Understanding the role of plant traits and their plasticity in N:P stoichiometry and competition

Ineke Roeling
Environmental Sciences
Copernicus Institute of Sustainable Development, Utrecht University
Heidelberglaan 2, 3584 CS Utrecht, the Netherlands
E: i.s.roeling@uu.nl
Supervisors: Prof. Martin Wassen, Dr Jerry van Dijk, Dr Maarten Eppinga

Background

Plant species richness in European grasslands has been declining for several decades. In most Dutch nature reserves species richness is also slowly but steadily declining. Restoration areas often show low species richness, even years after agricultural use has been ceased. Nitrogen (N) and phosphorus (P) are thought to play an important role in this plant species decline. Earlier research mainly focussed on the effects of N (e.g. Stevens et al., 2004; Bobbink et al., 2010), but more recently it was found that P also plays an important role (Wassen et al., 2005; Ceulemans et al., 2012). Prevailing plant competition theories suggest that there are trade-offs between plant traits used by the plant to deal with nutrient limitation and that these trade-offs influence the outcome of competition. Recent experiments, however, have shown that several grassland species have the flexibility (phenotypic plasticity) to adapt their plant traits depending on the type of nutrient limitation present (Fujita et al., 2010; Olde Venterink & Güsewell, 2010). We test the hypothesis that the competitive winners in modern grasslands are those species that have a high phenotypic plasticity for plant traits involved in nutrient acquisition, use and recycling. As such, they can adapt their traits more easily to changing nutrient limitations and thus outcompete less flexible species.

Identification of opportunist and specialist species

The type of nutrient limitation is based on the N:P stoichiometry (the ratio of N divided by P) of aboveground vegetation. N:P values of 13.5 to 16 indicate co-limitation of nitrogen and phosphorus, values > 16 indicate P-limitation, values < 13,5 N-limitation (Güsewell & Koerselman, 2002). We then used these limitation types to analyse an existing database containing field observations of nearly 700 plots from 11 different European countries (Fujita et al., 2013 in review). If a species occurred significantly more often under P-limited conditions and significantly less under N-limited conditions, it was classified as a P-limited specialist species (and vice versa). Species showing no significant preference were classified as opportunists. We expected these opportunists to have a higher phenotypic plasticity than the specialists.

Trait plasticity in the Netherlands: preliminary fieldwork

We would like to assess the plasticity of plant traits in the field. To do this accurately, we will focus on several selected species and analyse these along the full N:P range. We expect to find more N-limited than P-limited grasslands in the Netherlands. We did preliminary fieldwork to check the N:P ratio of potentially interesting study areas in the summer of 2012 (Figure 1). We visited nature reserves of Natuurmonumenten, Staatsbosbeheer and Dunea in seven different provinces. We determined which plant species where present and took plant and soil samples for analysis. In the summer of 2014 we hope to continue our fieldwork at selected sites, investigating plant trait plasticity in the field in relation to N:P stoichiometry. We would like to thank the nature managers and field staff members that helped us locating interesting areas.

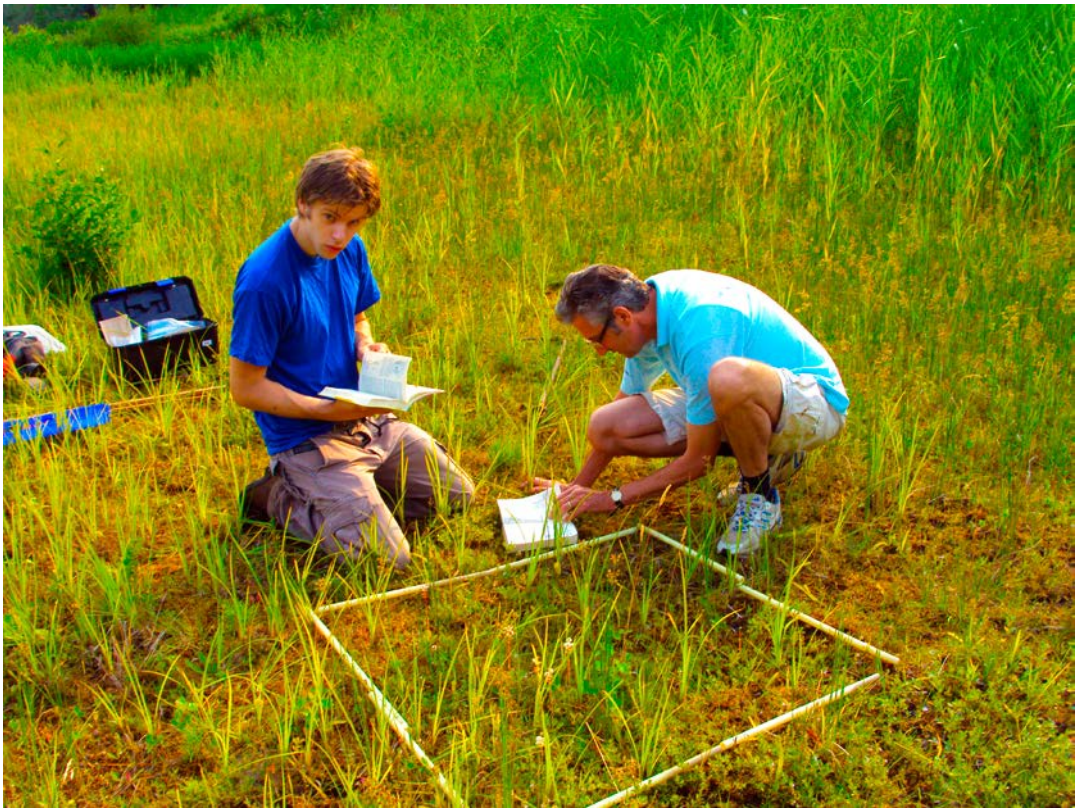

Figure 1 | Professor Martin Wassen and former bachelors student Stef Koop in nature reserve Middenduin, July 2012 *(Staatsbosbeheer/National Park Zuid-Kennemerland)*.

Trait plasticity and the outcome of plant competition

To investigate the effect of trait plasticity on the outcome of plant-plant interactions we carried out a greenhouse experiment in spring-summer 2013. Using the results of the database analysis and the preliminary fieldwork, we chose six interesting species for our experiment: *Alopecurus pratensis* (Meadow foxtail) and *Rumex acetosa* (Common Sorrel) as likely N-limited specialists, *Briza media* (Quaking Grass) and *Centaurea jacea* (Brown knapweed) as likely P-limited specialists and *Knautia arvensis* (Field Scabious) and *Prunella vulgaris* (Selfheal) as likely opportunists.

We wanted to assess the competitive response (biomass of species A in monoculture vs. biomass of A in competition) as well as the relative dominance (biomass of species A vs. biomass of species B in competition), following Olde Venterink & Güsewell (2010). We therefore placed all species in monoculture, and made competition pots with specialists vs. opportunists. We used five different N:P ratios to cover the range from severe N-limitation to severe P-limitation. Combined with 3 different total nutrient levels (low, medium, high) this resulted in 15 different nutrient treatments. To compare long-term effects with short-term effects, we chose to harvest half of the experiment this year and half of the experiment next year. In the end, our experiment consisted of more than 2100 pots, each containing 4 plants (see Figure 2). During the harvest of this year, we measured several plant traits, such as leaf length, root:shoot ratio, specific leaf area, specific root length and root phosphatase production. We are currently busy with the first analyses of the experimental data. We will present these and other results during the next meeting in spring 2014. For more information (in Dutch) visit our project website: www.uu.nl/copernicus/kasexperiment.

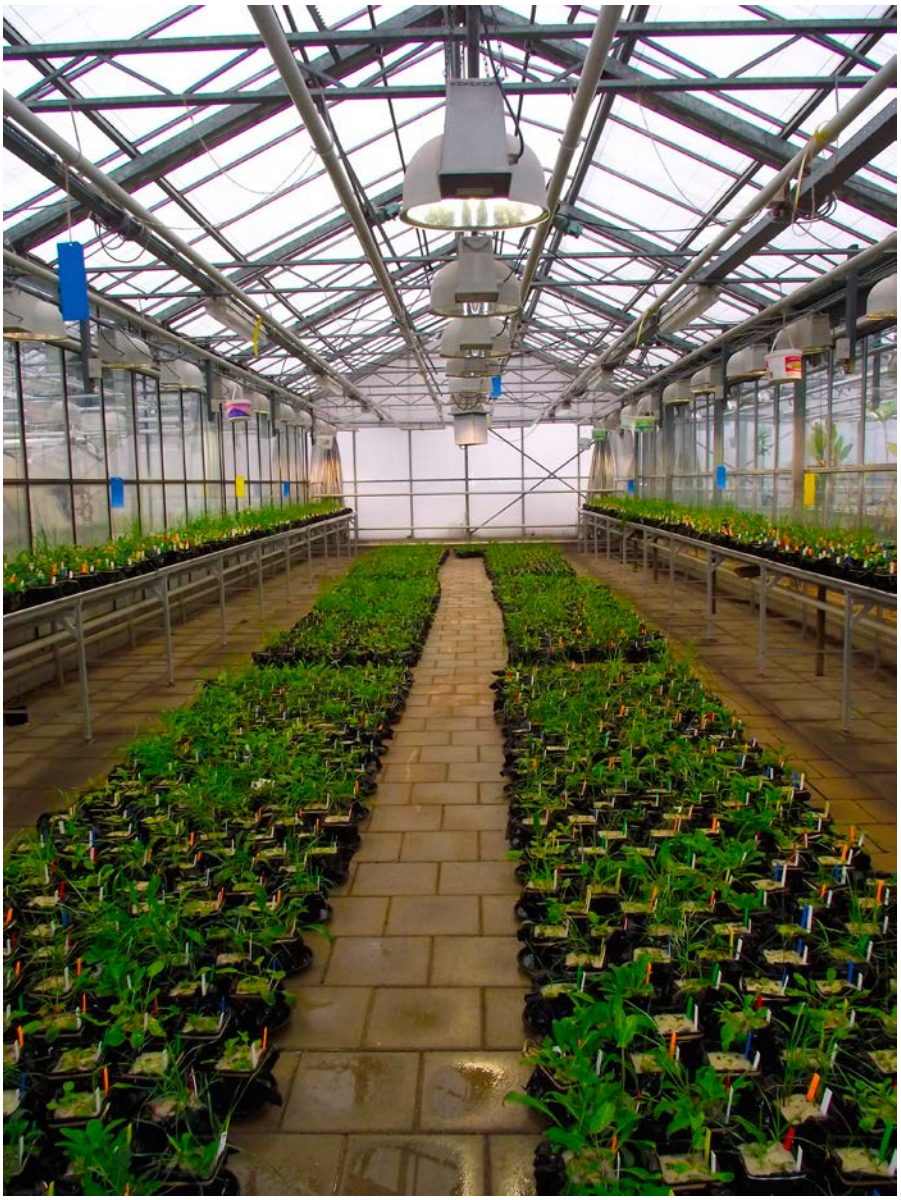

Figure 2 | The greenhouse experiment at the Botanical Gardens of Utrecht University, May 2013.

References

Bobbink, R., Hicks, K., Galloway, J., Spranger, T., Alkemade, R., Ashmore, M., Bustamante, M., Cinderby, S., Davidson, E., Dentener, F., Emmett, B., Erisman, J-W., Fenn, M., Gilliam, F., Nordin, A., Pardo, L. and De Vries, W., 2010. Global assessment of nitrogen deposition effects on terrestrial plant diversity: a synthesis. *Ecological Applications* 20: 30-59.

Ceulemans, T., Merckx, R., Hens, M. and Honnay, H., 2012. Plant species loss from European semi-natural grasslands following nutrient enrichment – is it nitrogen or is it phosphorus? *Global Ecology and Biogeography* 22:73-82.

Fujita, Y., Robroek, B.J.M., de Ruiter, P.C., Heil G.W. & M.J. Wassen. 2010. Increased N affects P uptake of eight grassland species: the role of root surface phosphatase activity. *Oikos* Vol. 119, Issue 10: 1665-1673.

Güsewell, S. & Koerselman, W., 2002. Variation in nitrogen and phosphorus concentrations of wetland plants. *Perspect. Plant Ecol. Evol. Syst.* 5: 37-61.

Olde Venterink H. & Güsewell, S. 2010. Competitive interactions between two meadow grasses under nitrogen and phosphorus limitation. *Functional Ecology* 24: 877-886.

Stevens, C.J., Dise, N.B., Mountford, J.O. & Gowing, D.J. 2004. Impact of nitrogen deposition on the species richness of grasslands. *Science* 303:1876-1879.

Wassen, M. J., Olde Venterink, H., Lapshina, E.D. & Tanneberger, F. 2005. Endangered plants persist under phosphorus limitation. *Nature* 437:547-550.