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Session 2 Environmental Stressors and Agricultural Sustainability

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Rhizosphere under pressure: how plastics disrupt plant growth and soil health

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Plastic pollution in terrestrial ecosystems is an emerging concern, particularly in agroecosystems where the rhizosphere – the narrow zone of soil surrounding plant roots – plays a central role in plant development, nutrient cycling, and microbial interactions. Despite the growing awareness of plastic contamination, the impacts of plastic particles on the early development of plants remain a relatively unexplored field, particularly with regard to species-specific responses and the physiological effects occurring at the level of the root.The objective of the research is to address a critical gap in understanding how both conventional and biodegradable plastic particles affect early plant growth and soil-related processes, with a focus on the biological consequences of plastic presence in the rhizosphere.

Using a semi-hydroponic screening system and soil-based rhizotrons, we investigated the effects of different types of plastic on several plant species. We quantified changes in germination rates and root elongation under different plastic fragment sizes and concentrations. The results show strong material- and species-dependent differences: certain plastics inhibited root growth in sensitive species such as radish, while others slightly stimulated root elongation in more tolerant species such as rapeseed. Biodegradable plastics were not necessarily harmless: in many cases, they exhibited inhibitory effects comparable to those of conventional polymers.

These findings suggest that plastic contamination may act as an abiotic stressor during early plant development, potentially affecting crop establishment and soil-plant-microbe interactions. As plastic inputs to soils continue to increase, from agricultural films to fragmented waste, their ecotoxicological impacts need to be integrated into sustainability frameworks for land management and agricultural policy. Our work highlights the urgent need for comprehensive risk assessments of both conventional and alternative plastics in soil ecosystems.

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Peptaibols: bioactive natural compounds with the potential to mitigate the adverse effects of climate change in agricultural crops

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Agriculture faces new challenges through increasing extreme weather conditions and the spread of new plant pathogenic microorganisms. The use of chemical pesticides can cause additional problems, thereby, new solutions are needed in biological plant protection. Trichoderma strains are already successfully used in practice. The raising temperature on agricultural fields due to climate change would require thermotolerant biocontrol strains of Trichoderma, however, this could result in the use of potential opportunistic human pathogens. To avoid this risk, bioactive compounds produced by thermotolerant Trichoderma strains could be used instead of the strains themselves. Peptaibols produced by them are small peptides characterized by variable amino acid composition and ion channel-forming ability. They have growth-inhibiting effects against several phytopathogenic bacteria and fungi, furthermore, they also exert beneficial effects on plants via induced systemic resistance. For future practical application of peptaibols it is also inevitable to gain a better understanding of their background mechanism of action by using computational molecular modeling techniques.

We investigated the peptaibol production of 12 Trichoderma strains using comprehensive methods. The produced peptaibols were determined using mass spectrometry. Peptaibol extracts were prepared using large-scale methods. The bioactivity of extracts was determined against 11 bacteria, as well as 6 phytopathogenic fungi. Structure of selected peptaibols produced in the largest percentages were investigated using accelerated molecular dynamics simulations. Comparing our laboratory and computational results revealed structure-activity relationships enabling to establish a rapid and targeted selection of bioactive peptaibol compounds. Our results may lay the foundation for the future practical application of peptaibol extracts, which can provide new alternatives in biological plant protection.

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Exploring the role of microbial infections in walnut production decline

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Walnut (Juglans regia) production in Europe has declined in the recent years. Climate change and drought decrease the systemic stress response of plants and pose a synergistic effect on pathogen invasion. Several bacterial and fungal pathogens have emerged in Europe that damage walnut production, such as Xanthomonas arboricola pv. juglandis (bacterial blight, brown apical necrosis), Brenneria nigrifluens and B. rubrifaciens (canker), Ophiognomonia leptostyla (anthracnose), Fusarium, Alternaria (brown apical necrosis), Geosmithia morbida (thousand cankers disease), etc. Insects also play role in the transmission of infections as vector organisms. The aim of the study was to observe if there is a connection between the spreading of the pathogens and the walnut husk fly (Rhagoletis completa), the larvae of which hatch and develop inside the husk. The field samples were designed systematically to possibly uncover the primary microbial infectious process leading to the crucial weakening of the walnut tree resistance. To gain predictive insights, we collected infected walnuts from the trees, kept them on sterile, neutral soil, harvested the larvae and grew the flies. Furthermore, soil and phyllosphere samples from walnut plantations that were severely and less affected by walnut pathogens were collected in Hungary. 16S rRNA gene amplicon sequencing was performed on Oxford Nanopore MinIon platform showing that the bacterial community of the infected leaves and walnuts were shifted from unknown Cyanobacteriota (up to 100 %) to Pseudomonadota (up to 98.5 %). Stenotrophomonas and Pseudoxanthomonas had the highest relative abundance in the infected walnuts and these genera comprised the majority of the pupae grown in the lab, as well. The imagos' microbial communities showed higher diversity with abundant Brucella, Raoultella and Pseudomonas spp. Pseudomonas, Raoultella, Daeguia and Enterobacter were characteristic to the infected leaves.

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The impact of global megatrends on microfungi in the Pannonian Biogeographical Region: a climate change perspective

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The European Environmental Agency (EEA) has set 11 global megatrends—slow processes that are hardly noticeable initially, but later cause long-term global effects—among which globalization, pandemics, technological advancements, and climate change exert major influence on microfungi in the vulnerable Pannonian Biogeographical Region. Globalization facilitates the introduction of fungal inocula through trade in tropical fruits, soil, and packaging materials, while technological developments create novel habitats for fungi in human surroundings, often under extreme environmental conditions. Climate change further accelerates the establishment of non-native fungal species in natural ecosystems, posing threats to human health, agriculture, and biodiversity.

To assess the effects of climate change on fungal communities, we conducted a controlled experiment exposing common fungal species—both endemic and introduced—to simulated heat waves under two climate scenarios: a moderate (RCP 4.5) and a strongly pessimistic (RCP 8.5) projection for July 2050. Results indicated that Aspergillus flavus, A. niger, A. tubingensis, and Fusarium spp., introduced from tropical regions, exhibited high heat tolerance, whereas native species such as Penicillium spp., Talaromyces spp., and Cladosporium spp. failed to grow under the extreme RCP 8.5 conditions.

Two years after this experiment, in 2024, airborne concentrations of A. flavus and A. niger in urban outdoor environments exceeded 3,000 and 5,000 CFU/m^3, respectively. Additionally, a high prevalence of A. flavus and its mycotoxins was detected in cereal crops. These findings suggest that climate change-driven heat waves are facilitating the establishment and proliferation of invasive fungal species at an accelerated rate, underscoring the urgency of incorporating fungal risks into climate adaptation strategies.

Black Soils of Eurasia: two-decade environmental analysis (2001-2022)

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Black soils play crucial roles in maintaining global environmental and social systems, contributing significantly to world food production and balancing carbon in the earth-atmosphere system. Monitoring productivity and land cover changes in relation to other environmental variables is essential for understanding global processes and implementing timely actions.

In our study, we analysed environmental changes of Eurasian black soils from 2001 to 2021 using time series remote sensing-based datasets. The Eurasian region is vast and exhibits highly diverse environmental conditions across its different areas; therefore, we conducted our analysis by dividing the region into distinct bioregions. Understanding the factors influencing Gross Primary Productivity (GPP) is crucial for evaluating ecosystem health and productivity under changing environmental conditions. This study investigates the relationship between GPP and various environmental variables across multiple regions, focusing on spatial and temporal dynamics. We examined the following key variables: Fraction of Photosynthetically Active Radiation (FAPAR), Solar Radiation, Soil Water Content, Temperature, Evaporation, Precipitation, and Vegetation Period.

Results show productivity increases in Chinese and Mongolian black soils, contrasting with significant decreases in large areas of Kazakh black soils. Notably, among countries with extensive black soil coverage, Russia and Ukraine exhibit areas with both declining and increasing productivity trends, reflecting the complex interplay of environmental and agricultural factors within these regions

Our findings indicate that climatic factors predominantly influence both negative and positive productivity trends, while cultivation technology levels also contribute significantly in specific regions. Climate change emerges as the primary driver of land cover change on black soils, with the net loss of croplands being the most alarming trend. This loss displays a scattered spatial pattern across Eurasia but is most prominent in the drying regions of Kazakhstan and Russia.

Ensuring sustainable management of black soils is crucial for addressing food security, mitigating climate change, and promoting sustainable land use practices in the face of ongoing environmental challenges.