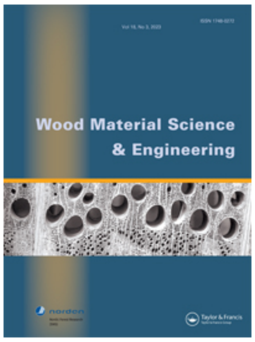

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ORIGINAL ARTICLE

Biological resistance of Phoenician juniper wood

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ABSTRACT
The aim of this study was to assess the biological resistance of Phoenician juniper *(Juniperus phoenicea L.)* wood against two fungal species. Two sources of wood materials were used, one from a naturally grown population and the other from a cultivated area on the island of Syros in Cyclades, Greece. The study tested sapwood and heartwood from both sources against cultures of *Coniophora puteana* and *Rhodonia placenta* basidiomycetes. The heartwood from both sources was categorised as class 1: very durable, whereas the sapwood from both sources was classified as class 5: not durable due to their high susceptibility to both *C. puteana* and *R. placenta*. The mass loss of the heartwood showed only a small variation due to the activity of fungi, while the variability for sapwood was higher. Comparing the biological resistance of cultivated and natural *J. phoenicea* wood, no significant differences in their heartwood or sapwood were revealed.

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Durability; brown-rot; *Coniophora puteana*; *Rhodonia placenta*

Introduction

Phoenician juniper, (*Juniperus phoenicea* L.), is a small- to medium-sized shrub or small evergreen tree, which has very characteristic scaled leaves and berry-like fleshy fruits with a red brownish colour. Along with other sclerophyllous species, this juniper shapes scrublands and open woodlands that belong to two different vegetation types, namely, *maquis* and *garigue* (Caudullo and de Rigo 2016).

Commonly, this woody species does occur in several patchy and isolated populations over the whole Mediterranean basin. Frequently, it is distributed across Morocco and Portugal, Canary and Madeira Islands, Greek islands particularly in Cyclades, Cyprus, Sinai Peninsula and Saudi Arabia along the Red Sea, and in other Mediterranean regions (Franco 1993). Most of the times, it normally grows principally on coastal dunes and cliffs, but also in a few mountain populations up to 2400 m like in Atlas Mountains in Morocco (Farjon 2010). The dune habitats where J. phoenicea expands have been diminishing and today are threatened by the human settlements as well as by the artificial plantations of pines settled for dune stabilisation (Caudullo and de Rigo 2016).

Actually, the wood of *J. phoenicea* trees does not have significant economic interest in the Mediterranean countries. This wood is rose in colour, rather hardand very resinous, mostly in the heartwood, having an aromatic odour like most of the junipers. It is fine in grain and is used for small fabricated objects and inlay works (Goldstein *et al.* 1995). In Algeria and Tunisia, when the trunk is straight, it is used also for joinery and carpentry. In the Greek islands, a recent study revealed that larger juniper wood elements were utilised in the past for small-sized house constructions such as flat roofs, columns and beams (Agnantopoulou 2020). In rural areas of Cyprus, people used to place small juniper pieces to protect clothes from insects and also for its sweet scent. Due to its acclaimed durability, *J. phoenicea* wood has been widely used for centuries in roofing, fencing and other wooden items such as the propellers of tread mills, and coffins (Anonymous 2009).

Typically, junipers are a source of natural oils collected either by steam distillation (e.g. essential oils) or by pyrolysis (e.g. empyreumatic wood oils). Juniper species which contain high percentages of oils include species such as *J. oxycedrus, J. communis, J. sabina* and also *J. phoenicea* (Chalchat *et al.* 1990). It is known that the essential oil of *J. phoenicea* was used centuries ago in cosmetics, and in nowadays, there is a high interest for pharmaceutical and hygienic applications (Mazari *et al.* 2010). Chalchat and his coworkers investigated the chemical composition of natural and empyreumatic oils and extracts from *Juniperus oxycedrus* and *Juniperus phoenicea* wood and found that both oils mainly contain sesquiterpenes, whilst the oil of *Juniperus phoenicea* wood is composed of a large percentage (44%) of a-cedrene (Chalchat *et al.* 1990). Mansouri *et al.* (2011) studied the composition of the essential oils of the branches and berries of *J. phoenicea* ssp. *lycia* (plain) and *J. phoenicea* ssp. *turbinata* (mountain), which was obtained by hydrodistillation and analysed by GC and GC/MS. They concluded that the essential oils of these species were mainly constituted of α-pinene.

Another study conducted on juniper wood (*Juniperus phoenicea* L.), naturally grown in Al-Jabel Al-Akhdar in Green Mountain, revealed that the wood material was comprised of cellulose, hemicelluloses and lignin at mean percentages of 48%, 17%, 35%, respectively (Alfitori *et al.* 2013).

Since data regarding the natural durability of *J. phoenicea* wood is scarce in the literature, this work was carried out to

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evaluate the biological resistance of *Juniperus phoenicea* wood against two known fungi species. Furthermore, the wood materials tested originated from two different origins, namely, one from naturally grown population and one from a plantation in the island of Syros in Cyclades.

Materials and methods

The sample material was collected from a natural forest environment consisting of shrubs and low tree vegetation and was located at Galissa area of Syros Island, Greece. (Coordinates: 37.413814, 24.886114). The dominant species in this area is *Juniperus phoenicea*, Pistacia lentiscus as well as various phryganic species. A *Juniperus phoenicea* sample was collected (Figure 1) during March of 2021. After the removal of the branches, a trunk 1.25 m long and about 22 cm in diameter emerged. Sampling of larger diameter specimen was difficult due to the dense branching of the species starting almost from the ground level. At the same time, and to be able to study the development of this species in fertile soil without competing species, another *Juniperus phoenicea* sample was also acquired from an agricultural area adjacent to the above. This trunk was 1.70 m long, and its diameter was 10–25 cm. Both trunks, prior to their processing, were naturally dried in a covered, freely ventilated arear.

The two trunks were used for the preparation of specimens with length (parallel to the grain) of 50 ± 0.5 mm and cross section of 15 ± 0.5 mm × 25 ± 0.5 mm. All specimens were free from cracks, stain, decay, insect damage or other defects. Specimens that included knots or any other defect which could potentially influence durability were rejected. Two sets of Scots pine specimens were also prepared to serve as reference species. One set of samples was Scots pine sapwood as control specimens. Another set of specimens consisted of Scots pine sapwood and Scots pine heartwood samples as virulence control specimens to validate the fungi cultures. All specimens were dried at 103 ± 2°C until constant mass, and thereafter weighed. Before placing them on fungi cultures they were conditioned at 65 ± 5% relative humidity (RH) and 20 ± 2°C for more than 2 weeks. Afterward, the test specimens were exposed to attack by cultures of *Coniophora puteana* and *Rhodonia placenta* (Strain: EMPA 45) basidiomycetes. All incubation flasks consisted of a control sample (Scots pine sapwood), a *Juniperus phoenicea* sapwood and heartwood sample. After 16 weeks of incubation under 22°C and 75 ± 5% RH, the mass loss based on oven-dry mass of the test specimens was determined and used to establish the durability classification of the tested wood according to the EN350-1 standard (CEN 2016). One-way analysis of variance (ANOVA, Least Square Difference test) at 95% confidence level was used to assess the significance of differences in ML between the species.

Figure 1. Transverse (up) and longitudinal (down) section of Juniperus phoenicea grown in natural forest environment. The sapwood and heartwood are distinct (scale in cm).

Results and discussion

The results of the mass loss and moisture content (MC) are presented in Table 1 as well as in Figure 2. The mean mass loss of control Scots pine sapwood subjected to *C. puteana* was 41%, while the respective value for *R. placenta* was 34%. These two means were significantly different ($p < 0.05$) indicating that *C. puteana* caused a stronger damage to the control Scots pine sapwood than *R. placenta* did. The above results validated the testing procedure because the acquired values were higher than the respective requirement set by CEN/TS 15083-1 (CEN 2005). Besides, the mean mass loss of virulence Scots pine heartwood subjected to *C. puteana* was 14%, while the respective value for *R. placenta* was 14%. The difference between these two means was not statistically significant. This corresponds to the durability classification of this wood species' heartwood according to the EN350 standard.

The results showed no apparent decay of *J. phoenicea* heartwood by the brown- rot fungi *C. puteana* and *R. placenta*. In more detail, the mean mass loss values of *J. phoenicea* induced by *C. puteana* were 1.1% for natural heartwood (NC) and 1.5% for cultivated heartwood (CH). The difference between these two means was not statistically significant ($p = 0.85$). According to these results, the heartwood of both origins could be classified to class 1: Very durable. However, both natural and cultivated *J. phoenicea* sapwood were much more susceptible to *C. puteana*. In more detail, the mean mass loss values induced by *C. puteana* were 35% for NS and 37% for cultivated sapwood (CS) and the difference between these two means was not statistically significant implying that the two tested materials are equally resistant to *C. puteana*. Moreover, according to the above results and the requirements of the EN350 standard, the sapwood of both origins could be classified to class 5: Not durable.

Regarding the resistance of the tested origins against *R. placenta*, the mean mass loss values of *J. phoenicea* were 1.7% for NC and 1.8% for CH while the difference between these two means was not statistically significant. According to these results, the heartwood of both origins could be classified to class 1: Very durable. Regarding *J. phoenicea* sapwood, the mean mass-loss values induced by *R. placenta*

Table 1. Results of mass loss (ML) and moisture content (MC) of the tested materials (SD: standard deviation).

		Coniophora puteana							Rhodonia placenta						
		Control sapwood	Cultivated heartwood	Cultivated sapwood	Natural heartwood	Natural sapwood	Scotch pine control heartwood	Scotch pine control heartwood	Control sapwood	Cultivated heartwood	Cultivated sapwood	Natural heartwood	Natural sapwood	Virulence heartwood	Virulence sapwood
ML (%)	Mean	40.56	1.47	37.14	1.10	35.36	14.16	36.13	34.12	1.82	31.72	1.71	32.50	14.09	31.70
	Median	39.15	1.44	37.35	1.01	35.02	14.10	35.41	32.49	1.76	31.18	1.73	31.93	13.89	31.24
	SD	8.93	0.16	2.17	0.27	5.52	0.72	3.64	7.89	0.25	1.86	0.24	2.71	1.70	2.67
	Min	23.68	1.16	33.03	0.82	28.45	13.40	30.58	24.20	1.47	29.89	1.36	29.16	11.22	27.46
	Max	55.62	1.73	40.33	1.58	41.88	15.63	42.13	47.42	2.22	34.71	2.08	36.30	16.98	35.78
DURABILITY CLASS (EN 350)		5	1	5	1	5	3	5	5	1	5	1	5	3	5
MC (%)	Mean	80.6	30.3	76.2	29.8	61.3	54.7	98.1	98.1	23.5	72.9	25.6	69.1	57.3	81.5
	SD	13.3	4.8	16.7	3.9	9.7	10.6	12.6	14.6	1.6	5.8	1.2	6.4	8.0	6.6
	Min	46.9	21.4	45.6	25.1	42.1	42.4	81.8	67.7	20.6	65.8	24.3	56.4	46.2	71.8
	Max	96.3	38.4	94.1	36.0	73.8	70.6	114.3	124.9	26.3	80.2	28.7	75.1	73.2	97.2
Specimen No.		12	10	8	10	7	8	10	20	10	6	10	9	10	10

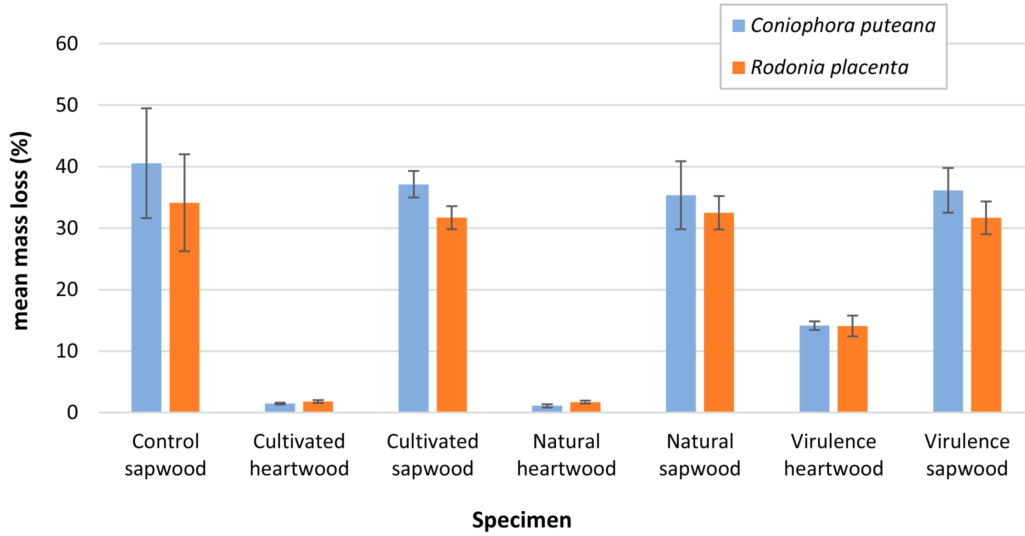

Figure 2. Mass loss values of the tested materials against biodeterioration induced by Coniophora puteana and Rhodonia placenta.

were 32% for NS and 32% for CS and the difference between these two means was not statistically significant ($p = 0.74$) which means that the two tested materials were equally resistant to *R. placenta*. According to these results, the sapwood of both origins could be classified to class 5: Not durable.

It is worth mentioning that, looking into the variability of mass-loss values, it can be noticed that both natural as well as cultivated *J. phoenicea* heartwood showed very low standard deviation (0.2–0.3%). In more detail, the respective standard-deviation values for the cultivated and natural *J. phoenicea* heartwood were 0.2% and 0.3% against *Coniophora puteana* while against Rhodonia placenta mass-loss values were 0.2% and 0.2%. For this reason, each separate specimen could be classified to the durability class 1: Very durable. The above finding is indicating a very strong and stable durability of *J. phoenicea* heartwood against both tested fungi.

On the contrary, the *J. phoenicea* sapwood, shows higher variability than heartwood: standard-deviation values for the cultivated and natural *Juniperus phoenicea* sapwood were 2.2% and 5.5% against *Coniophora puteana* while against *Rhodonia placenta* mass loss values were 1.0 and 2.7%. Moreover, even though the mean classification of the sapwood could be 5: Not durable, some of the individual specimens could be classified to the durability class 4: Very durable.

In any case, *J. phoenicea* sapwood was much less durable than heartwood and this also has been confirmed by many decay resistance studies (Taylor *et al.* 2002). Furthermore, the comparison of the durability of cultivated and natural *J. phoenicea* wood showed no significant differences both for their heartwood and their sapwood.

Conclusions

The heartwood of both tested origins of *J. phoenicea* was determined to be highly durable, classified as class 1 according to the EN 350 standard. However, both natural and cultivated *J. phoenicea* sapwood showed much greater susceptibility to C. *puteana*, resulting in their classification as class 5: Not durable.

Similar findings were obtained for the resistance of the tested origins against *R. placenta*, where the heartwood of both tested origins was classified as class 1: Very durable, while their sapwood was classified as class 5: Not durable. When comparing the durability of cultivated and natural *J. phoenicea* wood, no significant differences were observed in either their heartwood or sapwood.

Additionally, mass loss due to fungi activity exhibited a very small variation for *J. phoenicea* heartwood, while sapwood exhibited much higher variability.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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