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ROOT SYSTEM ARCHITECTURE OF OAK SEEDLINGS IN COMPETITION WITH GRASS

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Introduction

Herbaceous vegetation has been shown to have a significant negative impact on survival and growth of newly planted oak seedlings. Although oaks are usually grown at fertile sites, competition for belowground resources has been identified as the major factor limiting seedling survival and growth (Collet et al. 1996, Löf 2000). The outcome of belowground competition is related to the spatial distribution of the root systems, the spatial distribution of soil resources, the nutrient and water uptake capacity of the root systems, and the nutrient and water use efficiency of the plants (Caldwell and Richards, 1986).
The objective of the present study is to analyze the effects of grass competition on the spatial distribution of the roots of young oaks. We adapted a dynamic model of root system architecture developed for young peach trees (Vercambre et al. 2001) which was based on the modeling of elementary growth processes (axial and radial growth, branching, reiteration, decay and abcission). We used this model to examine the effects of grass competition on various parameters reflecting root system development.

Materials and Methods

The experiment was set up at a field near Nancy, eastern France. In May 1998 one-year-old bare root oak seedlings (*Quercus petraea*) were planted and grass (*Deschampsia cespitosa*) was sown in a former agricultural pasture. The soil was a pseudogley soil with a clay horizon at a 30-cm-depth.
Oak seedlings were periodically excavated for root system description. Seedlings were excavated at eighteen dates between June 1998 and July 2001, and 8 to 20 seedlings were excavated each time. All roots with diameter above 0.3mm were extracted. The topology of the whole root system was described, and the dimensions (total length, diameter along the root) of each root were measured. At two excavation dates, the position (spatial coordinates) of a sub-sample of roots was measured with a magnetic 3D digitizer (Danjon et al. 1999) on four seedlings.

Model

The model was adapted from those of Pagès et al. 1993 and Vercambre et al. 2001. It simulates the development of root systems in three-dimensional space. It represents the root system as a sequence of root segments and calculates the size (length and diameter) and the location of each root segment at each time step, using stochastic sub-models to describe elementary growth processes:

- *axial growth*. The length of each root segment within a root is calculated as a negative exponential function of root age, and the direction of each root segment is determined by a geotropism coefficient and a soil mechanical constraint resistance coefficient.
- *radial growth*. The radial growth of a root segment is the direct result of ramification. At each branching point, the cross sectional area is calculated from the cross sectional area of the daughter roots following:
  [1] $S = \alpha \Sigma\ S_i$

were S is the cross sectional area of the mother root in basal position to the branching point, S_i the cross sectional areas of the i daughter roots distal to this points, and α a parameter to be determined (close to 1).

- *branching*. Lateral roots are assumed to appear acropetally. Three main parameters are used to describe the branching process: (*i*) branching density, (*ii*) proportion of each root type in the lateral roots, (*iii*) duration from apex initiation to lateral root emergence,
- *reiteration*. A reiterated root is defined as a lateral root that has the same characteristics as its mother root. Reiteration events occur regularly and lead to the formation of the structural root axes. The reiteration process is described using two parameters: the frequency of reiteration events and the number of reiterated daughter roots at each reiteration.
- *decay and abcission*. The main parameter used to describe root decay and abcission is the life expectancy. The life expectancy is the time a root that does not have any living daughter root, may survive after it has stopped growing.

The model is based on a root typology, each root type being defined by a set of morphological and functional characteristics: axial growth (indeterminate or determinate; growth rate), radial growth rate, longevity, growth direction (orthotropic or plagiotropic), and external aspect (lignified or not lignified). The parameters describing the growth processes are determined for each root type (mean values and standard error). For oak seedlings, five root types were defined: (0) transplanted roots; (1) first order roots: vertically oriented structural roots with indeterminate axial growth and important radial growth; (1) lateral structural roots: horizontally or oblique roots with indeterminate axial growth and important radial growth; (3) intermediate roots: horizontal roots with determinate axial growth and small radial growth; (4) fine roots: horizontal roots with determinate axial growth and no radial growth.

Results and Discussion

Axial growth: For all root types, average root length and root growth direction three years after planting seemed to be similar in both treatments.

Radial growth: Linear regression was used to fit equation [1], and to test differences between the seedlings in the two treatments three years after planting. Analysis of variance revealed statistically significant differences between the two treatments ($p<0.0001$). However, the difference was small in magnitude ($\alpha=1.21$ for the seedlings in bare soil, and $\alpha=1.32$ for seedlings in grass) and an average value was chosen for both treatments ($\alpha=1.28$).

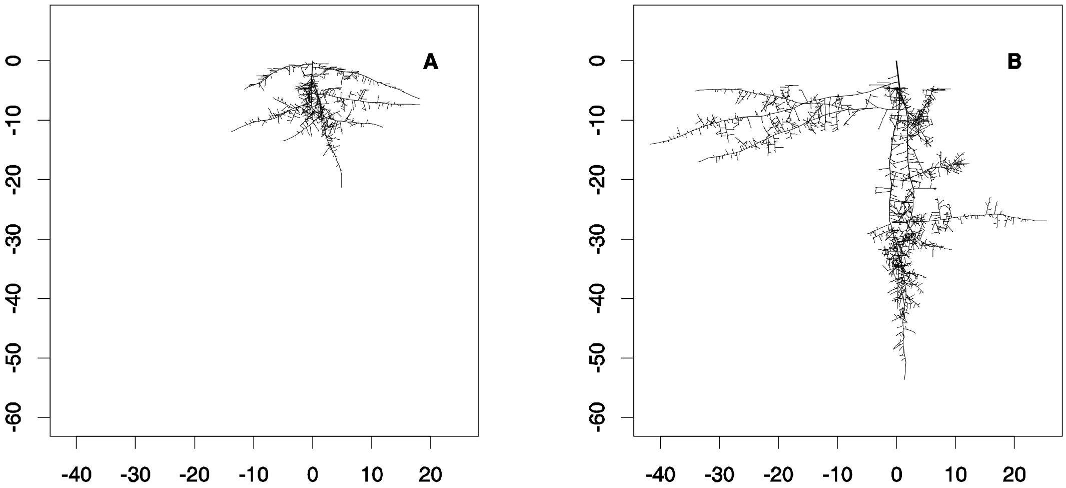
Branching: Mean lateral root density was calculated for each root type and for roots of the same age, and was similar for seedlings in both treatments. However, the proportion of each root type among the lateral roots differed with a proportion of type 2 roots (relatively to the number of type 3 roots) higher in the bare soil than in the grass treatment

Reiteration: Differences in the reiteration process were not analyzed.

Decay: Root decay was low for root types 1 to 5, for seedlings growing with or without grass competition.

Among the developmental characteristics that were analyzed, the only characteristics that significantly differed between seedlings grown in bare soil or in grass was the proportion of each root type in the lateral roots. Therefore, we presently simulate the development of the root system of oaks growing with or without grass competition using the same set of parameters, except the lateral root type proportion (Fig.1). Further analyses are still needed in order to test other differences (e.g. reiteration process) that may occur between the seedlings growing with or without grass competition.

Figure 1: Simulated root system of oak seedlings growing in bare soil A) one year and B) two years after planting.



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