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# Soil properties in plantations of sessile oak (*Quercus petraea*) and red oak (*Quercus rubra*) in reclaimed lignite open-cast mines of the Rhineland

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**Abstract**

We studied the soil properties of 18-year-old plantations beneath the crowns of the native sessile oak (*Quercus petraea*) and of the introduced red oak (*Quercus rubra*) growing on reclaimed lignite open-cast mines. The soil properties of both plantations, which are growing on either highly fertile (loess deposits, silty loam) or on low fertile (mixture of loess and sand deposits, clayed sand) soil, were measured and compared with values taken from 2-year-old *Quercus robur* plantations.

In plantations of *Q. petraea* we generally found higher values of total carbon ($C_{org}$) and total nitrogen ($N_{tot}$) in the upper soil, although the amount of organic matter in the O-horizon did not significantly differ. Soils of *Q. petraea* plantations also exhibited higher values for microbial and faunal life. For example, microbial activity, the respiratory quotient ($qCO_2$) and C-mineralization were about twice as high as for the *Q. rubra* plantations. Collembola and mites (Oribatei), both belonging to the soil mesofauna, reached higher densities in the *Q. petraea* plantations.

When growing on highly fertile soils, the amount of soil nutrients ($K^+$, $Ca^{2+}$, $Mg^{2+}$, and $PO_4^{3-}$P) did not differ between the two plantations. However, when oak trees grew on the less-fertile soil, the amount of soil nutrients was significantly lower beneath red oak. The amount of soil nutrients beneath red oak was even lower than beneath 2-year-old *Q. robur* plantations; the soil properties of which are almost at the beginning stage of succession. The results suggest that nutrient depletion beneath red oak when compared to sessile oak is caused both by increased immobilization into woody biomass, and by increased recalcitrance of organic matter.


*Keywords:* Afforestation; Mesofauna; Microorganisms; Nutrients; *Quercus petraea*; *Quercus rubra*

## 1. Introduction

The established restoration practices for reclaiming lignite open-cast mines in the Rhineland are primarily aimed at coverage of surface mines. Optimal substrates for plant growth, which cover the overburden

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to a thickness of 2–4 m, are either pure loess or a mixture of subsurface loess and sand from the Quaternary epoch layer (Kunde and Müllensiefen, 1998). Both substrates are characterized by low concentrations of organic carbon and nitrogen.

After dumping is finished, afforestation is carried out within the next planting season using either tree species from natural ecosystems in that geographic region (i.e. *Quercus petraea*, *Quercus robur*) or introduced species (i.e. *Quercus rubra*).

In natural ecosystems the forest floor is an important pool of organic matter and nutrients, especially when organic matter accumulates to substantial depths. Tree species can affect patterns of nutrient cycling. The effect of nutrient dynamics may be direct, through the uptake, use and loss of nutrients. For example, when fast-growing tree species were planted, the rapid uptake and accumulation of nutrients in tree biomass can serve as the main mechanism responsible for decreases in soil nutrients (Montagnini, 2000). Such a direct effect can be superimposed by an indirect one governed by the decomposer community living in the forest soil, which in turn results in an increase in soil nutrients. The decomposition rate based on the palatability of the substrate to decomposers and the rate of mineralisation by microbes varies among tree species depending on litter quality (Kautz and Topp, 1999; Pérez-Harguindeguy et al., 2000; Simon and Topp, 2001). Thus the substrate quality of an ecosystem in which a tree species grows not only influences the decomposer community (Swift et al., 1979), but is also able to affect decomposition processes and avoid nutrient deficiencies (Kautz and Topp, 2000).

In recent decades a decline in the concentration and amount of base cations in a variety of ecosystems has been observed (Likens and Bormann, 1995). Loss of nutrients from forest soils can be accelerated by acid rain (Ulrich et al., 1980; Johnson et al., 1994) and by declining inputs of base cations from atmospheric deposition (Hedin et al., 1994). Moreover, human activities have more than doubled inputs of nitrogen to terrestrial ecosystems (Matson et al., 2002). The problem of sustaining soil fertility becomes an important management issue.

We compared soil characteristics beneath red oak and sessile oak and attempted to determine the linkage of organic matter, soil fauna, microorganisms, and soil nutrition. The following questions were addressed:

1. What is the influence of the coverage of surface mines on succession of soil biota and exchangeable nutrients?
2. Is there a difference in the palatability of leaf litter between the two oak species?
3. If a difference exists, does it effect the degradation and mineralisation of leaf litter?
4. Is there an accumulation or a depletion of soil nutrients beneath the crowns of any oak species under the environmental conditions studied?

## 2. Area descriptions, methods, and material studied

The investigations were carried out at a lignite open-cast mine of the Rhineland. Cultivable substrates, which were either Pleistocene loess (=highly fertile soils) or a blend of at least 25% loess with underlying terrace material containing sand and gravel (=less-fertile soils) were deposited in a layer of up to 4 m thick on the surface (Zöttl and Möhlenbruch, 1989). Thus, thickness of coverage should not affect oak growth (Meredieu et al., 1996). The influence of the underlying Tertiary deposits, which mostly contain considerable amounts of sulfur, was not studied because these deposits are far below the soil surface and because there is no upward water movement. This is in contrast to the open-cast mines of Lusatia (Katzur and Haubold-Rosar, 1996). Variation in quality and decomposability of leaf litter through foliar uptake of atmospheric pollutants between sites can be excluded (Carreiro et al., 1999).

The various sites investigated in this study (1) were close to each other and thus influenced by the same external factors, and (2) contained definable substrates with relatively low heterogeneity within the sites, at least during the beginning of succession. Thus, the only remarkable variable during the continuous development after substrate placement was the tree species planted.

Eighteen-year-old plantations of predominantly red oak, *Q. rubra* (70%), and sessile oak, *Q. petraea* (70%), were compared. Measurements were taken beneath the crowns of oak trees from the upper 5 cm of the substrates. Accompanying tree species for all