Genetic differences within natural and planted stands of *Quercus petraea*

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Received 15 February 2011; Accepted 31 March 2011

**Abstract:** Five sessile oak (*Quercus petraea* (Matt.) Liebl.) stands from the Czech Republic were studied to learn about the impact of different types of forest management regimes on the genetic differences among tree populations and on population structures. One population had not been markedly affected by human activity, two populations represented unplanted stands that were extensively managed for a long period of time using the coppice system, and two populations were planted stands. Approximately 100 trees from each stand were mapped and subsequently genotyped using 10 nuclear microsatellite loci. We determined the spatial genetic structure of each population and the genetic differentiation among the populations. We found that: (i) the populations were genetically differentiated, but the differences between the unplanted and planted stands were not markedly significant; (ii) the genetic differentiation among the populations depended on the geographical distribution of the populations; (iii) within unplanted stands, a strong spatial genetic structure was seen; and (iv) within planted stands, no spatial genetic structure was observed. Our findings implies that the analysis of spatial genetic structure of the sessile oak forest stand can help reveal and determine its origin.

**Keywords:** *Quercus petraea* • Genetic structure within a population • Genetic differences among populations • Microsatellites • Forest management

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1. Introduction

Long-term human activity in European forests has influenced the genetic diversity of forest ecosystems [1] including forest trees [2]. Modified environmental conditions and forest structure, as well as the selective removal of trees during thinning and harvesting, can all potentially change the genetic structure of a forest [3,4]. Selectively favoring special phenotypes may strongly influence adaptive capability and economically important traits [5]. Artificial regeneration by means of sowing or intentional planting often results in changes in the genetic composition of the target species [5]. We can anticipate that a narrow selection of seed-producing trees will result in lower genetic variability in planted forest stands. Intensive forest management can also disturb the initial genetic structure of a population due to the planting of genotypes of alien origin within a species, *i.e.*, seedlings from remote geographic regions within a country or from abroad. This can even result in an outbreeding depression as described, for example, by Woessner [6].

To help protect the diversity of woody forest species, it is important to determine how forest management influences the genetic variability of these species.

In this study we examined sessile oak, *Quercus petraea*, a woody species of high economic value commonly found in the Czech Republic and in most of Europe. Recently, a number of genetic studies have been performed, as genetic markers allow quick surveys of variation within and between populations [7-8]. However, most of these studies aimed to assess the genetic characteristics of natural or semi-natural populations.

Studies concerning genetic structure and genetic variability at the population level were performed by several authors [10-13]. Finkeldey [11] analyzed 17 isoenzyme loci to reveal that differentiation among populations within a species is very low, reflecting the geographical location of populations to a certain extent. Bruschi *et al.* [14] also noticed a slight correlation between genetic distance and geographic distance among populations; they evaluated the diversity of several populations using both morphological and molecular
markers. Using microsatellites, a low or not significant genetic differentiation among populations of *Q. petraea* was reported in France [15,16], Belgium [17], Ireland [18], Denmark [19], and the Czech Republic [20]. Similar results were also reported by Bakker *et al.* [12].

When analyzing the genetic structure of populations using enzyme-coding loci, Zanetto and Kremer [21] observed significant differences in the frequencies of alleles in oak populations. Streiff *et al.* [10] used isozymes and six microsatelite loci to study the diversity and fine-scale genetic structure within a native oak forest containing *Quercus robur* and *Q. petraea* in the northwest of France. Their study demonstrated that the stand had a significant but low spatial genetic structure that was greater for *Q. petraea* than for *Q. robur*. Cottrell *et al.* [13] compared by means of microsatellites the genetic structures of two British oak woods containing both *Q. robur* and *Q. petraea*. One stand contained unplanted natural woods managed by coppicing, while the second stand was influenced by human-mediated planting. Significant spatial genetic structure was found in both stands, with the most substantial spatial genetic structure occurring in unplanted forests. In general, these studies point to high genetic diversity in the stands that were investigated. This diversity was attributed to the high level of outcrossing that occurs in *Quercus* spp., particularly *Q. petraea*.

In this study, we paid close attention to the relationship between genetic characteristics and management intensity and to the level of autochthonity of the *Q. petraea* populations. An autochthonous stand is a conspecific stand that has spontaneously arisen at a given location. The high correlation between spatial genetic structure and forest management regime for *Fagus sylvatica* was mentioned by Gregorius and Kownatzki [22]. In our study, we examined five stands of *Q. petraea* in Czech Republic. We tested whether there were any differences in genetic characteristics among the populations that could be attributed to the various management regimes. The aim of this study was to answer the following questions: First, are there any genetic differences between natural and planted stands? Second, does the type of forest management regime influence the genetic structure of the stands? Third, is there existing relation between the origin of the stand and the genetic structure of the population?

### 2. Experimental Procedures

#### 2.1 Localities

We choose five populations of *Quercus petraea* (Matt.) Liebl. that are managed using different forest management schemes. Stands 1, 2 and 3 are located in the Křivoklát Nature Reserve (50° 02´ 56˝ N, 13° 53´ 24˝): This locality represents a natural forest that has not been influenced by human activity. The habitat is located above the Berounka River on an extremely jagged slope with a south to southeastern orientation and occasional rock outcrops. In this area, the oak population forms a layered dwarf thermophilous oak forest that is typical of a wild service-oak forest (*Sorbus torminalis*-*Quercetum*; Svoboda ex Blažková 1962). The dominant *Q. petraea* cover comprises 25%–50% of the tree layer, and the admixture of *Pinus sylvestris* L. cover is 5%–25% (for details see [23]).

Stand 2. Červený Kříž Nature Reserve (49° 59´ 30˝ N, 13° 55´ 47˝): This locality represents a natural stand that has been managed for a long time using the coppice system. This habitat is located in a flat area. The oak population in the area is part of a thermophilous cinquefoils-oak forest (*Potentillo albae-Quercetum* Liblert 1933).

The tree layer is composed almost exclusively of oak, with a cover of 75–100%. Individuals of *Carpinus betulus* L., *Tilia cordata* Mill., and *Sorbus torminalis* (L.) Crantz can be found only sporadically in this stand. A shrub layer is absent in this community primarily due to wild animal activity (for details see [23]).

Stand 3. Křivoklátsko Protected Landscape Area, and *Sorbus torminalis* and *Quercus robur* with an admixture of *Quercus petraea* planted approximately eighty years ago on municipal land in the town of Křivoklát. The tree layer is composed primarily of planted *Q. Petraea* with an admixture of *C. betulus*, *Fagus sylvatica* L., *Larix decidua* Mill., and *P. sylvestris*.


Stand 5. Lipina (48° 52´ 45˝ N, 16° 01´ 13˝): The locality in the Podyjí National Park represents a semi-natural unplanted stand on a slope of approximately 20° inclination that was extensively utilized by coppice management, at least for the past 500 years [24]. From 1951 to 1991, only sanitation cutting was carried out. Since 1991, the year when the Podyjí National Park was established, the stand has been preserved without intervention. The oak population here comprises part of the wild service-oak forest with *S. torminalis* and *Vincetoxicum hirundinaria* Med. (*Sorbo torminalis-Quercetum* Svoboda ex Blažková 1962) transformed into an acidophilous woodrush oak forest with *Festuca ovina* L. (*Luzulo albidae-Quercetum* Hiltlitz 1932). Oak is dominant in the tree layer, comprising 70–80% of the total canopy layer. The admixture consists of *Tilia platyphyllos* Scop., *T. cordata* Mill., *Carpinus betulus* L., *Acer campestre* L., *Fraxinus excelsior* L., and *Sorbus aucuparia* L. (for details see [24]).