early spring in small garden for decorative purpose. For example, it can be designed as a decorative bush or screening hedge in garden and parks, in rrefuge or on the roadside, be planted in pots in homes or gardens, in xeriscape garden, even in roof-gardens. Moreover as this species is preferred to build nest by some birds (Aghanajafizadeh and Heydari, 2020), it can be used for bird parks. It is highly adapted to environmental

stresses such as drought and lack of annual precipitation and unfavorable soil conditions, it can be used to control soil erosion and to create wooded pastures in dry areas.

Seeds are bitter and not edible but it is traditionally used as a antidiabet antiinflammation, antibacterial and laxative agent (Abbaslou and et al, 2014; Ziarati and Alaedini, 2014). So it can be used as a medical-aromatic plant. In addition, as it have been used directly as rootstocks for almond usually for non-irrigated conditions (Khadivi-Khub and Anjam, 2016), can be used in breeding programs to generate new cultivars and rootstocks that are more adapted to climate change as a genetic resource.

'***P. spinosissima***' can play a vital rol in landscape as a a small shrubs that have an abundance of pink flowers in early spring and is native to dry areas. It can be used in lanscape as a hedge or border plants and as an ornamental plant in arid areas in continental climate or in xeriscape gardens due to adaptation to many soil types. It is excellent for massing on embankments or naturalized areas with attractive shape and for soil conservation operations on steep slopes. It can be pruned for a natural look or to raise the canopy.As its salted almonds is eaten as dry fruits by population, it can contribute to food forest ecosystem. Also, used in the Iranian folk medicine (Sajadi, et al, 2021) and having different biological properties including antibacterial, anticancer, antioxidant, antidiabetic, antiemetic, antihypertensive, hypoglycemic, hypolipidemic (Encyclopaedia Iranica, 2019), it can be used as a medical-aromatic plant. It is important as a rootstock or and as a genetic resource for growing sweet almonds, peaches, plums and apricots in arid regions due to its resistance to drought conditions (Açar et al, 2001).

Conclusion

Climate change has led to an increased frequency and severity of heat waves, droughts, and heavy precipitation events (IPCC. Climate Change 2023). Neverthless in the Mediterranean-type climate regions, where an important fraction of subgen *Amygdalus* grows, that the mean annual precipitation tends to decrease may result in harmful effect on all biodiversity, it stands out that subgen amygdalus taxa show a high capacity to tolerate drought conditions.

Therefore, it is imperative to support and utilize these taxa, which offer a higher resistance to pests, diseases, and the challenges posed by climate change, which can be contributed to food forest ecosystem, including carbon sequestration, and require minimal maintenance.

Moreover, apart from the cultivation of Prunus taxa for use as rootstock, it is also necessary to develop them in a way that overcomes the homogenization pressure brought by globalization in the ornamental plants market, creates a difference and responds to the evolving needs (Alp et al, 2020).

Additionally, it is crucial to consider the conservation of certain taxa, such as *P. trichamygdalus* var. *elongata*, which is endemic, as well as *P. kotschyi* and *P. carduchorum*, due to their limited distribution areas. Special attention should be given to relieving the pressures exerted by land use on these taxa. Policies and scientific projects aimed at promoting landscape sustainability and protecting both the taxa and their habitats have been developed to address these concerns.

References

Abbaslou, H., Martin, F., Abtahi, A., Moore, F., (2014). Trace element concentrations and background values in the arid soils of Hormozgan Province of southern Iran, Archives of Agronomy and Soil Science, 2014; 60 (8): 1125-1143. Available online: http://dx.doi.org/10.1080/03650340. 2013.864387).

Açar I., Ak, B.E., Sakar E., (2001). An investigation on the determination of pomological and morphological traits of wild almond grown at Sanliurfa province, XI GREMPA Seminar on Pistachios and Almonds. Zaragoza: CIHEAM, 2001. p. 139 -144 (Cahiers Options Méditerranéennes; n. 56)

Aghanajafizadeh, S., Heydari, F., (2020). Modeling of Scrub Warbler (Scotocerca inquieta) nesting selection in Baghshadi protected area, Yazd provinces, Journal of Arid Biome, Volume 9, Issue 2, March 2020, Pages 113-120. Doi 10.29252/aridbiom.2020.1820

Alonso, J.M.; Ansón, J.M.; Espiau, M.T.R. Socias i Company, 2005. Determination of endodormancy break in almond flower buds by a correlation model using the average temperature of different day intervals and its application to the estimation of chill and heat requirements and blooming date. J. Am. Soc. Hortic. Sci. 2005, 130, 308–318. [CrossRef]

Alp, Ş., Zeybekoğlu, E., Salman, A., ve Özzambak E., (2020). Doğal Bitkilerin Kültüre Alınması Süreci ve Süs Bitkisi Olarak Kullanılması. Bursa Uludag Üniv. Ziraat Fak. Derg., 34 (Özel Sayı), s. 351-357.

Atabeyoğlu, Ö. & Bilge, G., (2019). Corylus türlerinin peyzaj tasarım çalışmalarında kullanılabilirliği. Akademik Ziraat Dergisi, Cilt: 8 Özel Sayı, 145-156. DOI: 10.29278/azd.638966

Bean, W., (1981). Trees and Shrubs Hardy in Great Britain. Vol 1 - 4 and Supplement.

Booth, N. K., (1996). Basic Elements of Landscape Architectural Design, Waveland Press, Inc. Illinois.

Bown, D., (1995). Encyclopaedia of Herbs and their Uses, Dorling Kindersley, London, ISBN 0-7513-020-31

Browicz, K., (1969). Amygdalus. In: Rechinger KH. (ed) Flora Iranica. Akademische Druck-u. Verlagsanstalt, Graz, Austria, pp 166–187.

Browicz, K. and Zielinski, J., (1984). Chology of Trees and Shrubs in South West Asia and Adjacent Regions. Polish Scientific Publishers, Vol. 8. Warzsawa-Poznan 80 s

Browicz, K., (1989). Amygdalus. In: Davis PH (ed) Flora of Turkey. Edinburgh University Press, pp 21–28.

Browicz, K. and Zohary, D., (1996). The Genus *Amygdalus* L. (Rosaceae) Species Relationships, Distribution and Evolution Under Domestication. Genetic Resources and Crop Evaluation, 43: 229-247.

Cavalloro, V., Bracco, F., Collina, S. and Martino, E., (2020). Focus on Phytochemical and Pharmacological Profile of Prunus lycioides (=Amygdalus lycioides), Mini-Reviews in Medicinal Chemistry 2020; 20(20). https://dx.doi.org/10.2174/1389557520666200730153653

Çimen, Ş. & Ulus, A. (2020). Türkiye Milli Botanik Bahçesi'nde Bulunan Bazı Doğal Bitki Taksonlarının Süs Bitkisi Kullanım Potansiyelinin Belirlenmesi. Bursa Uludağ Üniversitesi Ziraat Fakültesi Dergisi, VII. Süs Bitkileri Kongresi, 9 - 11 Ekim 2019, Bursa, TÜRKİYE, 269-290. Retrieved from https://dergipark.org.tr/tr/pub/bursauludagziraat/issue/ 56984/646088

Dilaver, Z., (2014). İç Anadolu Doğal Bitki Örtüsü Örneklerinden Peyzaj Mimarlığında Yararlanma, İklim Değişikliğine Yerel Çözümler: Doğal Bitki Örtüsüyle Sürdürülebilir Uygulamalar, Doğal Bitkilerle İklim Dostu Çankaya Parkları Projesi Eğitim Kitapçığı, Ankara, Pad Yayın No: 1

Durmuş, A., (2008). Van Gölü'nde Yaşayan Gece Balıkçılı (*Nycticorax nycticorax* Linne, 1758)'nin Biyoekolojisi Üzerine Araştirmalar, Doktora Tezi, Biyoloji Anabilim Dalı, Mayıs 2008, 150 sayfa, Van

Encyclopaedia Iranica, (2019). BĀDĀM–www.iranicaonline. org. Retrieved 25 May 2019.

Grasselly, C., (1976). Les espèces sauvages d'amandier. Options Méditerranéennes 32, 28–43.

Guillamón, J.G.; Egea, J.; Mañas, F.; Egea, J.A.; Dicenta, F. Risk of Extreme Early Frosts in Almond. Horticulturae 2022, 8, 687. [CrossRef]

Huxley, A., 1992. The New RHS Dictionary of Gardening. MacMillan Press, ISBN 0-333-47494-5

IPCC. Climate Change 2023. Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change; Core Writing Team, Lee, H., Romero, J., Eds.; IPCC: Geneva, Switzerland, 2023

Kaşka, N., Ak, B.E. ve Açar, Ş., (1999). Dünyada ve GAP Bölgesi'nde Badem Üretimi, Yetiştiriciliği ve Geleceği. GAP 1. Tarım Kongresi, 26-28 Mayıs 1999, Şanlıurfa, 9-18

Khadivi-Khub, A. and Anjam, K., (2016). Prunus scoparia, a suitable rootstock for almond (Prunus dulcis) under drought condition based on vegetative and fruit characteristics, Scientia Horticulturae, Vol. 210, doi = 10.1016/j.scienta.2016.07.028

Korkut AB, Şişman EE, Özyavuz M (2010). Peyzaj Mimarlığı, Verda Yayıncılık, ISBN: 97860558838109.

Küden, A.B., and Küden A., (2000). Badem Yetiştiriciliği. TÜBİTAK TARP Yayınları. 18s.

Küden A. B., (2016). Ülkemizde Badem Yetiştiriciliği, Önemi ve Geleceği, Antep Fıstığı Araştırma Dergisi

Meikle, R. D., (1966). Rosaceae. In: Townsend CC, Guest E (eds) Flora of Iraq. Ministry of Agriculture, Republic of Iraq, Baghdad, pp 102–171

Meydan, İ., (2019). Badem (*Amygdalus trichamygdalus*) Meyvesinin Etanol Ekstraktı Ve Yağının Gs-Ms ile Karakterizasyonu, Turkish Studies Information Technologies and Applied Sciences, Volume 14 Issue 2, 2019, p. 241-250, DOI: 10.29228/TurkishStudies.22499, ISSN: 2667-5633, Skopje/MACEDONIA-Ankara/TURKEY

Mortazavi, M., 1986. Problems of grafting of cultivated almond on wild almond. Iranian Scientific and Specifi c Journal in Agriculture “Zeitun”, 71: 15-21.

Özturk M, Ozcelik H, Sakcali MS, Guvensen, A., 2004. Land degradation problems in the Euphrates basin, Turkey. Environews 10: 7-9

Özturk M, Guvensen A, Aksoy A, Beyazgul M., 2006. An overview of the soils and sustainable land use in Turkey. In: Gerger et al (eds): GAP V. Muhendislik Kongresi. Harran Universitesi, Urfa, 1548-1555

Özturk M, Guvensen A, Sakçalı, S., Görk, G., 2008. Halophyte plant diversity in the Irano-Turanian phytogeographical region of Turkey, Biosaline Agriculture and High Salinity Tolerance Edited by Ghedly Abdelly, Münir Oztiirk, Muhammad Ashraf and Claude Grignon © 2008 Birkhâuser Verlag/Switzerland

Robinson, N., 2004. The Planting Design Handbook, Ashgate Publishing Company, Hampshire, England.

Socias i Company, R. & Felipe, A.J. 1987 Self-compatibility in almond: Transmission and recent advances in breeding Acta Hort. 244 307 317

Socias i Company, R. , Felipe, A.J. , Gómez Aparisi, J. , García, J.E. & Dicenta, F. 1998 The ideotype concept in almond Acta Hort. 470 51 56

Socias, R., Ansón, J.M. and Espiau, M.T., 2017. Almonds: Botany, Production and Uses. R. Socias i Company and T.M. Gradziel (eds)

Thomas, D., 2019 Managing Almond Production in a Variable and Changing Climate; Hort Innovation: Sydney, Australia, 2019; ISBN 978-0-7341-4521-5.

Yazbek, M., M. 2010. Systematics Of Prunus Subgenus Amygdalus Monograph And Phylogeny, Ph.D. Tezis, Cornell University

Ziarati, P., Alaedini, S. 2014, The Phytoremediation Technique for Cleaning up Contaminated Soil By Amaranthus sp. J Environ Anal Toxicol., 4: 208. doi: 10.4172/2161-0525.1000208

Url-1. https://www.treesandshrubsonline.org/articles/prunus/prunus-dulcis/

Url-2. https://www.maltawildplants.com/ROSA/Prunus_dulcis.php

Url-3. https://www.agefotostock.com/age/en/details-photo/bitter-almond-prunus-amygdalus-avenue-from-bitter-almond-tree-in-cultural-landscape-germany-rhineland-palatinate-neustadt-gimmeldingen/BWI-BLWS087008

Url-4. https://www.iucnredlist.org/species/50393773/174150996#taxonomy

Url-5. https://en.hortipedia.com/Prunus_fenzliana

Submitted: 02.04.2023 Accepted: 12.10.2023

Eurasian Journal of Forest Science

2023 11(3): 137-150

https://dergipark.org.tr/en/pub/ejejfs

Evaluating the strength properties of standing trees through fractometry

Abdullah BERAM

Department of Industrial Design, Faculty of Architecture and Design, Pamukkale University, 20160, Denizli, Türkiye.

Corresponding author: abdullahberam@pau.edu.tr

Abstract

In recent years, significant advancements in non-destructive testing (NDT) methodologies have emerged, with applications spanning various domains, including structural wood quality assessment and planted tree characteristic evaluation. Within the context of planted trees, a range of non-destructive and semi-destructive techniques have been developed to assess the extent of degradation in tree trunks. In this study, various mechanical characteristics of brutian pine (*Pinus brutia* Ten.) trees near the Ertokuş Madrasah in the Atabey district of the province of Isparta are examined. Beside their historical significance, these trees are notable for the potential risk they present in terms of leaning towards the madrasah facade and the risk of falling over. To achieve the goals of research, the resistance characteristics of incremental cores were systematically determined by using a thermal imaging camera in conjunction with a portable, non-destructive testing device called a Fractometer. Totally 15 incremental auger specimens were obtained by extracting three increment core samples, each with a thickness of 5 mm, from the trunks of five distinct trees, all at a consistent height of 1.3 meters above ground level. Bending and compressive strength measurements were recorded at intervals of 6 mm from the core to the outermost layer. Furthermore, the moisture content of the incremental cores was assessed using thermal imaging technology. Following an analysis of the collected data, it was concluded that the mechanical properties of the investigated brutian pine trees within an acceptable range.

Keywords: Non-destructive testing, fractometer, thermal camera, standing trees.

Introduction

Wood has served as a cost-effective and renewable construction material for centuries (Fang et al. 2017; Aydemir et al. 2011; Kaya et al. 2021). In contemporary applications, wood continues to play a vital role in roofing, interior doors, exterior cladding, furniture, flooring, veneer production, barrel crafting, and various other sectors (Jones et al. 2019; Kilicarslan et al. 2020). A comprehensive assessment of wood properties is of paramount importance to determine the optimal utilization of this versatile material. Additionally, the identification of wood defects, including features such as knots, decay, insect infestations, splits, and checks, holds significant relevance, as these imperfections can substantially influence its overall performance. Early detection of these flaws, preferably before the final processing stages, can result in significant cost efficiencies within the manufacturing process (Bravery et al. 1987; Akbulut et al. 2008; Kilicarslan and Turker, 2021).

Wooden structures are vulnerable to degradation over time due to prolonged exposure to loading conditions and fluctuations in environmental factors, such as temperature and humidity. These deteriorations can compromise the structural integrity of wood-based materials, giving rise to safety concerns that necessitate their early identification. Consequently, there is a growing demand for non-destructive methodologies aimed at assessing the integrity of wood and wood-based materials. These methodologies find applications both during the manufacturing phase and throughout the service life of wood products to enhance their overall quality (Riggio et al. 2014; Tannert et al. 2014; Yu et al. 2020).

The strength of wood is significantly compromised by decay, making it a critical consideration in tree risk assessment. The primary objective of such assessments is to detect instances of decay within a tree and subsequently determine the extent and severity of this deterioration. A range of tools and instruments are available for accurately mapping out the degree of decay, with micro-drills and tomography being noteworthy examples. In cases where the extent of decay is either exceptionally high or exceptionally low, this information typically offers clear guidance for recommending appropriate courses of action (Allison et al., 2008; Ganesan and Hamid, 2010). However, there are scenarios in which uncertainty arises regarding whether the weakening caused by decay surpasses an acceptable threshold. In such instances, assessing the quality of the remaining wood becomes a valuable additional criterion to inform decision-making.

Non-destructive testing, as defined by Ross et al. (1998) and Liana et al. (2020), is the process of evaluating material properties without causing disruption to its integrity at its point of use. Non-destructive testing (NDT) is instrumental in gathering information about the physical and mechanical properties of a material, detecting defects without rendering it unusable, and assessing the suitability of a component without causing harm (Ross and Pelerin, 1991-1994; Bucur, 2003). Over time, the interiors of standing trees can decay due to various factors, resulting in imperceptible gaps within the tree's structure. As a consequence of external influences, these trees can suddenly fail or topple. Therefore, it becomes crucial to ascertain the reduction in resistance values of standing trees, which are invaluable natural resources, without causing harm to them, with the aim of their preservation. Various techniques are available to identify material defects within standing trees without causing damage.

The Fractometer II, a portable wood testing device (developed by Instrumenta Mechanik Labor (IML), Karlsruhe, Germany), serves as the central tool in this study. This device is specifically engineered to measure the elasticity and fracture strength of wood (Bethge et al., 1996; Malanowski et al., 2019). Furthermore, the Fractometer II, in addition to assessing fracture angles and radial bending strength, possesses the capability to determine longitudinal compression strength in wood samples, as highlighted by Mattheck et al. (1997) and Tang et al. (2016). Longitudinal compression strength indicates the wood trunk's resistance to failure under axial stress. The fracture angle offers insights into whether the wood sample experiences a brittle or non-brittle fracture, while radial bending strength indicates the wood's ability to withstand failure under perpendicular stress. It is essential to acknowledge a limitation associated with the use of the Fractometer II, namely that it requires prior knowledge of the expected breaking strengths for sound wood, as discussed by Lonsdale (1999), Živanović et al. (2019), and Li et al. (2022).

There are many studies that determine the mechanical properties of wood by Fractometer II device in the literature. Şimşek (2017) received increment core from brutian pine tree and determined the compressive strength values in the Fractometer device. Genesan and Hamid (2010) determined some mechanical properties of 25 different wood species by the Faktometre II device. They stated that the fractometer device can be used in determination of the mechanical properties of the standing tree. Chiu et al. (2006) and Lin et al. (2007) received increment core of Taiwania (*Taiwania cryptomerioids*) tree and the mechanical properties of the juvenile wood-mature wood parts were examined by the

fractometer. Matsumoto et al. (2008) had 5 mm increment cores of 2 Japanese wood (sugi, *Cryptomeria japonica* and akamatsu, *Pinus densiflora*) and evaluated compressive strength values of the cores. As a result of these studies, it was concluded that the mechanical properties can be determined with the Fractometer device while the tree is standing. In addition to these studies, there are many studies to determine the mechanical properties of the standing tree with the Fractometer device (Bethge et al. 1996; Wang et al. 2008; Matsumoto et al. 2010; Tang et al. 2016; Živanović et al. 2019). Thermography method is also used for the determination of rotten and cavities in the interior of planted trees (Catena et al. 1990; Catena, 1991, 1992; Catena and Catena 2000, 2008; Catena 2002, 2003; Dragavtsev and Nartov, 2015; Zevgolis et al. 2022).

This study was conducted on brutian pines located in front of the Ertokuş Madrasa in the Atabey district of Isparta. These historical trees exhibit a slight slope towards roof of the madrasah, raising concerns about potential risks, including the possibility of them falling over. These concerns were reported by madrasah officials and the general public, prompting the need for this study. In the context of this study, the mechanical properties of brutian pines were examined using a semi-destructive testing device known as the Fractometer. Additionally, the moisture level in the cores of these trees was evaluated using a thermal camera.

2. Material and Methods

2.1. Study area and sampling

In this study, the mechanical properties of pine trees near the Ertokuş madrasah in Isparta-Atabey district were investigated by non-destructive testing method. The image of the pine trees in front of the Ertokus madrasah is given in Figure 2.1A, B. In order to determine their mechanical properties, 3 increment core of 5 mm thickness were taken from 5 different trees at a height of 1.3 m from the ground. The image of receiving the increment core is given in Figure 2.1C.

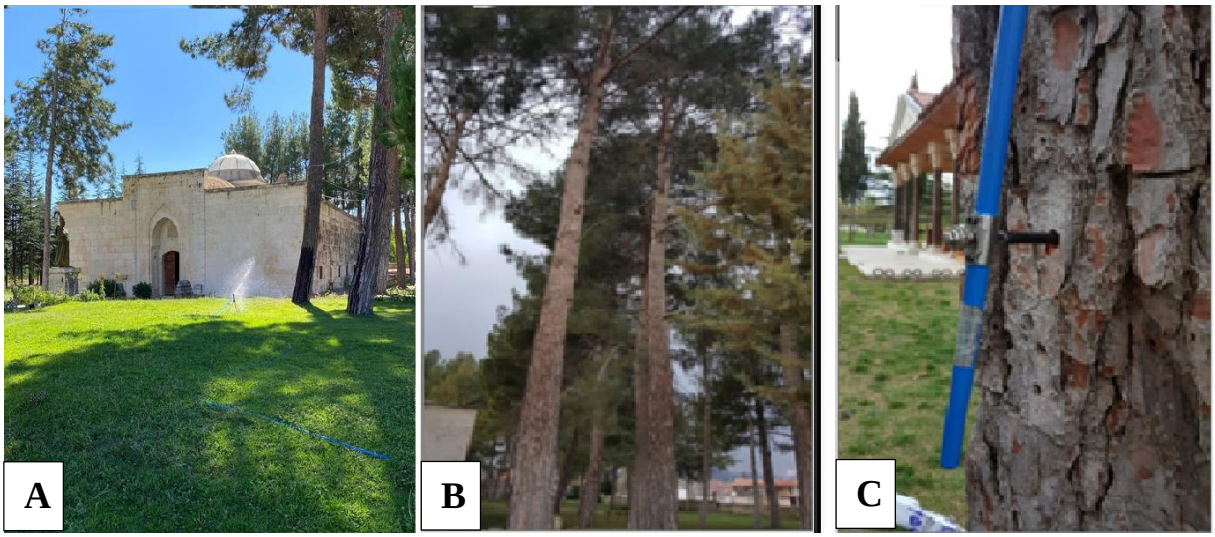


Figure 2.1. A and B: image of pine trees near the Ertokuş madrasah, C: image of receiving the increment core

After the increment core were removed, they were placed in plastic tubes and stored in a cooler bag. Later, increment cores was brought to Isparta University of Applied Sciences Faculty of Forestry to conduct experiments.

2.2. Determination of strength properties

Images of the increment cores were taken with a FLIR INFRACAM thermal camera (Figure 2.2). The characteristics of the thermal camera used in the measurements are given in Table 2.1.

Figure 2.2. Thermal camera used in the study

Table 2.1. Characteristics of the thermal camera used in the study

Operating temperature	−15°C +50°C
Storage temperature	−40°C +70°C
Battery type	Fast charging Li-ion battery
Lifetime	5 hour
Weight	0.34 kg
Dimension	223 mm x 79 mm x 83 mm
Measuring range	-20°C to +250°C

Thermal camera software and image analysis technique were used to evaluate the obtained images. Environmental temperature and relative humidity values were noted after the increment core were taken. These values were used during the measurements in the thermal camera software program. Surface temperature measurement images in the thermal camera software program are given in Figure 2.3.

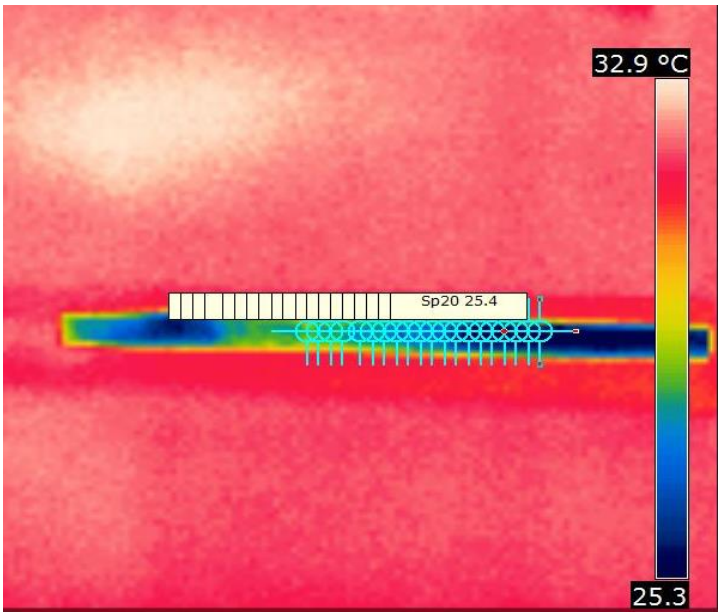


Figure 2.3. Surface temperature measurement image

The 5 mm increment core were first placed in the air conditioning cabin (20 C0, 65% relative humidity) and brought to 12% equilibrium humidity. In order to verify the temperature and relative humidity values displayed on the air conditioning cabin screen, the humidity and temperature meter device was placed

in the air conditioning cabin and measurements were made. The codes and properties of the increment core are given in Table 2.2.

Table 2.2. Tested increment core codes

Tree Number	Sample number	Code
1	1	1-a
1	2	1-b
1	3	1-c
2	1	2-a
2	2	2-b
2	3	2-c
3	1	3-a
3	2	3-b
3	3	3-c
4	1	4-a
4	2	4-b
4	3	4-c
5	1	5-a
5	2	5-b
5	3	5-c

The mechanical properties of the residuals were determined by the Fractometer device given in Figure 2.4. Measurements are made every 6 mm from the pith to the bark (Figure 2.5).

Figure 2.4. The image of the Fractometer device

Figure 2.5. Schematic image of measurement plan on increment core

To determine the resistance properties of wood, samples are generally prepared by cutting trees and resistance values are determined on the prepared samples in universal testing machines. In addition to the classical method, there is a device called "Fractometer", developed in cooperation with Instrumenta Mechanic Labor GmbH and Forschhungszentrum Karlsruhe, to determine some resistance properties without cutting down trees (Mattheck et al. 1995; Götz et al. 2002; Lin et al. 2007). In this study, in determining the increment items and resistance values, Chih-Ming et al. (2006) and Wang et al. (2008)

a parallel method to the method applied by was applied. In order to determine the compression strength and flexural strength properties of the Fractometer (Type II; IML, Germany) device, the experiments were carried out by placing the increment core in the chambers given in Figure 2.6. First of all, the bending strengths of the increment core from pith to bark were determined. Compressive strength tests were carried out by placing the increment core, whose bending properties were determined, into the compression strength determination chamber.

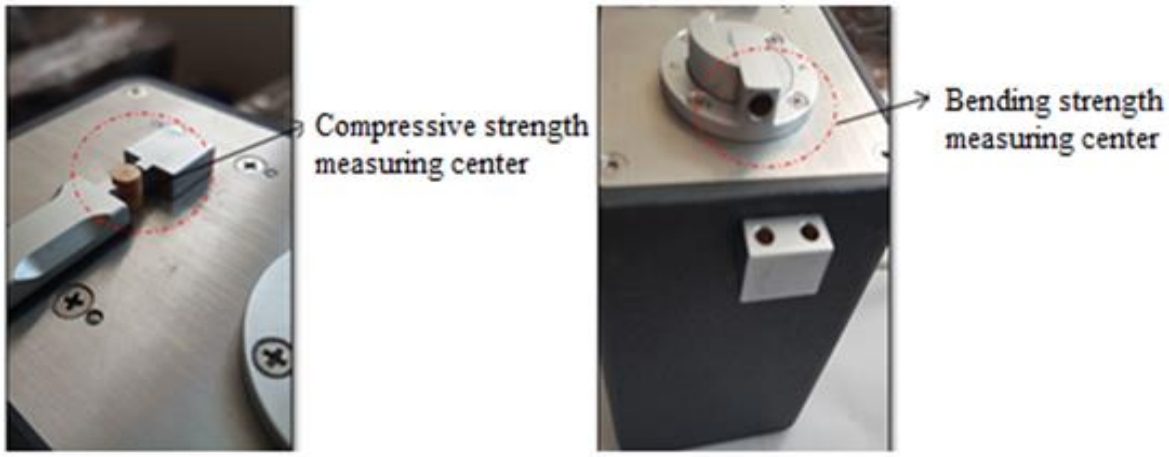


Figure 2.6. Bending and compressive strength measuring device

In addition to the fracture angle and radial bending strength, the Fractometer II measures longitudinal compression strength for a wood sample (Mattheck et al. 1995). The longitudinal compression strength is the resistance that the trunk opposes to a failure by applying axial stress. The fracture angle indicates whether the wood sample undergoes a brittle or non-brittle fracture while the radial bending strength is the resistance which the tree opposes to a failure by perpendicular stress (Lonsdale 1999).

2.3. Statistical Analysis

In the statistical analysis process, firstly, averages and standard deviations were determined for both compressive and bending strengths. Pearson correlation analysis was then applied to determine whether there was a significant relationship between compressive and bending strengths. All statistical analyses were performed in Rstudio software (Rstudio Team, 2020).

3. Results and Discussion

In this study, 3 increment core were taken from 5 different brutian pine trees in front of the madrasah. In order to determine the mechanical properties of the increment core, flexural and compressive strength values, thermal camera images were measured. Thermal camera images of the increment core are given in Figure 3.1, and surface temperature graphs are given in Figure 3.2. Thermal camera images of the increment core are given. It has been determined that the moisture content of wood material affects thermal camera images. Thermal image taken from the increment core in this study is similar to the data of the previous studies (Leuzinger et al. 2010; Simsek Turker, 2017; Beyaz and Ozkaya, 2021; Jiang et al. 2022). Therefore, the moisture content of the trees in front of the madrasah was determined to be equivalent to a brutian pine.

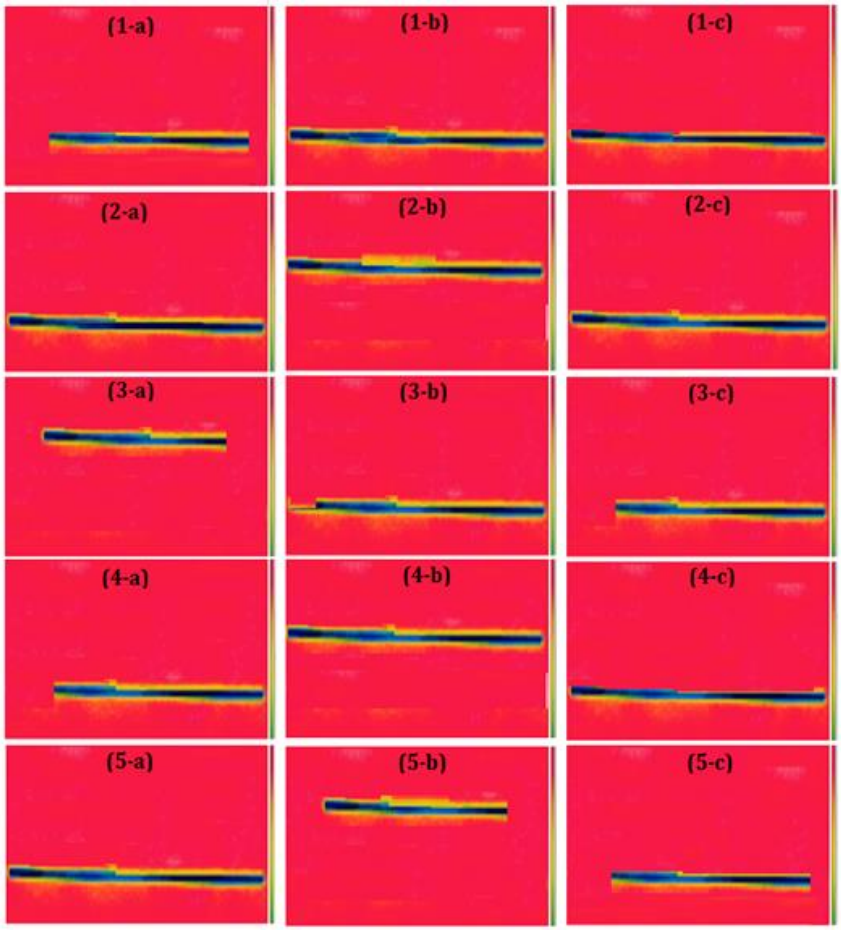


Figure 3.1. Thermal camera image of incremental core

For each sample, the average compressive and bending strength values were determined by calculating the mean of three individual measurements. These average values for compressive and bending strengths are comprehensively presented in Table 3.1. This approach ensures a robust and precise representation of the material's mechanical properties, as outlined in methodology.

Table 3.1. Means and standard deviations for compressive and bending strengths

			Compressive Strength		
Sample	1	2	3	4	5
Mean	36.14	38.79	37.83	36.38	36.48
Std. Dev.	3.67648	3.08735	3.89115	3.8472	4.61827
			Bending Strength		
Sample	1	2	3	4	5
Mean	62.19	63.07	62.90	60.33	58.24
Std. Dev.	6.74532	7.62158	8.20093	9.02229	9.97983

Pearson correlation analysis was applied using Rstudio software to determine whether there was a relationship between compressive and bending strengths.

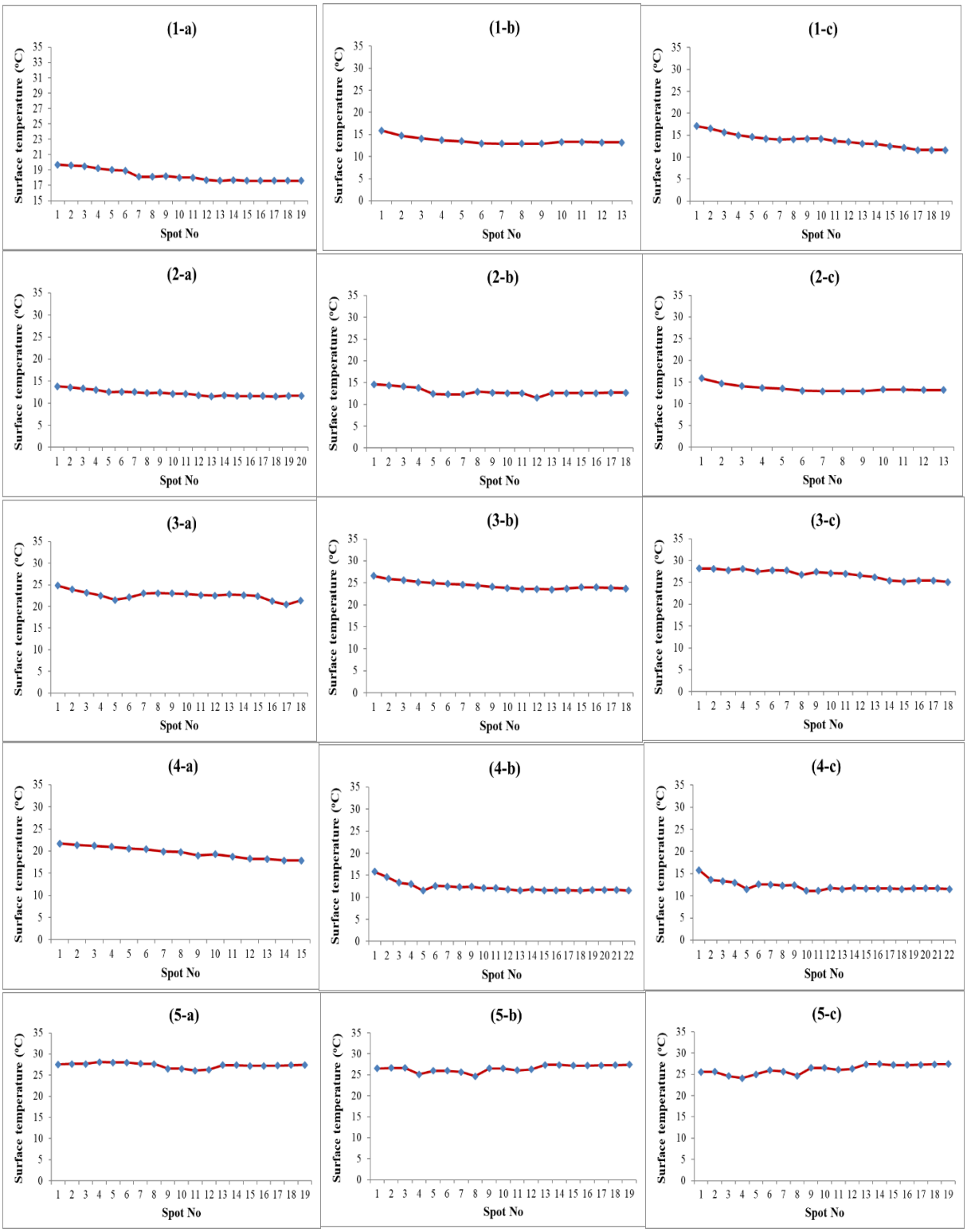
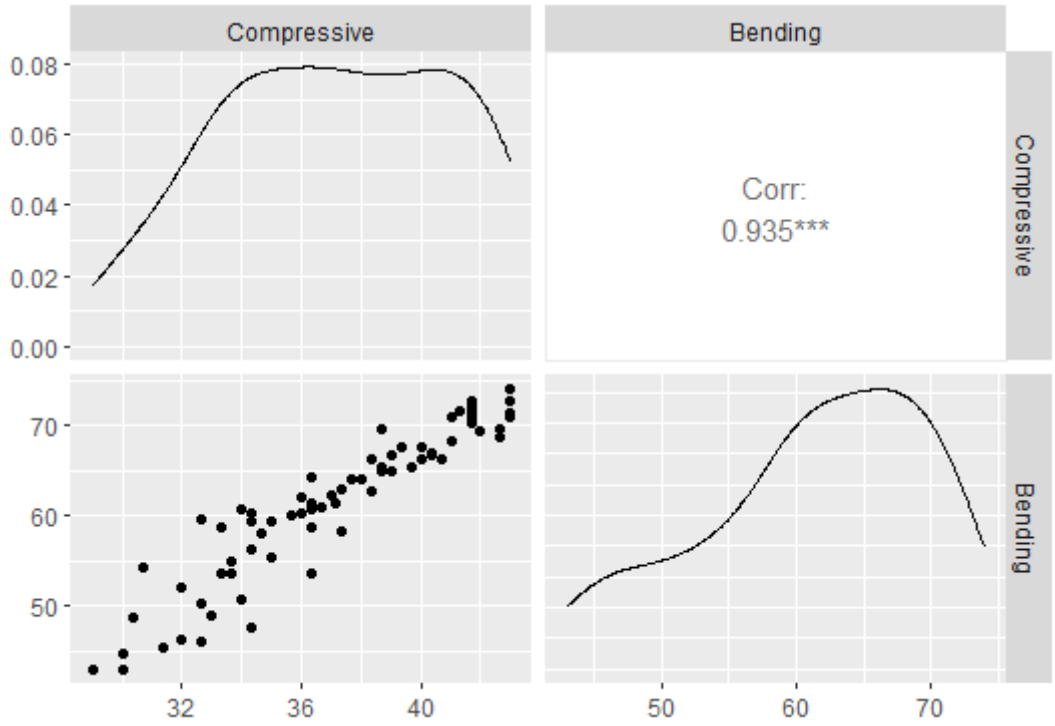


Figure 3.2. Surface temperature graphs of increment core

Upon close examination of Figure 3.3, a highly significant relationship ($p<0.001$) between compressive and bending resistances becomes evident. In essence, this relationship indicates that an increase in compressive strength corresponds to a concurrent increase in bending resistance. These findings underscore the strong correlation between these two parameters, which is a noteworthy observation in the context of study.



.

Figure 3.3. Pearson correlation analysis results between compressive and bending strengths

Figure 3.4 presents a graphical representation of the variations in compressive strength observed within the annual growth rings of the obtained incremental cores. Utilizing the Fractometer II device, compressive strength values of the brutian pine increment cores were assessed, revealing a consistent trend of increasing compressive strength values from the pith (innermost region) towards the bark (outermost region). The compressive strength of the brutian pine wood falls within the range of 27-44 MPa.

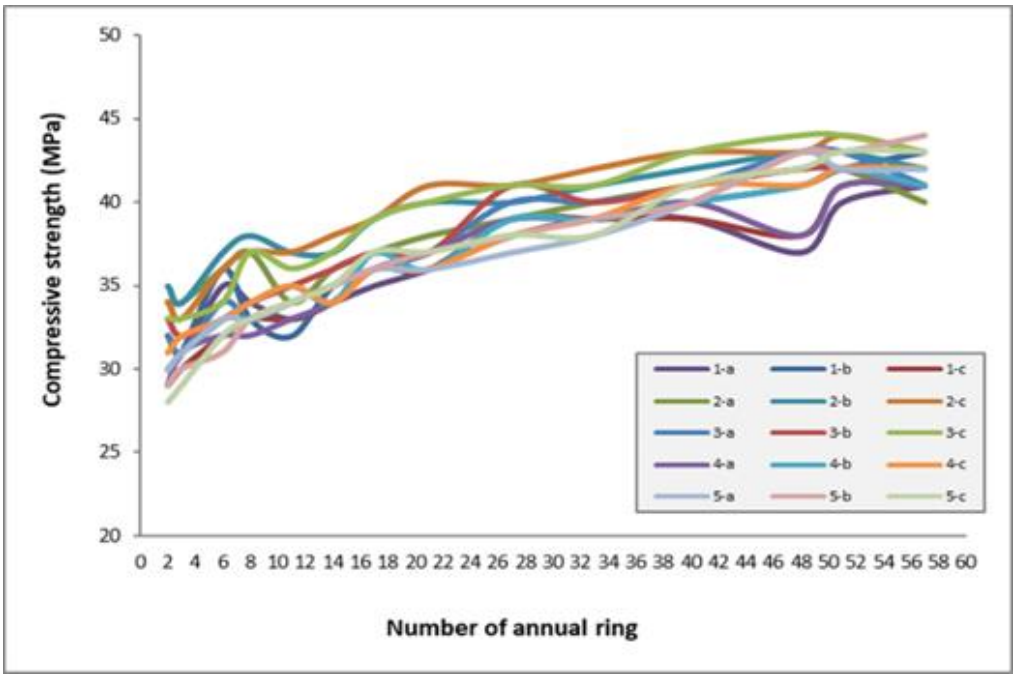


Figure 3.4. Compressive strength values based on annual ring

Notably, upon a comprehensive examination of the compressive strength data, it is evident that there is no discernible degradation in the mechanical properties of the wood. Furthermore, this consistency in results was reaffirmed by the similar compressive strength values obtained from increment cores extracted from five distinct trees. Şimşek (2017) measured the compressive strength of red pine wood increments in order to distinguish between young wood and mature wood. Red pine wood's compressive strength has been found to be between 20 and 50 MPa.

In the study, bending strength values of 6 mm were determined on the increment core. The bending strength values per annual ring are given in Figure 3.5. Upon examination of the bending strength values, a discernible trend emerged, indicating an increment in these values from the pith (innermost region) towards the bark (outermost region).

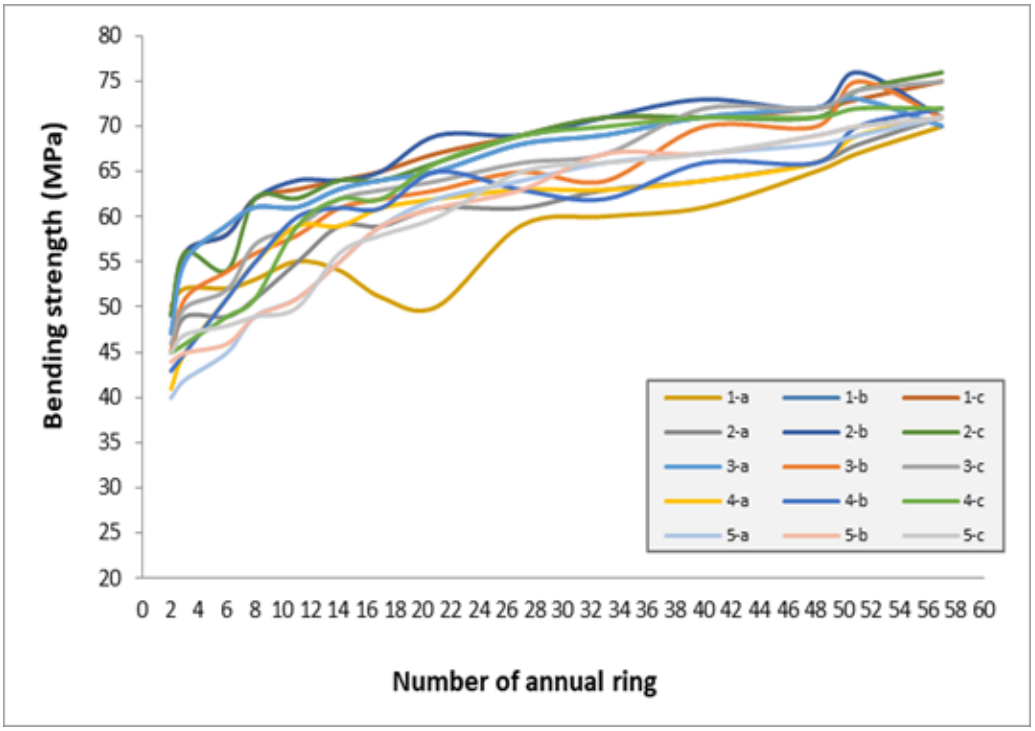


Figure 3.5. Bending strength values based on annual ring

This observed phenomenon aligns with findings articulated by Şimşek Türker (2017) and Clark (2007), who attribute this increase to the transition from the juvenile wood phase to the mature wood phase. Specifically, the bending strength values for brutian pine wood, as ascertained in this study, were found to range between 57 and 80 MPa. Notably, the work of Çetin and Gündüz (2017) provides a reference point, asserting that the resistance of pine trees typically hovers around 80 MPa. In contrast, the findings of the present study indicate a bending strength range of 40-75 MPa for brutian pine wood. Importantly, a meticulous analysis of these bending strength data demonstrates the absence of any significant mechanical property degradation. Furthermore, the consistency of results was reaffirmed through the parallel evaluation of increment cores collected from five distinct trees. A similar issue is revealed by other investigations in the literature. Data indicate compatibility (Lin et al., 2008; Wang et al. 2008; Matsumoto et al. 2010; Jonstone et al. 2010).

4. Conclusion

In this study, the compression and bending properties of standing trees were assessed using the non-destructive increment core method. Upon analyzing the data, it became apparent that the values for compressive and bending strength closely aligned with those of a typical, undried pine tree.

Additionally, upon evaluating the obtained bending and compressive strength values, a discernible pattern emerged, indicating a gradual decrease from the pith towards the bark. This finding sheds light on the structural variations within the tree and its implications for material properties.

Determining and monitoring the decay and cavities in the inner parts of the standing trees at the right time is an important issue in terms of taking the necessary protection measures for these trees. Depending on the species and environmental effects, after a certain age (especially in species whose heartwood is not resistant), fungus etc. With the effect of this effect, decay starts in the inner parts of the trees, and after a while, cavities are formed in these parts. Protection measures are taken when the internal cavities in some trees are visible or can be predicted with the help of some external indicators. However, when the rot and voids inside the trees cannot be detected from the outside, very valuable assets such as monumental trees and stands, which are taken under protection due to some of their qualities, are suddenly broken and overturned. In addition, trees in this situation in urban and roadside afforestation, wind, snow, etc. It can become a situation that threatens the safety of people and all kinds of objects by impacts or suddenly overturning.

As a result, it is of great importance to determine and follow up the rots and cavities in the inner parts of the planted trees, to protect these trees, to prevent material and moral damages, and to prevent situations that may even cost human life when appropriate. Determination and monitoring of mechanical losses in the interior of standing trees, protection of these trees, prevention of material and moral damages, and for preventing the situations that may even cost human life has great importance. So, it is possible to get an idea about them without cutting the trees, selection of sample trees in scientific studies or for the suppliers of wood raw materials.

References

Akbulut, S., Keten, A., Yüksel, B. (2008). Wood destroying insects in Düzce province. Turkish Journal of Zoology, 32(3): 343-350.

Akgün, K. 82008). The effects of tannin and heat treatment on some physical and mechanical properties of laminated chestnut (*Castanea sativa* mill.) wood. Zonguldak Karaelmas University, MsC Thesis, 79s, Zonguldak, Türkiye.

Allison, R. B., Wang, X., Ross, R. J. (2008). Visual and nondestructive evaluation of brutian pines supporting a ropes course in the USFS Nesbit Lake Camp, Sidnaw, Michigan. In Proceedings, 15th international symposium on nondestructive testing of wood. Madison, WI: Forest Products Society (pp. 43-48).

Aydemir, D., Gündüz, G., Altuntaş, E., Ertaş, M., Şahin, H. T., Alma, MH. (2011). Investigating changes in the chemical constituents and dimensional stability of heat-treated horn beam and uludag fir wood. BioRes, 6(2): 1308-1321.

Bethge, K., Mattheck, C., Hunger, E. (1996). Equipment for detection and evaluation of incipient decay in trees. Arboricultural Journal, 20(1), 13-37.

Bethge, K., Mattheck, C., Hunger, E. (1996). Equipment for detection and evaluation of incipient decay in trees. Arboricultural Journal, 20: 13–37.

Beyaz, A., Özkaya, M. T. (2021). Canopy analysis and thermographic abnormalities determination possibilities of olive trees by using data mining algorithms. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 49(1), 12139-12139.

Bozkurt, A.Y., Göker, Y. (1981). Orman Ürünlerinden Faydalanma. İstanbul Üniversitesi, Yayın No: 2840, 432 s. İstanbul.

Bravery, A. F., Berry, R. W., Carey, J. K., Cooper, D. E. (1987). Recognising wood rot and insect damage in buildings,3, Watford: Building Research Establishment.

Bucur, V. (2003). Nondestructive Characterization and Imaging of Wood, Springer Series in Wood Science, Springer-Verlag New York.

Catena, A. (1991). La Termografia per la salvaguardia di esemplari arborei monumentali (Thermography for safeguarding exemplary trees). Linea ecologica, 6: 18-20.

Catena, A. (2003). Thermography reveals hidden tree decay, Arboricultural Journal, 27: 27-42.
Catena, A., Catena, G., 2008. Overview of Thermal Imaging for Tree Assessment, Arboricultural Journal, 30: 259-270.

Catena, G. (1992). Using thermography as an application in phytopathology. Diagnosing the condition of sycamore trees. Phytoma La Defense des Vegetaux (France).

Catena, G., Catalano, M., Palla, L. (1990). Thermal infrared detection of cavities in trees. European Journal of Forest Pathology, 20: 201–210.

Catena, G., Catena, A. (2000). Termography for the evaluation of cavities and pathological tissues in trees, Agric Ricerca, 185: 47-64.

Çetin, F., Gunduz G. (2016). Türkiye'deki Bazı Ağaç Türü Odunlarının Fiziksel Özellikleri Üzerine Yapılan Araştırmaların Değerlendirilmesi. Bartın Orman Fakültesi Dergisi, 18(2): 175-193.

Chiu, C.M., Wang, S.Y., Lin, C.J., Yang, T.H., Jane, M.C. (2006). Application of The Fractometer for Crushing Strength: Juvenile-Mature Wood Demarcation in Taiwania (*Taiwanie cryptomerioids*), Journal Wood Science, 52: 9-14.

Clark, A., Daniels, R. F., Jordan, L. (2007). Juvenile/mature wood transition in loblolly pine as defined by annual ring specific gravity, proportion of latewood, and microfibril angle. Wood and Fiber Science, 2007; 38(2): 292-299.

Dragavtsev V., Nartov V.P. (2015), Application of thermal imaging in agriculture and forestry, European Agrophysical Journal, 2(1): 15-23.

Fang, Y., Lin, L., Feng, H., Lu, Z., Emms, G. W. (2017). Review of the use of air-coupled ultrasonic technologies for nondestructive testing of wood and wood products. Computers and Electronics In Agriculture, 137: 79-87.

Ganesan, S. K., Hamid, M. A. (2010). Survey of wood strength properties of urban trees in Singapore using the Fractometer II. Journal Of Tropical Forest Science, 97-105.

Jiang, A., Noguchi, R., Ahamed, T. (2022). Tree trunk recognition in orchard autonomous operations under different light conditions using a thermal camera and faster R-CNN. Sensors, 22(5), 2065.

Jones, D., Sandberg, D., Goli, G., Todaro, L. (2019). Wood Modification in Europe: a state-of-the-art about processes, products and applications (p. 123). Firenze University Press.

Johnstone, D., Moore, G., Tausz, M., & Nicolas, M. (2010). The measurement of wood decay in landscape trees. *Arboriculture & Urban Forestry*, *36*(3), 121-127.

Kaya, A. İ., Yalçin, Ö. Ü., Türker, Y. (2021). Physical, Mechanical and Thermal Properties of Brutian pine Wood-Gypsum Particleboard. Bilge International Journal of Science and Technology Research, 5(2), 139-145.

Kilinçarslan, Ş., Türker, Y. Ş. (2021). The Effect of industrial heat treatment on the wettability and dimensional stability of ash (Fraxinus excelsior) wood. Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 25(3), 473-480.

Kilinçarslan, Ş., Türker, Y. Ş., İnce, M. (2020). Prediction of heat-treated cedar wood swelling and shrinkage values with artificial neural networks and random forest algorithm. Mühendislik Bilimleri ve Tasarım Dergisi, 8(5), 200-205.

Leuzinger, S., Vogt, R., Körner, C. (2010). Tree surface temperature in an urban environment. Agricultural and Forest Meteorology, 150(1), 56-62.

Li, H., Zhang, X., Li, Z., Wen, J., Tan, X. (2022). A review of research on tree risk assessment methods. Forests, 13(10), 1556.

Lin, C,J., Wang, S.Y., Chiu, M.C. (2007). Crushing strength sampling with minimal damage to taiwania (*Taıwanıa cryptomerıoıdes*) using a fractometer, Wood and Fiber Science, 39(1): 39 – 47.

Lin, C. J., Wang, S. Y., Yang, T. H., & Tsai, M. J. (2006). Compressive strength of young Taiwania (Taiwania cryptomerioides) trees grown with different thinning and pruning treatments. Journal of Wood Science, 52, 337-341.

Llana, D. F., Short, I., Harte, A. M. (2020). Use of non-destructive test methods on Irish hardwood standing trees and small-diameter round timber for prediction of mechanical properties. Annals of Forest Science, 77, 1-13.

Lonsdale, W. M. (1999). Global patterns of plant invasions and the concept of invasibility. Ecology, 80(5): 1522-1536.

Mattheck CG, Breloer H, Bethge KA, Albrecht W & Zipse A. 1995. Use of the Fractometer to determine the strength of wood with incipient decay. Journal of Arboriculture 21:105-112.

Malanowski, N., Bachmann, G., Hutapea, L., Kaiser, O. S., Knifka, J., Ratajczak, A., Rijkers-Defrasne, S. (2019). Monitoring Innovations-und Technologiepolitik (Zyklus 1): Ergebnisbericht (No. 152). Working Paper Forschungsförderung.

Matsumoto, K., Ishiguri, F., Iizuka, K., Yokota, S., Habu, N., Yoshizawa, N. (2010). Evaluation of compressive strength of decayed wood in *Magnolia obovata*. Journal of Arboriculture, 36(2), 81.

Matsumoto, K., Ishiguri, F., Iizuka, K., Yokota, S., Yoshizawa, N. (2008). Evaluation of bending and compression strength of wood using fractometer. Wood Industry, Japan.

Mattheck, C., Kubler, H., Mattheck, C., Kubler, H. (1997). Stress-controlled strength distribution. Wood-The Internal Optimization Of Trees, 90-108.

Riggio, M., Anthony, R. W., Augelli, F., Kasal, B., Lechner, T., Muller, W., Tannert, T. (2014). In situ assessment of structural timber using non-destructive techniques. Materials and Structures, 47, 749-766.

Ross, R. J., Soltis, L. A., Otton, P. (1998). Assessing wood members in the USS Constitution using non-destructive evaluation methods. Apt Bulletin-Fredericksburg Va-, 29, 21-26.

Ross, R.J., Pellerin, R.F. (1991). Stress wave evaluation of green material: preliminary results using dimension lumber. Forest Products Journal, 41(6): 57–59.

Ross, R.J., Pellerin, R.F. (1994). Nondestructive testing for assessing wood members in structures: A review. Gen. Tech. Rep. FPL-GTR-70 (Rev.). Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 40 p.

RStudio Team (2020). RStudio: Integrated Development for R. RStudio, PBC, Boston, MA URL http://www.rstudio.com/.

Şimşek Türker, Y. (2017). Applicability of thermography in determination of juvenile wood part in *Pinus brutia*. Süleyman Demirel Üniversitesi, Fen Bilimleri Enstitüsü, Orman Endüstri Mühendisliği Anabilim Dalı, 107 s., Isparta.

Tang, A. M. C., Chu, P. P. L., Leung, M. W. K., Chu, L. M., Liao, W. H. (2016). Evaluating wood strength properties of subtropical urban trees using fractometer II. Journal of Tropical Forest Science, 249-259.

Tang, A. M. C., Chu, P. P. L., Leung, M. W. K., Chu, L. M., Liao, W. H. (2016). Evaluating wood strength properties of subtropical urban trees using fractometer. Journal Of Tropical Forest Science, 2016; 249-259.

Tannert, T., Anthony, R. W., Kasal, B., Kloiber, M., Piazza, M., Riggio, M., Yamaguchi, N. (2014). In situ assessment of structural timber using semi-destructive techniques. Materials and Structures, 47, 767-785.

Wang, X., Allison, R. B. (2008). Decay detection in red oak trees using a combination of visual inspection, acoustic testing, and resistance microdrilling. Arboriculture & Urban Forestry, 34(1), 1-4.

Wang, S. Y., Chen, J. H., Hsu, K. P., Lin, C. J., & Jane, M. C. (2008). Ring characteristics and compressive strength of Japanese cedar trees grown under different silvicultural treatments. Wood and Fiber Science, 384-391.

Yıldız, S. (2002). Isıl işlem uygulanan doğu kayını ve doğu ladini odunlarının fiziksel, mekanik ve kimyasal özellikleri. Karadeniz Teknik Üniversitesi, Doktora Tezi, Trabzon-Türkiye.

Yu, T., Sousa, H. S., Branco, J. M. (2020). Combination of non-destructive tests for assessing decay in existing timber elements. Nondestructive Testing and Evaluation, 35(1), 29-47.

Zevgolis, Y. G., Alsamail, M. Z., Akriotis, T., Dimitrakopoulos, P. G., Troumbis, A. Y. (2022). Detecting, quantifying, and mapping urban trees' structural defects using infrared thermography: Implications for tree risk assessment and management. Urban Forestry & Urban Greening, 75, 127691.

Živanović, I., Poduška, Z., Rakonjac, L., & Jovanović, F. (2019). Potentials of the evaluation of the wood quality in living trees by using semi-and non-destructive methods in order to reduce wood-processing costs. Sustainable Forestry: Collection, (79-80), 115-126.

Submitted: 13.09.2023 Accepted: 26.10.2023