

**75 Above- and belowground plant responses to long- and short-term frost manipulations**

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Boreal forests make up one third of the world's forested areas and store 30% of the global terrestrial carbon pool. They are shaped by distinct seasonality with a persistent snow cover during wintertime. However, with decreasing extent and duration of snow cover with climate change, soils will experience more severe frost which has been shown to affect soil carbon and nutrient fluxes. Vegetation responses, in particular root mortality, have been proposed as possible mechanisms.

We directly compared short- (1 year) and long-term (11 years) effects of an absent snow cover, and thereof resulting severe air and soil frost, on above- and belowground growth, phenology and biomass of vegetation in a Norway Spruce forest in northern Sweden.

In the long-term treatment vascular plants had reduced shoot growth, their cover had decreased by 93% and root biomass had decreased by 40% compared to the control. In the short-term manipulation, the same effects were seen as trends, yet were less substantial and thus not significant. However, the short-term manipulation resulted in severe visible frost damage of in average 30% on shoots of understory dwarf shrubs and delayed their spring phenology by over a week, compared to the control. Surprisingly, this was not present in the long-term manipulation, which could indicate either an adaptation of the vegetation to the long lasting severe frost, or a survival of only those individuals that can cope with these extreme conditions. Data on root growth, mortality and turnover, measured with minirhizotrons, are currently being analyzed and will be incorporated in the final presentation.

In general, we show that snow removal significantly affects boreal vegetation both above- and belowground with implications for soil carbon and nutrient cycling and that some of the more significant and far-reaching ecosystem effects were only seen in the long-term experiment.

**76 Phosphate depletion in *Olea europea* L. rhizosphere related to mycorrhizal colonization in different climates**

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In Algeria, olive groves are widespread due to their socioeconomic importance and their rusticity. However, since several decades these groves have been progressively neglected in profit of more yielding cultures. Such policies led to a deterioration of agroecosystems for which currently attempting to restore function. *Olea europea* L., a perennial plant is able to form arbuscular mycorrhizae. The aim of this work was to study the root induced chemical changes occurring in the rhizosphere of olive that can influence the dynamic of phosphorus. Bulk, rhizospheric soils, roots and leaves were collected in three orchards in summer, from sub-humid, semi-arid to arid regions of Algeria. P-available was obtained by the method of Olsen. The rhizosphere soil showed a significantly higher concentration of organic-carbon and total nitrogen. The concentrations of all phosphorus fractions in the rhizospheric soil were significantly lower than those in bulk soil. A P-available deficiency was measured in bulk and rhizospheric soil and confirmed by P-foliar. The uptake of phosphate by root induced a depletion of all P fractions in the rhizosphere. Philips and Hayman's technic applied to the root samples showed in the cells of roots characteristic structures of arbuscular mycorrhizae like hyphal coils, arbuscules and vesicles. Arbuscular mycorrhiza is a widespread symbiotic association between plants and fungal microsymbionts that supports plant development under nutrient-limiting and various stress conditions. However their frequency is higher in the root sample of arid orchard. Olive trees surveyed in the three climates showed heavy AM colonization, indicating a high mycorrhizal dependency of olive groves in this environment.

**77 Effects of plant-growth-promoting rhizobacteria on barley plants under different CO<sub>2</sub> and water regimes**

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Rising CO<sub>2</sub> concentrations in combination with drought stress are likely to influence not only aboveground growth, but also belowground plant processes. Plant-growth-promoting rhizobacteria (PGPR) colonize the rhizosphere of many plant species and confer beneficial effects under environmental stresses. Furthermore, root exudates play a role in interactions between plant roots and other organisms present in the rhizosphere.

Only few reports have been published on PGPR as elicitors of tolerance to abiotic stresses, such as drought. Furthermore, little is known about the influence of environmental factors on root exudation patterns. Therefore, this study was conducted in order to investigate the effect of two commercially available PGPRs on the growth and root exudation of barley (*Hordeum vulgare* L.) under different CO<sub>2</sub> and water treatments.

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In a growth chamber experiment climatic conditions of a field site close to Stuttgart were simulated. Barley plants were grown in pots filled with sand and exposed to ambient (380 ppm) or elevated (550 ppm) CO<sub>2</sub>. Plants received the normal daily amount of rainfall in the region of Stuttgart or 33% less. Plants were harvested at the stem elongation growth stage and when the inflorescences emerged. At both dates, data were collected on above and belowground variables. In addition, analyses of water use efficiency, stomatal conductance, SPAD values and composition of root exudates were performed. Preliminary results showed significant effects of the factors and their interactions on some of the measured variables.

In the context of food security and agricultural sustainability, further studies with other crop plants are needed to demonstrate whether PGPR cause a range of crops to be tolerant to environmental stresses improving crop production.

### **78 Drought effects on rhizodeposition and ecological implications**

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Drought intensity is predicted to increase in the next decades across many areas of the world. This phenomenon will affect plant production and consequently rhizodeposition with potentially large ecological impacts on soil carbon (C) and nutrient cycling. However, the direction and magnitude of these impacts are still unclear.

Here we investigate the effect of drought on rhizodeposition and the connection with C stabilization and nitrogen (N) cycling. We combine stable isotope techniques with chromatography and mass spectrometry analyses in order to understand how drought affects the allocation of C into different soil pools and the nature of compounds invested belowground. We investigate wheat, soybean and sunflower as species of major agro-economical value due to their wide spread use and potential to cause large ecological impacts.

Results illustrate that plants are able to allocate substantial amounts of C belowground through rhizodeposition, which have the potential to increase the amount of mineral associated C (a relatively stable form of soil C), most likely through microbial interactions (indicated by correlation between plant derived C found in microbial biomass and the stable C pool,  $R^2 = 0.54$ ,  $P < 0.001$ ). Organic compounds obtained from phloem sap, root tissues and exudates collection will then be discussed with reference to the effect of drought on the abundance of these compounds. Samples are being processed using a recently developed method for liquid chromatography – mass spectrometry targeting major metabolites in plants (sugars, amino- and organic-acids), important for different soil processes.

These results provide an improved understanding of biochemical exchange in the plant-soil system in a future of reduced water availability for agro-ecosystems.

**79 Characterizing root traits for edaphic stress adaptation**

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Sustainable crop production is challenged by the climate changes with likely increased production limitation and uncertainty in the future. Edaphic stresses, such as drought and low-fertility soils, are the main factors restricting crop production in many counties. Selecting and breeding cultivars with root architecture traits efficient in water and nutrient use becomes an important breeding strategy aiming for increased crop adaptation to edaphic stress. A serial of phenotyping experiments involving novel semi-hydroponic platform, soil-filled columns and rhizotrons were carried out to study phenotypic variability in root traits and root responses to water and phosphorus deficits in narrow-leaved lupin. Large variability among the tested genotypes was observed with 21 (out of 38) root traits had greater coefficient of variation values than 0.5. Multivariate root traits were constructed with Principal Components Analysis resulted in 9 components with eigenvalues greater than one. Observations confirmed the inability of this species in forming functional mycorrhizas nor cluster roots under any phosphorus (P) status. Significant variations were observed among genotypes in root architecture and distribution in response to drought and low-P stresses. Placing P fertiliser deeper enhanced root growth and P-use efficiency. Plants produced greater amounts of carboxylates in the rhizosphere when plants grown in low P environment. Localised P patches had significant impacts on root architecture and exudation compared to uniform P application. Alteration of root distribution and architecture and changes in rhizosphere exudation of carboxylates were important strategies for efficient P acquisition in low P soil. Our study provides detailed description of the phenotypic variability in root architecture and the insight into the mechanistic responses of root traits influencing water and nutrient acquisition in low-fertility drying soils.

**80 Microbial invasions - a complex interplay between soil properties and biology**

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Biological invasions are greatly facilitated by global traveling and trade and are widely recognized as potential threats to local biodiversity and ecosystem functioning. Some introduced species can be devastating. Yet, research has mainly focused on plants and animals. Microbial dispersal, except for crop and human pathogens and parasites, received much less attention so far, despite its potentially important consequences for soil and plant functioning, due to microbe-soil adaptation. Arbuscular mycorrhizal fungi (AMF) mediate elemental fluxes and plant productivity via assisting plants with mineral nutrient acquisition and protecting them from abiotic and biotic stresses. Here we report on the findings of a pot experiment where we simulated, based on a cross-factorial design, gradients of a major biotic

and abiotic perturbation event by mixing two soils from geographically well-separated, but climatically similar sites in Switzerland. We mixed the native living soils in nine different proportions and established control treatments in which one or both soils had their native AMF removed by gamma irradiation. Other native soil microbes smaller than the propagules of AMF were added back. The experiment so far revealed strong impairments to the growth of *Plantago lanceolata* when the two soils were alive, as compared to their sterilized counterparts. These impairments were to a great extent rectified by addition of just only 5% of foreign sterilized soil. The mechanistic basis behind this phenomenon will be elaborated based on combined elemental flux and microbial community analyses, using stable ( $^{13}\text{C}$ ,  $^{15}\text{N}$ ) and radioactive ( $^{33}\text{P}$ ) tracers and molecular genetic fingerprinting.

**81 Community assembly processes of N<sub>2</sub>O-reducing prokaryotes in the rhizosphere - effect of edaphic factors and plant species**

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Nitrous oxide (N<sub>2</sub>O) is the dominant ozone depleting substance and a potent greenhouse gas. Nearly 70% of global N<sub>2</sub>O-emissions can be attributed to terrestrial ecosystems, of which 45% originate from agricultural land. The rhizosphere is known as a hotspot for prokaryotes producing and reducing N<sub>2</sub>O. The only enzyme known to reduce N<sub>2</sub>O to nitrogen gas (N<sub>2</sub>) is the N<sub>2</sub>O-reductase (N<sub>2</sub>OR), which is encoded by two variants of the *nosZ* gene, clade I and clade II, the latter of which has been shown to be correlated with a higher N<sub>2</sub>O sink capacity. To determine the effect of plant species and soil type on the diversity, structure, and functioning of N<sub>2</sub>O reducing communities in the rhizosphere and on the root surface, we conducted a pot experiment growing sunflower (*Helianthus annuus*) and barley (*Hordeum vulgare*) in a clay and a silt soil. We observed higher potential N<sub>2</sub>O production rates in rhizosphere in the clay soil compared to the silt soil, and rates were higher when planted with barley than sunflower. In agreement, potential N<sub>2</sub>O production measurements on washed roots revealed a significantly higher production rate by attached microbial communities or endosymbionts of barley roots as opposed to sunflower roots. Using quantitative PCR, we demonstrate that low N<sub>2</sub>O production correlates with low *nosZ* clade I/clade II abundance ratios in the rhizosphere soil. The ratios overall were more dissimilar between the soils than between the plants, even on the roots, indicating a stronger effect of soil type than plant on the community assembly of N<sub>2</sub>O-reducing prokaryotes in the rhizosphere. Amplicon sequencing of both *nosZ* clades from rhizosphere soil and root surfaces was performed and additional analyses will be presented on the relative influence of soil and plant species on diversity and composition of N<sub>2</sub>O reducing communities in the different compartments.

**82 The Bryosphere as a regulator of peatland carbon balance in response to climate warming**

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In analogy to the rhizosphere, the bryosphere describes the interactions between bryophytes and their associated organisms and forms an important transitional zone mediating aboveground-belowground linkages in northern ecosystems such as peatlands. In particular, *Sphagnum* mosses are important players for ecological processes in peatlands, especially for carbon (C) cycle. For example, *Sphagnum* contributes substantially to aboveground leaf area and biomass, and therefore plays an important role in C assimilation. Furthermore, this moss is tightly linked to a wide range of microorganisms and microfauna, which interact and form a complex food web responsible of C cycling. Hence, *Sphagnum*-bryosphere can influence both primary production and decomposition processes in peatlands.

Using a five-year field warming experiment in a *Sphagnum*-dominated peatland, we studied the response of the *Sphagnum*-bryosphere to temperature increase. We showed that the response of *Sphagnum*-bryosphere affects a series of peatland functions with implications for C recycling. We found that a moderate warming (ca. +1°C) exacerbated the effect of drought on *Sphagnum*-photosynthesis. While rate of *Sphagnum*-photosynthesis declined by 70% compared to wet conditions with drought alone, it became negative under the combined effect of drought and warming, indicating a carbon loss. In parallel, we found that warming strongly decreased the biomass of microbial predators (-50%) after 5 years of warming, especially mixotrophic predators (i.e. organisms combining autotrophy and heterotrophy). Such decrease of mixotrophs, in turn, modified the structure of the microbial food web and shifted the microbial food web towards a bottom-up control. This implies potentially a faster C turnover, and enhanced organic matter decomposition. Interestingly, our findings also highlighted an important role for mixotrophs declining to overall *Sphagnum*-photosynthesis, which could explain the differences we found between controls and warmed plots.

Overall, our findings suggest that warming-effects on *Sphagnum*-bryosphere will alter the carbon cycle in peatlands.

**83 Use of light-use efficiency functions to describe CO<sub>2</sub> uptake at a semi-arid site, role of leaf-area index and leaf density**

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The Calperum-Chowilla OzFlux site (34°00.163S 140°35.261E) was established in July 2010 located about 20 km north-west of Renmark in South Australia within an extensive semi-arid Mallee woodland. Eddy covariance flux of carbon dioxide and water from a 20 m tower were recorded during the height of the millennium drought, its subsequent breaking during 2011 and then a wild fire in January 2014.

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During 2011 the perennial vegetation gradually increased in leaf area and hence sequestered carbon. With future projections of increased fluctuations in temperature and rainfall events in Autumn, we want to assess the role of perennials and the soil in carbon sequestering that is likely to have a long residence time.

Monthly leaf area index (LAI) using digital cover photography, leaf mass per area, thickness, soil respiration and above ground biomass additions and carbon budgets have been constructed splitting 24 hours into night and day using a shortwave radiation threshold of  $10 \text{ W m}^{-2}$ . Nighttime flux filtered by insufficient turbulence and corrected to match daytime temperatures was subtracted from daytime flux to estimate photosynthesis. Light use efficiency curves were solved for the light compensation point and then respiration in the light and dark as described by the "Kok effect".

With improved estimates of night and day respiration and photosynthesis we regressed ecosystem respiration against monthly LAI. We hypothesize the y-intercept is plant independent respiration or heterotrophic soil respiration. With this component we will be able to derive a more accurate estimate of this ecosystems accumulation or loss of carbon. We want to track this with prevailing environmental conditions such as water and temperature/seasonality and compare this with other ecosystems. We also want to see if changes in leaf area or leaf characteristics play a part in continual adjustment and adaptation to the variable environmental controllers, especially water.

#### **84 Deciphering transcriptomic profiles and Verticillium wilt development in olive cultivars under different scenarios of climate change**

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Plant disease epidemics result from interactions of a susceptible host, a virulent pathogen and conducive environment. Shifts in any component can change disease expression to still unknown directions. Verticillium wilt (VW) of olive caused by the soilborne fungus *Verticillium dahliae* (Vd) is of major concern for olive industry in the Mediterranean basin.

We carried out experiments using olive cvs. Picual and Arbequina, which grew in soil infested by the defoliating (D) or non-defoliating (ND) Vd pathotypes at 20, 24 and 28°C and CO<sub>2</sub> levels of 386, 550 and 750 ppm, representative of current and future SRES-IPCC A2 and B2 scenarios for southern Spain. Surface response models quantified the combined effects of temperature and CO<sub>2</sub> on VW intensity and plant growth, demonstrating a differential effect of biotic and abiotic factors. Optimum VW development occurred at 20-24°C and current CO<sub>2</sub>, being faster and severe in 'Picual'/D. Raising CO<sub>2</sub> delayed VW and Vd infection.

The transcriptomic profile of olive cultivars in response to Vd infection and the three climate SRES scenarios was assessed using a 12-plex microarray of 37,449 olive unigenes (OLEAGEN project). Main differences in the expression profiles were due to olive genotype, followed by the climatic conditions at the three SRES scenarios and in a lesser extent by Vd infection. Thus, plants growing at current climate showed higher number of differentially expressed genes compared to plants growing at SRES-IPCC A2 and B2 scenarios with a general trend to

decrease the number of significantly transcribed genes as temperature and CO<sub>2</sub> increased. Furthermore, a higher number of genes (up to 10x) were expressed differentially in 'Arbequina' than in 'Picual' in response to environmental changes as well as to infection by the D pathotype with a low number of genes being common for both cultivars.

### **85 Root exudates can control soil N dynamics**

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Agriculture represents the dominant source of the potent greenhouse gas nitrous oxide (N<sub>2</sub>O). This is largely due to the conversion of added nitrogen-based fertiliser through the action of the microbial nitrogen cycle in soil. Denitrification represents the main source of nitrous oxide emission and is a carbon driven process, as it maintains respiration under low oxygen conditions with nitrogen oxides acting as alternative electron acceptors. Initial experiments using barley plants (*Hordeum vulgare*) indicated that different cultivars support significant variation in N<sub>2</sub>O emission from denitrification from associated soil and that these effects are connected to root exudation difference rather than direct interaction or litter effects. In this study, a controlled microcosm experiment was designed to explore the interaction between root exudation and denitrification in terms of N<sub>2</sub>O production and community dynamics. Different quantities of artificial root exudates were added daily to soil at three different water regimes. N<sub>2</sub>O emissions were measured and community dynamics were assessed using T-RFLP and real time PCR. Results suggest that N<sub>2</sub>O emissions are driven by nitrous oxide reductase activity (consumption) rather than nitrite reductase activity (production). Soil condition, through differential aerobic status and variability, also appeared to have a marked effect both on flux through denitrification and community dynamics. Further work is underway to dissect the role of exudation quality in driving the alteration in nitrogen cycle flux and the end product of denitrification.

### **86 Impact of chemical fertilization and organic amendment on carbon and nitrogen lability between rhiz. and non-rhiz. ecosystems**

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Soil carbon and nitrogen stoichiometry is important for evaluating soil organic matter quality. Our study was conducted to evaluate the impact of chemical fertilization and various organic amendments on biological, chemical and physical C and N pools to assess soil C and N dynamics under wheat (*Triticum aestivum* L.) - corn (*Zea mays* L.) rotation in semi-arid Mediterranean climate of south-western Turkey. Treatments included control, chemical fertilization (NPK), compost, animal manure, and compost+mycorrhizal inoculations. Soil samples were randomly collected from 0 to 15 and 15 to 30 cm depth and analyzed for rhizosphere and non-rhizosphere total organic carbon (TOC) and nitrogen (TN), extractable phosphorus (EP), active carbon (AC), particulate organic C (POC) and nitrogen (PON), and soluble carbon (SC) fractions to calculate C and N lability and management indices (CMI).

Results showed that the organic amendments such as compost and manure applications significantly increased TOC, TN, EP, AC, POC, PON and SC as compared with the chemical fertilization and control, respectively. In 0-15 cm depth AC in control treatment was 2.37 mg kg<sup>-1</sup>, however in mineral fertilizer, manure, compost and compost +mycorrhiza treated soils 252, 272, 302, and 274 mg kg<sup>-1</sup> respectively. Similar repose was got in non-rhizosphere soil. The C and lability was higher in the rhizosphere than in the non-rhizosphere ecosystems. Our results suggest that higher C and N lability is associated with organic amendments to improve soil quality for crop production.

**87 Plant parasitic nematodes attraction by root exudates of range expanding plant species and native congeners**

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Global climate changes enable many plant species to shift their ranges to higher latitudes and altitudes. Range expansion leads to novel interactions with a non-co-evolved multitrophic belowground community in the new range. It is possible that the novel traits of range-expanding plant species make them unattractive, toxic or even not recognized as a new food source to the enemies in the invasive range, resulting in reduced herbivore pressure. This novelty, however, may go at the expense of indirect control of enemies by higher trophic level organisms, as these will not recognize the cues emitted by the novel plant species. So, it may be an advantage of range-expanding plant species if novel enemies do not recognize and respond to chemical signals of host, but it will be a disadvantage when the enemies recognize the host plants, but their natural enemies not.

Our study makes a first step in unravelling bottom-effects on root-feeding nematodes in the rhizosphere of range-expanding plant species and comparing this to congeneric plant species that are native in the invaded range. We present pilot results of two such pairs of congeneric plant species and two types of root-feeding nematodes (ectoparasitic or endoparasitic species). We performed experiments on petri dishes and in a greenhouse in order to study root attraction of ectoparasitic and endoparasitic nematodes. Our hypotheses are that (1) nematodes are more attracted by native plant species than by related range expanders and (2) ectoparasitic nematodes, which have less specific relations with the roots than endoparasitic nematodes, will show a less strong preference for native plants than endoparasites.

**88 The role of plants in methane flux of upland soils and their influence on archaeal community composition in the rhizosphere**

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Methane is an important greenhouse gas that is produced and consumed in soils by microorganisms. Until recently, studies of the contribution of plants to the global methane flux have focused on the role of plants as conduits for soil-borne methane emissions from

wetlands, but pretty barely examined to date are the influence of plants on methane flux and the presence of methanogenic and methanotrophic microorganisms in aerobic upland soils.

The present study used soils from grassland sites from siliceous and calcareous bedrock located in Northern Tyrol, Austria at ~750 m a.s.l. Besides *in situ* methane measurements and profound soil microbiology analyses, *lab-scale* gas measurements with two different site-typical grassland plants were conducted at different temperatures. Gas samples were withdrawn and subsequently analyzed via gas chromatography. To characterize the archaeal community structure in bulk and rhizosphere soil of the respective plants and soil sites, next-generation sequencing was conducted.

In our investigations we could prove a distinct influence of plants on net methane emissions out of upland soils. Our data proved not only a clear influence of plants on methane flux in comparison to uncovered soil but between the investigated plants as well. On a *lab-scale* basis temperature was a crucial factor that influenced the effect of plants on methane fluxes significantly. Community analyses revealed clear differences within the archaeal community of the investigated rhizosphere and bulk soils. Furthermore, the two plant species led to different archaeal community shifts within the soils and the shifts were different between siliceous and calcareous bedrock. The study emphasizes the need to better resolve the influence of plants on the methane cycle and its involved microorganisms.

### **89 Drought affects spatial distribution of enzyme activities in the rhizosphere**

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Due to high inputs of easily degradable organic compounds from the roots, the rhizosphere is a very important and dynamic hotspot of microbial activity in soil. Consequently, the enzyme activities in the rhizosphere are a footprint of complex plant-microbial interactions and may reflect functional response to climate changes.

We modified the *in situ* soil zymography for identification and localization of hotspots of  $\beta$ -glucosidase activity in the rhizosphere of maize under drought stress (30% of field capacity). Zymographic images showed highlighted spots of  $\beta$ -glucosidase activity along the roots. The  $\beta$ -glucosidase activity was especially high at root tips and was much stronger under drought as compared with optimal moisture (70% of field capacity). The high  $\beta$ -glucosidase activity under drought was confirmed by enzyme assay based on fluorogenically labelled substrates applied to the root exudates. The activity of  $\beta$ -glucosidase of root exudates (produced by roots and root-associated microorganisms) was significantly higher by drought stressed plants as compared with optimal moisture. In contrast, the  $\beta$ -glucosidase activity in destructively sampled rhizosphere soil was lower under drought stress compared with optimal moisture. Without roots, drought did not affect  $\beta$ -glucosidase activity in soil. Consequently, the release of organic compounds (such as mucilage) by roots under drought increased  $\beta$ -glucosidase activity in the rhizosphere. Thus, the zymography visualized the distribution of  $\beta$ -glucosidase activity and allowed assessment of consequences at the root-

soil interface under drought. Furthermore, coupling of zymography and enzyme assays in the rhizosphere and non-rhizosphere soil enabled not only the precise mapping of the two-dimensional distribution of enzyme activities, but also allowed quantitative assessment of soil depth imaged on the zymograms.

**90 Does fungal community matter to drought tolerance of cork oak (*Quercus suber* L.)?**

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Mediterranean forests are one of the biodiversity “hotspots”. The cork oak (*Quercus suber* L.) forest (“montado”) is an unique and emblematic resource for Portugal, both social and economic manner, protected by EU (Habitats Directive 92/43/EEC). Portugal is the greatest cork producer with 50% of cork extraction worldwide. Nowadays, cork oak faces a severe global climate change and a reduction in water availability is expected for the near future, which is expected to decrease cork oak growth and productivity. Plant benefits from many symbiotic relations that occur between microorganisms and roots that are able to enhance nutrient and water supply. However, root colonization efficiency and fungal community structures are dependent on environmental conditions, such as water availability. The main goal of this work was to evaluate the relationship between fungal abundance and diversity conferred by different drought scenarios. The effect of drought in cork oak fungal ecosystem was accessed by studying cork oak field trees in 7 different Portuguese forests. Five different locations (Gerês, Macedo de Cavaleiros, Vimeiro, Grândola and Moura) were evaluated according to a gradient of water-availability. Samples from extreme conditions, the driest (Moura) and wettest (Gerês) places were sampled in two different sites. Soil samples (35) were analysed by ITS barcoding on ECM tips and metabarcoding using Illumina platform. The obtained results will help to understand not only the importance of fungi to drought tolerance in cork oak forest, but also which are the main fungal colonizers.

**91 Combined effects of climate change induced shifts in the plant community and drought on the structure and functioning of the rhizosphere microbiome**

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The rhizosphere microbiome and its functioning are directly affected by plant root exudates. Given the fact that these exudates differ between plant species, climate change induced shifts in the abundance of plant species changes the structural and functional composition of the microbial soil community. Besides this, increasing drought is expected to directly (due to reduced soil moisture) and indirectly (due to stress-induced, altered plant root exudates

production) affect the soil microbiome. In order to study the combined effects of drought and altered plant community composition on the functioning of the rhizosphere community, we performed a common garden experiment. Two plant pools were defined and sown on experimental plots. The first pool included plant species that are predominantly distributed in southwestern Europe and, in the context of climate change, may potentially become more dominant in central Europe. The second pool included species mainly distributed in northeastern Europe, which are predicted to become increasingly displaced in central Europe. To simulate drought half of the plots were roofed for five weeks in early and late summer. After each roofing period we determined different plant root traits as well as structural and functional responses of the rhizosphere community. We observed drought-induced, morphological changes in the root structure whereas stronger effects occurred after the second roofing period. Microbial activity indices (nitrification potential and soil enzymes) as well as selected activities of isolated microorganisms were generally reduced by drought, but the extent of the reduction was related to the plant community, indicating different buffering capacities against drought stress. In terms of phosphate solubilization, contrasting responses to drought of bacteria and fungi suggest functional redundancies in the rhizosphere microbiome. In conclusion, plant root morphology was strongly affected by drought. Microbial traits were also highly affected by drought but these changes were possibly mediated through plant community responses.

## **92 Influence of climate change and heavy metal on the plant-microbe interactions**

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The various biotic and abiotic stress factors can affect the growth and development of crops. Particularly, the change of climatic condition and also heavy metal stress like lead (Pb), arsenic (As), cadmium (Cd), copper (Cu) etc. influence various plant physiological and metabolic process as well as development and yield of the crops. The change of climate especially the elevated atmospheric CO<sub>2</sub> condition enhance the biomass production and also metal ion accumulation in most of the plants and help plants to support greater microbial populations and protect the microorganisms against the impacts of heavy metals. Besides, the indirect effects of climate change on the function as well as structure of plant roots, diversity and activity of rhizosphere-microbes would lead to altered metal bio-availability in soils and thus affect plant growth. However, the effects of rising of global temperature, drought or combined climatic stress on the growth of plant and metal accumulation vary substantially across physical, chemical and also biological properties of the environment (e.g., soil pH, heavy metal type and its bio-available concentrations, microbial diversity, and interactive effects of climatic factors). Overall, direct and indirect effects of climate change on heavy metal mobility in soils may further hinder the ability of plants to adapt and make them more susceptible to stress. In this study we have discussed how the various climatic parameters including atmospheric CO<sub>2</sub>, temperature and drought influence the plant–metal interaction in polluted soils. The effects of climate change and heavy metals on plant–microbe interaction, heavy metal phytoremediation and safety of food have also been narrated. This review shows how the plant–metal interaction responds to changing climatic

condition and how is it beneficial in selecting crops that would be able to produce more yields without accumulating toxic heavy metals for future food security.

**93 Influence of drought on the antioxidative stress defense and root exudation of european grassland species**

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Extreme weather situations like prolonged periods of drought as well as heavy precipitation within short periods of time as a consequence of climate change have an impact on our terrestrial ecosystems. It's likely that these conditions will not only affect the vegetation but also plants associated rhizosphere bacteria and fungi. Grassland vegetation fulfills a large number of ecosystem functions that need to be preserved. With its high biodiversity, it forms natural habitats for animals and bird species. It serves as an important source for animal fodder, protects the environment from erosion and leakage of nutrients as well as it maintains our countryside and landscapes.

Plants actively influence the chemical properties of the rhizosphere by exuding a variety of compounds via their root system. Many of these compounds, mostly low molecular weight organic acids, alter distinct processes within rhizospheres that might have an impact on the interactions between different plants species as well as the interactions between plants, microbes and fungi.

In this study we investigated the influence of drought on the antioxidative stress defense system of typical European grassland species (*Plantago lanceolata*, *Lotus corniculatus*). For collection and analysis of root exudates we introduce a rhizotron–microsuction cup–system that allows for a continuous and noninvasive collection of exudate samples while growing the plants in a natural soil system. Analysis of exudates was done by a combination of HPLC-UV/VIS, ion chromatography and LC MS/MS techniques.

Analysis of different biomarkers (e.g. stress enzyme activities, thiol contents) suggests the formation of reactive oxygen species in water stressed plants. Qualitative analysis of root exudates revealed the occurrence of different phenolic and aliphatic acids with the potential to affect rhizosphere processes and its biota.

**94 The complex roles of lignin and suberin in plant micronutrient uptake**

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Roots are specialized tissues with a central function in water and mineral nutrient uptake from the soil, to support the progressive plant growth and development. Radial transport across the root to the vascular system occurs through the apoplastic, symplastic or transmembrane pathway. To regulate the non-selective apoplastic transport, a ring-like

structure composed of lignin, named Casparian strip (CS), surrounds the endodermis cells. As the root develops, transmembrane transport is blocked through the deposition of suberin at the endodermal layers. The specific mechanism underlying the generation of this diffusional barriers is not fully known, but a few studies show that defects in the barrier composition and structure can have major effects in transport of water and solutes. Thus, understanding the biosynthesis and function of such barriers will allow the future manipulation of root systems in important crops, to improve water and nutrient uptakes. To assess the role of CS/lignin and suberin in plant adaptation to mineral stress we selected several *Arabidopsis* mutants affected in the composition and/or structure of these polymers, such as *esb1*, *ralph* and *horst*. The root and shoot phenotype are studied under both deficiency and excess concentrations of zinc, copper, manganese and iron, as well as toxic amounts of cadmium. By integrating the mineral stress-response in the different root properties of each mutant, we will further understand how root structure affects metals metabolism. In addition, analysis of root structure in the natural heavy metal hyperaccumulator *Noccaea caerulescens* showed additional cell layer adjacent to the endodermal cells displaying lignin characteristics. Previous studies showed that several genes involved in lignin and suberin metabolism are up-regulated in *N. caerulescens* compared to *Arabidopsis* plants. Thus, modifications of the root structure may account for the extraordinary ability of *N. caerulescens* to tolerate and accumulate high metal concentrations.

## 95 Hypoxia induces changes in root maintenance costs of *Prunus* rootstocks

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Low oxygen in the rhizosphere (hypoxia) induces alterations in root respiration. Under hypoxia, the regulation of the energy requirements by roots seems to be necessary to cope with the energy unbalanced produced by hypoxia. Maintenance requirements can be one of them, however no much studies have been done on this matter particularly in rootstocks. In this work, we investigated whether the hypoxia tolerance in *Prunus* rootstock is associated to changes in the maintenance costs.

Three *Prunus* rootstocks with contrasting tolerance to hypoxia: Marianna 2624 (tolerant), CAB6P (semi-tolerant) and Mazzard F12/1 (sensitive) were grown in nutrient solution and exposed to normal (normoxia: 7.8 mg O<sub>2</sub> L<sup>-1</sup>) and low (hypoxia: 0.5 mg O<sub>2</sub> L<sup>-1</sup>) oxygen concentration. Hypoxia treatment was achieved by bubbling gaseous nitrogen into the nutrient solution (0.1% agar). The root respiration components were obtained by multiple regression analysis of the root oxygen evolution and the root biomass accumulation.

Under hypoxia, tolerant *Prunus* rootstock showed a significant decrease in root maintenance respiration from 1.8 mmol O<sub>2</sub> g<sup>-1</sup>DW d<sup>-1</sup> under normoxia to 0.7 mmol O<sub>2</sub> g<sup>-1</sup>DW d<sup>-1</sup> under hypoxia (60% reduction). This reduction in maintenance costs was paralleled by an increase of the ion uptake respiration from 5.6 mmol O<sub>2</sub> mmol<sup>-1</sup>N under normoxia to 9.4 mmol O<sub>2</sub> mmol<sup>-1</sup>N under hypoxia (70% increase). In this case no changes were observed in growth respiration, which in average was 7.8 mmol O<sub>2</sub> g<sup>-1</sup>DW in both oxygen conditions. In the sensitive rootstock the maintenance respiration increased from 2.3 mmol O<sub>2</sub> g<sup>-1</sup>DW d<sup>-1</sup> under normoxia to 3.8 mmol O<sub>2</sub> g<sup>-1</sup>DW d<sup>-1</sup> under hypoxia (65% increase). But the growth respiration,

decreased to 1.8 mmol O<sub>2</sub> g<sup>-1</sup>DW under hypoxia (65% reduction). In this case, no differences were observed in ion uptake respiration.

These results showed that sensitivity to hypoxia in *Prunus* rootstock is related to the respiratory maintenance costs.

**96 Climate warming effects on plant belowground biomass allocation in tundra**

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Climate warming is known to have large impacts on tundra ecosystems. Increases in aboveground plant biomass in response to climate warming in the Arctic have been widely reported. However, little is known about the belowground.

In order to improve our understanding of the climate warming effects on the belowground part of tundra vegetation, we did both a meta-analysis and a field experiment. We collected belowground biomass and annual temperature data from 38 published studies which were performed in tundra vegetation. Aboveground biomass increased with increasing temperature, as earlier observed. However, the belowground temperature response was significantly lower than aboveground. Moreover, belowground temperature response differed between vegetation types, as in shrub dominated vegetation belowground biomass significantly increased with temperature, but in graminoid dominated vegetation it did not change. These findings have important implications for the C and nutrient cycling in tundra ecosystems as we expect that a shift in vegetation types will occur in the future warmer conditions.

We also performed a soil warming experiment in northeastern Siberia by using heating cables connected to solar panels. The experiment lasted for 5 summers and the warming treatment significantly increased soil temperature and active layer thickness during the growing season. We will present aboveground and belowground biomass results for deciduous shrubs, evergreen shrubs and graminoids harvested at the end of the growing season of 2014. We expect that the warming treatment changed the biomass allocation of different plant functional types along soil depth and thus affected the competitive relationships.

**97 Impacts of atmospheric CO<sub>2</sub> on root exudation chemistry and rhizosphere-colonizing bacteria**

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Atmospheric CO<sub>2</sub> concentrations have fluctuated in historic times to present day and are set to increase due to anthropogenic emissions. Little is known about the effects of altered CO<sub>2</sub>

levels on interactions with beneficial root-colonizing microbes in relation to the chemical composition of root exudates. This study aims to address the impact of low (200ppm), ambient (400 ppm) and high CO<sub>2</sub> (1200 ppm) on root exudation chemistry and root-microbe interactions in the model plant species *Arabidopsis thaliana*. Our data indicate that CO<sub>2</sub> influences root colonisation activity of the rhizobacterial strains *Pseudomonas putida* KT2440 and *Pseudomonas fluorescens* WCS417r, and these effects are associated with changes in root exudation chemistry. Additionally, previous data indicates that there is a positive relationship between CO<sub>2</sub> concentrations and ontological factors that influence the speed at which plants develop. We have therefore considered the effects of developmental stage of the plant on root colonisation and exudation chemistry. Further investigations aim to reveal the physiological mechanisms and ecological consequences of these responses, as well as the impact of atmospheric CO<sub>2</sub> on global rhizosphere communities.

**98 Comprehensive analysis of rhizosphere effect in top and deep horizons of podzolic soil under spruce trees**

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Global warming is known to affect the carbon cycle in forest ecosystems through the intensification of soil organic matter (SOM) decomposition. It is well established that rhizodeposits stimulate CO<sub>2</sub> efflux from the topsoil, whereas the role of rhizosphere effect in deep horizons in C and nutrients cycling has not been sufficiently estimated. We hypothesized that the rhizosphere effect is significantly different in top and deep soil horizons.

C turnover rate and nutrients stoichiometry were determined in rhizosphere and bulk soil sampled from the experimental plots with podzolic soil (Albeluvisol) under spruce trees (*Picea abies* L.) in the Central Forest Reserve (Tver region, Russia). The rhizosphere factors ( $R_f$ ) expressed as a ratio of soil characteristics in rhizosphere to that in bulk soil were determined in the top AEL (3 – 15 cm) and deep EL horizons (15 – 46 cm).

We subdivided soil characteristics into 2 groups according to  $R_f$  value. The group I with  $1.05 < R_f < 1.5$  includes SOM, acidity, available N, P and exchangeable K. The group II with  $R_f > 1.5$  includes microbial biomass, basal respiration and SOM turnover rate. Increased SOM turnover rate is connected with better SOM quality in rhizosphere soil as evidenced by the increase in polysaccharides portion in rhizosphere SOM revealed by <sup>13</sup>C-MAS-NMR spectroscopy. C:N:P stoichiometry in microbial biomass might also affect the SOM susceptibility to decomposition; C:N ratio in rhizosphere microbial biomass was higher than that in bulk soil, while C:P displayed the opposite tendency.

The most drastic differences between top and deep rhizosphere were found in basal respiration and SOM turnover rates.  $R_f$  for SOM turnover in top soil was about 1.5, while in the deep soil horizon it was as high as 6. Thus, deep rhizosphere was found to be the more pronounced hot spot of biological activity than top one.