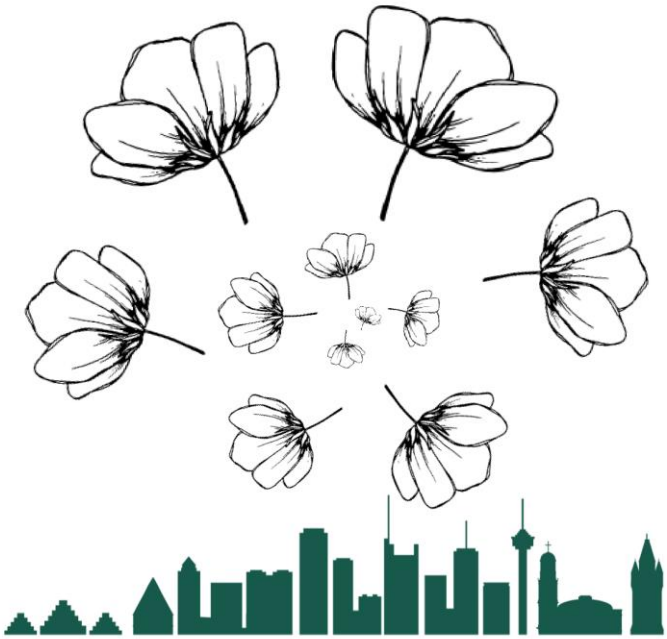
POPBIO 2024

36th Conference of the Plant Population Biology Section of the Ecological Society of Germany, Austria and Switzerland



Frankfurt am Main, 2-4 May

The university hosting PopBio in 2024 is named after Johann Wolfgang von Goethe. Being known as one of the most famous German "Dichter und Denker" (poets and thinkers), less well known is that Goethe was also an influential botanist. Drawing by Damien de La Faye.

POPBIO 2024

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36th Conference of the Plant Population Biology Section of the Ecological Society of Germany, Austria and Switzerland (GfÖ)

2-4 May, 2024, Frankfurt am Main, Germany

Editors:
Martí March Salas
Stefania Przybylska
Niek Scheepens

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CONTENTS

Welcome to Frankfurt am Main and the 36th PopBio meeting!

We warmly welcome you to the *36th annual conference on Plant Population Biology*, PopBio 2024!

Continuing PopBio's tradition of embracing a wide range of topics, this year we are delighted to host five distinguished **keynote speakers** with backgrounds spanning various fields, from population ecology to biogeography. The 30+ oral and 40+ poster contributions also cover diverse themes that will interest many of you.

The conference is organized as **two and a half days of talks**, **two sessions of poster presentations**, a '**meet-the-keynote**' event for students during lunchtime on May 2nd and a short tour through the Science Garden on May 3rd. The **conference dinner** will take place on May 3rd and after the official closing of the conference on May 4th this year's guided excursion will take some of you to Monte Scherbelino.

Monte Scherbelino is a former waste deposit in the outskirts of Frankfurt that has been turned into a nature reserve and is slowly building up an exciting portfolio of biodiversity – a hopeful example of how humankind's negative effects on its environment can be undone.

We hope you will enjoy Frankfurt and POPBIO 2024!

The organizing team

Niek Scheepens, Connie Anken, Martí March Salas, Stefania Przybylska, Max Roberts, Lutz Stübing

A brief introduction to Frankfurt am Main (Hessen)

Frankfurt am Main, often referred to as Frankfurt, is a dynamic city in Germany with a rich history and vibrant cultural scene. Founded in the 1st century AD by the Romans, it has evolved into a major financial hub and a global center for commerce and trade. One of its most iconic landmarks is the Frankfurt Stock Exchange, which dates back to the 16th century, as an example of the financial character of the city.

Despite its modern reputation, Frankfurt boasts a charming blend of old and new. If you have any spare time, you can explore the historic but rebuilt part of the Altstadt (Old Town) with its picturesque half-timbered buildings, including the famous Römerberg square and the Gothic-style Frankfurt Cathedral (so-called 'Kaiserdom', meaning emperors got crowned there). The city's skyline is dominated by sleek skyscrapers, earning it the nickname "Mainhattan," a nod to both its location on the River Main and its resemblance to Manhattan's skyline.

For art enthusiasts, the Städel Museum is a must-visit, housing an extensive collection of European art spanning from the Middle Ages to the present day (don't forget to visit its rooftop!). Meanwhile, the famous Palmengarten but especially the less known Botanical Garden offer tranquil escapes with diverse botanical displays.

Frankfurt is also known for its culinary delights, with traditional Apfelwein (apple wine) taverns and cozy cafes serving up hearty German fare. Don't miss trying the local specialty, Grüne Soße (green sauce), a tangy herb sauce typically served with boiled eggs and potatoes. The great environment of the Sachsenhausen quarter with its many bars and restaurants, the nice but sometimes overcrowded Kleinmarkthalle, and the laidback Main river front are some places that you may also enjoy.

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PROGRAMME

Thrusday 2 May
Registration open from 08:00
Morning Session – Chairperson: Anna Bucharova
09:00 - Welcome speech
09:15 - Keynote talk: Rubén Milla
An ecological look at crop evolution
10:00 - Dirk Granse *Whole genome duplication: A driving force in plant evolution and adaptation under climate change?*
10:15 - Johanne Gresse *Resource-use and seed dormancy drive population temporal stability*
10:30 - Jörn Pagel *The importance of biotic interactions for demography, niches and geographical ranges of South African Proteaceae*
10:45 - Coffee break
11:15 - Lea Kerwer *Environmental filters shape seedling recruitment in a tropical dry forest*
11:30 - Renáta Schnablová *Temperate herbs in winter: exploring diversity of their belowground renewal buds*
11:45 - Barbara Meyers *Does light availability or heterogeneity drive seed bank diversity in temperate forests?*
12:00 - Mialy Razanajatovo *The dark side of pollination: Why we should talk more about nocturnal plant-pollinator interactions*
12:15 - Lunch + Meet the keynote
Afternoon Session – Chairperson: Robert Rauschkolb
13:45 - Keynote talk: Elena Hamann
Contemporary evolution in plants: what the resurrection approach (fore)tells about climate change adaptation
14:30 - Bojana Stojanova *Contemporary evolution in arable weeds revealed by the resurrection method*

14:45 - Helene Villhauer *Phenotypic and genetic variation within the barley Hordeum murinum across Europe*
15:00 - Ramona-Elena Irimia *Clone invasion – insights into a global plant invasion through museomics*
15:15 - Coffee break
15:45 - Katja Springer *Does the evolution of ecological strategies in response to resources lead to trade-offs in adaptation to contrasting environments in Arabidopsis thaliana?*
16:00 - Charlotte Møller *A study across space and time: phenotypic plasticity and local adaptation in two Hypericum species*
16:15 - Valentin Graf *Effects of intraspecific trait variation on seedling establishment of Swiss stone pine*
16:30 - Johannes Metz *Are mesic populations locally adapted to competition and arid populations to stress? Summarizing key findings along a macro- and microclimatic aridity gradient*
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Friday 3 May
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09:00 - Keynote talk: Severin Irl
Treasure island in peril? Drivers of insular biodiversity and human-induced threats to islands
09:45 - Michael Boxriker *Land use drives significant decline of glacial relicts*
10:00 - Lirey Ramirez *Microsite preferences of three conifers in calcareous and siliceous treeline sites in the French Alps*
10:15 - Viktoria Ferenc *Different facets of diversity show no general decline over 53 years of floristic mapping*
10:30 - Poster session B + Coffee break
11:30 - Maud Moes *Plant community response to climate change and grazing in Middle Eastern rangelands*
11:45 - Xiong Shi *Interacting effects of global change factors on plant invasions*

12:00 - Anna Mária Csergő *Effects of climatic conditions and geographic isolation on the performance of woodland sage (Salvia nemorosa L.) populations. Opportunities for a coordinated distributed study*
12:15 - Tsipe Aavik *Morph balance in heterostylous Primula veris revisited: novel insights from a pan-European citizen-science study*
12:30 - Group photo + Lunch
Afternoon Session – Chairperson: Michal Gruntman
13:45 - Keynote talk: Marina Semchenko ***Plant-soil feedbacks: major drivers and evolutionary implications***
14:30 - Kailing Huang *Effects of precipitation change and plant-soil feedback on plant coexistence*
14:45 - Michaela Davidová *Effect of climate on plant-herbivore and plant-pathogen interactions*
15:00 - Frank Reis *Influence of host age and genotype on the microbiome of Lotus corniculatus*
15:15 - Coffee break
15:45 - Sayantika Banerjee *Individual and combined effect of climatic factors on root fungal biota in Rhododendron anthopogon*
16:00 - Lena Reimann *Residence time and functional traits determine plant-soil feedbacks of alien and native species*
16:15 - Elizaveta Shcherbinina *Microplastic mediates the effect of heavy metals on plant performance*
16:30 - Christoph Rosche *First results from iCONNECT, the integrative CONyza NEtwork for contemporary trait evolution*
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09:00 - Keynote talk: Hendrik Poorter
How to make experiments under controlled conditions relevant for understanding plants growing in the field?
09:45 - Jana Duchoslavová
Nitrogen sharing strategies of clonal plants
10:00 - Agueda De la Vega Diaz
Waiting for the light: temporal conditioning in plants
10:15 - Iveta Marešová
Carbohydrate storage in perennial herbs is strongly associated with phylogeny
10:30 - Coffee break
11:00 - Robert Rauschkolb
Seasonal patterns in flowering intensity in herbaceous species is strongly influenced by temperature and flowering duration
11:15 - Maaike Y. Bader
Treeline seedlings under stress: responses to temperature and radiation manipulation
11:30 - Martin Bitomský
The first rule of rhizome stoichiometry is you do not talk about rhizome stoichiometry!
11:45 - Michal Gruntman
Belowground plant competition: uncoupling root response strategies of peas
12:00 - Assembly
13:00 - Excursion

KEYNOTES

Goethe is the author of what is likely the first description of intraspecific variation. Drawings of twigs from Spix *sp., depicting specimens from low (Fig. 1) and high elevation (Fig. 2), can be found in his diary dated September 9th, 1786 (LAII 9A, p. 339). Source: Stegmann (2021) Ann Bot*

Keynote speakers

Rubén Milla – University Rey Juan Carlos of Madrid
An ecological look at crop evolution.

Elena Hamann - Heinrich-Heine University Düsseldorf
Contemporary evolution in plants: what the resurrection approach (fore)tells about climate change adaptation.

Severin Irl – Goethe University Frankfurt
Treasure island in peril? Drivers of insular biodiversity and human-induced threats to islands.

Marina Semchenko – University of Tartu
Plant-soil feedbacks – major drivers and evolutionary implications.

Hendrik Poorter - Wageningen University
How to make experiments under controlled conditions relevant for understanding plants growing in the field?

Rubén Milla

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Universidad Rey Juan Carlos, Spain

Biosketch

Rubén Milla is an Associate Professor at Universidad Rey Juan Carlos (Madrid, Spain). He teaches plant anatomy to undergraduates and trait evolution to master students. His research background is plant ecology. He uses that background to try to understand the evolution of plants under agricultural cultivation. For this he uses comparative and experimental approaches, utilizing crops and their wild relatives as study systems. Currently, he is simulating the early emergence of crops using experimental evolution, to evaluate if and how traits associated with domestication can evolve in the short term under strong directional selection.

Talk

An ecological look at crop evolution

A substantial portion of the collective population of individual plants on Earth thrives in agricultural ecosystems. In these environments the influence of the human species on eco-evolutionary dynamics is stronger than in any other type of ecosystem. This unique impact has led to distinct evolutionary trajectories for plants, shaped by domestication and cultivation. We have substantial knowledge regarding how domestication and cultivation have affected specific phenotypic traits crucial for yield and agricultural management. But our understanding remains limited concerning the broader consequences of this transition to the agricultural setting, particularly regarding plant characteristics that affect their ecological behavior. In this contribution, we aim to outline our current understanding of the ecological profile of agricultural plants and explore the diverse effects that their evolution under cultivation has exerted on the various services demanded from agricultural ecosystems.

Elena Hamann

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Heinrich-Heine University Düsseldorf, Germany

Biosketch

Elena Hamann is Jun.-Prof of Plant Evolutionary Ecology at the Heinrich-Heine University Düsseldorf, Germany. She works on a variety of topics in plant ecology and evolution, with a particular focus on the responses of plant populations to changing environmental conditions (i.e., climate change and novel biotic interactions). In her research, she uses the “resurrection approach", which compares ancestors and descendants, to examine rapid contemporary evolution and uncover the ecological genomics of climate change adaptation. One of her study systems includes *Brassica rapa* (field mustard), a wild relative of many important Brassicaceae crops. She is now expanding into new native and crop relative systems to identify the drivers of rapid evolution and compare the adaptive potential of species. After seven years in the USA, she is looking forward to establishing and growing her research team at HHU, reviving former European collaborations, especially in Alpine Ecology, and to creating new ones.

Talk

Contemporary evolution in plants: what the resurrection approach (fore)tells about climate change adaptation

Whether populations can keep pace with ongoing climate change remains a long-standing question in evolutionary biology. To study contemporary evolution, the resurrection approach, where ancestors and descendants are compared under common conditions, has emerged as a powerful tool. Using this approach, it is possible to directly quantify evolutionary responses to changes in abiotic conditions or biotic interactions and to uncover the genetic basis of climate change adaptation. In the first part of my talk, I will introduce and illustrate the resurrection approach with the case study of rapid evolution of flowering time in Californian field mustard (*Brassica rapa*) in response to increasingly severe and frequent drought episodes. In the second part, I will elaborate on how we can use this approach to compare the adaptive potential of species and populations along their distribution range and identify the drivers of rapid evolution. Ultimately, this work can help predict the responses of populations to rapidly changing environments, forecast evolutionary rescue and range shifts, inform targeted conservation efforts for native species, and contribute to crop improvement and sustainable agriculture.

Severin Irl

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Goethe University Frankfurt, Germany

Biosketch

Severin Irl is Professor of Biogeography and Biodiversity at the Institute of Physical Geography at the Goethe-University Frankfurt, Germany. He is a biogeographer and ecologist with a general interest in ecological and evolutionary processes, predominantly working on oceanic islands, habitat islands and other insular systems. His main interests encompass how different aspects of biodiversity, particularly endemism, are generated in space and time and how human activities threaten the unique insular biodiversity via habitat destruction, introduction of non-native species and climate change. Recently he has been part of developments in the new sub-disciplines of functional island biogeography and habitat island biogeography. Currently, he's the secretary of the newly established Society of Islands Biology. In case you're in need of travel suggestions for islands, drop him a note!

Talk

Treasure island in peril? Drivers of insular biodiversity and human-induced threats to islands

Islands contribute disproportionately to global biodiversity.
This is particularly due to the high degree of endemism on islands worldwide. It is important to understand what drives biodiversity and endemism on islands, on the one hand, because islands can serve as model systems to understand general processes in biogeography, ecology and evolution and, on the other, because of their particular value for nature conservation. Traditionally, island biogeography has had a strong focus on taxonomic diversity (such as species richness). However, recent developments in island biogeography highlight the need to also address further dimensions of biodiversity, leading to the emergence of functional island biogeography as a new subdiscipline. Due to their limited distribution and unique evolutionary circumstances, endemic species are especially threatened by human influences such as changes in land use, invasive species, and climate change. The second part of this talk will illustrate - using endemic plant species from the Canary Islands as an example - the dangers to which the unique biodiversity on islands is currently exposed and how future environmental changes might affect their distribution and diversity.

Marina Semchenko

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University of Tartu, Estonia

Biosketch

Marina Semchenko is a professor of Plant Evolutionary Ecology at the University of Tartu, Estonia. In her research, she aims to improve our understanding of how plants adjust to their environment throughout their lifetime, adapt across generations within a single species and over longer evolutionary periods across species. The studied environmental factors can be abiotic, such as the availability of light or soil nutrients, or biotic – a neighboring plant of the same or different genotype or species, or the soil microbial community. More recently, she started investigating how species growth strategies affect their interactions with soil mutualists and pathogens, how this affects plant-soil feedbacks and what are the wider consequences of these feedbacks for species co-existence, population-level processes and soil functions. The focus of her current research is on eco-evolutionary dynamics in grasslands undergoing major land use transitions.

Talk

Plant-soil feedbacks: major drivers and evolutionary implications

Plant-soil feedbacks describe a process where plants modify chemical, physical and biotic properties of soil and these changes feedback in a positive or negative way to the growth and performance of subsequent plant generations. Such feedbacks play an important role in vegetation dynamics by either stabilizing species co-existence or promoting monodominance or successional changes. However, the mechanisms underlying variation in plant-soil feedbacks are notoriously difficult to disentangle. Improving our ability to predict the direction and strength of plant-soil feedbacks across ecosystems, species and populations is particularly important in the era of rapid global change where both plants and soil biota are experiencing biodiversity loss and selective pressure for particular trait combinations. In this talk, I will review main plant functional traits and soil microbial properties that have been implicated in driving variation in plant-soil feedbacks across plant species and highlight the potential role of root exudates in regulating plant-soil interactions.

Hendrik Poorter

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Wageningen University & Research, The Netherlands

Biosketch

Hendrik Poorter is an ecophysiologist currently employed at the Horticultural Department of Wageningen University in the Netherlands. He focuses on the general response of plants to their a-biotic environment and aims to provide a comprehensive overview on how (specific groups of) plants acclimate to various environmental conditions. This involves establishing generalized dose-response curves through meta-analysis of a substantial number of experiments, covering approximately 100 (eco)physiological variables (see www.metaphenomics.org for around 250 dose-response curves). Another area of interest for Poorter is how to set up experiments under controlled conditions, with a focus on how to grow plants, and how to apply a-biotic stress to plants in ways that yield meaningful insights about what plants experience outside in the field.

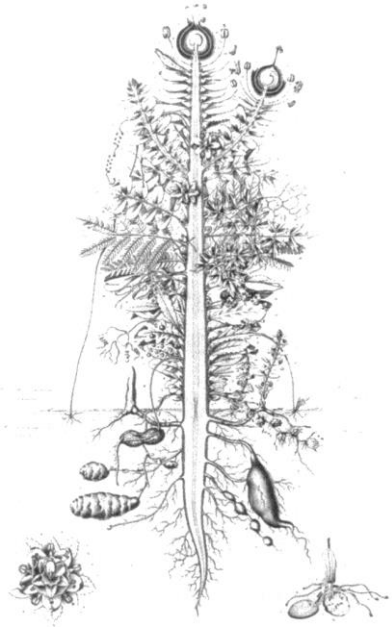
Talk

How to make experiments under controlled conditions relevant for understanding plants growing in the field?

In this talk I discuss how representative plants grown under controlled conditions (growth chamber, glasshouse) are for those growing in the field. A meta-analysis showed that lab-grown plants had faster growth rates, higher N concentrations, and higher SLA. They remained smaller, however, because lab plants are grown for much shorter time. We compared glasshouse and growth chamber conditions with those in the field and found that the ratio between the daily amount of light and daily temperature (photothermal ratio) was consistently lower under controlled conditions, especially for experiments with Arabidopsis. This may strongly affect a plant's source:sink ratio and hence their overall morphology and physiology. Plants in the field also grow at higher plant densities. A subsequent meta-analysis showed that a doubling in density leads on average to 34% smaller plants with strong negative effects on tiller or side-shoot formation and yield per plant, moderate effects on allocation and photosynthesis, but little effect on plant height or reproductive effort. We found the r^2 between lab and field phenotypic data rather modest (0.26), although still larger than the across-genotype r^2 for year-to-year variation in yield in the field (0.08). Based on these insights, I discuss various alternatives to facilitate the translation from lab results to the field, including options to apply growth regimes closer to field conditions.

TALKS

in chronological order



The Urpflanze (primordial plant) is a term that Johann Wolfgang von Goethe occasionally used in the context of his botanical studies and scientific writings, particularly in his discussions of Carl von Linné's botanical system. Conceptualized before Darwin published his theory of evolution, it reflects the evolutionary plasticity of plant forms and functions. Wood engraving by Pierre Jean François Turpin.

Whole genome duplication: A driving force in plant evolution and adaptation under climate change?

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Whole genome duplications (WGDs) have historically led to key evolutionary innovations in plants, broadening ecological tolerances and enhancing stress resistance through morphological and physiological changes. Our study investigates the role of WGD in *Spartina*, i.e., the F1-hybrid Spartina x townsendii and its genome-duplicated descendent *Spartina anglica*, focusing on evolutionary development and plant responses to climate change. We combined multivariate plant functional trait analysis with microsatellite marker analysis to explore genetic diversity across Spartina populations in the Wadden Sea. To assess phenotypic plasticity, we evaluated plant responses to varying environmental conditions in a greenhouse experiment, specifically comparing drought vs. well-watered conditions and ambient vs. elevated (950 ppm) atmospheric CO_2 concentration. We identified 18 multilocus genotypes, with a dominant genotype suggesting low genetic diversity. Despite increased stomatal length post-WGD, we found no significant difference in phenotypic plasticity among the genotypes across different environmental treatments. However, the hybrid on a lower ploidy level showed variation in belowground biomass allocation in response to different water availability treatments under elevated CO_2, while its descendent on a higher ploidy level did not. The study emphasizes the importance of considering WGD, genetic diversity and phenotypic plasticity for understanding plant responses to climate change.

Student contribution

Resource-use and seed dormancy drive population temporal stability

Johanne Gresse*, Lars Götzenberger, Jan Lepš, Pierre Liancourt, Merav Seifan, Katja Tielbörger, Maria Májeková

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Understanding population temporal stability is essential, particularly given the expected climate variability increase. Traits respond to biotic and abiotic environments and should therefore provide mechanistic insights for the drivers of stability. However, which traits drive stability can vary across climates and local microhabitats as a consequence of changes in abiotic stress and biotic factors, such as competition. We studied the year-to-year variation in abundance, measured by the coefficient of variation, of 91 populations (covering 66 species) of winter annuals over 13 years. We carefully selected traits known to be involved in buffering against harsh and dry conditions in temporally unpredictable environments: seed dormancy, seed size, and traits involved in resource-use (i.e. RGR, SLA, LDMC, turgor loss point, carbon isotopes ratio). We worked in a biodiversity hotspot in Israel in three climates along a steep rainfall gradient of decreasing mean and increasing interannual variability: Mediterranean, semi-arid, and arid. We assessed the populations in two microhabitats representing the natural spatial heterogeneity in these ecosystems: away or underneath perennial shrubs which can locally ameliorate abiotic conditions and potentially decrease the extent of the year-to-year variation in precipitation. We expected higher dormancy and/or bigger seeds and/or more conservative resource-use to lead to higher population temporal stability. We expected this relationship to be more pronounced towards drier environments with higher unpredictability, where the need to buffer against bad years should be stronger. We found that conservative resource-use increased stability throughout the gradient, with a more pronounced relationship towards the arid and in open microhabitats. Dormancy predicted stability in the arid climate only, enhancing it in open microhabitats and decreasing it under shrubs. Our findings reveal the overlooked diversity of ecological strategies within annuals, so far considered functionally equivalent, and how it shapes population temporal stability in the context of changing abiotic and biotic conditions.

The importance of biotic interactions for demography, niches and geographical ranges of South African Proteaceae

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A major contribution of Hutchinson's niche concept is the distinction between fundamental and realized niches (the sets of environments where intrinsic population growth rate $r0 > 0$ in the absence and presence of interacting species, respectively). Differences between fundamental and realized niches reflect the impact of biotic interactions on population dynamics and geographic ranges of species, thereby playing an important role in ecological and biogeographical theory. However, disentangling abiotic and biotic factors and quantifying fundamental vs. realized niches is hardly possible based on species occurrence data alone. In our study we thus combine measurements of fundamental demographic rates in 5085 populations across the geographic ranges of 29 Proteaceae species in the South African Fynbos with data on environmental variation and abundance of co-occurring species to parameterize demographic niche models that integrate abiotic and biotic effects on population growth rates. Analysing the thereby quantified niches reveals distinct variation across our study species, where the effects of biotic interactions and thus the differences between fundamental and realized niches are largest for species with wide fundamental niches (environmental generalists) and smallest for species with narrow fundamental niches (environmental specialists). We furthermore find that larger differences in the geographic projections of fundamental vs. realized niches (i.e. the area, where species' geographic distributions are limited by biotic interactions) can often be attributed to biotic effects on specific demographic rates and along specific abiotic gradients. Investigating these underlying processes as well as the consequences of differences between fundamental and realized niches is not only the key to understand present patterns of biodiversity, but also crucial for predicting the vulnerability of plant species and communities to ongoing environmental change.

Student contribution

Environmental filters shape seedling recruitment in a tropical dry forest

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Seedling recruitment is a crucial step for plant regeneration. Germination, seedling growth and survival are determined by several abiotic and biotic filters, such as water, light or litter. Species-specific functional traits, such as seed size, can shape species' responses to these filters. To understand the assembly of plant communities and the recolonization of disturbed habitats, it is essential to comprehend how plant functional traits shape seedling recruitment under different environmental conditions. In our study we asses, how abiotic and biotic filters shape seedling recruitment in a tropical dry forest in Southern Ecuador. Tropical dry forests are of special interest, as these highly specialized ecosystems only occur in small areas and are strongly affected by human activities. We conducted a one-year seed-sowing experiment with eight native semi-deciduous and deciduous tree species of different seed sizes and manipulated shade and litter depth. Experimental sites covered both natural forests and silvopastures disturbed by humans at two elevations (600 m and 1200 m asl). Preliminary results show that seedling establishment generally increased with seed size. Shade application increased seedling establishment (early life stage), but had a negative effect on seedling growth (e.g. seedling height and -weight; later life stages). The manipulation of litter depth had no significant effect on seedling establishment or growth. Our experiment contributes to a mechanistic understanding of the limiting factors of seedling recruitment in tropical dry forests and will help to make predictions of seedling recruitment under altered environmental conditions.

Temperate herbs in winter: exploring diversity of their belowground renewal buds

Renáta Schnablová*, Alena Bartušková, Eva Horčičková, Petr Šmarda; Jitka Klimešová, Tomáš Herben

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In temperate climates, the seasonal regrowth of perennial plant species relies on renewal buds. While tree buds (located aboveground) have received much attention in the past, we know very little about herbaceous renewal buds (located belowground), despite the dominance of herbaceous species in the temperate flora. As early spring conditions change, there is an increasing need to understand the traits of herbaceous buds. We measured bud traits in a phylogenetically representative set of temperate herbaceous species in winter. We analysed bud protective traits as potentially readily observable proxy traits that may capture the functional diversity of renewal buds in herbs. We tested how bud protective traits are related to phylogeny and how they are associated with other bud bank traits (bud volume and bud preformation). We then focused on the relationships between bud traits and plant traits related to light competition (plant height), carbon storage (volume of belowground bud-bearing organs), morphological constraints (bud-bearing organ type), and soil protection (bud bank depth). We found a strong gradient in bud traits, ranging from well-differentiated large buds covered by bud scales to more numerous small naked buds. The latter tended to be positioned close to the soil surface, while the large-scale-covered buds were generally deep in the soil and were associated with larger volumes of belowground storage organs. Combinations of bud traits were also closely associated with the type of bud-bearing organ. Our results show that renewal buds of temperate herbs exhibit diverse strategies for winter survival and spring regrowth, reflecting complex adaptations of temperate herbs to seasonal cold periods, but at the same time potentially limiting plant growth under climate change.

Does light availability or heterogeneity drive seed bank diversity in temperate forests?

Barbara Meyers*, **Laura Thanopoulos, Michael Scherer-Lorenzen**
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* University Freiburg, Germany

In temperate forests, management practices increasingly aim at enhancing forest structural complexity. These changes have important repercussions on the environmental conditions to which the vegetation is exposed to, especially via variations in light availability and heterogeneity. The understory plant communities have shown to be sensitive to these changes. However, it remains unclear how these variations in light conditions drive responses in the soil seed bank communities. In this research, we assessed how light availability and heterogeneity impact soil seed bank diversity and community composition and its correspondence to aboveground plant communities. We hypothesized that higher light heterogeneity would increase diversity in the soil seed bank as germination and replenishment would be promoted for a larger range of species. To test this, we sampled soil on six subplots (25 m^2) in 30 locations in the Southern Black Forest, Germany, and we identified species found in the seed bank via a germination experiment. Additionally, we measured light availability at each location, and we assessed the species composition of the aboveground plant community. In total, we counted and identified 1075 seedlings belonging to 44 taxa, most of which were characterized as light demanding (47%). Neither, light availability, nor light heterogeneity (cv) explained variations in seed bank diversity. Only seed bank density increased with light heterogeneity but the trend was not strong. Although species richness in the seed bank was positively correlated with species richness aboveground, the seed bank community composition differed drastically from the understory community (84% dissimilarity). Importantly, this dissimilarity increased with increasing light heterogeneity per site. These results enabled us to reject the hypothesis that the seed bank diversity is directly driven by current light availability in forest. Also, the research highlighted that light indirectly impact the correspondence between aboveground plants and seeds community composition.

The dark side of pollination: Why we should talk more about nocturnal plant-pollinator interactions

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* University of Hohenheim, Germany

Declines in pollinating insects associated with global change are in the center of current scientific and societal debates. As nighttime temperatures increase faster than daytime temperatures, nocturnal and diurnal pollinators can be impacted differently by climate change. Increasing light pollution is adding to the pressure on nocturnal insects. However, our knowledge of nocturnal plant-pollinator interactions remains limited. To assess the importance of nocturnal pollinators for seed set, we conducted a pollinator exclusion experiment which consisted of four treatments: exclusion of diurnal flower visitors, exclusion of nocturnal flower visitors, exclusion of both diurnal and nocturnal flower visitors and open pollination. In summer 2023, we collected data in this way for two common grassland species, *Daucus carota* and *Trifolium pratense*. Seed set was largely pollinator dependent, and did not significantly differ under exclusion of diurnal flower visitors, exclusion of nocturnal flower visitors, and open pollination. This indicates that nocturnal and diurnal pollinators can mutually compensate for loss of the other group. Such a mutual compensation may provide an important buffer under global change, given that nocturnal and diurnal insect communities are exposed to partly different pressures.

Contemporary evolution in arable weeds revealed by the resurrection method

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The resurrection method is a novel approach which ‘instantly’ reveals the occurrence of contemporary evolution in organisms with diapause by growing side-by-side ancestral genotypes ‘resurrected’ from dormant propagules and their contemporary descendants. Taking advantage of material from seed repositories, resurrection assays are a powerful tool for the study of contemporary adaptation of plants in response to fast-paced, human-induced environmental changes. The aim of this study was to assess evolutionary trait shifts occurrence in populations of two annual, entomophilous, arable weeds with contrasting ecological features over 30 generations, and to evaluate whether these shifts are consistent with contemporary plant evolution in response to global climate change and pollinator decline. Ancestral and descendant genotypes were grown side-by-side in a common environment, allowing to assess trait shifts that were not due to temporal variation in the environment. The ancestral genotypes came from seeds harvested and stored in seed repositories between 1993 and 2003 and the descendant genotypes were harvested from the exact same population 20-30 years later. Traits related to phenology, attractivity to pollinators, mating system, and fitness were measured. The results show that adaptation of flowering time in each species is consistent with their life cycle, suggesting adaptation to climate change. Pollinator attractivity traits (floral display, flower size) show increased attractivity to pollinators, and mating strategy traits (reproductive organ size, anther-stigma distance) do not differ between ancestral and contemporary genotypes. Altogether these results suggest contemporary evolution of floral and mating traits towards maintenance of plant-pollinator interactions in response to pollinator decline over the past few decades. These results suggest that plant-pollinator interactions could be maintained in arable weeds through contemporary adaptation at least in the short term, allowing additional time for devising effective conservation strategies for arable weeds and the ecosystem services they provide.

Student contribution

Phenotypic and genetic variation within the barley *Hordeum murinum* across Europe

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Intraspecific genetic variation between plant populations is common and can reflect local adaptation. Understanding the phenotypic and genetic variation along a geographical gradient is crucial for predicting a species' adaptive ability and assessing its vulnerability to climate change. In this ongoing project, we study genetic variation in *Hordeum murinum*, a common wild annual with different ploidy levels. We combine common garden experiments with genetic tools to identify adaptive variation, its underlying genetic regions and ploidy variants. In 2023 in collaboration with researchers from Europe, we scored *H. murinum* in wild across Europe to define its ecological niche and collected seeds. *H. murinum* grew in a wide range of environments and plants were larger in wetter and colder areas. In a preliminary common garden experiment with eleven populations, we found significant phenotypic differentiation between populations, for example in winter hardiness, root traits or flowering time, but not in plasticity of these traits. Molecular genetic analysis revealed substantial differentiation between four populations, but unexpectedly low variability within populations.

Clone invasion – insights into a global plant invasion through museomics

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Natural history collections provide key information how species and communities change over time. Evolutionary studies using ancient DNA can inform about the spatiotemporal genetic processes that contribute to species adaptation to changing environments. The polyploid *Reynoutria* species complex (aka Japanese knotweed, Polygonaceae) comprises some of the world's worst invasive weeds and it is a powerful system to investigate the mechanisms of plant colonization, range expansion and invasion success at a regional and continental scale. We generated DNA sequence information from preserved specimens of Japanese knotweed collected over the past 200 years since the plant introduction into Europe and North America and conducted population genomic analysis to reconstruct the species evolutionary history. Our preliminary results suggest different invasion dynamics in the two ranges with evidence of multiple introductions from Japan, on both continents. Future work will reveal what genomic regions are involved in shaping the invasion success of this species complex.

Student contribution

Does the evolution of ecological strategies in response to resources lead to trade-offs in adaptation to contrasting environments in *Arabidopsis thaliana*?

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Over millions of years plants have been competing for limited resources and suitable space while adapting against herbivores. Resource limitation, population density, and herbivory have been highlighted as major drivers of ecological strategies, *i.e.* sets of covarying traits that match with environmental conditions in a potential adaptive way. However, direct evidence of the evolutionary drivers of ecological strategies and whether they lead to local adaptation is still largely missing. In a previous study with *Arabidopsis thaliana*, it was shown that conservative vs. acquisitive strategies evolved in response to contrasting resource availability within only three generations and that these evolutionary responses were linked with population density. Using seeds from this experimental evolution project, we tested if the evolution of ecological strategies entailed early-life fitness trade-offs in contrasting environments. For that, we used seeds of plants from the third generation of evolution to contrasting resource x herbivory conditions, as well as seeds from the population that started the evolution experiment. We sowed them under low and high density (6 vs. 16 seeds) and recorded germination rate and seedling establishment. We found that XXXXXX

A study across space and time: phenotypic plasticity and local adaptation in two *Hypericum* species

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Accurate predictions for the future trajectory of plant populations hinge on a mechanistic understanding of how species adapt to changing environmental conditions. However, a lack of empirical data on how intraspecific variation in traits acts across a species distribution range hinders our ability to understand its role for species persistence. Here, we aimed to investigate variation in phenotypic plasticity in core- and leading-edge distribution ranges and whether patterns of mean response and plasticity differ between ancestors and descendants by using a combined semi-reciprocal transplant and resurrection approach. We used two perennial plant species, the widespread generalist *Hypericum perforatum* and the habitat specialist *Hypericum montanum*. Seeds from the core- and leading-edge study populations were transplanted to four different common gardens across Europe simulating historical and contemporary climatic conditions. Additionally, ancestral populations of *H. perforatum* were transplanted side by side with their descendant counterparts in all four common gardens. Vegetative, phenological, and fitness traits were measured over one growing season. We investigated phenotypic plasticity and local adaptation using relative distance plasticity index, random regression mixed model approaches, and reaction norm plots. Contrary to our beliefs, our results showed higher plasticity in *H. montanum* individuals originating from the core distribution ranges, but higher trait means in leading-edge populations. Despite high performance and fitness in *H. perforatum* individuals, they were less plastic. Furthermore, distinct patterns show that whereas descendants flowered earlier, ancestors generally had a higher number of leaf pairs. Both ancestors and descendants showed higher fitness when transplanted back to their origin sites within their core distribution range. To summarise, low amounts of phenotypic plasticity in *H. perforatum* is yet to show detrimental effects in face of a changing climate. However, the earlier flowering start in descendant individuals points towards that adaptation to a warmer climate might already have happened.

Student contribution

Effects of intraspecific trait variation on seedling establishment of Swiss stone pine

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Trait variation is a key aspect of how organisms may respond to changing environmental conditions. In plants, seed size is considered one of the most important traits determining early establishment, and it varies greatly across species distributional ranges. Here we investigate how variation in seed size in relation to the origin of mother trees across an elevational gradient affects seedling establishment in a population of Swiss stone pine (*Pinus cembra*) in the Swiss Alps. We harvested seeds across the population's elevational range and sowed them in a reciprocal translocation experiment. We recorded seed sizes, collected material to analyze the genetic variation of the mother trees, and measured the environmental conditions at the experimental sites. Seed size did not differ across elevations. We found seed size to be a main driver of establishment success, with larger seeds establishing better than smaller seeds. Despite this, seeds from the population center tended to establish better than seeds from upper and lower range edges, while seeds harvested at the upper range edge showed significantly lower establishment success than seeds from the lower range edge. In the future, we will also investigate the effect of genetic diversity at the harvesting stands on the establishment of Swiss stone pine. For now, we conclude that seeds originating from population range edges have lower establishment success compared to seeds from the population center. This has important implications for the regeneration potential of Swiss stone pine under changing climatic conditions.

Are mesic populations locally adapted to competition and arid populations to stress? Summarizing key findings along a macro- and microclimatic aridity gradient

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The trade-off between competitive ability and stress tolerance
is frequently assumed to govern local adaptation along aridity gradients. Although reports of diverging functional traits appear to support this assumption, direct experimental evidence is scarce. Moreover, most studies focus on macroclimatic aridity gradients. Whether local adaptation occurs also at microclimatic scale between north (more mesic) and south (more arid) exposed hill-slopes is poorly known. However, if nearby south slopes were to harbor conspecifics better adapted to drier climates would provide an important adaptive reservoirs under climate change. Here, I summarize a series of experiments with ecotypes of Mediterranean annual species sampled in 15 sites along a macroclimatic aridity gradient in Israel (89 – 926 mm annual rainfall) on both north and south exposures. We studied plant performance and functional traits under three key factors that characterize natural aridity gradients: drought stress, competition, and short vs. long growing seasons. Along the macroclimatic aridity gradient, we support key aspects of the stress - competition trade-off, namely that local adaptation to a drier macroclimate comes at the cost of lower competitive ability under benign conditions, and vice-versa. Unexpectedly though, drier populations were no better adapted to drought stress per se, highlighting that drought escape via short life-cycles is the primary adaptation to drier climates in annual species, and indicating that arid ecotypes may be equally susceptible to declining rainfall under climate change. Moreover, south exposures showed overall little potential as nearby genetic reservoirs for climate change adaptation in our study region.

Student contribution

Land use drives significant decline of glacial relicts

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Climate change affects species distributions along both elevational and poleward gradients. Additionally, land use contributes to the change in the distribution of plant species, making it challenging to pinpoint the primary driver and their respective contributions. Glacial relicts excel as reliable indicators of climate change impact due to their postulated heightened sensitivity and responsiveness to emerging climate shifts. This study investigates climate change and land use influencing the distribution of glacial relicts. We used four vascular plant species specifically adapted to open, wet, and cold environments, to investigate the effect of climate change on their distribution ranges by applying species distribution models. Our models use high-resolution environmental variables on climate, topography and geology, paired with accurate and comprehensive species occurrence data of a long-term monitoring program from Baden-Württemberg, Germany. The resulting suitability maps were masked with land use class raster maps, to assess the additional effects of land use. This enables precise projections of current and potential future distributions. Across various future climate scenarios, the overall available suitable area for all species exhibited a notable decrease of 73% on average. Land use contributes to a drastic reduction, decreasing the suitable space by 79% on average in current and future climate change scenarios. Despite the severe susceptibility to climate change, our findings reveal an even stronger influence of land use on the distribution of glacial relicts. Ultimately, our findings can facilitate development of conservation strategies essential for the preservation and sustainable management of glacial relict populations.

Student contribution

Microsite preferences of three conifers in calcareous and siliceous treeline sites in the French Alps

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The advance of the treeline ecotone is controlled by new establishment of tree seedlings, but the characteristics and availability of safe sites for tree regeneration in this ecotone are not well understood. We evaluated the microsite preferences of the conifers *Larix decidua*, *Pinus uncinata* and *Pinus cembra* in areas with two different types of bedrock chemistry and relate signs of stress and disturbance in the individuals of the tree species to microsites characteristics. In four sites in the French Alps, two with calcareous and two with siliceous bedrock, we contrasted the microsites of 50 tree-species individuals (seedlings, saplings and small-stature adults) in the upper treeline ecotone to 50 randomly placed reference microsites. Microsite characteristics included substrate, ground cover, macro- and microtopography, and nearest shelter. We also evaluated the shape and health status of the individuals. The three species were established in similar microsites and usually with shelter. The microsites occupied by the tree species were a good representation of the available microsites in the respective areas, nonetheless, some extreme types of available microsites were unoccupied. Approximately two-thirds of the individuals were krummholz or bent, while only a small proportion showed signs of recent mechanical damage, desiccation, snow mold, or herbivory, regardless of microsite characteristics. Our study shows that the availability of safe sites is unlikely to limit the establishment of the three-tree species in the treeline ecotone. This suggests that seed availability is likely to be a major limitation for tree establishment in these alpine treeline ecotones. In addition, even in "safe" sites, stress and disturbance appear to limit tree growth, biomass maintenance, and survival more than in the forest at lower elevations, thus slowing, if not preventing, ecotone filling and treeline advance.

Different facets of diversity show no general decline over 53 years of floristic mapping

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Biodiversity encompasses multiple facets, including taxonomic, phylogenetic and functional diversity. To comprehensively understand the impacts of contemporary environmental change on biodiversity, it is essential to consider these different facets. We use the floristic mapping of Baden-Württemberg, Germany, with over three million observations of 2000 vascular plant species, to evaluate the change in biodiversity over the last 50 years. We also assessed the influence of key environmental drivers, climate, land use and topographic variables, on these diversity facets. Overall, we did not detect a general decline in biodiversity. Instead, we observed an increase in diversity in areas with initially low diversity and a decline in areas initially with high diversity. We surmise the observed pattern reflects 'biodiversity homogenization' on all facets of diversity. Additionally, environmental variables contributed to the different facets differently, with climate and human modification influencing more taxonomic diversity and functional diversity, while phylogenetic diversity was also influenced by soil and topography. Beside the general trend in biodiversity change detected in the region, the incongruent response between the different facets of biodiversity emphasizes their complementarity for biodiversity assessment and conservation.

Student contribution

Plant community response to climate change and grazing in Middle Eastern rangelands

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Climatic models and observations of recent years indicate that the Eastern Mediterranean is suffering from an increased frequency of extreme droughts with an overall reduction in precipitation, potentially leading to adverse impacts on vegetation and grazing opportunities. While theory states that eastern Mediterranean rangelands are highly resistant and resilient against drought and grazing, it is unclear what will be the consequences of more extreme drought interacting with different grazing regimes. To test the potential responses of plant communities to different drought and grazing scenario's, we experimentally manipulated previously grazed rangeland vegetation in three sites ranging from xeric to mesic mediterranean conditions in the east Mediterranean. We have used an experimental design consisting of 17 permanent plots with rainout shelters with a gradient of 30% to 90% precipitation reduction with 10% intervals. Additionally, we simulated two grazing regimes in each plot by implementing clipping treatments early and late in the growing season. In each plot we collected data on plant abundance, species richness and species diversity early and at the peak of the growing season. The first results have shown that plant community responses to drought and grazing differ between the climatic regions. We focus on the xeric Mediterranean plant communities, were plant abundance, richness and diversity decrease with precipitation reduction. Species turnover and composition similarity decreases when the climatic differences increased between plots. Early grazing caused species composition to be more diverse between plots with increasing drought, whereas late grazing had only limited effects on species composition. The data will contribute to a long-term study focussed on identifying indicators for ecological tipping points in rangelands with which we can anticipate on unfavourable changes in plant communities. Our findings will serve as the basis for decision making regarding sustainable rangeland management in the eastern Mediterranean.

Student contribution

Interacting effects of global change factors on plant invasions

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Numerous studies have consistently highlighted the propensity for invasive alien plant species to derive greater benefits from individual global change factors (GCFs) compared to native species. However, it remains unclear how these GCFs may interact to influence alien and native plant performance. In this study, we conducted a meta-analysis to address this critical question. Our findings reveal that alien plants exhibit a distinct advantage in response to fertilization. Furthermore, we observed additive effects when fertilization was combined with both increased and decreased water availability. Surprisingly, our analysis did not identify any significant interactive effects of GCFs on alien plant invasion. This suggests that, while alien plants may capitalize on individual GCFs and their additive effects, the interactions between these factors do not seem to significantly enhance their invasion potential.

Effects of climatic conditions and geographic isolation on the performance of woodland sage (*Salvia nemorosa* L.) populations. Opportunities for a coordinated distributed study

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Plant populations in remnant natural habitat fragments face the double threat of geographic constraints from isolation and habitat loss and the changing climate conditions that may render their current habitats unsuitable. We hypothesize that populations alter their demographic strategies of persistence in response to each of these threats. In 2021 we set up a long-term landscape demography study in the Great Hungarian Plain, using the dry grassland specialist *Salvia nemorosa* L. as a model species. We have been following the demographic fates of 915 permanently marked individuals (survival, change in size and sexual reproduction) and changes in plant density in 15 populations. While habitat isolation and area exerted a measurable impact mostly on the reproductive traits of *S. nemorosa*, increased heat load and large yearly weather fluctuations affected both the vegetative and reproductive traits and the reproductive phenology, with cascading effects on the demographic processes. We propose to continue this study within the framework of a spatially distributed coordinated study system. We invite new participants to join and benefit from its advantages in exchange for data collection from own site(s).

Morph balance in heterostylous *Primula veris* revisited: novel insights from a pan-European citizen-science study

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A distylous grassland plant *Primula veris* has long served as one of the model species for bringing insight into the phenomenon of heterostyly. Habitat loss, reductions in population size and decline in pollinator abundance have raised questions about the short- and long-term consequences of these factors for heterostylous plants. To examine the patterns of floral morphs of *P. veris* in response to population size, landscape context and environmental factors, we carried out a citizen-science campaign involving more than 30 European countries and covering most of the distribution range of this species in Europe. Information from over 3000 populations retained after quality filtering of data revealed a slight (9 %) but significant dominance of short-styled S-morphs over long-styled L-morphs. Morph deviation from isoplethy was substantially higher in smaller populations. Higher precipitation in the warmest quarter of the year led to unequal morph frequencies and, in particular, increased the proportion of S-morphs. In addition, increasing built-up area in the landscape increased the proportion of S-morphs. Populations hosting individuals with anthers and style of the same length, i.e., individuals with homostylous phenotypes, were reported from three locations (Germany, Poland and Sweden), indicating signs of possible transition of *P. veris* from distyly to homostyly. The unexpected findings about the dominance of S-morphs requires further attention to clarify whether this is due to partial intra-morph compatibility, breakdown of heterostyly or survival advantage of one morph. Our study shows that changes in landscape characteristics and related population declines in combination with climate change may alter the balance of morphs in short term and can therefore cause disruptions of heterostyly with potential short- and long-term consequences.

Student contribution

Effects of precipitation change and plant-soil feedback on plant coexistence

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Modern coexistence theory predicts that two species could coexist when their niche differences exceed fitness differences. A changing environment, such as changes in precipitation, might alter both niche and fitness differences through direct competition and indirect interactions mediated by soil biota, i.e., biotic plant-soil feedback. However, we still lack studies that assess the relative importance of plant-soil feedback and competition in shaping coexistence in a changing environment. In the current study, we used three precipitation levels (wet, control, and dry) combined with the addition of soil biota that had previously experienced wet or dry conditions. Then, we tested for species coexistence in six grassland plant species pairs in a situation with competition only and in a situation with plant-soil feedback in addition. We found that plant-soil feedback promoted species coexistence, especially when the soil biota had previously experienced the same precipitation condition as the current one. More specifically, in the wet treatment with soil biota that previously experienced wet conditions, plant-soil feedback promoted species coexistence by increasing niche differences. In the drought treatment with soil biota that had previously experienced drought, plant-soil feedback promoted species coexistence by increasing niche differences or reducing fitness differences. Our study highlights that plant-soil feedback plays an important role in species coexistence under altered precipitation. Further, in addition to changes in precipitation, the influence of environmental stability on coexistence should also not be neglected.

Student contribution

Effect of climate on plant-herbivore and plant-pathogen interactions

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Interactions between plants and other organisms, such as herbivores and pathogens, are key factors determining plant population performance. Studying how climatic conditions influence these interactions is becoming increasingly important, as it enables us to predict the future responses of plant communities to the changing global climate. For ten years, experimental grassland plots have been grown under treatments of elevated CO_2, temperature and drought, both alone and in combinations, to simulate possible changes to local climate due to climate change. This system was used in this study to determine the effects of climate change on plant-herbivore and plant-pathogen interactions. The model species was *Plantago lanceolata* – a common plant in European grasslands. Sampled *P. lanceolata* leaves were used to measure plant traits, specifically those that were hypothesised to change with climate or to interact with herbivory and pathogeny. The traits included Leaf Dry Matter Content, phenolic concentrations, C/N ratio and leaf toughness. To assess herbivory and pathogeny, we analysed the extent of field leaf damage, the type of said damage, and the composition of sampled insect communities. Consequently, a laboratory experiment was carried out to observe if the climatic conditions in which leaves are grown affect the feeding preferences of a generalist herbivore (*Locusta migratoria*). So-far results show a relationship between climatic conditions, certain plant traits and field leaf damage. For example, a substantial positive effect was that of temperature on the extent of total herbivore and pathogen damage of the leaves. The effect was both direct and indirect, the latter being through its influence on leaf toughness. Moreover, the herbivore preference experiment showed *L. migratoria* favouring leaves from higher CO_2 and lower temperature conditions. In conclusion, changing climate has been seen to influence plant-herbivore and plant-pathogen interactions. However, the effects differ between plant traits and types of herbivory and pathogeny.

Student contribution

Influence of host age and genotype on the microbiome of *Lotus corniculatus*

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Like all eukaryotes, plants are colonized by a wide range of microbes which collectively form the plant microbiome. The beneficial effects of this colonization for the host, which range from increased growth, nutrient uptake and stress tolerance to protection against pathogens, became better understood in the last years, but we still have a poor understanding of which factors shape such complex communities during the life of a plant. In this study we examine the influence of host age and genotype on the composition of the natural plant microbiome. Across seven natural populations in Southern Germany, we collected a total of 126 plants over three consecutive years. We divided each plant in roots, shoots, flowers, and seeds and analysed the microbiome (bacteria, fungi and eukaryotes) for each organ separately. In addition, we genotyped each plant using ddRADSeq and determent the plant age by counting the annual ring in the hypocotyl. Our results show the plant genotype influences the diversity, richness, and composition of the associated microbiome. The alpha-diversity of both bacterial and fungal communities significantly differed among plant genotypes. Moreover, while a large number of taxa were shared among plant genotypes and age groups, a linear discriminant analysis (LDA) indicated that the abundance of some microbes differed between both genotypes and age groups. Our study demonstrates the influence of both host age and genotype on the plant microbiome, and that it is important to take both into account when exploring the dynamics of plant-microbe interactions.

Student contribution

Individual and combined effect of climatic factors on root fungal biota in *Rhododendron anthopogon*

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Recently studies on root-microbe interactions have gained prominence as plant roots in their natural environment are in constant interaction with diverse microorganisms. Plant roots assemble two distinct microbial compartments - rhizosphere and endosphere. Root biota influences plant growth by modulating the effects of biotic and abiotic stressors. However, climate change is causing changes in the composition of root biota that affects host plant functions. These changes occur in combination of temperature, moisture and their fluctuations. Understanding the individual and combined effects of different climatic drivers is important. Vegetation composition and soil chemistry also strongly affect root biota. Identification of the direct effect of climate on root biota is difficult as other factors such as soil chemistry and vegetation composition are also changing along climatic gradients. We studied the effect of climate on root fungal communities, along a climatic gradient in a dominant alpine Himalayan shrub species and controlled for variation due to vegetation and soil chemistry. Five sites with different precipitation levels were selected for the study. At each site, populations along three elevation gradients were selected, resulting in 15 studied populations per species. From each population 9 replicates of rhizosphere and root samples were collected and analysed. The results showed that the individual effects of moisture and temperature were significant and comparable but did not interact and the effects were largely unchanged after controlling for vegetation composition and soil chemistry. Climate had stronger effects on endosphere than on the rhizosphere communities, although highest number of fungal OTUs were present in rhizosphere. Fungal species that responded most to changes in climatic factors belonged to saprotrophs and mycorrhizae fungal guild. This study contributes to our knowledge of below ground biotic mechanisms that affect the functioning and adaptation of natural plant populations under stressful conditions in vulnerable ecosystems.

Student contribution

Residence time and functional traits determine plant-soil feedbacks of alien and native species

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Plant-soil feedbacks (PSF) describe the altered performance of plants driven by growing in the same soil another plant grew in before. PSF arise from plants changing soil properties, e.g., by attracting soil mutualists and pathogens. Because conspecific PSF are often negative (resulting in reduced growth of plant species on their own soil), this phenomenon may contribute to species co-existence. Accordingly, PSF are expected to play a key role in the failure, short-term success and long-term performance of alien invasive plant species. While alien species initially often benefit from enemy release, resulting in more positive conspecific PSF, over time they may accumulate soil pathogens and PSF become more negative. Using a species-for-time approach, this study aims at revealing the potential impact of soil organisms on invaders across species from an early stage of invasion (neophytes) up to species that have resided in Germany for thousands of years (archaeophytes, natives). PSF experiments consist of two phases: 1. conditioning, where soil is conditioned by all plant species of interest; 2. feedback, where plant performance is assessed on conspecific and/or heterospecific and unconditioned soils. Our PSF experiment included 33 alien and native species, investigating conspecific and heterospecific conditioning treatments as well as unconditioned controls across 90 interspecific species pairs. We found that neophytes (or species with lower residence times) produced more biomass and seeds in conspecific compared to heterospecific conditioned or unconditioned control soils. This effect decreased with increasing residence time. This suggests that more recently introduced species might be initially released from species-specific soil pathogens, while these later may accumulate over time. Furthermore, we show how functional traits explain strength and direction in plant-soil feedback. Our study contributes insights not only into the short- but also long-term dynamics of plant invasions, which is highly important to comprehend and manage their threat to biodiversity.

Student contribution

Microplastic mediates the effect of heavy metals on plant performance

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Recently, microplastics (MP) have become a significant environmental concern, infiltrating soil through pathways like biosolid and mulching film application. Despite ongoing research, the complex effects of MP on soil properties and plant-microbiome interactions remain largely unknown. Emerging research suggests that MP may interact with another pollutant found in soil: heavy metals (HM). Coming from fertilizer use, HM negatively affect plant growth and photosynthesis. While research has shown that MP can increase HM bioavailability in soil, their consequent effects on plants are rarely studied. We hypothesized that MP would increase HM bioavailability in soil, intensifying the negative impact of HM on plants. In a greenhouse experiment, we investigated the combined effects of MP and Cadmium (Cd), an HM common in agricultural soils. We selected two study species: *Arabidopsis halleri* and *Arabidopsis thaliana*, known for their differential tolerance to HM contamination. We assessed several morphological plant traits alongside Cd bioavailability in soil and its uptake in plants using inductively coupled plasma optical emission spectrometry (ICP-OES) and analysed soil metal composition via X-ray fluorescence spectroscopy (XRF). Our preliminary findings suggest that MP addition increases Cd bioavailability in soil and plant uptake. *A. halleri*, with higher tolerance to HM, showed a weak response to Cd and MP treatments. However, *A. thaliana*, which is known to be negatively affected by Cd, benefited from MP addition under high Cd concentrations. This unexpected result may stem from alterations in other HM abundance in soil due to MP presence, with consequences on plant performance. Our study highlights the complexity of MP effects on soil and plants, especially in combination with other stressors. Future research should explore the MP-Cd interaction's influence on soil microbiome, conduct hydroponic plant experiments, consider varied MP and Cd concentrations, and explore different MP types to clarify plastic-specific responses and patterns.

First results from iCONNECT, the integrative CONyza NEtwork for contemporary trait evolution

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Contemporary evolution is a common occurrence where plant species colonize non-native ranges and encounter novel interaction partners. However, our understanding of contemporary evolution is limited because most native vs. non-native range comparisons overlook within-range variation among populations and lack interdisciplinary frameworks utilizing multi-omics approaches. The integrative network iCONNECT addresses these research gaps. Here, we introduce the framework and present results from an initial study conducted within iCONNECT. We performed a greenhouse experiment with 108 native and 176 non-native *Conyza canadensis* populations, collected across broad spatio-environmental gradients in both ranges. The populations were exposed to a competition × drought treatment combination. The samples from this experiment were analyzed in a coherent manner to study their 1) phenotype (competitive ability under dry and mesic conditions), 2) eco-metabolomics (mass spectrometry analyses of root exudates), 3) root-fungal interactions (amplicon sequencing), and 4) population genomics (ddRADseq). 1) Interspecific competition had more detrimental effects on native than non-native populations and experimental drought exacerbated the effects of competition. 2) Drought led to increased metabolomic diversity in non-native but not in native populations. 3) Drought altered the composition of root-colonizing fungal communities in non-native but not in native populations, and these changes correlated with the effects of drought on plant performance in the non-native populations. 4) Bayesian clustering revealed significant correlation of the population genetic structure with spatio-environmental gradients and with the phenotypic and eco-metabolomic traits measured in the greenhouse. Integrating multi-omics data can help unraveling how belowground mechanisms determine contemporary evolution in complex biotic interactions. Future research may focus on identifying metabolites and genomic regions associated with competitive ability and root-fungi interactions under dry and mesic conditions. We encourage collaboration with interested researchers who want to use our sampled populations in order to perform add-on studies that investigate drivers of contemporary evolution in diverse biotic interaction traits.

Student contribution

hat formatiert: Englisch (Vereinigte Staaten)

Nitrogen sharing strategies of clonal plants

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Clonal growth allows plants to spread horizontally and integrate resources from a larger area. Such integration of resources across the plant body is usually expected to compensate for environmentally induced differences in resource availability. However, some species may translocate resources almost exclusively to younger parts of the plant (i.e. acropetally), even if the older parts are resource-limited. We hypothesised that, in the case of soil-borne nutrients, a bidirectional "equalisation" resource-sharing strategy may take place in productive environments, where it can help plants to buffer local deficiencies and maintain their position in the occupied space. In contrast, an "acropetal" resource-sharing strategy, which emphasises the exploration of new areas, may take place in less productive conditions. We used six stoloniferous species occurring in habitats of different productivity, grew pairs of parent and offspring ramets in homogeneously poor or poor to rich nutrient conditions, and measured nitrogen fluxes between parent and established offspring ramets by stable isotope tracing. The species consistently translocated nitrogen either towards the parent or towards the offspring ramets, regardless of nutrient conditions. Contrary to our expectations, these two different nitrogen partitioning strategies had no clear relationship with the natural habitat productivity of the species. Our results demonstrated that nutrient-sharing strategies of clonal plants can vary between species, but determinants of this variability remain to be explained.

Student contribution

Waiting for the light: temporal conditioning in plants

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Plants' responses to environmental changes have been shown to be more than simple reflexes, but rather involve complex information processing. However, the idea that such processing could involve associative processes remains inconclusive. In two separate experiments, we tested the ability of *Mimosa pudica* and *Phaseolus vulgaris* to exhibit temporal conditioning and associate between an honest signal and a temporal pattern. To study this associative response, we followed the non-circadian, photonastic leaf movement of *M. pudica* and *P. vulgaris*. During a 4-6 day training session, the plants were assigned to either a temporal conditioning treatment, where they were repeatedly presented with light at fixed intervals, or a control treatment where light was presented randomly. During the following testing session, *M. pudica* from the temporal-conditioning treatment exhibited greater leaf openness during the dark period compared to plants from the control treatments. Similarly, *P. vulgaris* exhibited increased leaf angle at the time intervals it used to receive light, compared to no response in plants from the control treatment. These results suggest that plants can show temporal conditioning to improve their light foraging in light-deprived environments, thus adding support to the idea of associative processes in organisms without a nervous system.

Carbohydrate storage in perennial herbs is strongly associated with phylogeny

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Carbohydrates play a central role in plant metabolism as a source of carbon and energy and form the basic structural units of plant bodies. In perennial herbs, they are stored belowground in specialized organs such as roots, rhizomes, tubers or bulbs. These reserves contain different types of nonstructural carbohydrates (NSC), mainly starch, fructans, raffinose family oligosaccharides (RFOs) or sucrose. NSC mediate different key functions in plants (e.g. transport, signaling, osmoregulation, symbiotic interactions), cope with environmental stresses (e.g. drought, cold, salinity) and are crucial for plant recovery. The main carbohydrate type can differ among plant families or even genera and the levels of NSC also vary during the day and season. We used these variations of NSC types and concentrations in belowground growth organs to see the variability within and across species, and further to investigate the role of phylogenetic relatedness and correlations with other plant characteristics. Analyses of 77 herbaceous species comprising 17 families collected at the end of growing season in temperate zone, showed high variability in carbohydrate concentrations across species and high species effect (above 75 % of explained variance) for all main storage carbohydrates, such as starch, fructans, stachyose, raffinose and sorbitol. For ubiquitous glucose, fructose and sucrose, were typical lower values of species effect and lower dispersion in carbohydrate concentrations among species. Almost all measured carbohydrates revealed strong association with phylogeny, which indicate that NSC evolved along the phylogenetic tree under a Brownian process probably as distinct plant adaptations and strategies for coping with changing biotic and abiotic factors in the environment. From studied plant characteristics, the most aligned to carbohydrate concentration profiles were start of flowering and belowground storage organ type.

Seasonal patterns in flowering intensity in herbaceous species is strongly influenced by temperature and flowering duration

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Phenological research often focus on single events in time such as first flowering day, and assume that species specific differences remain consistent over the season. However, species-specific differences in first flowering day or also flowering duration do not provide enough information when it comes to the evaluation of the role of these phenological patterns for biotic interactions. The consideration of the availability of flowers, for example, becomes particularly relevant when studying plant-pollinator interactions. However, most large-scale phenological observation networks do not take the temporal course of the availability of open flowers into account and therefore data on this is scarce. A counter-example is the PhenObs network (www.idiv.de/en/phenobs). Besides other phenological stages scientists of this network record the flowering intensity during weekly monitoring of populations in botanical gardens, providing unique data to analyse species-specific differences in seasonal flowering patterns in response to abiotic and biotic cues. In this study we analysed flowering intensity curves of more than 250 perennial herbaceous species across a spatial gradient to detect associations with climatic conditions, species' functional traits while accounting for species' phylogeny. We considered data collected in 14 botanical gardens between 2019-2023. Using linear-mixed effect models we explained the skewness of the flowering intensity curves per year, garden and species with variations in climatic variables of the different sites and years, and species' functional traits. We further tested for underlying phylogenetic signals. We found that the flowering curves were more right-skewed at warmer temperatures indicating that the populations reached peak flowering with a steeper slope before the flowering intensity slowly decreased. Furthermore, species with a longer flowering duration were also more right-skewed. Our findings contribute significantly to a more detailed understanding of the seasonal variation flowering intensity in herbaceous species, which will be of crucial importance for future phenological research, especially on plant-pollinator interactions.

Treeline seedlings under stress: responses to temperature and radiation manipulation

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Seedling establishment in treeline ecotones is a crucial first step for the elevational advance of tree cover, which is expected to occur as the warming climate shifts the climatic treeline uphill. Tree seedlings establishing above the current forest limit are expected to suffer from being exposed to excess solar radiation during the day and freezing due to radiative cooling during the night, which is particularly harmful when combined in sequence. To study the importance of such environmental stressors for different species of treeline-forming tree species, we exposed seedlings to ambient treeline conditions as well as ameliorated conditions under shade, night warming (nightly cover), daytime warming (open-top chambers) and combinations of these treatments. Two seedling cohorts of *Picea abies*, *Pinus cembra*, *Pinus uncinata*, *Larix decidua*, and *Sorbus aucuparia* were planted in eight treatments, replicated in five blocks, near treeline elevation in the French Alps. In the first cohort, daytime warming caused higher seedling mortality, unless accompanied by watering, while shading and night warming, especially when combined, tended to decrease mortality. However, in the second cohort, planted one year after the first, mortality was generally very low and the treatments had little effect on survival. Dense grass cover tended to increase mortality and decrease growth and starch reserves consistently in both tree-seedling cohorts. Chlorophyll fluorescence reflected an ameliorating effect of shading on photosynthetic efficiency, but no ecologically-relevant photoinhibition was detected in any treatment. We conclude that for well-acclimatized seedling, the subalpine conditions of our study site should not inhibit the early establishment of trees, although competition with alpine vegetation could strongly slow it down. In addition, a lack of viable seeds, slow growth and biomass loss due to e.g. ice blasting once seedlings emerge from the protected ground layer may further slow forest expansion towards the rising climatic treeline.

The first rule of rhizome stoichiometry is you do not talk about rhizome stoichiometry!

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Different plant organs serve different functions, which can be reflected in their composition and balance of chemical elements (stoichiometry). Thus, plants should allocate elements differently into acquisitive organs (e.g., leaves) vs. storage organs (rhizomes or storage roots). However, this hypothesis has never been tested because element concentrations are rarely measured in rhizomes. We examined the allocation of carbon (C), nitrogen (N), phosphorus (P), sulfur (S), potassium (K), calcium (Ca), magnesium (Mg) and iron (Fe) into leaves, rhizomes and storage roots in a set of rhizomatous herbs sampled from a natural environment. We observed that plants allocated less N, P, K and Mg into rhizomes than to leaves, and less N, K, Ca and Mg into roots compared to leaves. Rhizomes and storage roots exhibited similar concentrations of all measured elements, except for Ca that was, on average, higher in rhizomes than in roots. In all three organs analysed, we found a consistent tendency for N, P and K to be aligned in the same direction across the first axis (the cell metabolic axis). In rhizomes, the second axis was defined by positively correlated S and Mg concentrations, such phenomenon was not found in the other organs. Variation of C and Fe concentrations was independent of organ or other elements. We found support for the hypothesis that plant organs with the same function exhibit similar elemental composition. However, concentrations of Ca in rhizomes appear to be closer to the leaves than storage roots, a phenomenon that merits further exploration.

Belowground plant competition: uncoupling root response strategies of peas

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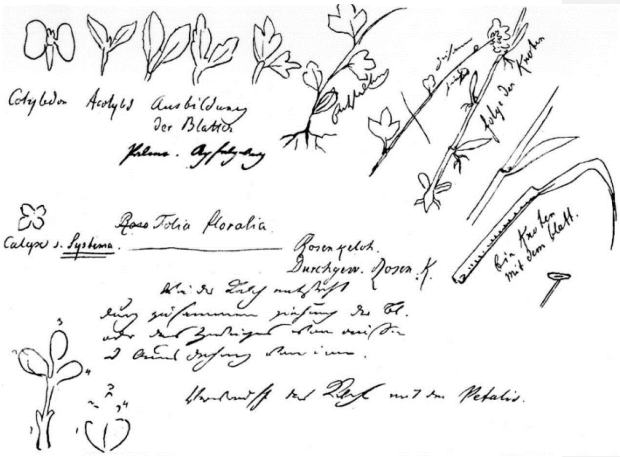
Plants can sense the presence of neighbors belowground but were shown to respond to them with either increases or decreases in directional root growth or

in root biomass allocation. These inconsistencies might stem from variations in size hierarchies between plants, but this hypothesis was not studied previously. Here, we examined the effects of neighbor size and density, as well as the distribution of soil resources on both biomass root allocation and directional root placement in *Pisum sativum*. We found that while increased neighbor size induced greater root allocation in *P. sativum*, it had no effect on directional root placement. Instead, root placement toward neighbors was contingent on the distribution of soil resources. Interestingly, our results suggest that root allocation and directional root placement might serve as uncoupled strategies that can simultaneously provide stress tolerance and spatial responsiveness to neighbors.

POSTERS

in alphabetical order of the first author



Botanical engravings by Goethe showing the development of a plant from the appearance of cotyledons to reproduction

Student contribution

Soil seed banks for revegetating degraded rangelands – an experimental study in semi-arid Jordan

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The seed banks are vital components for the reestablishment of degraded lands since they contain seeds that can be long-lived. However, often the density and species composition of seed banks used for restoration is not the same as in the recipient area. Also, the determinants of success, such as degradation stage of the recipient community, origin of the seeds, as well as seeding methods have not been evaluated in detail. Here, we present a novel experiment conducted in semi-arid rangelands in Jordan, which tries to establish a practical method for rangeland restoration. The region is dominated by annual plants with long-lived seed banks, making them an ideal case for such restoration methods. To that end, we selected three rangeland areas with different degradation stage and precipitation, and conducted reciprocal transplants, including local transplants as procedural controls, with seed banks from all areas. We hypothesize that seedbanks from drier areas and local origin will have higher establishment rates than those from wetter ones and non-local origin. We analyzed species density and composition of the established vegetation (i.e. realized community), as well as of seed bank samples germinated under optimal conditions in a nethouse (i.e. potential community). The resemblance of the standing vegetation and the potential vegetation will yield the restoration potential. Here, we will present the inital results of our experiment, including management recommendations.

Population connectivity in a naturally fragmented landscape: inter-island connectivity of widespread plants across Galápagos

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Oceanic archipelagos are naturally fragmented landscapes, as they have emerged lifeless from the sea floor and most of the islands are independent volcanic buildings. In this context, some plants have managed not only to colonize these oceanic archipelagos by long-distance dispersal, but also to spread across them by colonizing multiple islands. However, the distribution of a species across an archipelago does not necessarily indicate extensive gene flow between islands. In this study, we aimed to detect differences in gene flow in three widespread species across the Galápagos archipelago by assessing their inter- and intra-island population connectivity. These three species differ in fruit dispersal traits that may favour different dispersal modes mediated by different vectors; i.e. *Cryptocarpus pyriformis* with corky fruits floating in seawater (thalassochorous), *Lantana peduncularis* with fleshy fruits (endozoochorous), and *Waltheria ovata* with no apparent trait for dispersal (unspecialized). Using SNPs from ddRADseq and landscape genetic methods, we tested different hypotheses for population connectivity: (1) isolation by sea resistance, considering sea currents as the main dispersal vector; (2) isolation by sea and inland resistance, considering sea and inland dispersal in combination; (3) isolation by barrier, considering the sea as an obstacle to seed dispersal; (4) isolation by wind resistance, considering wind as the main dispersal vector; and (5) isolation by geographical distance. We found differences in genetic structure and population connectivity between species, as well as evidence for the role of different dispersal vectors on this genetic structuring. The combination of genomic and landscape genetic techniques helps to understand how landscape features modulate gene flow in naturally fragmented landscapes, ultimately modulating evolutionary processes.

Student contribution

How plastic germination favors plant diversity

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Seeds have the capacity to enter a dormant state and germinate at favorable conditions. The ability to adapt the germination to a varying environment is called germination plasticity. Empirical studies often describe germination plasticity, in particular when either temperature or water availability is varying. However, a comprehensive understanding of its effects on biodiversity is missing. We use individual-based simulations to explore how germination plasticity affects biological diversity with spatial and temporal environmental variation. We show that germination plasticity leads to greater local and regional plants diversity when water availability varies over space or between years. We also investigate how the combination of germination plasticity and interannual environmental variation leads to an additional kind of diversity: diversity in plant composition between years. This work advances our understanding of conditions that favor biological diversity and might improve our interpretation of empirical data.

Student contribution

Competition and soil fungi mediated priority effects in native and exotic European grassland plants

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In natural plant communities, species often don´t arrive simultaneously at a new site. The effect of an early-arriving species on the establishment, growth and reproduction of a late-arriving species is referred to as priority effect. Despite increasing evidence that priority effects play an important role in plant community assembly processes (Ejrnæs, Bruun and Graae, 2006; Körner et al., 2008), the underlying mechanisms are not fully understood (Fukami, 2015). To achieve a deeper understanding of the processes underlying the priority effects of native and exotic plant species, we conducted a multi-species field experiment, with late-arriving species arriving two years later than early-arriving species. To gain better insights into the role of direct competition and soil fungi accumulation in this process, we implemented two treatments: a fungicide treatment (for the removal of the soil fungi accumulated by early-arriving plants) and a herbicide treatment (for the removal of early-arriving plants and in consequence their direct competitive effects). We tested the following hypotheses: H1a) Competition-driven priority effects are negative, with their strength being correlated to the biomass of the EA. H1b) Exotic species have a stronger priority effect when arriving early and can establish themselves more effectively when arriving late. H2a) The performance of LA is hampered by the soil fungi accumulated by EA. H2b) Due to enemy release, exotic species accumulate fewer inhibiting soil fungi when arriving first and are less inhibited by them when arriving late compared to native species. H3a) The soil fungi inhibiting the establishment of LA also affect EA, potentially diminishing their competitive effect. H3b) The influence of fungi exclusion on the competition effect is strongest when both species are native. In the oral presentation I will present the first preliminary results of the experiment.

Student contribution

The effect of seed collection timing on plant traits

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Conservation seed banks around the globe are storing seeds of millions plant species with the aim to protect both species itself and its genetic diversity. Each seed conservation starts with seed collection. Collection guidelines (e.g. from the Kew Garden) describe, for example, how seeds should be collected only from large populations to ensure genetic diversity, one should collect only such amount of seed that does not threaten the source populations, and collected seeds should be fully ripe to achieve the best possible quality. However, guidelines of major seed-banking institution do not specify how often seeds should be collected. This is surprising, because reproductive phenology typically varies within wild populations, and for example flowering time is genetically determined trait. Collecting only once per season thus likely selects for such genotypes that flowered and thus had ripe seeds at a specific time, and excludes earlier or later flowering genotypes. This would have far-reaching consequences for seed bank practice, because seed collection would cause selection and the stored seeds would represent only a subset of genotypes present in the wild population. Surprisingly, whether plant traits depend on the timing of collection of the seed from which the plant grew, has never been tested so far. We focus on *Stellaria media*, a weedy species that grows, flowers and produces seeds nearly the whole year, including in winter. We collected seeds from the same population every week from April to February. The first results show that the seed weight varies during the year, with seeds collected in spring and autumn being twice as heavy as seeds collected in summer and winter. As seed weight determines early growth, it is likely that seed collection time affects traits of young plants or adults. We are currently testing this in a common garden experiment.

Student contribution

Nitrogen sharing strategies of clonal plants

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Clonal growth allows plants to spread horizontally and integrate resources from a larger area. Such integration of resources across the plant body is usually expected to compensate for environmentally induced differences in resource availability. However, some species may translocate resources almost exclusively to younger parts of the plant (i.e. acropetally), even if the older parts are resource-limited. We hypothesised that, in the case of soil-borne nutrients, a bidirectional "equalisation" resource-sharing strategy may take place in productive environments, where it can help plants to buffer local deficiencies and maintain their position in the occupied space. In contrast, an "acropetal" resource-sharing strategy, which emphasises the exploration of new areas, may take place in less productive conditions. We used six stoloniferous species occurring in habitats of different productivity, grew pairs of parent and offspring ramets in homogeneously poor or poor to rich nutrient conditions, and measured nitrogen fluxes between parent and established offspring ramets by stable isotope tracing. The species consistently translocated nitrogen either towards the parent or towards the offspring ramets, regardless of nutrient conditions. Contrary to our expectations, these two different nitrogen partitioning strategies had no clear relationship with the natural habitat productivity of the species. Our results demonstrated that nutrient-sharing strategies of clonal plants can vary between species, but determinants of this variability remain to be explained.

Student contribution

Poly affairs: the agricultural landscape composition affects pollen influx in isolated populations of the forest herb *Polygonatum multiflorum*

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Forest herbs significantly contribute to the biodiversity of agricultural landscapes. In Central Europe, a substantial portion of their habitat exists as spatially isolated forest patches within agricultural landscapes. Many of these species can reproduce vegetatively, allowing them to survive in isolated habitat without strong reactions to the surrounding landscape matrix. However, concerning the genetic diversity of *Polygonatum multiflorum*, a forest herb species associated with bumblebees, we found landscape effects of recently introduced land-use types, such as maize cover. This suggests a higher pollen flow than expected between the isolated forest herb populations. Building on these findings, we conduct a paternity analysis of *P. multiflorum* for nine isolated forest patches. This analysis includes 20 mothers with ten individuals of offspring and all individuals within the patch considered as potential fathers. We estimate both individual and population-level pollen influx for each forest patch and examine whether the pollen influx is influenced by the surrounding landscape composition. We anticipate observing moderate levels of pollen influx. Individuals and populations, surrounded by a higher proportion of maize cover are expected to experience a greater influx of pollen from other populations. Conversely, individuals and populations with higher levels of semi-natural grassland cover should exhibit a lower pollen influx, as bumblebees are likely to be less attracted to the forest habitat in such areas. The results of this analysis will be presented.

Student contribution

ExploreNiche: using the oxygen stable isotopes approach to determine belowground niche partitioning in grasslands

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The "ExploreNiche" project investigates the complex dynamics of belowground niche partitioning across various land-use gradients, aiming to illuminate the fundamental principles sustaining biodiversity and ecosystem productivity in temperate grasslands. This initiative seeks to fill critical knowledge gaps in our understanding of species coexistence, highlighting the essential role of belowground niche differentiation in promoting ecosystem resilience and integrity under varied land management strategies. Employing non-destructive methodologies such as the oxygen stable isotope analysis approach, this research enables the non-destructive determination of plant species' water uptake depths from the soil. By analyzing the stable isotope composition of oxygen ($\delta^{18}O$) in the plant's root crown xylem water and correlating these isotopic signatures with those in soil water across a range of soil depths up to a maximum of 50 cm, the research can infer the depth of water uptake by different species within grassland ecosystems and their water uptake overlaps. This comparison facilitates the identification of distinct patterns of resource use, providing detailed insights into how different plant species partition water resources spatially. The technique serves as a powerful tool for elucidating the belowground ecological niches of plants, significantly enhancing our understanding of species coexistence and ecosystem functioning. Conducted over 75 plots in three distinct regions in Germany within the Biodiversity Exploratories, the water uptake of targeted grassland species has been measured using this approach. Subsequently, the results from the hydrological niche partitioning will be integrated with an overall land use intensity dataset, such as mowing, fertilization, grazing, and leveraging extensive existing datasets on biotic/abiotic factors, species temporal richness to understand the dynamics of species diversity under varying conditions of resource availability, stress, and disturbance in grassland ecosystems.

Chemical patterns of anti-herbivore defense in invasive Japanese knotweed using herbarium specimens

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Plants produce various specialized secondary metabolites that have repellent or toxic effects on herbivores. Herbaria are a treasure of temporally and geographically broad plant samples but have so far been underused for studies exploring their chemical diversity. The success of invasive plants has often been attributed to a release from adapted enemies selecting for an evolutionary shift in resource allocation patterns from herbivore defense to increased size. Over time, enemy release effects at the introduced range might attenuate, leading to a recovery of resistance against herbivores. This pilot study explores the temporal and spatial dynamic of anti-herbivory defense of Japanese knotweed specimens (*Reynoutria japonica*) from 42 herbaria since its introduction to Europe and North America in the 1820th and 1860th. Alkaloids, phenolics and lignin were detected in dried leaf tissue up to 150 years of age. The leaf content of alkaloids, flavonoids and tannins showed increasing concentrations over the century scale study period, indicating that herbivores adapted to introduced Japanese knotweed over time. Higher levels of lignin were measured for specimens collected at northern latitudinal locations. Lignin acts not only as a plant defense compound but also has high relevance as a stabilizing element for plants exposed to harsher climatic conditions. Alkaloids were more abundant in younger more vulnerable leaves compared to leaves collected later in the year. The present study demonstrates that herbaria can provide a rich source of secondary metabolite data. Analyses of correlations between the age and chemical compound quantities in old samples are still necessary to make claims about historical absolute abundance values.

Student contribution

ExploreNiche: belowground niche partitioning along land-use gradients in grasslands

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Anthropogenic demand for increased agricultural production is a driving force in the decline and degradation of Central European semi-natural temperate grasslands. Unlike many other high diversity landscapes, these grasslands thrive under consistent land management efforts, which are essential in preventing their abandonment and subsequential species loss. However, the relationship between land-use practices and the mechanisms supporting diversity in these grasslands is still under heavy debate. Belowground niche partitioning of resources and space along vertical gradients in soil has been proposed as a stabilizing mechanism that promotes species coexistence and diversity. It postulates that each species within a community has its distinct depth for water uptake, optimizing the utilization of resources and reducing the effects of competitive exclusion. Here, we aimed to explore the effects of land-use type and intensity on belowground niche partitioning in semi-natural grasslands spanning 75 sites, across three regions in Germany, collectively referred to as the Biodiversity Exploratories. We utilized naturally occurring oxygen stable isotopes found in the soil and plant root crowns to identify the water uptake depths of grassland species, allowing us to assess the overlap of depths and determine niche partitioning in the vertical soil profile. Land use was defined by an overall land use intensity index (LUI) and its three components – fertilization, grazing, and mowing. We hypothesized that belowground niche partitioning will decrease with increased fertilization and that it will be the most pronounced at the intermediate intensity of grazing and mowing.

How perennials exploit vegetation season in temperate climates

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Plants in temperate climates must cope with a limited window of favourable conditions for growth. While annuals fit their whole life cycle into this window and woody species maintain living tissue aboveground, perennial herbs are truly perennial only belowground and their aboveground parts are as a rule annual. They start growing in spring using resources stored in their belowground organs, develop shoots aboveground, capture carbon by photosynthesis and invest it in growth, reproduction and in building belowground resources for the next year. As any field naturalist would know, there are tremendous differences among species of temperate floras how they handle this problem. We examined strategies that perennials use to exploit the limited time of one growth season, by linking data on growth and flowering phenological niches, senescence onset, final height, storage organ size and overwintering bud development, in 200 temperate species. Using these data, we identified five major growth strategies, showing a strong gradient from extreme "capital growers" that rely on belowground storage in their growth, to extreme "income growers" that rely on growth maintained by continuous carbon capture throughout the season. These differences are phylogenetically conservative, implying that key innovations in exploitation of the seasonal window are fairly rare.

Student contribution

Impacts of small-scale soil resource heterogeneity on interspecific understory plant trait variation in the Southern Black Forest

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It is widely accepted that resource heterogeneity is a major driver of biodiversity. However, very few experimental field studies have incorporated the diversity of plant functional traits into heterogeneity-diversity relationships. Soil nutrient availability is known to affect plant functional traits, which in turn can be associated with plant adaptation strategies. This thesis determines whether the heterogeneity at small spatial scales of soil nutrients promotes key functional trait variation of leaf nitrogen concentration (LNC) and specific leaf area (SLA) between understory plant species. During a three years fertilization experiment, ten locations in the Southern Black Forest in Germany were manipulated. Each plot consisted subplots of 6.25 m^2 with different patterns of fertilization, ranging from heterogeneous to homogeneous distributions. An abundant weighted coefficient of variation (CV) was used to quantify interspecific variation in LNC and SLA of understory vegetation. Results show that subplots with heterogeneously applied fertilizer resulted in significantly increased LNC variations and suggest that nutrient heterogeneity might have promoted different nitrogen utilization strategies among understory species, thus enhancing functional trait diversity. Conversely, heterogeneously applied fertilizer did not enhance SLA variations. Instead, these variations were strongly related to light availability, which highlights that plant functional traits can be impacted by distinct environmental factors. Overall, this study argues that soil nutrient heterogeneity can further be linked to microhabitat variability as a promoter of functional trait diversity at the forest floor level. Therefore, these findings might have implications for forest management practices, proposing that promoting microhabitats could enhance biodiversity and support forest ecosystem resilience in the face of environmental changes.

Student contribution

A glimpse into the past: how does the historical landscape matrix explain current population genetic structures?

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One of the most important, however often neglected determinants of the population genetic structure is landscape history. Today, most population genetic studies at the landscape scale quantify the historical gene flow, which integrates the functional connectivity of the landscape over an unknown time. It may reflect the past rather than the present-day landscape structure because it takes some generations of time (time lag) to reach an equilibrium between the population genetic structure and corresponding functional connectivity. The typical agricultural landscape found in central Europe has been established for centuries. The number and distribution of land-use types, i.e., landscape matrix, have changed ever since. The population genetic structure of forest herbs living in isolated small forest patches that are embedded in this agricultural matrix is highly influenced by gene flow, both historical and current. Here, we reconstructed the landscape matrix of three regions in four different time points (the 50s, the 80s, the 2000s, and after 2010), using aerial photographs. We then used these historical landscape matrices to explain the population genetic structure of three forest herb species with different generation times. We expected that (i) historical landscape matrices can explain more variance of the population genetic pattern than the current landscape matrix; (ii) species with longer generation time has a longer time lag than species with a shorter generation time; (iii) species that associated with mobile pollinators has a shorter time lag than species that is with less mobile pollinators.

Student contribution

The effect of temperature fluctuation on the plant microbiome

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Plants face an ever-changing world. In the model organism Arabidopsis thaliana, we have a relatively good understanding of how plants react to various stressors, both abiotic and biotic. The plant microbiome is an essential component in plant functioning, yet the impact of these stresses on the microbiome is less known. In this study we inoculated four *A. thaliana* genotypes with a known microbiome community and exposed them to varied lengths of heat fluctuation cycles. The heat fluctuation cycle involved 1, 3, or 9 days of continuous heat treatment followed by an equal number of days of recovery. The stress treatment lasted 18 days in total, equating to 9, 3, and 1 full heat-recovery cycles for the different treatments. We harvested and analysed the microbiome composition across different time point and different stress cycles and made phenotypic observations of the plants. In this presentation, I will talk about the impact on heat fluctuation on the plant and microbiome.

Student contribution

Comparative analysis of diversification rates in clonal and non-clonal plants

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Clonality is present in about half of the plant species. Many plant species are clonal, meaning they can reproduce vegetatively by placing stems horizontally and using adventive roots or roots that bear buds that can produce stems. Clonality in plants influences various factors such as effective population size, meiosis frequency, and genet lifetime, all of which can significantly shape the diversification rates. However, the role of clonality in influencing species diversity has been largely overlooked. Here, we aim to investigate the potential impact of clonality on rates of diversification and whether the patterns of diversification in clades where clonal species predominate differ from those with non-clonal species. In order to do this, a wide range of taxonomic groups with different proportions of species capable of clonal growth were sampled. Worldwide clonality data was sourced from the CLOPLA database and linked with existing phylogenetic information on these species, namely the Smith & Brown (2018) Angiosperm phylogeny. Our approach involves a variety of phylogenetic methodologies, each characterized by specific assumptions. We employ hypothesis-free tip rate estimations using different methods, like DR metrics, BAMM, and ClaDS, to assess diversification rates. Statistical analysis involves regressing tip diversification rates against the clonal status of plants, employing phylogenetic linear models. The study has the potential to clarify the role that clonality plays in measuring observed variation in diversification metrics.

Student contribution

The 'marriage' of heterostylous plants in an era of habitat fragmentation

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Habitat loss and fragmentation are one of the main reasons for recent widespread biodiversity loss. Especially affected among plants are insect-pollinated species, as they depend on pollinators to be able to move between different populations to distribute pollen. This also includes species characterized by heterostyly – a unique reproductive system defined by the presence of two or more distinct floral morphs within a population, each with differing positioning of anthers and style. The spatial separation of reproductive organs restricts self-pollination while also favouring cross-pollination between different morphs. Both floral morphs are usually needed in equal frequencies for optimal reproduction. However, as habitats become fragmented, heterostylous species can be affected in many ways. Reduced connectivity between habitat patches can impede the movement of pollinators between different populations and individuals, leading to reduced gene flow and genetic diversity. Reduction in population size can disrupt the morph ratio balance, resulting in fewer compatible mates. Small and isolated populations are also more vulnerable to genetic drift and inbreeding, which can reduce the populations' adaptability to changing climatic and environmental conditions. Consequently, populations with a biased morph ratio might have an increased risk of extinction. In this talk, I will give an overview of recent studies that have investigated the consequences of habitat fragmentation on different heterostylous species from different plant families and present some results from my recent research. Understanding the effects of habitat fragmentation can help us make better conservation efforts not only for insect-pollinated heterostylous species but also for other species living in such conditions.

Interacting effects of drought and range expansion on *Geranium* sp.

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The ecological effects of climate change on plant populations are complex. Increased extreme weather events may reduce plant growth and reproduction, while the habitat conditions of plant species may alter under changing climate conditions. As a result, some regions may lose species while other areas gain new colonizing species from nearby areas. In this study, we examine the interacting effects of drought and range expansion using closely related geranium species as model species. According to their distribution areas, *Geranium lucidum* has expanded its range northwards and is defined as a range-expander, while *Geranium dissectum* is a native throughout the examined range. We used a greenhouse experiment to test if seed origin influences plant growth in regular and under stressful conditions caused by early-season and late-season drought. We hypothesized that plants of range-expanding *G. lucidum* from the northern part of its range (the Netherlands) are more suppressed by drought than plants from southern populations (Slovenia). For both species, we found that early-season drought suppressed plant biomass more than late-season drought. Plant species' response to drought did not vary by range. However, while the biomass of range expanding *G. lucidum* in regular condition did not differ between ranges, native *G. dissectum* plants originating from Slovenia had significantly higher aboveground biomass and lower belowground biomass than those from the Netherlands. These results suggest that species (like *G. lucidum*), that have gradually expanded in response to climate change, do not lose their ability to cope with drought; however, compared to native species (like *G. dissectum*), they lack local adaptation in the new range.

Student contribution

Drivers of genetic diversity across South African Protea species

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The genus Protea is a flagship species in the Cape Floristic Region (CFR) of South Africa, a region of exceptional plant diversity and endemism. There is extensive data on the demography, plant traits and environmental conditions of the genus but data on the drivers of genetic diversity across the species is rare. The objective of the project is to understand the genetic drivers within and among populations of Protea. During the seed collection process for a project aimed to explore intraspecific variation and microevolutionary processes within the Protea system, 1077 leaf samples (219 populations) from 16 species were collected, with the project being established by the research groups of Frank Schurr and Oliver Bossdorf in collaboration with Stellenbosch University in South Africa. Using ddRAD sample libraries will be generated and sequenced after DNA extraction from the leaves, followed by the identification of polymorphic loci in the sequences of all 219 populations. Single Nucleotide Polymorphic (SNPs) loci will be mapped to study the hotspots of genetic diversity with the populations (alpha genetic diversity). To understand drivers of genetic diversity between populations across the 16 species of Protea I would like to employ various partition beta diversity methods including multiple matrix regression, Bayesian FST outlier analysis. I will take advantage of the power of a 16-species data set and attempt to understand species differences in (average) genetic diversity and genetic differentiation from their variation in life-histories.

Student contribution

The effect of seed harvest timing on plant traits

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While restoration efforts are increasing, many grassland restoration projects are limited by the quality and availability of seeds. As a result, wild plants are propagated in large-scale monocultures using common agricultural practices, but this can cause unintended selection. For example, seeds are typically harvested once, at the peak of seed ripening, effectively selecting only for genotypes that have ripe seeds at the time of harvest. This can affect other traits like flowering time or seed mass of the plants that grew from the harvested seed. To test whether such evolutionary changes indeed happen, we are carrying out an experiment, where we compare plants from seeds that have been harvested from the same production field several times per season. To ensure generality, we include 12 herbaceous plants, including summer and winter annuals, biennials, and perennials. The first results show that the timing of the harvest affects seed mass: later harvested seeds are heavier in summer annuals, the trend is opposite in winter annuals, biennials, and perennials. Since seed mass is related to many other plant traits like germination, early growth or even flowering time, we expect that harvest time will affect also traits of the plants that grew from the seed. We are currently testing this in a large common garden experiment.

Intraspecific variability of seed longevity in storage

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Stored seeds serve as repositories of plant genetic diversity, especially of endangered and wild species, and are valuable resources for evolutionary research, species conservation, and ecosystem restoration. However, long-term storage inevitably leads to the deterioration and loss of viability of the seed. While seed longevity is known to be species-specific, the significance of intraspecific variability in seed longevity remains unexplored, particularly in non-cultivated crops. Here, we used artificial seed ageing to test interspecific and intraspecific variability of seed longevity in storage. We focused on 42 common grassland species and 182 accessions. In 32 species, we had more than two accessions from different regions and in 16 species more than 5 accessions. We obtained the seed from seed producers across Europe that produce native regional seed for ecosystem restoration. We exposed the seeds to artificial ageing conditions (60% RH, 45°C) and tested, how long it takes until the germination rate decreases to half in comparison with the fresh seed (P50). The seed longevity in artificial ageing conditions ranged from 5 days (*Bupleurum rotundifolium*) to several 100 days (*Lotus pedunculatus*). Species-specific seed longevity was predicted by seed weight: Heavier seeds lost viability earlier than lighter seeds. Within species, the seed longevity massively varied, and the difference between of the accessions was often more than tenfold. In contrast to cross-species comparison, the accession-specific longevity was not predicted by the accession-specific seed weight, but by the germination rate of the fresh seed: Accessions with lower initial germination rates decayed faster than accessions with higher initial germination rates. We are currently testing whether the longevity in storage can be predicted by climatic conditions in the source populations, a pattern that was previously demonstrated in cross-species comparisons.

What rhizomes, tubers and bulbs tell us about plant strategies?

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Plants possess diversity of belowground coarse organs like storage roots, rhizomes, tubers or bulbs that have numerous roles in plants life and affect ecosystem functions. They enable plants clonal multiplication, vegetative regeneration after damage or seasonal rest, space occupancy, foraging, storing and sharing resources. They also protect soil from erosion, affect carbon and nitrogen cycle, and ensure biomass production. Using CLO-PLA database of clonal growth of plants of Central European flora, we analyzed phylogeny, distribution along environmental gradients, and plant life-history strategies of plants with various belowground morphologies of coarse belowground organs, clonal and bud bank traits. Our results imply that (i) mere dichotomy distinguishing clonal and nonclonal plants is oversimplification hindering important ecological differences among non-clonal annual and perennial herbs on one side and clonal plants having different clonal growth organs on the other side; (ii) Clonality is phylogenetically flexible trait easily attained as well as lost in central European flora with two independent roads to clonality – through stem versus root bud bearing organs; (iii) Clonal and bud bank trait variations are independent of variations observed in fine root traits as well as in leaf traits, plant height and seed size. We are discussing limitations of our analyses and remaining gaps in our knowledge of the belowground coarse organs.

Vegetation change along resource gradients in the forest understory

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The retention of specific structures in forests alters the degree of habitat heterogeneity, not only for insects, birds and bats, but also for plants. Plant diversity is known to be promoted by spatial heterogeneity in environmental conditions, that can be created by such forest management measures. Species diversity and functional diversity of understory plants in temperate forests are considered key to ecosystem functioning. From literature, we know that there is a strong interrelation between resources and plant diversity. Aside from stochastic processes, species coexist in communities because they use either a) different resources or b) use the same resource but partition the use in time and/or space. Heterogeneous availability of resources in space and time can thus secure species coexistence, however this effect depends highly on the scale of observation. In this study, we observe spatio-temporal heterogeneity in resources, as well as gradients in resource availability on a small scale in forest environments and analyse the effects of these variables on vegetation change in the understory layer. In 12 small patches along 10m transects in 55 plots of the Southern Black Forest, we measured soil nutrients, light availability across space and time and carried out vegetation surveys. We expect that transects with higher differences in spatial distribution of resources might not host a more diverse set of species on the given scale (both taxonomically and functionally), however we expect that higher total availability of resources increases species and functional richness on the scale of individual and combinations of patches. With this, we aim at understanding if there is a threshold effect of variability in resources on vegetation change in small scale forest environments and how resource availability and variability interplay in shaping plant communities.

Clonality as a determinant of plant species diversity across gradients

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Diversity of plant communities is determined by both local processes and species pools. One of the rather overlooked local determinants is plant clonality which has been shown to be similarly or more important than the more commonly examined plant traits. Clonal growth has a number of ecological effects, namely space monopolization, resource accumulation, regeneration after injury, and sharing of resources among plant individuals. We know that clonal plants prefer disturbed, wet and cold places but otherwise our understanding of the effect of clonality on community assembly processes is rather limited. We plan to use plant community data spanning from south to north Europe (from EVA database) and analyse how proportion of clonal species changes along the environmental gradients. This will be achieved with the help of an updated version of the CLOPLA database and will be also analysed in phylogenetically corrected fashion. We will further inspect which clonal traits (e.g. lateral spread, multiplication rate) vary the most and what is the proportion of clonal plants in various habitat types. As clonality is not one uniform but rather several different growth forms, we will also show how proportion of these changes along the gradients (e.g. stolons, epigeogenous and hypogeogenous rhizomes, bulbs etc.). The data are still analysed so we will show fresh results at the conference.

Student contribution

Sleepy time: effects of light-competition cues on seed dormancy in a heterocarpic plant

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Seed dormancy is an important life history trait that allows seeds to avoid germination during unfavorable conditions. Dormancy was shown to be affected by different environmental cues including light competition. Studies so far have assessed that the light competition (low R/FR) can either promote or inhibit germination depending on the species. However, very few studies examined the effects of competition cues on dormancy in heterocarpic plants, which produce different fruit types with varying dormancy levels. We examined the effects of light-competition cues on the germination of two fruit morphs (ray vs. disc achenes) of the heterocarpic plant *Heterotheca subaxillaris*, which vary in their dispersal ability and dormancy. Achenes of *H. subaxillaris* were randomly subjected to one of three shading treatments, including control, neutral shade and light competition. Neutral shade and light competition treatments were identical in terms of light transmittance, with the latter treatment also reducing the R/FR. The disc achenes, which bear a pappus and have high dispersal ability, exhibited high germination rates that were unaffected by the different shading treatments. In contrast, the ray achenes, which lack a pappus and fall near the maternal plant, had lower germination rates that were notably decreased by the light-competition cues. These results reveal that light-competition cues can enhance seed dormancy in seeds that remain close to the mother plant, and thus facilitate competition avoidance even prior to germination.

Student contribution

Plant clonality along the gradient of aridity: Lamiaceae in Iranian Plateau

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Clonal growth, a widespread growth form in plants, can play a crucial role in their survival and persistence, while we already know that their occurrence changes along environmental gradients, there is very limited data on their distribution in arid and subtropical regions. We aim to address a broader question how clonal growth strategies occur along climatic gradients with special focus on dry conditions. We thus broaden our scope, shifting our focus to Iran and the Middle East as our study region, beyond the previously explored territories. Iran's unique climate gradients, spanning from high mountains to lowland deserts, provide an ideal region for understanding the adaptive role of clonality, particularly in extending the range of the water availability gradient well beyond what has been studied. We study Lamiaceae family, which diverse clonal growth forms and high species diversity makes it an excellent candidate for investigating the relationship between clonality and environmental factors. We analyzed the diversity of clonal growth traits across Lamiaceae species and linked them to species distribution patterns. We explore whether gradients in environmental conditions, namely drought, correlate with shifts in the frequency and types of clonality.

Identifying risk factors for the rare, endangered fen orchid Liparis loeselii in NE Germany with a fresh approach

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The cultivation of fens in Europe has led to massive anthropogenic degradation of these complex ecosystems over the past centuries, accompanied by drastic declines and even local extinctions of typical fen species. This includes the rare,

endangered yellow widelip orchid (*Liparis loeselii*), which is typical for alkaline fens and strictly protected in the European Union. However, habitat preferences and threats to Central European populations have been poorly studied, which hampers effective conservation measures. In this study, we investigated habitat preferences of the species in Brandenburg, NE Germany, to identify main drivers for its ongoing decline. Therefore, we compared the habitat conditions of 17 sites harboring extant populations with those in 11 sites where *Liparis loeselii* had recently gone extinct. We developed a special sampling design to tackle both the rarity of the species and the heterogeneity within sites, in order to quantify various abiotic and vegetation parameters. Sites with extant *Liparis loeselii* populations were characterized by e.g. higher soil moisture, lower peat degradation, lower nutrient availability and lower litter cover, and they differed in plant community composition from sites with extinct populations. Within sites, *Liparis loeselii* required a narrower, specific range of microhabitats with even lower nutrient availability, lower vegetation height, higher light availability, and a high cover of brown mosses. These results suggest that a key risk for *Liparis loeselii* are declining water tables, which lead to peat degradation and eutrophication, and thus promote tall growing, competitive species. Conservation management should thus ensure sufficiently high water tables, supported by measures that reduce nutrient availability and ensure low-growing vegetation.

AdapTest: testing rapid plant adaptation across broad climatic conditions

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The biosphere is affected by rapid anthropogenic climate change, which has drastic consequences for global biodiversity. While tracking rapid climatic shifts may be impossible for many plant species, populations can develop adaptive evolutionary responses. The scientific community has made significant progress in understanding species' adaptive evolutionary responses. But the question that

has not yet been answered is: Can evolutionary adaptation to different climates occur rapidly? The AdapTest project tackles this question using an integrative experimental approach to fill gaps in understanding the capability of plant populations to rapidly adapt to novel climatic conditions. The potential of experimental evolution approaches to study adaptive evolution is well recognized, but applications are generally limited to controlled ex-situ studies and there is a scarcity of methods capable of testing rapid evolutionary processes under natural conditions across broad climatic ranges. Moreover, strict tests of adaptation following evolution experiments, i.e., using reciprocal transplantations in the field, are scarce. In this poster, we present the new AdapTest project that sets out to foster an understanding of rapid adaptation through direct testing with unprecedented accuracy. Specifically, in AdapTest we will use lineages from an evolution experiment with *Arabidopsis thaliana* (the GrENE-net former project) which evolved under natural climatic conditions in 12 sites along a broad climatic range in Europe for a direct experimental test of rapid evolutionary adaptation. We will (i) measure fitness and functional traits in an in-situ reciprocal transplant experiment across Europe and (ii) use cutting-edge genomics tools to identify allele variants associated with phenotypes and climatic variables. AdapTest project implies a major step forward compared to previous work with its explicit and direct test of rapid adaptation of experimentally evolved lineages under natural conditions and its outstanding integration of in-situ common gardens and genomics.

Student contribution

Does length matter? A case of FAR5: different alleles, different response in alpine environment

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Adaptation towards an environmental change is an important topic. A great opportunity to study how the environment triggers local adaptation is along the altitudinal gradient. It presents a steep change of conditions towards a harsh alpine environment and provides us with a textbook example of how plants react. Multiple examples of similar phenotype modifications after colonization of the alpine environment are known. Rapid development of sequencing methods enables us to examine adaptation at the genetic level. An emerging model species, *Arabidopsis arenosa*, repeatedly colonized the alpine environment and independently formed a distinct alpine ecotype. Previous research revealed a list of candidate genes with strong signals of selection, including FAR5 as one of the top candidates. Furthermore, we show its association with environmental variables significant in the alpine environment. In our study we used a unique crossing design utilizing natural variation of FAR5 alleles in populations of *Arabidopsis arenosa*. The ancestral foothill and derived alpine alleles are rarely present in their non-native environment. Thus, we were able to cross rare heterozygotes carrying contrasting alleles and obtain alpine homozygotes for FAR5 with foothill background, foothill homozygotes with foothill background and likewise for plants originally from alpine population. Moreover, we did a transplant experiment with the results of our crosses in the actual alpine environment. Our results from GC-MS show there is a detectable phenotype of different FAR5 alleles in the composition of wax layers. Plants with alpine allele produced shorter fatty alcohols compared to the foothill allele. Hence, we provide a functional validation of candidate alpine-adaptive allele and contribute to understanding the mechanisms underlying the adaptation to challenging environments in *Arabidopsis*. Understanding how the organisms react in order to survive a change in environmental conditions could be useful in the future due to global changes in temperature or water availability.

Student contribution

Can hybridization allow the emergence of a Super-Genotype in Arabis floodplain species?

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Deciphering the genetic basis of ecological differences among hybridizing species is crucial for predicting their adaptive responses to climate change and human activities. Previous works identified a hotspot of hybridization on the banks of the Rhine River, revealing episodic gene flow between the close relatives *Arabis nemorensis* and *A. sagittata*. We genotyped a large interspecific F2 population (ca. 1000 individuals) resulting from the cross between sympatric individuals of these species, generating a high-density genetic map across 8 linkage groups. Quantitative trait loci (QTL) mapping for 24 traits revealed over 50 QTLs scattered along the genome, with flowering time exhibiting the strongest effect size QTL. Five QTLs indicating fertility trait incompatibilities. This study enhances our understanding of the genetic architecture of these species and provides insights into the potential existence of a "super genotype" capable of navigating complex ecological challenges in the presence of gene flow.

Soil microbiota contribute to the population growth rate of a nitrogen-fixing herbaceous legume

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Soil microbiota have the potential to modify plant growth and chemistry, with ramifications to plant population persistence. The effects of soil microbiota on plants have been typically assessed at the individual level, while effects on plant populations remain to be discovered. Here, we investigated the effects of soil microbiota on the performance of the nitrogen-fixing perennial legume *Lupinus polyphyllus* at the individual and population levels. Using seeds collected from native (North-American) and invasive (Finnish) populations of the species, we conducted a greenhouse experiment, in which we manipulated soil microbiota by adding either an intact or autoclaved soil inoculum obtained from invasive populations to potted plants. We grew the plants for two growing seasons, recorded six fitness-related plant traits (height early and later in life, survival, flowering probability, inflorescence length, seed production), and estimated the asymptotic population growth rate (λ) using a demographic model. With the intact soil inoculum, half of the fitness-related traits (height early in life, flowering probability, seed production) were 14-107% greater than those recorded from plants grown in the autoclaved soil inoculum, suggesting that individual plants benefitted from soil microbiota, while the rest of the traits did not differ between soil inocula treatments. Demographic models confirmed the positive effect of the intact soil inoculum at the population level, resulting in 47% and 108% greater λ for plants of native and invasive origins, respectively, as compared to those grown in the autoclaved soil inoculum. These results demonstrate that soil microbiota contribute to plant population persistence at least under greenhouse conditions, having the potential to affect species abundances. Moreover, the findings indicate that the net effect of soil microbiota on plant population growth rates may not be assessed based on individual fitness-related traits, but a demographic approach that considers the entire life-cycle is needed.

The secret youth of root-hemiparasitic plants

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Root hemiparasites require no host for germination. They have an early independent stage before their roots attach to the roots of host plants, and they are capable of their own photosynthesis. However, it is still poorly understood how long and how independent this early life stage is. Here I present a series of experiments to understand early parasite-host interactions. (1) In pots with and without hosts overwintered in a common garden, seeds of *Melampyrum arvense* and *Rhinanthus alectorolophus* (RA) germinated in November/ December. Their roots grew over winter, but above-ground growth only began in February/ March. In contrast, Odontites vulgaris started to germinate in February and emerged in March. In all species, host presence did not influence germination or emergence and did not increase parasite growth before May. (2) Similarly, in lab experiments at 5 °C neither germination nor emergence of RA was influenced by host presence. Parasite seedlings were even smaller in the presence of a host, suggesting competition for water or nutrients. (3) In reciprocal pot experiments with parasites and hosts from different populations, RA seedlings were largest as early as four weeks after planting when grown with sympatric compared to allopatric hosts, suggesting an adaptation of parasites to local hosts related to differences in host recognition or host defense. (4) When grown in agar plates between two different host seedlings, roots of RA grew preferentially towards the sympatric compared to the allopatric host seedlings, but only when host seeds had not been surface sterilized. This may indicate a role of seed-epiphytic microbial communities in parasite-host interactions. Taken together, these results suggest that the timing of germination and emergence, as well as parasite growth until the formation of the first leaves, are host-independent. However, host recognition and directed root growth may already occur at this 'host-independent' stage.

Student contribution

Increased connectedness among plant traits, root exudates, and the rhizosphere microbiome under drought

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Plants interact with soil microbes by secreting root exudates that nourish them. In turn, soil microbes improve access to macro- and micronutrients that plants take up with soil water. Both exudates and microbes may increase their importance for plant performance under drought stress, as they increase soil water availability and as such support the plants' continued access to water and nutrients. Consequently, tighter interactions between plant performance and allocation traits, exudates, and microbes are hypothesised under drought. We performed a drought experiment with *Arabidopsis lyrata* and tested for increased connectedness among exudates and microbes. Exudates were quantified using gas chromatography and the rhizosphere bacteria and fungi were identified by sequencing. We discovered that drought significantly affected the composition of root exudates and rhizosphere bacteria and reduced plant performance. Correlation network analysis revealed stronger and more significant relationships under drought suggesting a central role of exudates and microbes for plant performance. Specifically, the centrality of the correlation network was higher under drought, revealing a more interconnected system than under control conditions. Positive correlations were found between aboveground growth traits and plant growth-promoting bacteria, highlighting the role of microorganisms in plant adaptation to drought stress. The study reveals interconnected dynamic responses of plants, root exudates, and soil microorganisms to drought, underlining the importance of these interactions for plant survival and growth under challenging conditions.

Student contribution

ExploreNiche: belowground niche partitioning, diversity and productivity in grasslands

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The intricate balance between competition and coexistence within diverse plant communities depends on the ability of species to partition resources effectively, a concept at the heart of understanding biodiversity and ecosystem productivity. Our study delves into the mechanisms of belowground niche partitioning, focusing on water resource usage as an important factor in maintaining species diversity and driving community dynamics in temperate grasslands. By using oxygen stable isotopes ($\delta^{18}O$) in soil water and plants xylem, we traced the sources of water uptake across different coexisting plant species within three distinct German grassland regions, all part of the long-term integrative Biodiversity Exploratories project. The oxygen stable isotopes approach aims to reveal the intricacies of resource partitioning by examining the isotopic composition of extracted water, thereby providing a quantitative assessment of the vertical distribution of water sources among coexisting plant species. Our hypotheses posit that increased plant species diversity is related with more pronounced belowground niche partitioning. Furthermore, we hypothesize that higher productivity may lead to higher niche partitioning as a result of increased species diversity, more efficient resource use and intensified competition for belowground resources. Alternatively, increased productivity may lead to reduced belowground niche partitioning due to enhanced belowground resource availability which could shift the competitive dynamics to other limiting factors. This research not only advances our understanding of the ecological mechanisms that are underlying plant coexistence but also emphasizes the critical role of niche partitioning in sustaining biodiversity and productivity in temperate grassland ecosystems.

Student contribution

Effect of grassland management on clonal traits and rhizome biomass

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Plant belowground organs such as rhizomes, tubers, and bulbs, serve not only for clonal growth but also as storage and regenerative organs. Most of the studies so far have been focused on how clonal growth organs improve plant fitness and how different clonal traits respond to disturbance and environmental gradients, but they also affect ecosystem functions such as carbon, nutrients, the water cycle, erosion protection, or biomass production. We know that rhizome biomass and its longevity is negatively affected by frequent disturbance and therefore we hypothesize that grasslands with more intensive management have a lower rhizome to aboveground biomass ratio than meadows with less intensive management. Such effect of management may lead to altered soil carbon sequestration and lower soil erosion protection Using a manipulative field experiment on ten wet meadows running for ten years we tested whether the biomass of rhizomes is affected by the intensity of management and whether the possible effect is due to changes in species composition or due to intraspecific variability.

Fitness consequences of trait-mediated interactions between the invasive plant *Impatiens glandulifera*, native plants and their pollinators

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Plant-pollinator interactions can be strongly altered by the arrival of a new dominant species such as an invasive plant. So far, little is known about the impact of invasive plants on pollinator fitness. Moreover, there are conflicting results on how pollinators mediate interactions between invasive and native plants. These pollinator-mediated interactions can either be negative if invaders compete for pollinators or positive if native plants benefit from the spill-over of pollinators attracted to invaders. In this project we aim to reconcile these seemingly conflicting findings by analyzing how traits determine fitness consequences for invasive plants, native plants and pollinators. Specifically, we will quantify 'biotic interaction landscapes', which relate the fitness consequences of an interaction to the traits of two interaction partners. To this end, we will investigate how intra- and interspecific variation in plant and pollinator traits determine interactions between the invasive plant *Impatiens glandulifera*, native plant species and the pollinator community. We hypothesize that fitness effects of *I. glandulifera* on native plants and pollinators range from negative to positive depending on the traits of native plants and pollinators. Our research approach includes experimental measurements of biotic interaction landscapes hypothesized to be shaped by plant-pollinator trait matching and alien-native plant trait similarity. These are complemented by field studies of plant-pollinator communities under natural conditions, investigating interaction networks in landscapes with high vs. low pollinator diversity. The results from this project will allow us to understand the mechanisms and predict the fitness consequences of the impact of an invasive plant on native plants and pollinators. Furthermore, by extending the concept of fitness landscapes to biotic interactions, we contribute to advancing theory on how biotic interactions shape biodiversity dynamics.

URBANPOLL call for collaborators: parallel adaptation of plants to URBAN POLLinators

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Urban areas are characterized by peculiar conditions when compared to surrounding rural areas and might represent “unintended but highly replicated experimental evolution systems” to test the resilience of plant species facing rapid anthropogenic environmental changes. Whilst adaptations to abiotic urban factors have been well investigated, less is known on the selective pressures imposed by biotic interactions of plants and in particular those with mutualistic organisms as insect pollinators. In URBANPOLL we aim at filling this gap by investigating how urbanization influences local adaptation of floral traits involved in pollinator attraction and whether this process follows parallel trajectories in urban areas with contrasting climates. To achieve this, we are looking for collaborators interested to participate with field surveys and plant material collection from pairs of urban and natural populations of *Trifolium repens*, an emerging model for studies on urban adaptation. Collaborators can participate at three levels of engagement: 1. Harvesting material for ex situ floral trait measurement and pollinator attractivity, DNA sequencing, and common garden experiments; 2. Measuring in situ floral traits involved in insect attraction and plant reproductive success; 3. Surveying pollinator communities. Upon a positive accomplishment of the project, we expect to detect repeated adaptations of floral traits involved in pollinator attraction that can represent a signature of parallel phenotypic selection. In addition, we expect to document differences in urban/natural pollinator community across European bioclimatic regions. Results of this project will produce a significant advance in our understanding of urban plant adaptation and resilience, and the effect of urbanization on plant-pollinator interactions.

Fungal community effect strengthens niche differences – implications for species coexistence

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How large number of species coexist is a highly debated and still unresolved question in ecology. This question is especially interesting for semi-arid ecosystems, where plants have to compete for very limited resources. One mechanism often proposed to explain such diversity in plant communities is niche partitioning. However, in dryland communities, the limited range of available resources and the high overlap in plant life forms likely limit the potential for niche partitioning. Recent studies suggested that species-specificity in plant-soil microbes interactions may be an additional mechanism operating in conjunction with niche partitioning, and that it may have a stabilizing effect on species coexistence. However, few studies tested how resource availability and fungal communities can affect plants' fundamental niche. In this study we tested how different levels of water and nutrients in combination with manipulation of soil fungal communities may influence germination and biomass of six dryland annual species thus resulting in potential niche differentiation. We found that soil fungal communities had a strong species-specific effect on germination (i.e. regeneration niche) and aboveground biomass production. The effect of fungal communities on biomass was mediated by resource availability in highly species-specific ways, supporting our hypothesis that fungal communities expand niche differentiation, and hinting that this may be a mechanism for coexistence in resource limited environments.

Student contribution

Impact of long-term grazing abandonment on intraspecific variation in plant functional traits

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Grazing abandonment causes changes in grassland plant species richness but little is known about evolutionary changes within species. Yet functional diversity within species is critical for the adaptive potential to future climate change. We collected genotypes of a common grass, *Briza media*, from 11 pairs of grazed and abandoned sites and measured a range of functional traits in the field and after a period of propagation in common conditions to quantify the heritable component in trait variation between populations. In addition, we measured a range of microclimatic, soil and vegetation properties to evaluate the impact of grassland management on environmental conditions. Grazed sites were characterized by lower soil phosphorus content, lower levels of shading, warmer microclimate, and higher plant species richness and abundance of *Briza media* compared with abandoned sites. Abandoned sites were characterized by higher litter accumulation, more variable shading from tree canopies but less variable soil moisture and temperature conditions. We detected significant differences in plant functional traits between sites with different land use that were primarily driven by phenotypic plasticity: plants were taller and produced leaves with higher specific leaf area and lower leaf dry matter content, indicating that plants responded to shadier field conditions in abandoned sites with a switch to a less protected phenotype with higher light capture ability. Genotype propagation under controlled conditions revealed heritable trait shifts that were in the opposite direction to the phenotypic plasticity: genotypes from abandoned sites had higher leaf dry matter content and lower specific leaf area that genotypes originating from grazed sites. The opposing trends in trait plasticity and heritable trait shifts suggest that plant populations may be responding to divergent selective pressures triggered by land use change.

Student contribution

Variability of *Stellaria holostea*, a characteristic understory species of oak-hornbeam forests

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The greater stitchwort *Stellaria holostea* is one of the characteristic species of oak-hornbeam forests. These broadleaved woodlands were severely affected by human activity leading to forest fragmentation and degradation. In Poland these forests remained mostly as isolated patches with rather small area. Older and bigger ones are nowadays usually protected by national and European law, as valuable habitats of high biodiversity. Hitherto, knowledge concerning the influence of environmental and landscape changes on understory species of deciduous forests is still insufficient. In particular, we lack data about *Stellaria holostea* – the clonal species known as an indicator of old-growth forests. Exploring the topic can give us insights about the plasticity of old growth forest species response to unfavorable conditions and what are the first withdrawal symptoms of still widespread species. To accomplish this, we designed research involving phenological, morphological and genetic analyses of the species. We selected 21 populations with various environmental and landscape backgrounds across Poland. They differ in e.g. longitude, proximity to urban fabric, stand age or overall patch area. To compare the phenological and morphological traits we set up a common garden experiment, which also gives a possibility of manipulating cultivation conditions. Additional in situ sampling of plant developmental traits as well as soil characteristics and gathering more information about the forest community features is planned. Also genetic analyses are planned to be conducted in the following years. Here, at the beginning of the project, we share the general assumptions and ideas to answer the main research question: how landscape, isolation and climatic regimes impact population characteristics of an old forest species, *Stellaria holostea*?

Student contribution

Intraspecific variation across two continents

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When a species is widespread it needs to be successful under a wide range of environmental conditions. On one hand, populations of a single species can occur under very different environmental conditions, potentially leading to the evolution of different adaptations and strategies. Intraspecific variation of traits or their plasticity is thus expected to be high in widespread species. On the other hand, distant cross-continental locations with similar environmental conditions may evoke similar phenotypes. We asked whether genetically based intraspecific phenotypic variation shows repeated patterns along spatially separated environmental transects. To study this, we conducted a common garden experiment with the grass *Milium effusum* from 37 locations in Europe and North America. *Milium effusum* is a forest understorey grass widespread in the northern hemisphere. We grew plants from newly collected seeds and measured eleven functional traits covering phenology, fitness, and leaf traits. Overall, our results show trait differentiation between the two continents. Biomass and seed production are strongly influenced by the continent of origin. North American populations germinate and flower earlier with increasing latitude – whereas the opposite is observed for European populations. This suggests that climatic variables may have led to different adaptations or strategies in the two continents. Based on our results we conclude that intraspecific variation across continents follows non-uniform patterns in *M. effusum*, likely due to different strategies evolving on the two continents.

Factors influencing the creation of new populations of a rare rock

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Saxifraga rosacea Moench subsp. *sponhemica* (C.C. Gmel.) D.A. Webb is an extremely rare rock-dwelling plant endemic to Central Europe. It is considered a conservation priority species in Europe. In Luxembourg, populations have declined, with approximately half of the previously documented locations now devoid of this species. The remaining populations are small and isolated and face genetic erosion, potentially leading to reduced reproductive success and survival. Moreover, the considerable distances between extant populations and suitable new habitats (often several km), hinder the establishment of new populations.
To mitigate the risk of extinction, a species action plan has advocated for the establishment of new populations. We aim to create 10 new populations of *S. sponhemica* at sites with habitat characteristics similar to those of natural populations, where local air temperature and humidity are monitored. We conduct the introductions as experiments to address the following questions: (1) Is sowing seeds or planting young plants the more effective way of creating new populations? (2) How do microhabitat characteristics influence establishment success? (3) Does the removal of vegetation from rock ledges or wall crevices prior to planting or sowing facilitate plant establishment? We either transplanted 5 young plants or we sowed a batch of 500 seeds per site at 160 microsites, of which half had the vegetation removed. Microhabitat characteristics were recorded. Preliminary findings from three sites show that the removal of vegetation significantly enhanced both the establishment of young plants and the recruitment from seeds by approximately 55% after five months. Although the proportion of plants established from young plants exceeded that from seeds, sowing has yielded more plants and was more efficient and cost-effective. Nevertheless, further monitoring the long-term survival of the plants is necessary and will continue.

Student contribution

Spatial soil heterogeneity in combination with increasing water availability tends to inhibit the growth of native invaders but not of alien ones

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Soil heterogeneity has been found to promote plant invasion success, and variability in precipitation can affect species coexistence and plant invasion. However, how these two environmental factors together impact the invasion process remains unclear. Here, we designed a multispecies pot experiment and tested how soil heterogeneity and different precipitation regimes together affect the interactions of an experimental plant community with naturalized alien and native invaders. To quantify the effects of stable high, stable low, and two fluctuating precipitation treatments on the biomass of invaders and communities, we calculated effect sizes (log-response ratios; LnRR) relative to a stable medium watering treatment. Overall, precipitation intensity (i.e. the amount of water received) greatly impacted the LnRR of the plant biomass production. The more water received, the higher the aboveground biomass produced by the invaders and the plant communities. Although, in general, soil heterogeneity did not greatly impact the growth performance of plants, the relative abundance of the native invader populations was negatively impacted by soil heterogeneity when the amount of precipitation increased. Our study revealed that spatial soil heterogeneity and simulated precipitation patterns together impacted the interactions between invaders and the native plant community. Native invaders will be less competitive in the plant community under joint increases in water availability and soil heterogeneity. Furthermore, the risk of plant invasion might increase in wetter seasons in the future as the chance to successfully establish for alien plants will increase.

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in alphabetical order of surname

Ginkgo biloba

Dieses Baums Blatt, der von Osten
Meinem Garten anvertraut,
Giebt geheimen Sinn zu kosten,
Wie's den Wissenden erbaut,

Ist es Ein lebendig Wesen,
Das sich in sich selbst getrennt?
Sind es zwei, die sich erlesen,
Daß man sie als Eines kennt?

Solche Frage zu erwidern,
Fand ich wohl den rechten Sinn,
Fühlst du nicht an meinen Liedern,
Daß ich eins und doppelt bin?

Ginkgo biloba

In my garden's care and favour
From the East this tree's leaf shows
Secret sense for us to savour
And uplifts the one who knows.

Is it but one being single
Which as same itself divides?
Are there two which choose to mingle
So that each as one now hides?

As the answer to such question
I have found a sense that's true:
Is it not my songs' suggestion
That I'm one and also two?

Johann Wolfgang von Goethe, 1819, West–östlicher Divan (English translation by XXXX)

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We hope you enjoyed the conference ☺

Thank you for attending and participating!

See you at PopBio 2025 in… (?)