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RESEARCH ARTICLE

Assessing the Biodiversity of Wood Decay Fungi in Northern Forests of Iran

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Abstract Fungal diversity in the Hyrcanian forests can greatly vary due to diverse ecological conditions. The scope of the present research was to investigate the diversity of wood decay fungi at three sites in the northern forests of Iran. Fruiting bodies of fungi were collected in three plots dominated by *Quercus castaneifolia* C.A.M. (oak) and *Carpinus betulus* L. (hornbeam) in the Hyrcanian Forest. As many as 19 and 13 taxa were found on hornbeam and oak, respectively. The identification of these fungi revealed *Fomes fomentarius* (L.) Fr. and *Ganoderma lucidum* (Curtis) P. Karst. as highly abundant on hornbeam and oak, respectively. Highest fungal abundance was observed at an altitude range of 1150-1200 meters above sea level. Diversity of macro-fungi was determined and the mean Shannon diversity index was found to be 2.52 and 1.94 for hornbeam and oak, respectively, and mean equitability was calculated as 0.84 and 0.73 for hornbeam and oak, respectively. There were no significant differences in the Shannon Diversity Index or equitability. Overall, current work showed that most of the identified fungi were classified as white rot fungi.

Keywords Fungal ecology · Forest management · Fungal diversity · Wood decay fungi · Forest protection · Single-selection Hyrcanian

Significance statement The current work includes several first reports for the Iranian forest pathology and has not been reported before for the Iran. Therefore, the new host as well as fungal colonization behaviors were detected for fungal strategies on the hosts in Iran.

Introduction

Forest management is a branch of forestry that includes a variety of aspects: administrative, economic, technical, legal, social, and science [1]. Some forests are managed to only obtain products such as firewood, fiber for paper, and timber; however, with the progression of environmental

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awareness management of forests for additional uses is becoming increasingly common [2]. Wood decay fungi play an important role in forest ecosystems [3]. It is imperative to determine the role of wood decay fungi in relation to certain ecological processes [4, 5]. Aphyllophoroid fungi affect forest age, structure and gap dynamics [6]. Wood-inhabiting fungi are considered to be good indicators of dead wood communities and the overall naturalness of a particular forest area [7], to aid in the conservation of boreal forests [8], and contribute to species diversity of other dead-wood associated taxa [9]. In deciduous forests, there is also evidence that stumps and tree tops that remain after cutting develop different communities of decay fungi than unmanaged wood [10]. Old growth or virgin forests harbor more deadwood and associated fungal species than managed forests [11]. As a result of the reduced volume of dead wood in managed forests, there is a decline in the wood-inhabiting organisms [7, 12, 13] along with a reduction in fungal diversity [13–16]. Various forest activities affect the composition of fungal communities [17, 18], diversity [19, 20], species richness, abundance, [21] and fungal structure in forests [19, 22, 23]. Recently, it has been shown that fungal abundance is greater in un-managed forest [24, 25]. This text details the influence of forest management on fungal abundance and diversity of the Nowshahr forests, which are one of the main forests in northern Iran, with emphasis on management history.

Material and Methods

Test Plots

The study area, dominated by temperate broadleaved forests, extends throughout the southern coast of the Caspian Sea (Fig. 1). The studied areas was a section of a research and education forest, Kheyroud Forest, which is located

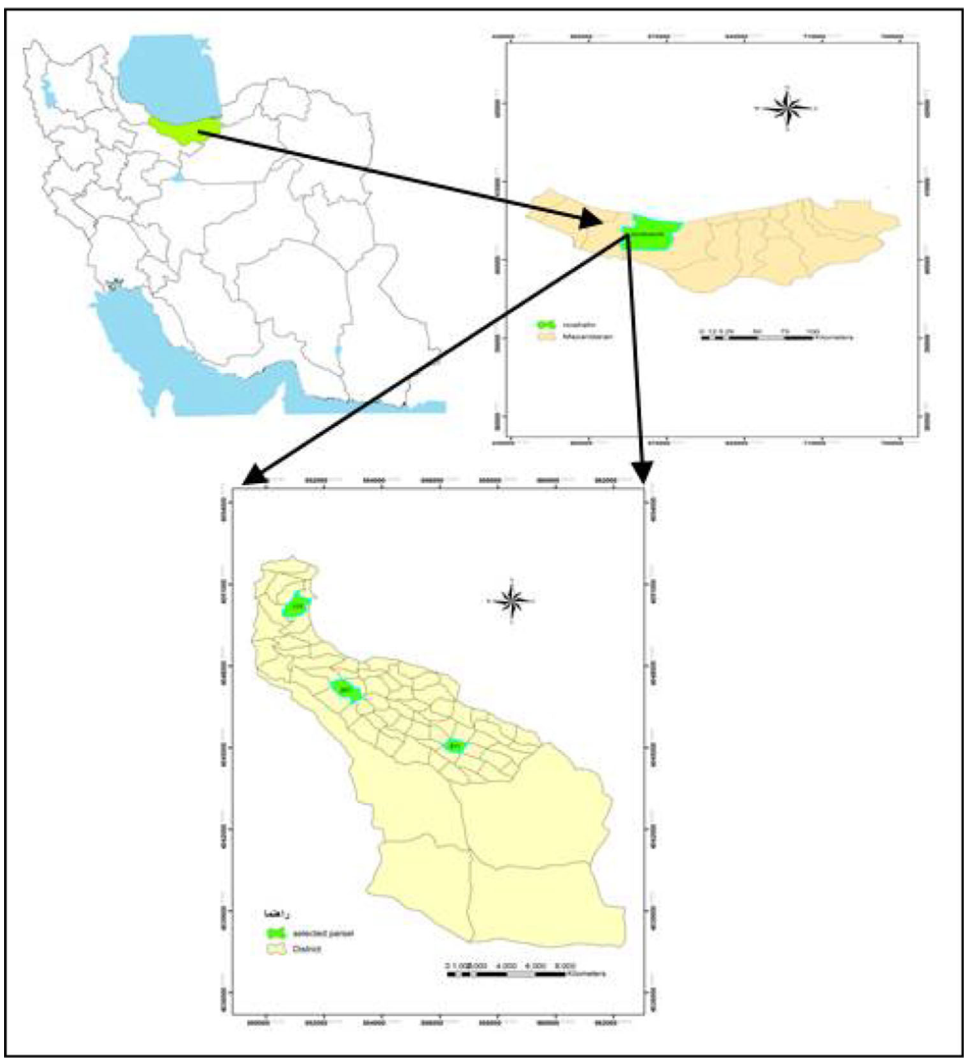

Fig. 1 The distribution of Caspian forest in Iran

Table 1 Plot sites in the Kheyroud forests of Nowshahr in Mazandaran

Plot	Species dominance	Status	Year history	Soil type	Area (ha)
Pattom (P1)	Oak, hornbeam, and beech mixed	Managed	1973–2015	Brownish	48.4
Namkhaneh (N2)	Oak, hornbeam, and beech mixed	Managed	1983–2015	Brownish	50
Gorazben (G3)	Oak, hornbeam, and beech mixed	Un-Managed	–	Brownish	27.82

7 km East of Nowshahr in Mazandaran (36°27′ to 36°40′N, 51°32′ to 51°43′E). This area is limited to the Najardeh and Koliak villages from North to South, respectively. Due to the humid climate and fertile soil, the area under investigation is highly productive. The Hyrcanian forest typically contains oriental beech (*Fagus orientalis* Lipsky.), chestnut-leaved oak (*Quercus castaneifolia* C.A.M.), common hornbeam (*Carpinus betulus* L.), ironwood (*Parrotia persica* C.A.M.), false walnut (*Pterocarya fraxinifolia* Land. (Spach.) caucasian alder (*Alnus subcordata* C.A.M), Caspian honey locust (*Gleditschia caspica* Desf.), velvet maple (*Acer velutinum* Boiss.), and wild service (*Sorbus torminalis* (L.) Crantz.) as the dominant woody species. The climate in this region is sub-Mediterranean with a mean annual temperature of 15° to 18 °C and precipitation of 1000 mm [26]. The area of study contained a community of oak and hornbeam (Table 1).

Test Plot Conditions

Average annual rainfall and temperature in the Nowshahr forest station from 1994 to 2014 was recorded as 1273 mm and 19.6 °C, respectively. October was the wettest month (4/227 mm) and August was the driest month (1/32 mm) (Fig. 2).

Field Sampling

There were several sampling sessions during the summer through autumn months at the three Nowshahr forest plots: Pattom (P1), Namkhaneh (N2), and Gorazbon (G3). Of the three test locations selected, P1 is a research and managed forest with a long-term management history close to the Najardeh village. Test plot N2 is a moderately managed forest while test plot G3 is unmanaged. Details pertaining to the type of forest, tree health, and number of fungi at the test sites were also documented (Fig. 3), and tree health was also classified [27].

Identification of Fungi

The fungal fruiting bodies were collected from trees during the spring and autumn months (1 May to 31 October, 2010–2012) and immediately placed on ice. For identification of fungi, macro and microscopic characters were determined [28–32].

Statistical Analysis

The values of the Shannon index and equitability were computed using the PAST software. One- way ANOVA was performed and determined significant differences at

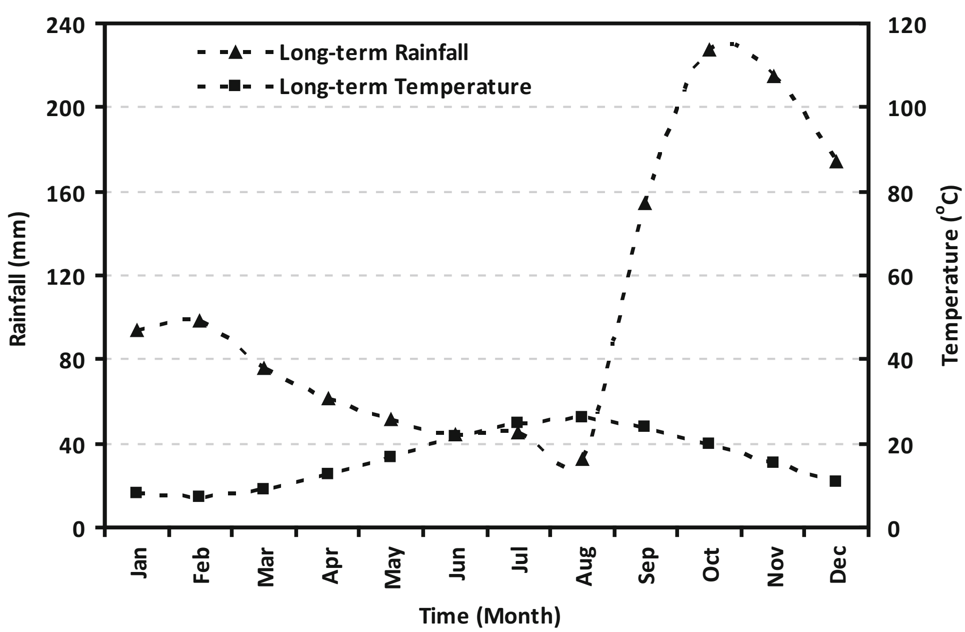

Fig. 2 Embrothermic curve of Mean rainfall and temperature at the Nowshahr station

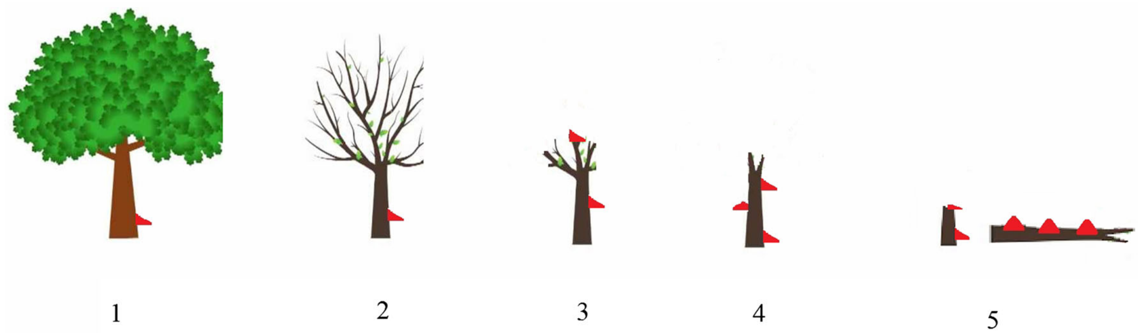

Fig. 3 Clasification of deciduous tree health in Northern forest of Iran [25]. **1** Living and healthy tree, standing, hard wood, hard skin, green top; **2** Living tree, dead top, standing, hardwood, dead crown; **3** Standing tree, soft wood, broken crown; **4** Snag, loosed wood, without crown; **5** Fallen dead wood, fine and coarse woody debris, log, loosed wood, soft wood

Table 2 The Shannon Diversity Index and equitability for wood decay fungi in hornbeam and oak

Species	Taxa	Shannon diversity index	Simpson	Menheninck	Margalef	Equitability
Carpinus betulus	20	2.5255	0.88714	1.644	3.8021	0.84304
Quercus castaneifolia	14	1.9428	0.74959	2.135	3.4563	0.73619

Table 3 The Shannon Diversity Index and equitability for wood decay fungi at the three test sites

Sites	Taxax	Shanon index	Equitability
P1	4	1/17	0/84
	13	2/26	0/88
N2	9	1/95	0/89
	16	2/47	0/89
G3	11	1/98	0/82
	11	1/92	0/80

the 95% confidence level. Grouping was made between factors using Duncan's multiple range tests via SAS (Version 16) (Tables 2 and 3).

Results and Discussion

Fungal Taxa Encountered

As many as 25 fungal taxa were characterized from the study area (Fig. 4). The two tree species, hornbeam and

Fig. 4 The abundance of wood decaying fungi on hornbeam and oak trees

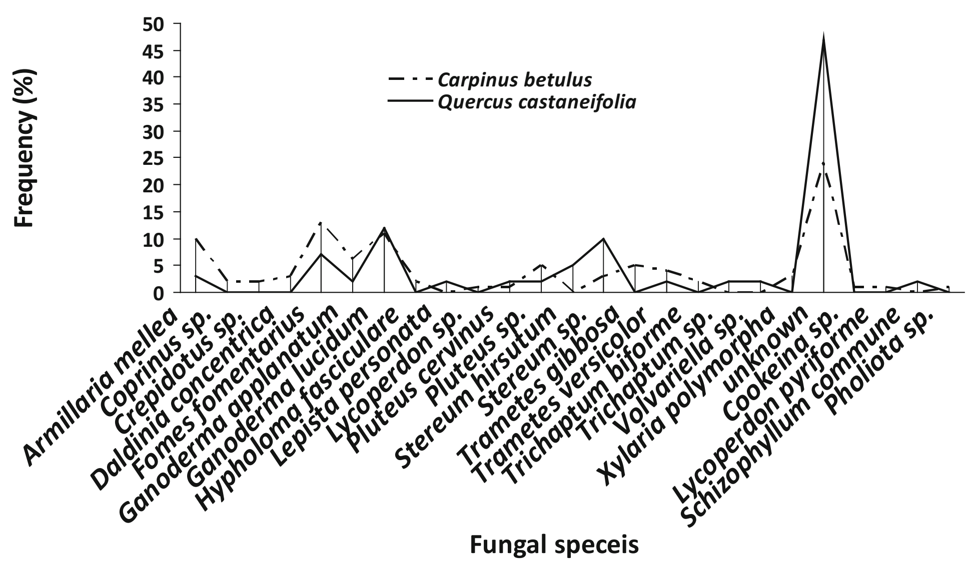

Table 4 Snag and fallen dead wood in the three test sites

Sites	Snag	Fallen dead wood	Total		
	(m^3/ha)	(%)	(m^3/ha)	(%)	(m^3/ha)
Gorazben (G3)	4.9	30	11.6	70	16.5
Namkhaneh (N2)	1.86	36.7	3.3	63.9	5.1
Patom (P1)	1.01	31.9	2.15	68.03	3.17

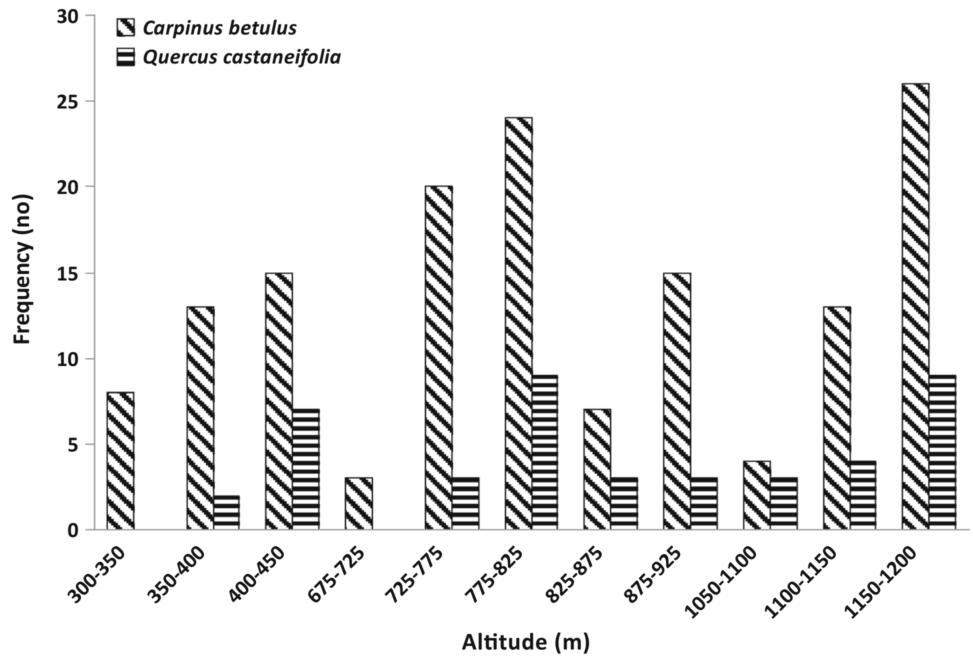

Fig. 5 The relationship altitude and mean of fungal abundance of hornbeam and oak

oak, were colonized by 19 and 13 taxa, respectively. The results further reveal that wood decay fungi are more frequently reported in association with snags and fallen, dead wood (Table 4).

Fungal Diversity

Fungal diversity was determined and the mean Shannon diversity index was found to be 2.52 for hornbeam and 1.94 for oak. The mean of equitability was 0.84 for hornbeam and 0.73 for oak (Table 2). Both the Shannon diversity index and equitability showed no significant differences between the two tree species. However, both these indices were statistically significant for the test sites (Table 3). Studies of fungal biodiversity in forest ecosystems can provide baseline information for determining interrelationships among organisms and indicate potential roles of fungi in forest ecosystem dynamics [24, 33, 34]. Understanding the role of fungi in forest ecosystems is key to characterizing stability and the succession of biological components (i.e. trees) [35], while information on fungal biodiversity can provide insight on sustaining fungi as beneficial resources (Fig. 5).

Presence of Wood Decay Fungi at Different Altitudes

The observations also demonstrate the abundance of wood decay fungi being significantly different ($p = 0.05$) at different altitudes. The trend of wood decay fungal abundance was observed to be ascendant then descendant. The species of *Fomes*, *Ganoderma*, *Stereum*, and *Trametes* were highly abundant in the three test sites. The increasing moisture content with increasing attitude along with management and logging practices at the P1 site also indicates the role of physiographic agents in the diversity of these fungi. Robledo and Renison [36] reported that attitude was conducive to the presence of fungal polypores and is highly affected by forest structure.

Relation of Wood Decay Fungi and Tree Health

The results showed that the relationship between wood decay fungi and tree health was significantly different ($p = 0.05$). Most of the fungi present were reported in association with sangs and fallen, dead wood (Fig. 3) as a result of the large substrate material for fungal colonization [22]. The main constituent of the carbon cycle in forest ecosystems is obtained by fungal decomposition of lignocellulosic material [24, 34]. Decay fungi play an important role in carbon and nitrogen cycling, while helping to convert organic debris into humus. Some fungi such as *Fomes fomentarius*, *Ganoderma applanatum*, and *Pleurotus ostreatus* attack living trees, while others especially *Trametes versicolor* invade dead or fallen timber and slash on the forest floor [37]. Wood-decay basidiomycetes colonize and degrade wood using enzymatic and mechanical processes [38, 39]. This group includes polypore or bracket fungi (a polyphyletic group with representatives in Hymenochaetales, Polyporales, Gloeophyllales and others), and corticioid fungi (another polyphyletic group represented in Hymenochaetales, Corticiales, Russulales and others) [34].

The species richness and equitability of fungi characterized in this study (Table 1) may seem small in comparison to other descriptions of macrofungi from this region [40, 41]. In the present research eight taxa (*Armillaria mellea*, *Stereum* sp., *Pluteus cervinus*, *Ganoderma applanatum*, *Trichaptum* sp., *Fomes* fomentarius, *Pluteus* sp. and *Schizophyllum commune*) on hornbeam and six taxa (*Armillaria mellea*, *Hypholoma fasciculare*, *Crepidotus* sp., *Pluteus* sp., *Coprinus* sp. and *Ganoderma applanatum*) on oak have been reported.

Conclusion

The study reported some effects of forest management on distribution of wood decay fungi in the forests of Northern Iran. It was determined that the highest fungal abundance found in the Kheyroud forests was characterized as *Fomes*, *Ganoderma*, *Stereum*, and *Trametes*. The current research demonstrates that fungal diversity and abundance becomes reduced when forest management practices occur, which is in accordance with the earlier reports. Assessing the ecology of wood decay fungi as well as their biodiversity has not yet been reported in Iran. In addition to sampling and identification of wood decay fungi at the three test sites, some wood decay fungi in hornbeam and oak are distinguished in Iran.

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Compliance with Ethical Standards

Conflict of interest The authors declare that there is no conflict of interest.

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