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Effect of invasion by *Robinia pseudoacacia* on floristic diversity of *Quercus suber* forests in Chrea, Algeria

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Abstract

The floristic composition and diversity analysis of forests is considered an essential aspect of cork oak ecosystem. Both can contribute to our knowledge of their functioning, and assist in our conservation efforts. Chrea woodland is located in the central part of the Tellian Atlas region of the Atlas Mountains in northern Africa. *Quercus suber* L. (cork oak) is a dominant tree in this woodland. A number of non-native species have established themselves in this woodland, including black locust (*Robinia pseudoacacia*). Urbanization, uncontrolled cutting, and wildfires are the main processes that affect at present the species composition and ecological dynamics of these woodlands. To investigate the floristic richness and diversity patterns of Chrea woodland, and the possible effects of invasive spreading of *R. pseudoacadia,* we sampled stands dominated by black locust and dominated by cork oak, during April, May, and June 2019–2021, collected species abundance for each plot. Overall, we identified 171 species representing 136 genera, belonging to 49 botanical families, with significant differences in species richness and species heterogeneity on the stands dominated by cork oak and stands co-dominated with black locust. The analysis of this flora also enabled us to identify medicinal plants, aromatic plants, and plants of economic interest in this region. Our data showed that the flora of Chrea woodland is dominated by Mediterranean vegetation, with life forms represented by Therophytes, Hemicryptophytes, Cryptophytes, Chamephytes and Phanerophytes. The dominance of therophytes and hemicryptophytes in both stand types illustrates how the woodland may be affected by processes, such as urbanization, uncontrolled cutting, wildfires, and the introduction of non-native species. The conservation of these peculiar woodlands with high values of plants diversity must be part of a sustainable development programme that will make it possible to protect existing heritage and improve the socio-economic conditions of local populations.

Key words: black locust, cork oak, medicinal plants, native oak, plant diversity, richness.

Introduction

One of the fundamental ecological justifications for protecting biodiversity is that its decline could affect ecosystem functions that support human life, such as primary productivity, carbon storage, water retention, and clean water supply (Lazzaro et al. 2018). Often the specific and generic richness of the region is threatened because the biodiversity continues to be reduced very rapidly due to human pressure, which leads to fragmentation, degradation, and loss of habitat (Rabhi et al. 2018). The Mediterranean region is known as one of the most important 51 areas in the world for ecosystem diversity. However, there is not much information on the 52 habitats present in the southern and eastern Mediterranean (Médail and Quézel 1997, Véla 2018).

Cork oak (*Quercus suber* L.) forests are common within the Tellian Atlas region of the Mediterranean forest. Nevertheless, comparatively little research has been conducted on the floristic richness of these cork oak woodlands (Agrillo et al. 2018, Casella et al. 2020).

Cork oak is an endemic species of the Mediterranean basin, a descendant of the Upper Pliocene flora, which dates back to the Tertiary (Boudy 1950). It is considered to be of economic and ecological importance. The cork oak forest, which mostly stretches along the humid coastal regions of north-eastern Algeria until the Tunisian border, is one of the most significant forest types in Algeria in terms of covered area. These forests contain several biodiversity hotspots, including the Kabylias-Numidia-Kroumiria region (Véla and Benhouhou 2007, Meddour et al. 2022) and Chrea Park (Meyers et al. 2000).

Containing numerous rare and endemic species, this flora is being affected by a variety of events and processes, including urbanization, uncontrolled cutting, wildfires, and the introduction of non-native species. In particular, the effect of non-native plant species on native vegetation diversity has not been previously studied (Bennadja et al. 2013). At present, alien species, that has become abundant in the cork oak forests, is black locust (*Robinia pseudoacacia* L.) (GBIF Secretariat 2023).

The objective of this study was to assess how *R. pseudoacacia* may affect the species composition and dynamics of the cork oak forest in Chrea Park. To accomplish this, we compared the species richness and species heterogeneity of cork oak stands and co-dominated by *R. pseudoacacia.* We also wanted to categorize the life forms of the species and to identify species of medicinal, aromatic, and economic value.

Material and Methods

Study area

Chrea woodland occupies a mountainous territory, culminating at 1627 m a. vfbsddcxs.l. in Koudiat Sidi Abdelkader (Sbabdji et al. 2015). It is characterized by significant topographical and floristic heterogeneity, including ecosystems dominated by *Q. suber* and *Q. ilex* L. (Derridj 1990). *R. pseudoacacia*, an introduced species, is common in *Q. suber* stands. The study area is located between the two sites of Hakou Feraoun and Béni Ali, between 700 to 1000 m altitude, among the northern latitudes 36°25’00’’ to 36°30’00’’ and the eastern longitudes 2°50’00’’ to 2°52’30’’ (Fig. 1). Using aerial photos with a scale of 1/20.000, dated 1999 (I.N.C.T), we were able to highlight the different iso-

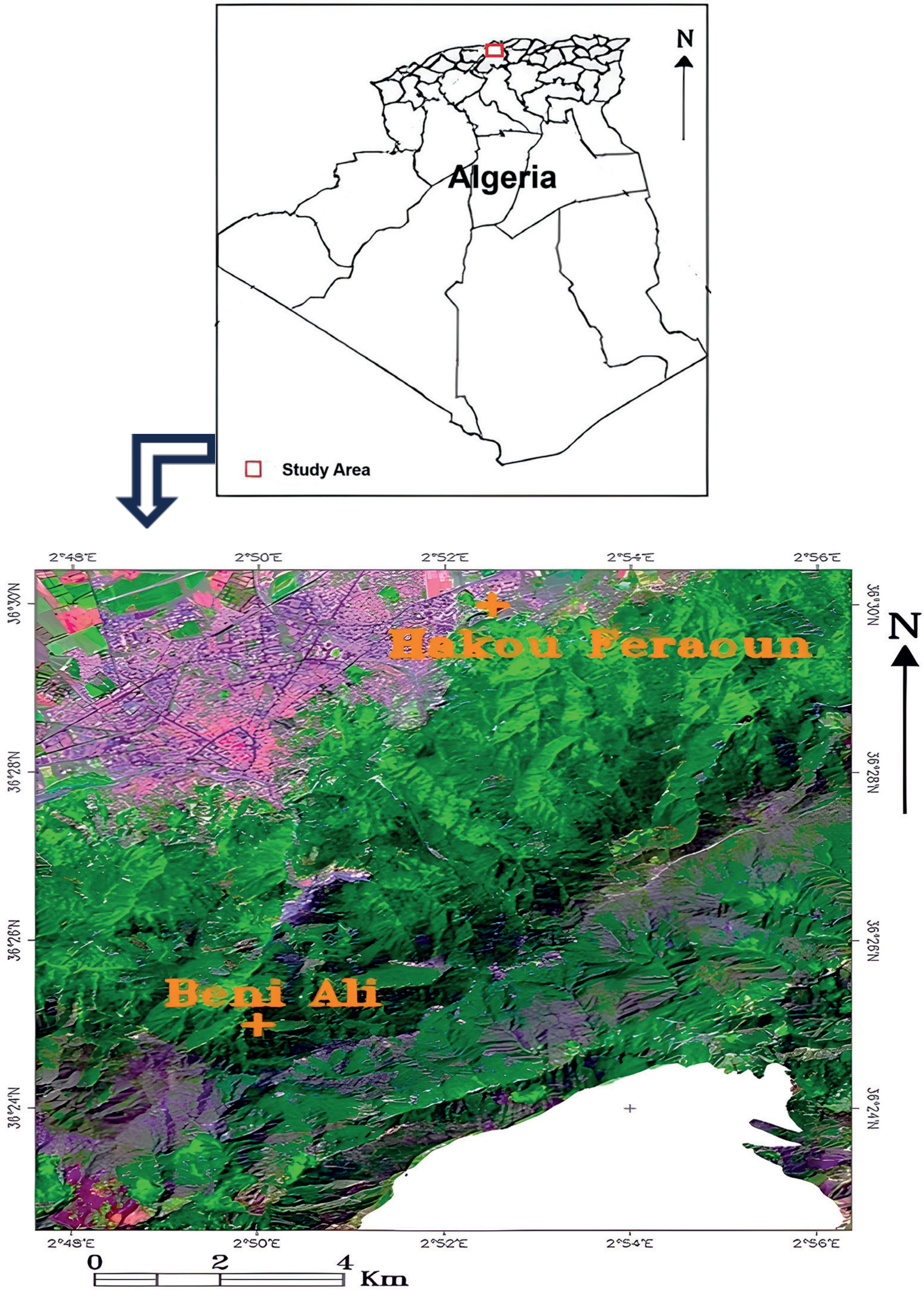

Fig. 1. Geographical location of the study area of the Chrea forest (INCT 2022).

phenes zones (large homogeneous plant formations).

The bioclimate location of the study area is subhumid at low altitudes (661 m) with an average maximum temperature 32 °C in July and an average minimum temperature of 2 °C in January, with annual average rainfall of 686 mm. The dry season lasts three months at low altitudes and two and a half months at high altitudes. The two study sites are located in the Meso-Mediterranean vegetation stage dominated by sclerophyll oaks (*Q. suber* and *Q. ilex*) in the altitudinal range from (600 and 1000 m) (Halimi 1980).

Data collection

To investigate the floristic richness and heterogeneity of Chrea woodland, species lists were extracted from floristic surveys conducted between 2019 and 2021 during April, May and June in Hakou Feraoun and Béni Ali sites between 700 and 1000 m a.s.l.

The floristic surveys were carried out in plots with a minimum area of 100 m^2 with presence of the cork oak and black locust. Overall, 32 plot surveys were collected by the Braun-Blanquet (1932) method (16 plots on cork oak stands dominated by black locust tree, 16 control plots in native cork oak forest). We sampled 100 m^2 as a minimum area for all stands with and without black locust. We used the plant species check-list 'New Flora of Algeria' (Quézel and Santa1962–1963) and 'Flora of North Africa Maire' (1952–1987), supplemented also by 'Flora Corsica' (Jeanmonod and Gamisans 2007). The rarity and plants endemism in Algeria were checked from 'New Flora of Algeria' list. The assessed species were divided in four categories namely rare, very rare, fairly rare and extremely rare according to the criteria of rarity provided in the Algerian flora (Quézel and Santa 1962–1963). Life of found species list were categorized in: phanerophytes, chamaephytes, hemicryptophytes, cryptophytes and therophytes according to the Raunkiaer classification. The Raunkiaer's classification is the most accepted and used classification system for plants life form (Klimeš 2003, Leuschner and Ellenberg 2017). The Raunkiaer classification system groups terrestrial plants are: therophytes (annual plants surviving harsh conditions as seeds), hemicryptophytes (plants with buds at or near to soil surface), chamaephytes (plants with buds within 0.25 m above the soil surface), phanerophytes (plants taller than 0.25–0.5 m, with buds on aerial shoots) and geophytes (plants with belowground buds as storage organs, i.e., rhizomes or bulbs) (Ellenberg and Müller-Dombois 1967, Müller-Dombois and Ellenberg 1974).

Moreover, by the analysis of this the flora list of vegetation plot allowed us to develop a list of medicinal plants, aromatic plants, plants of economic interest, in Chrea Park 'New Flora of Algeria' (Quézel and Santa1962–1963).

Data analysis

Independent t-tests (SPSS v17.0) were applied to compare the means of two independent groups in order to determine whether there is statistical evidence of stand type on: 1) species richness calculated as the number of species per plot; 2) species heterogeneity, which was calculated based on the additive components of diversity (Lande 1996, Roschewitz et al. 2005), by subtracting the mean number of species per plot from the total number of species found in each stand type; 3) Species abundance calculated as the number of individuals of all species combined per plot. All tests were performed at the 0.05 level of significance. The mean values of richness, heterogeneity and abundance for both stands. were calculated with standard deviation.

Moreover, we computed the proportion of species collected in all plots in each life form class.

Results and Discussion

Floristic diversity in native and black locust stands

Our sampling yielded 171 species (143 in stands with black locust and 133 in stands dominated by cork oak), representing 136 genera and 49 families. This number of species represents 6 % of the flora of northern Algeria, estimated at 3150 species (Médail and Quézel 1997). The documentation of 171 species in the study area illustrates the higher level of plants biodiversity in Mediterranean cork oak savannas (Bugalho et al. 2011).

However, the species richness is lower than other Algerian regions, such as Kabylian cork oak forest, 311 species (Meddour et al. 2022); the Kéfrida woodlands, 332 species (Bouchibane et al. 2017); the Akfadou forest, 435 species (Messaoudene et al. 2007). It is also lower than those reported in eastern Numidia, 292 species (Bennadja et al. 2013) and the cork oak forests in the Tlemcen mountains, 429 taxa (Medjahdi et al. 2018). However, this richness was higher than that obtained in other regions, such as in Edough peninsula 123 species (Iboukassene 2008); in Djebel Bissa, 151 (Letreuch-Belarouci et al. 2009); in Theniet El Had, 157 (Naggar et al. 2019); in El Kala, 162 (Bennadja et al. 2013); in Bissa forest, Chlef, 151 (Zemmar et al. 2020). The most represented families in our study were Asteraceae and Fabaceae, each with 22 species, followed by Poaceae (20), Caryophyllaceae (9), and Brassicaceae, Lamiaceae, and Rosaceae, each one represented with 7 species, other families were less represented (Fig. 2).

The species richness is significantly different between cork oak stands and stands with the black locust ($t(30) = 2.62$, $p = 0.014$), with the mean richness in stands with black locust (43.50 ±12.00) being higher than in stands without black locust (34.06 ±7.98). However, there was no difference in species abundance between native and invaded stands ($t(30) = 1.13$, $p = 0.264$), where the mean abundance of black locust (62.87 ±14.7) being higher than in native stands (57.94 ±9.19). Our results showing that species richness is greater in plots with black locust differ from the findings of Benesperi et al. (2012), who found that plant communities were more diverse in areas without black locust. This diversity due probably to effect of black locust, which is known to significantly increase soil nitrogen reserves (Rice et al. 2004). As a result, this process is probably going to affect the understorey's composition and plant diversity.

Our findings are similar to reported by Levine and D'Antonio (1999) and Stohlgren et al. (2003), where local species richness might positively correlate with numbers of non-native species due to common promoting factors. With respect to species heterogeneity, stands without black locust exhibited reduced species heterogeneity (25.6 ±6.06) vs (30.41 ±8.39) in the stands with black locust ($t(30) = 1.86$, $p = 0.072$), with no significance difference between them.

The higher species heterogeneity in the stands with black locust in our study

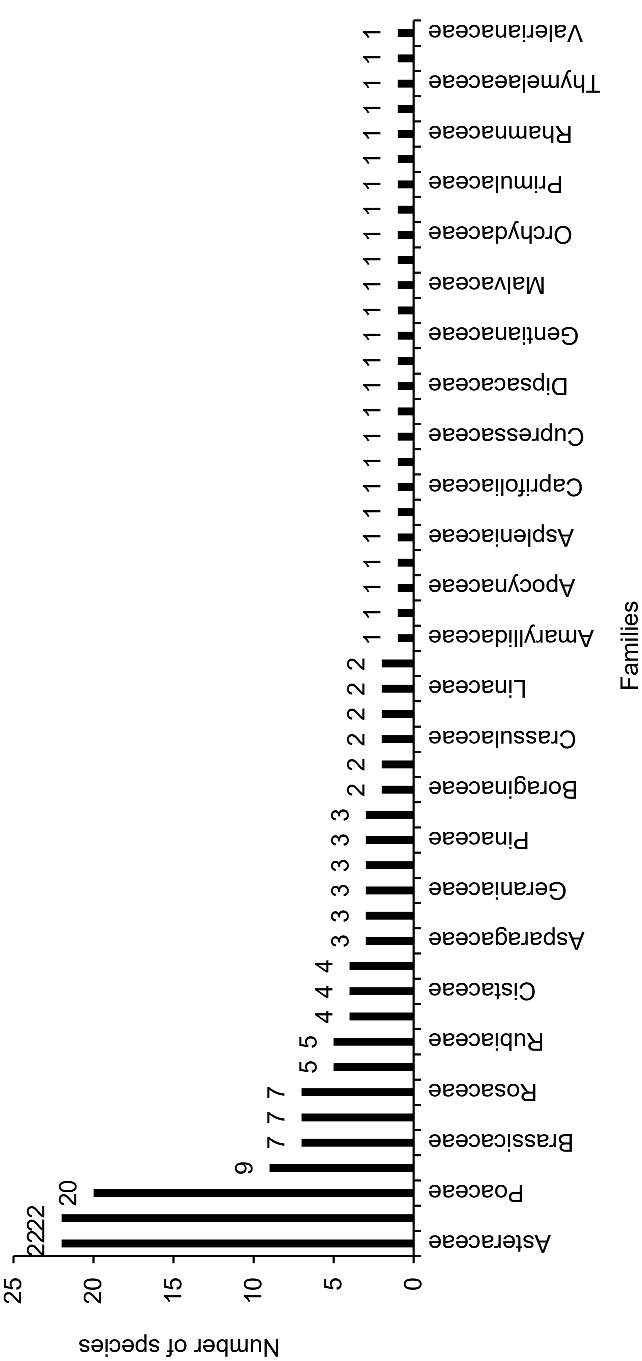

Fig. 2. Distribution of species in the Chrea forest according their taxon (families).

contrast with those reported by Benesperi et al. (2012), where forests species heterogeneity was higher in native stands than those of black locust. Whereas, some of the earliest evidence of heterogeneity-diversity-relationships in forest stands (MacArthur and MacArthur 1961), are similar to our finding on the high heterogeneity related to diversity in non-native stands. Alternatively, Huston and DeAngelis (1994) demonstrate that the heterogeneity is the result of large number of species can coexist.

Medicinal plants

Considering plants used in traditional medicine, our results included 47 medicinal species belonging to 29 families. Asteraceae had the highest number of species (7). Three medicinal species were found in Lamiaceae, Rosaceae and Papavveracea, and two species were found in Fabaceae, Pinaceae, Cistaceae, Apiaceae and Plantaginaceae (Fig. 3).

That many of the medicinal species were found in the Asteraceae and Lamiaceae families are consistent with findings for the whole of the Mediterranean region (González-Tejero et al. 2008), particularly in Algeria (Meddour and Meddour-Sahar 2015), and Morocco (Ennabili and Gharnit 2000).

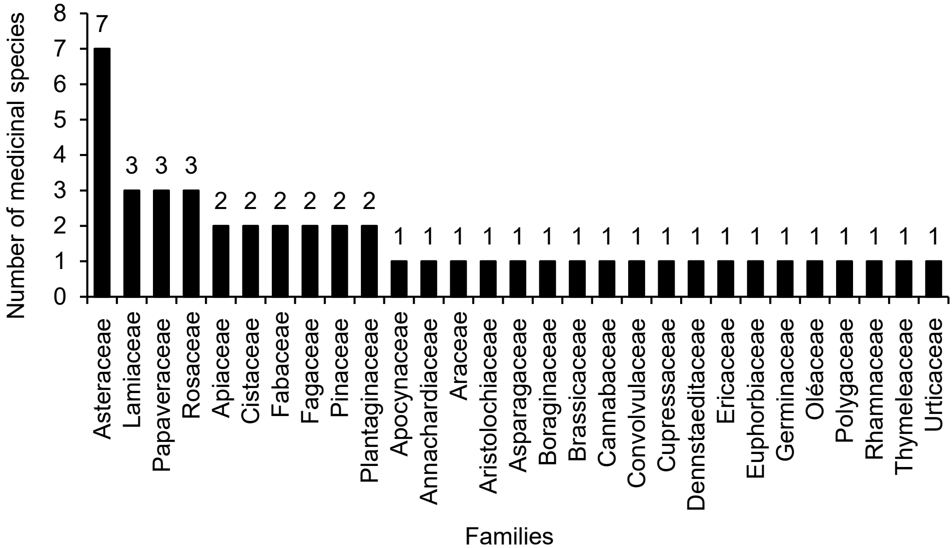

Fig. 3. Distribution of medicinal plant species in the Chrea forest according their taxon (families).

Rare species

According to the floristic diversity analysis, we found 14 rare species representing 12 families (Fig. 4), their abundances ranging from rare (6), very rare (4), fairly rare (2), to extremely rare (2) (Fig. 5).

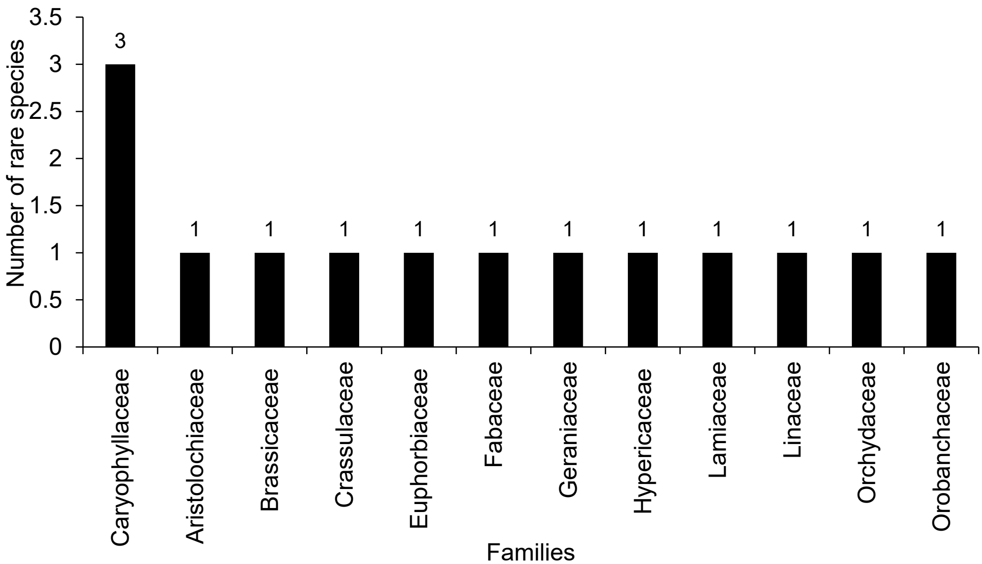

Fig. 4. Distribution of rare species per family in the Chrea forest.

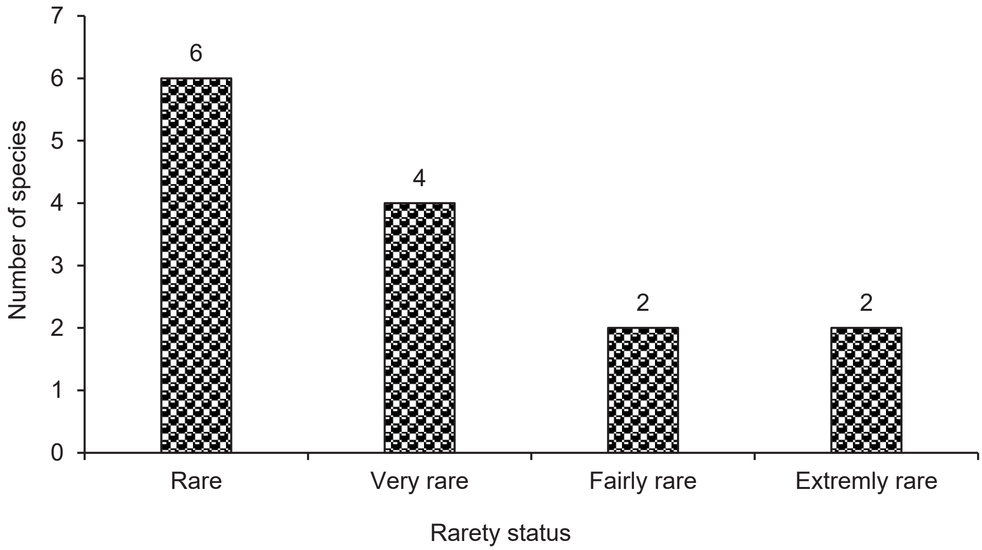

Fig. 5. Distribution of species following their rarity status.

Raunkiaer life forms species in Chrea woodland

Therophytes were by far the dominant life form in both types of stands, 50 % of the species in the stands with black locust (Fig. 6), and 53 % in the stands without it (Fig. 7). Phanerophytes and hemicryptophytes were the second and third most common life form types, again with comparable abundances in both stand types. Cryptophytes and chamephytes were the least common life forms, neither exceeding 10 %.

The relative proportion of the life forms in an ecosystem is a descriptive and physiognomic value, in addition to having ecological significance (Berghen 1984). The relatively high number of therophytes illustrates adaptation to the Mediterranean bioma (warm, and periodically dry climate conditions), as well

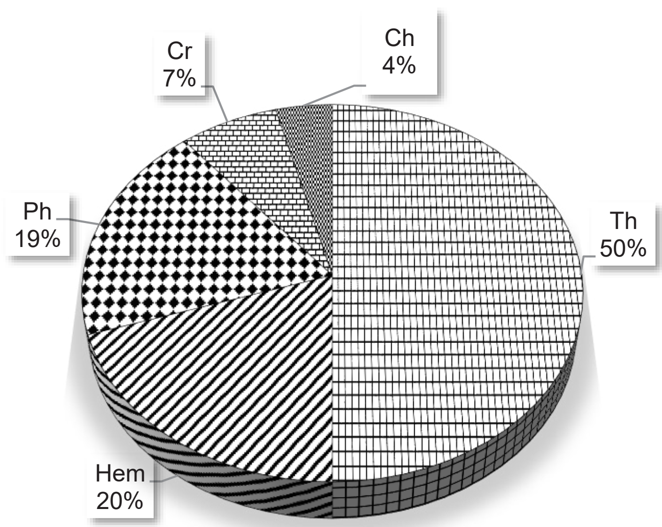

Fig. 6. Raunkiaer life forms species of the invaded woodland by *Robinia pseudoacacia* L.

Note: Th, He, Cr, Ch, and Ph indicate Therophytes, Hemicryptophytes, Cryptophytes, Chamephytes, and Phanerophytes, respectively.

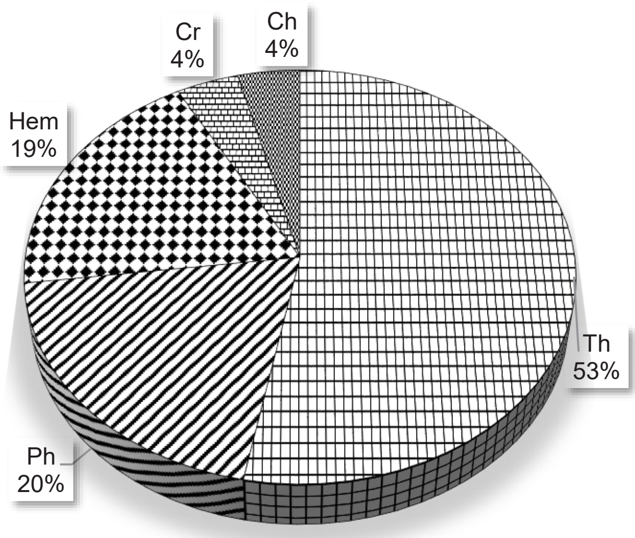

Fig. 7. Raunkiaer life forms of the woodland not invaded by *Robinia pseudoacacia* L.

Note: Th, He, Cr, Ch, Ph, and Ge indicate Therophytes, Hemicryptophytes, Cryptophytes, Chamephytes, Phanerophytes, and Geophytes, respectively.

as the effects of human disturbance, such as overgrazing (Letreuch-Belarouci et al. 2009, Rožac et al. 2018). The dominance of therophytes and hemicryptophytes in both stand types may indicate changes in both environments associated with increased wildfire frequencies, anthropization, and land clearing, all of which would be expected to make the landscape warmer and drier. The proportion plants found to be therophytes in this study is similar to that documented by Naggar et al. (2019) at Theniet el Had National Park in Algeria (50 %) and in the Mamora forest in Morocco (50.5 %) (Aafi et al. 2005).

The relative abundance of therophyte life forms in the study area is higher than that recorded in El Kala cork oak forest (38 %) (Ouelmouhoub and Benhouhou 2007), this lower rate may be explained by its location in the sub-humid climatic stage. Overall, the high presence of therophytes is due to characteristics of arid Mediterranean zones, in which high-water stress dominates (Médail and Myers 2004). Contrary to that found in our study results, the hemicryptophytes are the dominant life form (43.8 %) in the forest woodlands of Babors, in Algeria (Bouchibane et al. 2021).

Conclusions

The present study investigated the effects of the introduction of black locust into a cork oak forest on the species composition, species richness, species heterogeneity, species abundance and plant life forms of the forest. The results demonstrated that in the cork oak forest sampled, species richness, species diversity and species heterogeneity were predominantly higher in stands with locust than in stands without locust. Vítková et al. (2017) reported significant differences between habitats with and without black locust. In accordance with the results of our study and those of other researchers, this suggests that the introduction of species can, on occasion, increase local species richness (Sax et al. 2002, Stohlgren et al. 2003). However, species richness did not differ between stands with and without *Robinia*.

It is recommended to establish a programme that integrates general forest management with the objective of preserving highly desirable species, including rare or endangered species, as well as the valorisation of medicinal species.

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