GENERAL INFORMATION

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MATERIALS & METHODS

study area	5l, 5n (scientific zone), 6b
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goal	
set-up	see papers below
data collection	see papers below
remarks	C2: An intraspecific application of the leaf-height-seed ecology strategy scheme (DeFrenne_etal_2011_Ecography) C5: Significant effects of temperature on the reproductive output of the forest herb *Anemone nemorosa* L. (DeFrenne_etal_2010_ForEcMan) C6: The use of open-top chambers for evaluating warming effects on forest understorey plants (DeFrenne_etal_2010_EcolRes) C7: Temperature effects on understorey plants assessed by warming and transplant experiments along a latitudinal gradient (DeFrenne_etal_2011_GCB) C8: Latitudinal variation in transgenerational plasticity in seedlings of temperate understorey perennials (DeFrenne_etal_2012_AnnBot)

ABSTRACT

Climate change is considered to be one of the major threats to biological diversity. The global average earth surface temperature has increased by 0.8°C between 1956 and 2005 and is predicted to increase by an additional 1.8-4°C by the end of this century. Biodiversity of temperate forests is mainly a function of the herbaceous understorey community. Many forest understorey plants, however, are probably not able to track the shifting climate due to their limited colonisation capacity. The acclimation potential to climate change within their occupied habitats will likely determine their short- and long-term persistence. Yet, it remains largely unclear to what extent forest understorey plants will be able to respond to climate change.

In this thesis we contributed to fill this knowledge gap by quantifying the response of growth and reproduction of a set of herbaceous forest understorey plants to temperature variation along a latitudinal gradient from northern France to northern Sweden and to experimentally elevated temperatures. We

mainly focused on the spring flowering geophytic forb *Anemone nemorosa* and the early summer flowering grass *Milium effusum* due to their slow colonisation, distribution range, reproductive traits, phenology and growth form.

The plant height of *A. nemorosa* and *M. effusum* showed an increase in natural populations along a latitudinal gradient. Hence, plants grew taller in the north. This phenomenon could be attributed to northward increasing light availability due to increasing canopy openness and photoperiod in the growing season. Furthermore, by sampling *A. nemorosa* seeds in natural populations along the gradient, we were able to demonstrate a decline in the seed nitrogen concentration with increasing latitude. This can be caused by (i) the lower soil nitrogen (N) availability as a consequence of lower N depositions towards the north or (ii) a greater investment in clonal reproduction in northern populations. Since the degree of seed provisioning co-determines seedling survival, changes in the seed N concentration can affect the reproductive success along the gradient. Finally, we also showed that temperature and latitude explained most of the variation in reproductive output for early flowering understorey plants with a northerly distribution range edge (e.g. *A. nemorosa*, *Paris quadrifolia*, *Oxalis acetosella*). Reproduction of the more southerly distributed later flowering species (e.g. *Brachypodium sylvaticum*, *Circaea lutetiana*) was best explained by local environmental variables such as overstorey canopy cover.

Subsequently, experimental warming and transplant experiments have been used to examine the effects of temperature on phenology, growth and reproductive performance of the two selected understorey plants. Firstly, we validated the use of open-top chambers (OTCs) in deciduous forests for evaluating warming effects on understorey plants. OTCs are small greenhouses with inclined walls and an open top that passively heat a small vegetation plot. They raised average air and soil temperature with ca. 0.2 to 1.5°C, mostly before overstorey canopy flush. Next, we used OTCs in combination with common garden experiments in three sites (Belgium, southern Sweden and northern Sweden). In a common garden, populations of the same species are transplanted in a common environment with different climate. We clearly demonstrated that vegetative growth and reproductive success of the vernal *A. nemorosa* benefited from higher temperatures. No such response could be noted for the early summer flowering *M. effusum*, probably because it mainly grows after canopy flush and was thus limited by light availability. We conclude that not all understorey plants respond equally to temperature variation, which may alter understorey community composition and dynamics in the future.

Since recruitment from seeds is an important phase in the life cycle of plants, we also assessed seedling establishment. We quantified the plasticity in growth of seedlings of the two species sampled along the latitudinal gradient in growth chambers. Seedling biomass of northern *M. effusum* populations responded stronger to increases in temperature than seedling biomass of southern populations. Seedlings of *A. nemorosa* did not show such a latitudinal cline in plasticity to temperature. Higher plasticity in *M. effusum* seedling growth in the north may thus offer an important way to cope with climatic changes.

Finally, we compiled distribution patterns of 90 understorey plants in both ancient (i.e. continuously forested since the first available maps) and post-agricultural forests from 18 studies across Europe. We demonstrated that the colonisation of faster species (mainly short-lived herbs) into post-agricultural forests increased with the amount of forest habitat within the landscape. Conversely, the characteristic slow colonising woodland flora (mainly small perennial herbs) was generally unsuccessful in colonising post-agricultural forests - even in relatively densely forested landscapes. Variation in mean annual temperature across Europe had no effect on the recovery of post-agricultural forests, which we attributed to long-term adaptations to the local environment, the larger significance of habitat loss and microclimatic heterogeneity within forests.

We conclude that climate change will likely have significant effects on forest understorey plant dynamics across Europe. We here clearly showed that growth and reproduction of understorey species can show divergent responses to temperature variation. Climate change can thus result in changed biotic interactions in understorey plant communities, and in enhanced regeneration from seed for some species. Clearly, more research is needed to further our understanding of possible changes in forest plant dynamics in a warmer climate.

RESULTS

Climate change can affect forest understorey plants in different ways

- phenology and adult plant performance: *A.nemorosa* might advance its emergence and flowering and increase its growth in warmer climates
- reproduction: increasing temperatures might have a positive impact on the reproductive success of *A. nemorosa*, i.e., in terms of seed mass, germination percentage and seedling mass; the N concentration of seeds decreased from southern to northern populations of *A. nemorosa*
- spring-flowering species, e.g., *A. nemorosa*, seem to be affected more by changes in temperature than later-flowering species, e.g., *M. effusum*