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Light-mediated influence of three understorey species (*Calluna vulgaris*, *Pteridium aquilinum*, *Molinia caerulea*) on growth and morphology of *Pinus sylvestris* seedlings.

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Key words

Regeneration, competition, light, Scots pine, vegetation type

Introduction

Pinus sylvestris is a light-requiring pioneer species. Therefore, its natural regeneration may be jeopardized by some forest understorey species that can intercept a significant amount of light depending on their development, which is also affected by light availability (Balandier et al. 2006, Gaudio et al. 2008). Although the negative effect of underground competition for resources was often highlighted (Nambiar and Sands 1993), the literature does not offer much information on the growth response of Scots pine seedlings to different kinds of vegetation relative to light. The study focused on three common understorey species in acid temperate forests: *Calluna vulgaris*, *Pteridium aquilinum* and *Molinia caerulea*. Our objectives were (i) to quantify their impact on light quantity and quality according to their density, (ii) to record pine seedlings growth and morphology accordingly, and (iii) to compare the interactive effects of those three species. Our assumptions were that *Pteridium* has the worst impact on both light quality and quantity and, therefore, on pine seedlings growth and morphology, followed by *Molinia* and then by *Calluna*.

Materials and methods

An experiment that mimics early competition of weeds and pine seedlings in a forest gap was set up in a nursery in spring 2007. Two factors were studied: the understorey species (*Calluna* C, *Pteridium* P and *Molinia* M) crossed with the density at planting (0, 10, 16, 33, 57 young individuals harvested in forest per m²) defining 15 modalities replicated in three complete blocks. In each of the resulting 45 plots (2 m² large), 50 pine seedlings (2 week-old) were planted at 20 cm intervals among the vegetation.

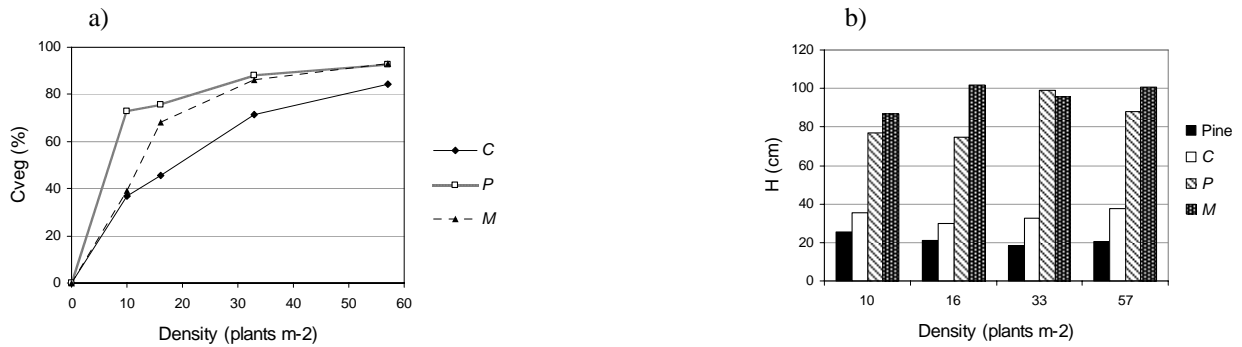
Vegetation development (height and cover, i.e. percentage of the ground area occupied par the vertical projection of the foliage), pine growth (diameter, height and leaf mass area) and light quantity (PAR, 400-700 nm) and quality (Red: Far Red ratio, R:FR, 660:730 nm) were measured in 2007 and 2008.

The data were analysed by variance analyses and simple regressions using Statgraphics software.

Results and discussion

Cover of C, P and M increased logarithmically with density, with a higher increase for P and M than for C (Fig. 1a). Vegetation height did not vary with density, P and M being higher than C that had approximately the same height as pine seedlings (Fig. 1b).

Figure 1: Vegetation cover (Cveg) (a) and vegetation and pine height (H) (b) according to density of C, P and M.



At both highest vegetation densities, the light available at pine seedlings apex was reduced by 60% under P and M (Fig. 2) whereas there was no statistical difference among densities for C.

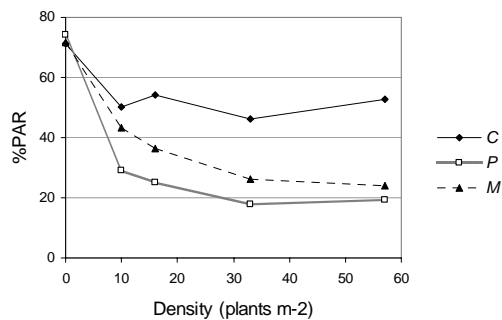
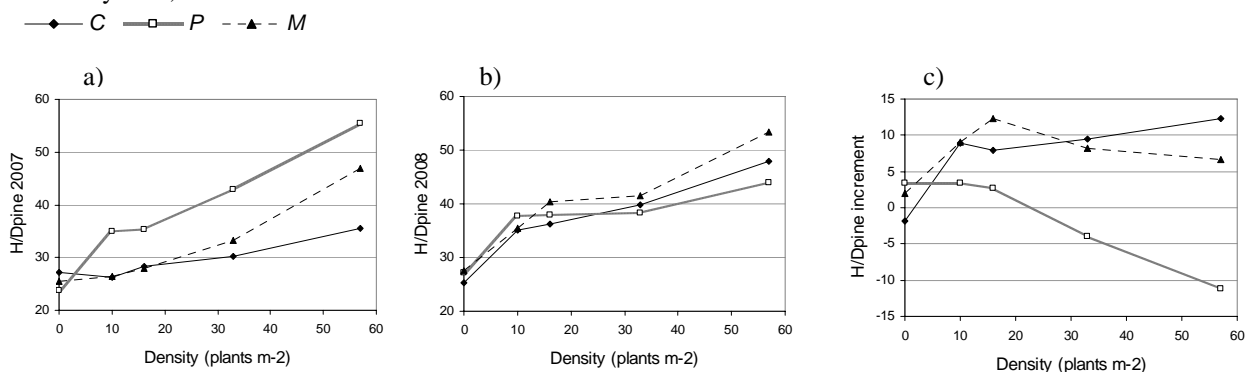


Figure 2: Light quantity (%PAR) available at the pine seedlings apex according to density of the three species in the second year.

Regarding light quality, R:FR was significantly reduced only under P cover (1.20 and 0.14 for densities 0 and 57 plants m⁻², respectively).

The increase in vegetation density caused a decrease in pine seedlings diameter ($p < 0.0001$, $R^2 = 56\%$) without any pronounced effect on seedling height. As a result, the height / diameter stem ratio (H/D) increased with vegetation density. However, year and species effects were observed (Fig. 3). In 2007, pine seedlings in P had the highest H/D and those in C the lowest one. In the second year, H/D slightly increased or remained stable in C and M whereas it significantly decreased in P (Fig. 3c).

Figure 3: Height/diameter stem ratio (H/Dpine) in 2007 (a) and 2008 (b) and H/Dpine increment (c) according to density of C, P and M.



Leaf mass on an area basis (LMA) has been reported as a functional trait of acclimation to light in the sense that shaded plants tend to increase their light interception area per biomass unit (King 2003). In accordance with measured light, such an effect was recorded in this

experiment with a decrease of pine LMA with increasing vegetation density ($p < 0.0001$, $R^2 = 68\%$, Fig. 4). For all the densities, LMA was systematically higher for seedlings growing in C than in P and M. At low densities, LMA was higher beneath M than beneath P whereas it was the contrary for the highest density ($p = 0.0204$) where pine needles were thinner ($p = 0.007$) and lighter ($p = 0.0008$) beneath M. This effect could be attributed to competition for underground resources, *i.e.* water and/or nutrients, in addition to light (Provendier and Balandier 2008).

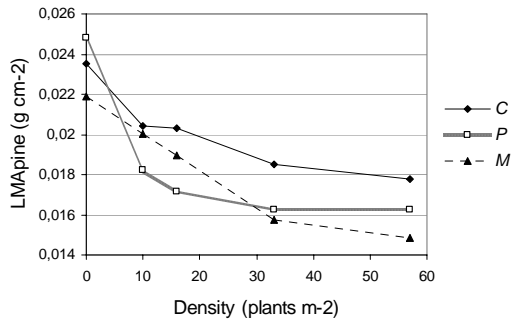


Figure 4: Leaf mass on an area basis (LMA_{pine}) of the pine seedlings according to density of C, P and M.

Conclusion.

P reduced the quantity of light available for pine and modified the light quality whereas C that was characterized by the same height as pine seedlings had only a limited impact. M greatly decreased light available for pine seedlings, whereas it had no effect on light quality. This result came probably from floral stalks that represent two-third of plant height for a negligible contribution to photosynthesis (*i.e.* they intercepted light without modifying its quality) whereas the leaf tuft had nearly the same height than pine seedlings.

As a consequence, the three weeds affected the pine diameter but with a strong species effect. P strongly decreased the pine diameter growth in the first year and also height growth in the second year. The main effect of M and C was delayed to the second year, particularly for C. However, it is noteworthy that C had an impact on pine seedlings diameter growth without any pronounced effect on light availability. This result suggested that others factors than light are involved in the effect of C.

With a fast development of its aerial part and an important cover, P is the most competitive species for light. At high density, M also seems to play a role via belowground resources in addition to light. LMA is confirmed to be a functional trait accounting for the effects of competition between species.

In the light of these results, identifying the vegetation type and thus its effect on resource availability and then on seedlings growth and morphology seems to be a key factor to consider in order to improve forest vegetation management.

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