SILVA BALCANICA

Silva Balcanica 26(1): 65-80 (2025)
doi: 10.3897/silvabalcanica.26.e124633

RESEARCH ARTICLE

Effects of biotopes on the quality of cherry wood (*Prunus avium*) in Tunisia

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Academic editor: Georgi Georgiev | Received 03 April 2024 | Accepted 05 August 2024 | Published 11 June 2025

Citation: NouriJ., Houcine S., Chaabane A. 2025. Effects of biotopes on the quality of cherry wood (*Prunus avium*) in Tunisia. Silva Balcanica 26(1): 65-80. https://doi.org/10.3897/silvabalcanica.26.e124633

Abstract

Cherry (*Prunus valium* (L.) Rosaceae) is native to Europe, Afghanistan and North Africa. Its native range extends from the British Isles to Morocco and Tunisia down south, to the region of Norway in the north, the Caucasus in the east and northern Iran, Anatolia, Maghreb, and Western Asia in the west. There is also a small, isolated population located in the western Himalaya. The plant has been extensively farmed in other parts of the world and is now native to Australia, New Zealand, and North America. This species is exploited in forestry for its quality of wood. The objective of this study is to evaluate the physical and mechanical properties of cherry wood and to investigate the influence of growth sites to provide value-added assessment pathways. The study was carried out within the Tabarka and Ain Draham stations. In each site, we selected 75 dominant *P. avium* specimens. The dendrometric characteristics, the observations of the degree of infection, the straightness of the stems, and the physico-mechanical properties were studied. The result of the statistical analysis showed a significant difference in the dendrometric parameters according to the stations. The results obtained showed that 66% of the trees inventoried in Tabarka have straight stems. The number of trees affected by rot varies according to the stations, with 44% in Ain Draham. The rate of decay varies with age, so most infected trees are old (diameter at breast height > 30 cm). The wood is characterized by a density of 627 to 629 kg/m3 and is classified as medium hardwood with a Monnin hardness of approximately 4.3. Moreover, the values of the static bending breaking stress and the axial compression vary respectively from 94.95 to 99.85 MPa and from 44.5 to 51.7 MPa. These values vary according to the sources and have a significant effect at the 1% level. Accordingly, we classify cherry wood as having moderate strength.

Cherry was cultivated for its noble uses such as interior carpentry and cabinet making as an excellent alternative to very expensive precious woods. Thus, in order to improve the condition of the trees, careful monitoring of the plantations must be carried out.

Keywords

P. avium, Tunisia, wood, technological properties, rots

Introduction

All silvicultural practices produce effects on wood properties and thereafter on market value. For instance, practices such as initial planting, growing space, thinning and / or timing and intensity of pruning may have a great influence on the extent of branching and therefore on the final product (Gort et al., 2010; Carson et al., 2014). Silvicultural practices have an impact on the structure of the forest stand. Peltola et al. (2007) showed that thinning artificially alters stand structure, opening up space for remaining trees and increasing light, temperature and air currents within the canopy. Similarly, the remaining trees grow more in diameter, developing larger crowns with larger branches (Gort et al., 2010). Thinning also has important effects on tree structure, reducing the photosynthetic capacity of trees, decreasing their growth (Neilsen and Pinkard, 2003) and producing more cylindrical trees (Zobel and Van Buijtenen, 1989).

Recognizing standing trees that have resonance wood has always been a challenge for luthiers. Long-time observations revealed the distinct physiognomy of resonance trees (Domant, 2019), but the topic remained somewhat unsolved until some of the physiognomic features were acoustically verified (Fedyukov et al., 2018). The literature provided a few morphological descriptors of the stem and crown of resonance trees (Zugliani and Dotta, 2009a) and of raw resonance wood (Zugliani and Dotta, 2009b). Normally, the width of the bark reflects the growth traits of the tree (Popescu, 1984) and, with these; they are related to age and site (Arco Molina 2016). Besides the ecological and functional significance, bark morphology can be a good indicator of wood properties (Wang et al., 2011). The study of the characteristics of the wood of standing trees is very important from the point of view of certain properties of the wood. Stem shape and frequency of injury and rot are the most important determinants of wood quality for saw timber production and depend on poor forest management and competition from neighboring trees.

P. avium occurs naturally in all temperate forest regions from Europe to Afghanistan and in the North African regions (Welk et al., 2016). Wild cherry (is a forest fruit tree of the Rosaceae family (Hedhly et al., 2004), its growth is quite rapid with an erect habit, which exceeds 20 to 30 m in height in about 80 to 90 years (Stojecová and Kupka, 2009) with an average diameter around 50 cm at breast height (Stojecová and Kupka, 2009). Wild cherry is a mesophytic, relatively shallow-rooting, light-demanding species that can grow in quite a variety of soil types. However, it prefers deep fertile soils with a good water supply. The tree does not tolerate heavy, waterlogged, or poorly drained clays and can be sensitive to drought (Jdaidi and Hasnaoui, 2017, Jdaidi et al., 2019). This species can be found and adapted under varied climatic conditions, yet good quality wood production should be an exigent demand because of its role in the wood processing industry (Jdaidi et al., 2014). *P. avium* is known as an economic species for local people in Tunisia. It is used in various fields such as forestry for its quality wood and in horticulture for its fruits and its capacity as a rootstock for *Prunus* varieties (Jdaidi et al., 2022). Wild cherry is one of the noble hardwoods (Jdaidi, 2023).

Recently, the use of wild cherry wood has gained popularity in Tunisia due to the high demand for this species. The technological properties and characteristics of the wood of this species have been studied previously, but there is little or no information on how heat treatment would affect its mechanical and physical characteristics.

Because of human activity using the cherry trees' wood for cabinet making and as a rootstock, wild cherry wood experienced a significant perturbation over time in all the regions in Tunisia.

The main object of this study is to examine the physical and mechanical properties of cherry wood and to study the influence of the biotope to ensure value-added evaluation ways.

Material and methods

Methods

Study area

The study was carried out in the two most populated cherry stations in Tabarka (N36°52'10"E008°46'33") and Ain Draham (N36°46'13"E008°46'36") in northwestern Tunisia (Figure 1). These two forests have a moderately rugged relief (5 to 15%). The altitude varies between 200 and 600 meters in Tabarka (seaside) and between 600 and 1100 meters in Ain Draham.

The study area is located in a humid Mediterranean bioclimatic stage that goes from the warm winter variant in the Tabarka region to the temperate winter variant

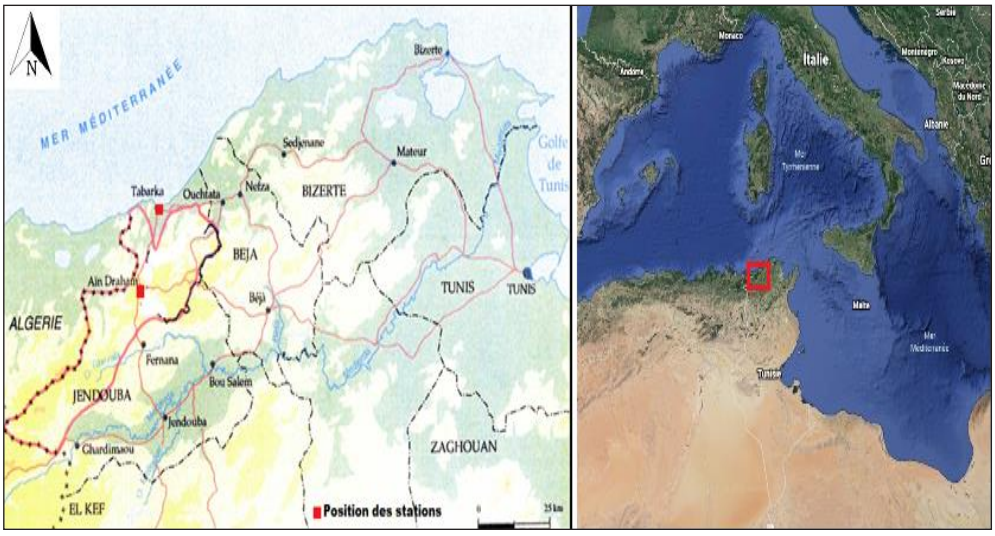

Fig. 1. Location of the two sampling sites in northwestern Tunisia

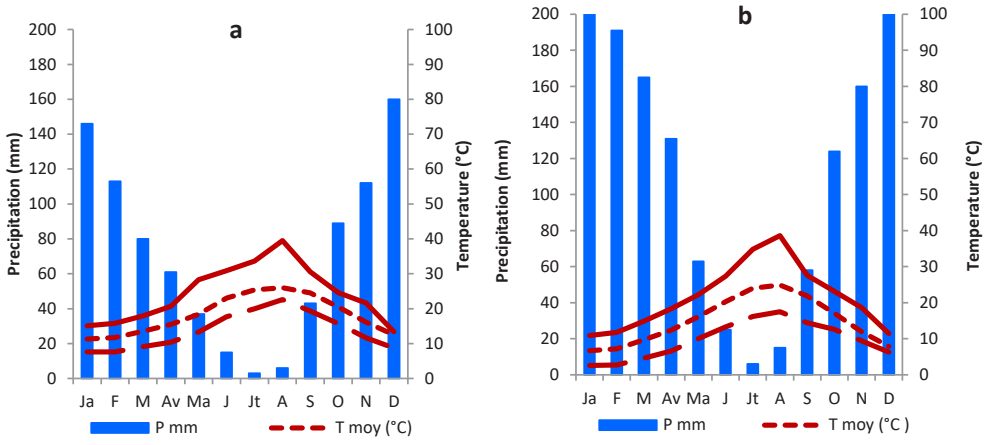

Fig. 2. Ombrothermic diagram of Bagnouls and Gaussen (Gaussen and Bagnouls, 1953) of the Tabarka station (a) and Ain Draham (b)

in the Ain Draham region. According to the data collected from the two meteorological stations of Tabarka and Ain Draham, the average annual rainfall ranges from 980 – 1512 mm respectively, while a minor variation in the annual average temperature occurred between the two sites (11 – 13°C). The data from the ombrothermal diagrams showed the presence of dry summer periods at the two stations Ain Draham (3 months) and Tabarka (5 months) (Figure 2). The prevailing winds in winter and spring blow from north to west.

Within our study area, *P. avium* is associated with *Quercus canariensis*, *Quercus suber*, *Viburnum tinus*, *Erica arborea*, *Myrtus communis* and *Rhamnus alaternus* (Jdaidi et al., 2022).

Characterization of standing cherry wood

We have selected a set of 150 dominant trees of *P. avium* in the two stations which are distributed as follows; 75 trees in Tabarka and 75 trees in Ain Draham. On each of the trees we measured: the total height, the merchandise height, the diameter at 1.30 m, the diameter at 1.50 m, and the diameter at mid-height were measured. We counted all the rots (Figure 4) on each stem:

- healthy (0 rot);
- moderately infected (1 – 2 rots);
- heavily infected (> 2 rots).

The shape of the rod and the length of the curvature are determined using a square and a tape measure:

-straight upper (no curvature);
- stem with simple curvature: 1 flexion of the trunk of 2 – 5 cm;
-stem with complex curvature: > 2 flexions of the trunk of 2 – 5 cm.

Fig. 3. *P. avium* in a forest environment (Photo by N. Jdaidi, 2019)

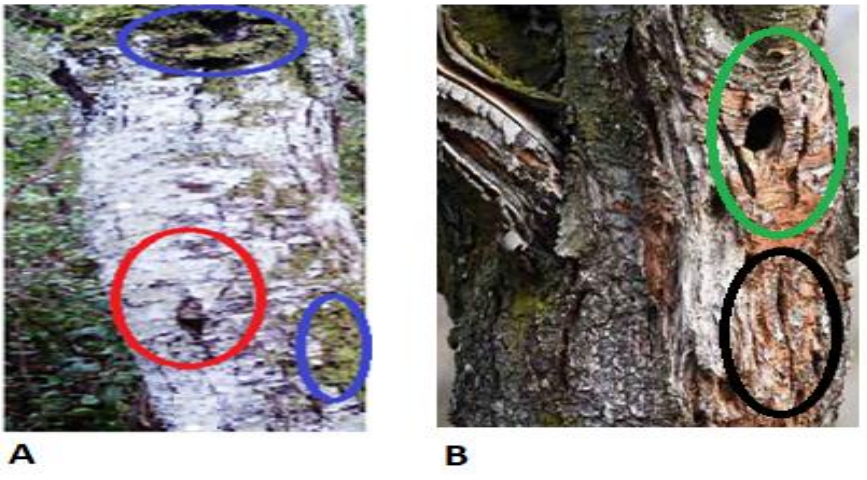

Fig. 4. Identification of white rot (red circle) and lichens (blue circle) (photo A) and holes (brown circle), red rot (black circle) (photo B)

Technological properties of cherry wood

To study the technological properties, we focused on wood samples from three cherry trees of the same age (60 years) for each population (Tabarka and Ain Draham). The experimental material includes a dozen specimens 1.2 m long and 2 cm thick taken from each source (Figure 5).

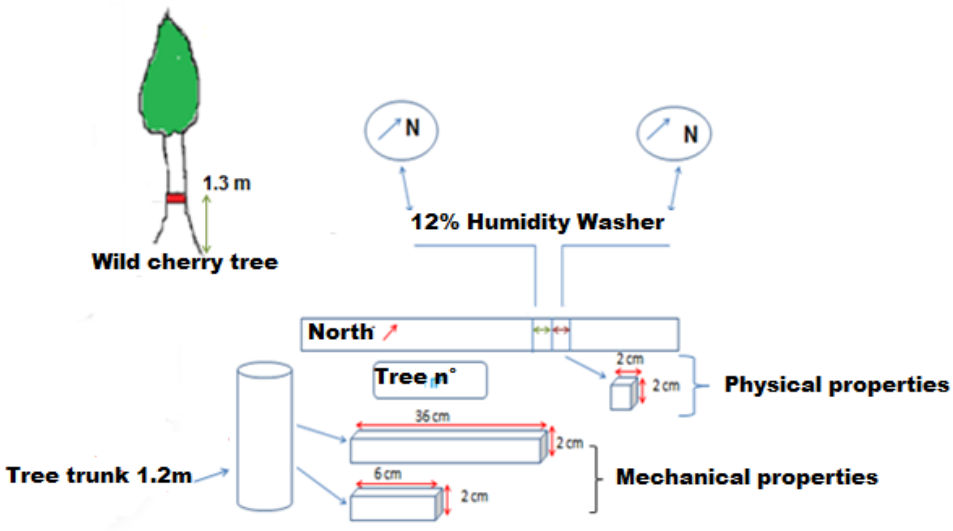

Fig. 5. Specimen sampling method for the 12% humidity and mechanical properties tests

Moisture density 12%

To determine the moisture density, we followed the following protocol: First, we cut four 1.2 m logs two each station in the form of 20 mm thick washers. Then, we traced on the transverse face strips 2 mm thick in the longitudinal direction. Then we drew strips with thicknesses of 2 mm perpendicular to the first in transverse direction to obtain cubes of 20 mm * 20 mm (Figure 5). In total, we took 320 specimens for each station. Subsequently, we place the samples taken in a particular temperature (20°C) and relative humidity (65%) condition, which corresponds to 12% humidity in the wood. The wood balance (12%) is reached when the mass of the cubes is stabilized. We measure the mass and dimensions of specimens using a precision digital caliper with an accuracy of 0.01g. The density of each sample was calculated by the following equation (1):

$$D\ 12\% = M/V \quad , V = L \times l \times e \qquad (1)$$

D represents the density 12%, M (kg) is the mass of the sample, V is the volume of the sample after stabilization at 12%, and L (m), l (m), and e (m) are the lengths, the average width and the average thickness of the test sample in mm, respectively.

Mechanical properties

For each site, six 1.2 m ridges were cut into two small 42 cm ridges. Subsequently, the 42 cm specimens were cut in the form of 20 mm thick specimens according to the following protocol (Figure 5):

- For the compression test, the length is 60 mm;

Fig. 6. The measurement of the mass of the test pieces by using a precision balance (photo A) and the dimensions following the three RTL directions (photos B and C) using a precision digital caliper

- For the static bending test, the length must be 360 mm.

A total of 240 specimens were cut, 120 for each site for the two tests. The specimens were conditioned at 65% relative humidity and 24° C. to obtain a wood humidity of 12%. These tests were performed using a Controls Accredia LAT #092 universal test machine, which has an accuracy of approximately 2 microns in measuring sag (Figure 6).

Static bending

Three-point static bending tests were performed. The specimen size was 360 x 20 x 20 mm^3 (L x R x T). At constant speed, the machine causes the break of the specimen within 2.5 ± 0.5 min (Fig. 7). The flexural strength (σ_ω), is expressed in Mega Pascal (MPa), and represented by the following equation;

$$\sigma_\omega(f) = \frac{3\,FRr\,I}{2\,b\,h^2} \qquad (2)$$

FRr: the breaking load in Newton N;
I: distance between the centers of support in mm;
h: height of the specimen in mm;
b: dimensions of the cross section of the test specimen, in millimeters.

Axial compression

The application of the load should continue for 1.5 to 2 minutes until the specimen breaks. The maximum load of the tensile stress parallel to the fibers of the axial compression was determined (Figure 7). The measured breaking stress σ_w is expressed, with its reference in humidity, in mega Pascal and is calculated by the following formula (3):

$$\sigma_\omega(c) = \frac{Frm}{a \times b} \qquad (3)$$

Frm: maximum load in Newton;
a and b: the dimensions of the cross section of the specimen, in millimeters.

A B

Fig. 7. Device for the measurement of the axial compression and static binding of cherry wood

Statistical analyzes

For the statistical analysis (mean, standard deviation, etc.), the dendrometric variables (total height, market height, diameter at 1.30 m, and diameter at 1.50 m) relating to selected attacked and healthy trees at each station were calculated. In addition, the influence of the provenance on the rate of decay, the physical and mechanical properties were determined. The differences in the obtained values are evaluated by using XLSTAT software, one-way analysis of variance (ANOVA), and the Newman Keuls test for ranking of means. The results were considered significant when $P \leq 0.05$.

Results and discussion

Sites effect on the different dendrometric properties of wild cherry

As illustrated in figure 8, there is a significant difference in the dendrometric parameters (density, mean diameter, dominant diameter, and mean total height) of natural populations of *Prunus avium* from Tabarka and Ain Draham. Indeed, the average density of trees is higher at the level of the origin in Tabarka than that in Ain Draham and is evaluated at 45 trees / ha and 35 trees /ha, respectively. The average and dominant diameters of the trees were evaluated in the two stations. It was approximately 13.2 cm and 32.2 ± 2.7 cm in the station of Tabarka and approximately 15.6 ± 5.5 cm and 42.1 ± 1.7 cm in the station of Ain Draham.

The average total height of the trees is estimated to be 9.0 ± 3.6 m in Tabarka and 11.5 ± 1.6 m in Ain Draham. As we can see, there is no significant difference in the cutting height average of the provenances of Tabarka and Ain Draham.

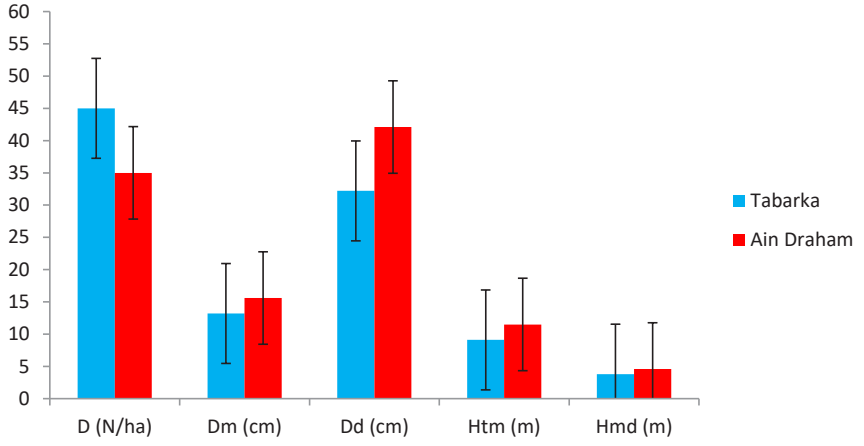

Fig. 8. Comparative study of the dendrometric parameters of wild cherry trees from Tabarka and Ain Draham in north-western Tunisia

D: Density (N / ha); Dm: Average diameter (m); Dd: Dominant diameter (cm); H-tm: Average total height (m); H-md: Average cutting height (m).

In this section, the overall study has been investigated. The average and dominant diameters of the trees are evaluated at 13.2 cm and 32.2 ± 2.7 cm in Tabarka and at 15.6 ± 5.5 cm and 42.1 ± 1.7 cm in Ain Draham. However, the average of the total height of the trees in both regions is estimated at 9.0 ± 3.6 m (Tabarka) and 11.5 ± 1.6 m (Ain Draham). These outcomes in performances showed that the stands of the Tabarka region are less vigorous than those of Ain Draham. Thus, this result can be explained by the average density of trees for the provenance of Tabarka which is higher than that of Ain Draham.

Cherry is a sensitive species to the competition which greatly reduces its growth and affects its straightness (Franc and Ruchaud 1996). Therefore, the density has influenced the dendrometric characteristics of the trees at each station.

This competitive factor can be added to climatic characteristics and in particular the number of dry months which is higher at Tabarka station than at Ain Draham station. Indeed, the station in Tabarka has 5 dry months compared to Ain Draham station with only 3 dry months (ombrothermal diagrams).

Variation of stem shape classes according to provenance

By examining figure 9, we notice that the rate of inventoried trees with straight stems and stems with simple curvatures varies with the provenances at the 1% threshold. According to the same figure, trees with straight stems are better represented in Tabarka with a rate of 66%. On the other hand, a rate of 57% of the trees inventoried cover Ain Draham is characterized by simple curvatures of 2 to 5 cm in length. However, rods with complex curvatures do not show a significant difference (P> 0.05).

According to the results in this section, the inclination or basal curvature of wild cherry trees from Ain Draham is generally linked to the phenomenon of slope and deformation of snow at a young age.

To evaluate the stem shape of the cherry tree in this study, it is clearly shown that the maximum of the trees in the Tabarka population has straight stems; however, 57% of the trees in Ain Draham station have simple curvatures of 2 to 5 cm. In this matter, the deformation and severity of the stems can be explained not only by the action of climatic factors such as wind and snow but also by the absence of silvicultural interventions. Falcone (1986) already specifies the factor that influences the shape of the trees in the stand. He proposed that this factor is related to the silvicultural treatment and in particular the mode of breeding of the plants, the density of the stand, and the maintenance of the plantations, etc. Further, by examining the health of the stem of the cherry from the two provenances, it is clearly shown that some trunks and branches are affected by severe heart rots in individuals with diameters greater than or equal to 40 cm. According to Nepveu (1992), the main factors influencing the quality of cherry wood are tree shape and diameter, as well as heart rots and other internal defects. Thus, it is very difficult to get healthy cherry trees of good size. The wild cherry that exists in the Tabarka and Ain Draham resorts has undergone nosilvicultural intervention. In this regard, our species often strives for nutrition and light by competing with *Quercus canariensis*, *Quercus suber*, *Viburnum tinus*, *Erica arborea*, *Myrtus communis*, and *Rhamnus alaternus*. In this case, a good selection will ensure the straightness and pruning of the preselected stand. Thereby, cleanses will take place for the benefit of the most beautiful dominant stems to ensure their growth. All of this will lead to an overall improvement of the stand (Falcone 1986).

Variation of the tree rots number with the provenances

The data illustrated in figure 10 shows a significant difference at the 1% threshold for healthy trees which are slightly affected by rots depending on the provenance. According to the result, the healthy wild cherry trees inventoried in Ain Draham were about 21% while the less infected with white or red rots can reach 49%. At the station of Tabarka, the healthy individuals presented about 40% and the inventoried trees slightly infected by rots were about 27%. In contrast, there is no significant difference in the stems heavily infected with rots between the two stations which presented 33% in Tabarka and 30% in Ain Draham.

Considering the age of the tree, the results obtained reveal that the healthy cherry trees at the two stations Tabarka and Ain Draham does not exceed 40 years, however, the trees that are over 45 years are all infected with red or white rots, holes, and fungi (lichens).

This species is particularly more susceptible to wounds and white or red rots on the trunk. In our study area, it is very difficult to find healthy cherry trees with large diameters (> 40 cm) and good dimensions. Two types of rots were distinguished on the inventoried trees; the white rot always begins at the bottom of the foot and never

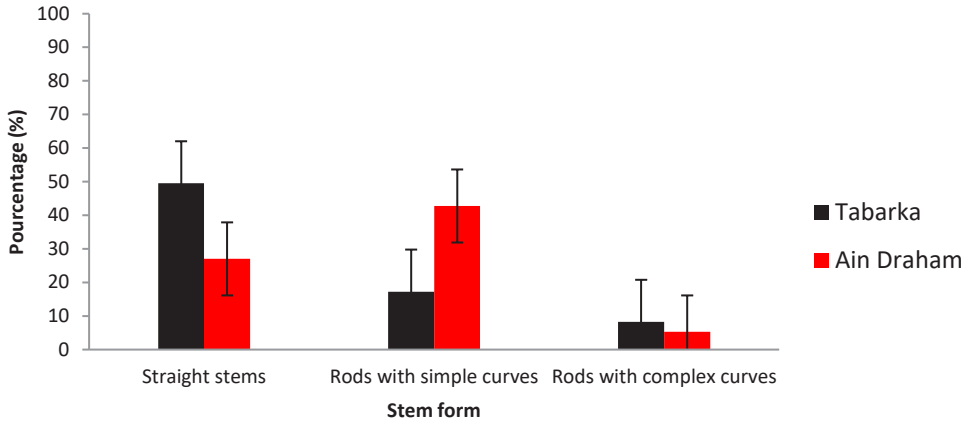

Fig. 9. Comparison of stem shape classes with the provenances studied

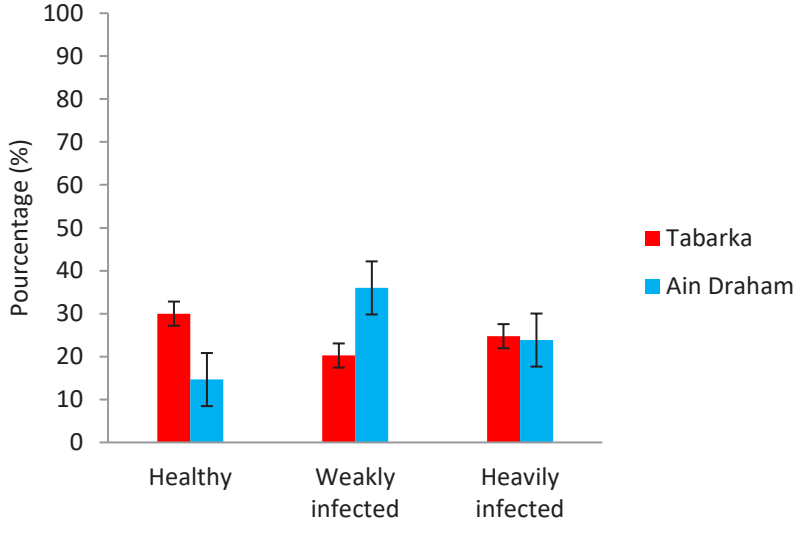

Fig. 10. Rate rots variation with provenance

goes up very far in the observed trees while the red rot is the most dangerous: it develops at the level of the foot and level of the top of the tree through wounds and fungi (lichens).

Similar information concerning the wood was obtained by Majcen et al. (2005) for other wood species. They have shown that the quality of the wood depends on the curvature of the rod, in order to ensure maximum use of the volume of wood for the sawmill industry. It also depends on the vigor of the stem, which influences the quantity of wood to ensure sufficient quality for the various areas of the wood processing industry.

Furthermore, the quality of the wood also depends on the proportion of heartwood which has an added value especially the aesthetics of the wood (color) and resistance to fungi and insects. It depends on the vigor of the tree in the sense that a diseased or poorly vigorous tree frequently contains discolored or "stained" areas of lower commercial value for cherry wood (Nolet et al. 2007; Nepveu 1992).

Influence of provenance on the physical and mechanical properties of the wood

As illustrated in table 1, the average values of the density at 12% of cherry wood are very similar for the two stations of Tabarka (627 kg / m^3) and Ain Draham (629 kg / m^3). Hence, there is no significant difference between density and sites ($P < 0.05$). According to the values of the density obtained at 12%, it is possible to classify the woods studied as light wood. As shown in the same table, the site at the 1% threshold had a significant influence on the mechanical properties (axial compression and static bending) of the timber in both regions. In this matter, the mean values of the static bending stress vary from 94.95 MPa for the population of Tabarka to 99.8 MPa for the population of Ain Draham. However, the values of axial compression are more significant in Ain Draham (51.7 MPa) than in Tabarka (44.5 MPa). In general and according to the classification scale of Keller (1994), these values classify the wood of this species as wood with medium axial compressive strength.

Table 1. Comparison of the 12% density, axial compression and static bending of cherry wood from Tabarka and Ain Draham station

	density 12% (kg/m^3)		**axial compression (MPa)**		**static bending (MPa)**	
	m	e	m	e	m	e
Tabarka	627a	6,15	44,5b	0,53	94,95 b	0,89
Ain Draham	629a	7,68	51,7 a	0,69	99,85 a	1,12
p-Value	0,89 ns		0,001***		0,001***	

m: average; e: standard error; ***: significant difference at the 0.1% threshold; ns: not significant.

A common rootstock for other (ornamental) cherry trees is *Prunus avium*. Additionally, its wood has great value and is in high demand in the furniture business. Medically speaking, this species is frequently offered as juice, syrup, or herbal tea. Its fruit has anti-inflammatory qualities, and its peduncles have diuretic qualities.

As shown in Table 2, the three-point static bending and axial compression of the two Tunisian populations of Tabarka and Ain Draham is close to that of France, Spain (Gonzalez, 2004), Scandinavian countries, and North America (Benoit 2008). Regarding the physical properties, we can conclude that for the two populations (Tabarka and Ain Draham) the density of 12% is higher than that of the other provenances.

As shown in Table II, the three-point static bending and axial compression of the two Tunisian populations of Tabarka and Ain Draham is close to that of France, Spain

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Table 2. Comparison study of the mechanical and physical properties of wild cherry populations in Tunisia and in the world

Country	Density at 12%	Static bending (Mpa)	Axial compression (Mpa)	Source
Espagne	610	93	49	Gonzalez (2004)
France	598	95	50	Benoit (2011)
Scandinavian countries	600	96	49	Benoit (2008)
North America	550	85	49	Benoit (2008)
Tabarka (Tunisia)	627	94,95	44,5	
Ain Draham (Tunisia)	629	99,85	51,7	

Similar to beech, poplar, zeen oak, and walnut, it is a homogenous wood. Because of the relatively enormous length of its large woody rays, cherry wood stands out when compared to other hardwoods such as elm and zean oak. In comparison to *Prunus domestica* L. (762 kg/m^3) and *Prunus virginiana* (866 kg/m^3), the densities of *Prunus avium* from the two provenances, Tabarka (627 kg/m^3) and Ain Draham (629 kg/m^3), are low.

According to this comparative study, our species have a higher axial compression than *Castanea sativa* Mill (46 Mpa) (Benoit 2008), yet very close to *Fraxinus excelsoir* (51 Mpa) (Benoit, 2008) and Acer pseudo platanus (54 Mpa) (Benoit 2008). In addition, the three-point static bending is higher than that of other hardwoods such as *Castanea sativa* Mill (71 Mpa) (Benoit, 2008) and lower than that of *Fraxinus excelsoir* (113 Mpa) (Benoit, 2008), Acer pseudo platanus (110 Mpa) (Benoit, 2008) and *Fagus sylvatica* (107 Mpa) (Benoit, 2008), but equivalent to that of *Quercus canariensis* (121 Mpa) (Derbal 2015).

Based on this comparative evaluation, the cherry in Tunisia can be a suitable timber for construction because it largely meets the requirements stipulated that are used in construction. A strength class timber must have a flexural modulus of greater than 30 MPa and a modulus of rupture in compression greater than 23 MPa (Masset 1979; Lambillon 1986; Nepveu 1992, Messaoudène et al. 2008). However, cherry wood is characterized by a density of 0.6 to 0.7, fine grain, and medium hardness. The Heartwood has a natural color ranging from light honey to reddish-brown, passing through orange hues while the sapwood is light yellow. It performs well at all levels of processing: sawing, planing, sanding, turning, carving, and slicing (Nepveu 1992). Its fine

grain provides a polish appreciated in cabinetmaking (CRPF 1999). It is considered a noble wood and a global production that has great demand by consumers worldwide. Nevertheless, it presents certain alterations and defects such as green veins, persistent dead branches, red rot, and white rots (Bessieres 1992).

Conclusions

Briefly, we report herein the technological and standing timber characteristics of the two populations of *Prunus avium* in the north-west of Tunisia. The results show that over 66% of the trees were inventoried in Tabarka with straight stems and 57% in Ain Draham with simple curvature of 3 cm. In addition, about 7 to 11% of the trees inventoried present complex curvatures of 5 cm / m, respectively in Tabarka and Ain Draham. An average number of rots affected half the individuals inventoried in Ain Draham, while 40% of the trees selected are healthy in Tabarka. The rate of rots develops especially on relatively old trees (60 years and over). According to the study of technological properties, this species exhibits distinct heartwood, varying in color in pink-orange hues. Based on the density study, the cherry tree is relatively average, very close to the chestnut tree. In addition, the static bending and the axial compression are as well as average.

There is no doubt about the importance of the quality of the wood of this species which is intended for particularly noble uses. Thus, careful monitoring should motivate at the level of the experimental plantations being set up in Tunisia. Appropriate silvicultural care at the juvenile stage and dynamic silviculture will ensure quality timber with the best possible technological characteristics.

Acknowledgments

Authors gratefully acknowledge the help with the physical and mechanical properties received from the Wood Technology Laboratory at the University of Huelva in Spain.

Moreover, the researcher expresses gratitude to the respondents' cooperation during the research.

Disclosure of conflict of interest

The author declares no conflict of interest.

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