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Plant species diversity in alien black locust stands: A paired comparison with native stands across a north-Mediterranean range expansion

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ABSTRACT

Black locust (*Robinia pseudoacacia* L.) is a widespread alien tree species commonly thought to influence plant assemblages. The aim of this study was to compare the plant diversity between black locust and native recent secondary stands within the European Mediterranean Mountains environmental zone. Spontaneous reforestation was detected by comparing historical aerial photographs and the most recent images. Distributed throughout a 2700 km^2 hilly and piedmont area, 32 black locust and 32 paired native stands were selected and all vascular plant species were surveyed in a 100 m^2 area. Analyses of the α and β-diversity were performed separately for six identified plant groups. Despite a clear difference in the tree diversity between the black locust and native recent secondary stands and a homogenisation of the tree layer by the black locust stands, we found only inconsistent hints for homogenisation of the ground-layer vegetation by the black locust stands. There is no evidence to suggest that the presence of black locust in recent secondary stands plays a major role in shaping the diversity of the understory plant groups compared to native stands.

1. Introduction

Black locust (*Robinia pseudoacacia* L.) is one of the most important examples of an invasive tree in a temperate environment (Richardson and Rejmánek, 2011) and is one of the top three alien plant species based on its distribution throughout Europe (Lambdon et al., 2008). This nitrogen-fixing tree is able to outcompete a wide range of native trees during spontaneous reforestation on abandoned areas in which agricultural practices have ceased (Bertacchi and Onnis, 2004).

The characteristics of black locust, i.e., a light-demanding species with a prompt vegetative reproduction, particularly through root sprouts, and a fast growth, makes it an extraordinary pioneer tree species even in its native range (Boring and Swank, 1984). Furthermore, these attributes, together with its use in erosion control, land reclamation and firewood production (Boring and Swank, 1984; Dzwonko and Loster, 1997; Laiolo et al., 2003; Pividori and Grieco, 2003), are at the base of its spread in North America and Europe. However, black locust invasion has been proven to have an impact in comparison with the native habitats on plant (e.g., Peloquin and Hiebert, 1999; Matus et al., 2003; Essl et al., 2011; Trentanovi et al., Unpublished results), bird (Laiolo et al., 2003; Caprio et al., 2009) and lichen (Nascimbene and Marini, 2010) communities and nitrogen cycling (Rice et al., 2004).

Prior work on the effects of black locust have considered the understory vascular plant communities by focusing on and detecting various effects (e.g., facilitating the invasion of alien species; Peloquin and Hiebert, 1999; Von Holle et al., 2006; Essl et al., 2011). In particular, black locust is thought to trigger species loss on sites with low nutrient availability (Kowarik, 1996; Rice et al., 2004). However, over several decades and in the absence of disturbance, black locust is likely to be outcompeted by native plant species and stands will return to be dominated by native species (Motta et al., 2009).

This study aims to compare plant data in secondary stands of black locust and native tree species in the young development stages (<35–40 year). We apply an original sampling design to conduct a comparative investigation on spontaneously growing forests over a representative area within the Mediterranean Mountains environmental zone (Metzger et al., 2005). The plant data are divided into six groups on the basis of investigating potential responses according to their ecological niches and/or origin of the species. On the basis of this approach, the effects of black locust on the α and β plant diversity of alien and native recent secondary forests are investigated.

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2. Methods

2.1. Study area

The study was conducted in the foothills of the Eastern Alps within the Mediterranean Mountains environmental zone (Metzger et al., 2005) (Northern Italy, Veneto Region), a region that has undergone recent spontaneous reforestation. The study area (approximately 2700 km^2; 45°74′N, 11°52′E) is located within the elevational range of black locust; hence, between 0 and 100 m to generally 900–1000 m (Gellini and Grossoni, 1997). The climate in these areas is relatively homogeneous. The rainfall distribution (peaks during spring and autumn) and temperature (hot summers and harsh winters) patterns are similar throughout the year (ARPAV, 2011); however, precipitation increases when moving northward and with increasing elevation. Black locust has been described to be adapted to a broad variety of substrates (Buffa and Ghirelli, 1993) and within the study area it is found on substrates ranging from calcareous to siliceous.

Precedent research has highlighted an increase of 4.1% of the forest cover between 1991 and 1999 (Salvadori, 2005) within a representative location of the study area (Pilli et al., 2006; Lamedica et al., 2007). On the local scale, Del Favero (2001) has recorded a spontaneous frontal expansion of 1.98 (±0.6) m/year. The alien woodlands dominated by black locust cover an area of 11205 ha of the Veneto Region (Gasparini and Tabacchi, 2011), and this alien species is thought to be expanding into abandoned lands.

2.2. Sampling design

One method of investigating the effects of alien compared to native stands is to use nearby paired sampling units, invaded and non-invaded (see Vanderhoeven et al., 2005; Chabrerie et al., 2008, 2010; González-Muñoz et al., 2012). For example, Dzwonko and Loster (1997) selected a black locust and a neighbouring native secondary stand with the same age of colonisation and observed changes in the ruderal and nitrophilous species communities. To identify the secondary stands we compared historical aerial photographs from 1978 to the most recent 2006–07 (See Appendix A Supplementary materials), as this approach has revealed to be suitable in detecting forest expansion (Fensham and Fairfax, 2002).

The recognition of the two groups of forest types (i.e., black locust and native) was based on the forest-type map of the Veneto Region (Del Favero, 2006). The identification was first applied to the black locust secondary stands and only areas that showed clear evidence of spontaneous reforestation were selected. Successively, within a 500 m radius from the detected alien stand a native secondary stand was identified by applying the same method, if such stand was present. This maximum distance buffer increases the probability that stands will have the same land-use context and disturbance regime. The identification of nearby paired sites, having similar geology, climate and land-use history, is a reasonable approach for measuring the effect of invasive species (Walker and Smith, 1996). A minimum distance between the stand pairs was fixed to 1 km to avoid autocorrelation.

A total of 312 hypothetical sampling pairs (corresponding to the stand pairs) were identified. We visited a subset of these stands in the field with the aim of obtaining a random sample of at least 30 of these pairs, which were stratified based on elevation, to represent a gradient of potential forest vegetation communities along black locust's ecological alien range. In order to define black locust and native stands, a cluster analysis based on the basal area of each tree species for each sampling unit was performed. The groupings from this cluster analysis helped to resolve discrepancies between the direct observations of the tree composition and what was indicated on the forest type map. The number of sampling pairs was fixed, after the cluster analysis, to a final value of 32, distributed throughout the study area (Fig. 1).

2.3. Data collection

Each secondary forest stand was sampled using a single randomly located sampling unit maintaining a precautionary minimum distance of at least 5 m from the inner part of the forest mantel (even more if a wider edge effect was observed), as edge-oriented plant species are most commonly found within 5 m of the disturbance line (Matlack, 1994). A vegetation survey was performed in square sampling units of 100 m^2 area each, as suggested by Wheater et al. (2011) and commonly applied in forest floristic surveys.

Each tree (dbh $\geqslant$ 5 cm) was identified at the species level, and its dbh and height were recorded. The understory plant species were identified and their cover was recorded according to the scale of Braun-Blanquet and Pavillard (1928). The understory plants were those not sampled as trees. In each sampling unit, an increment core was collected from a representative tree (i.e., the largest tree or, in the case that this was a tree that pre-existed the succession, the largest among those established during the colonisation) to determine the age of the stands.

The investigated stands were located between 24 and 693 m, and their age ranged between 10 and 36 years, with a mean age of 21.8 (±6.4) for the black locust stands and 23.1 (±4.9) for the native stands. Mean dbh values of 11.0 cm (±5.4) and 9.4 cm (±3.8) and mean height values of 10.8 m (±4.2) and 9.5 m (±3.3) were found for the black locust and native stands, respectively. A total number of 21 and 26 tree species were recorded for the black locust and native stands, respectively.

2.4. Data analysis

The tree species' basal area matrix was subjected to agglomerative cluster analysis with the coefficient of Bray–Curtis as a function of the similarity and the Ward's clustering method as a method of classification to validate the categorisation of the sampling units. To identify the indicator species for each cluster group Indicator Species Analysis (ISA) (Dufrêne and Legendre, 1997) was performed. These species were identified for each cluster using the indicator value (IndVal) method, which combines the specificity of a species (uniqueness to a particular sampling unit) and its fidelity (frequency within that sampling unit). For each species, the IndVal ranges from 0 (no indication) to 1 (maximum indication). The statistical significance of the IndVal was tested using of a Monte Carlo test, based on 999 randomisations.

The plant information was used to investigate the differences that could arise between the black locust and native secondary stands. For the purpose of this study, the understory plant species were divided into six groups: (1) total, to provide a general measure of richness and diversity; (2) aliens, following Pignatti (1982), Masin and Tietto (2005) and Celesti-Grapow et al. (2010) and (3) natives, to understand the role of black locust on favouring the spread of biological invasion; (4) ground-layer species, those <1 m height and (5) forest species, those herbaceous and shrub species indicated as largely restricted to forests by Schmidt et al. (2003) and (6) grassland species, those belonging to a selection of grassland alliances extracted from Ellenberg (1979), to provide three indicators of the understory layer development along the secondary succession. According to Tüxen and Ellenberg (1937), the raw data of species cover was converted to percentage data.

The richness and diversity of the abovementioned plant groups were calculated for each sampling unit and the related α and β values were compared based on among-sampling pair comparisons.