Warsztaty dla Młodych Badaczy

think green

5TH WORKSHOPS FOR YOUNG RESEARCHERS

BOOK OF ABSTRACTS

5. WARSZTATY DLA MŁODYCH BADACZY

KSIĄŻKA ABSTRAKTÓW

LUBLIN, 18-19.11.2025

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Spis treści

Distribution and colonization of *Bacillus megaterium* B107/23 in *Microgreens* - First insights

Barańska D., Panek J., Pertile G., Siegieda D., Gryta A., Frąc M.

Institute of Agrophysics, Polish Academy of Sciences, ul. Doświadczalna 4, 20-290 Lublin, e-mail: m.frac@ipan.lublin.pl

Microgreens are young seedlings of edible vegetable and grain species, valued by consumers for their high content of health-promoting phytochemicals as well as their appealing appearance and intense flavor (Xiao et al. 2019). However, their cultivation involves considerable risk, as microgreens are highly susceptible to abiotic stresses, particularly drought stress, which leads to rapid water loss, wilting, and degradation of bioactive compounds (Kyriacou et al. 2016). To enhance their tolerance to abiotic stress, we introduced a bacterial inoculum containing *Bacillus megaterium* B107/23, a species reported to improve plant drought resistance and promote growth (Bhattacharyya et al. 2012; Kang et al. 2021; Park et al. 2025). *B. megaterium* is a Gram-positive, endospore-forming soil bacterium known for its ability to synthesize phytohormones, solubilize phosphates, produce siderophores, and generate osmoprotectants and stress-related enzymes that can enhance plant drought tolerance and stimulate biomass accumulation (Idris et al. 2007; Lin et al. 2023). Additionally, it can increase resistance to pathogens (Gowda et al. 2025). In our study, we evaluated the colonization efficiency and microbiome-modulating effects of *Bacillus megaterium* B107/23 in microgreens cultivated under controlled conditions. *B.* megaterium B107/23 was introduced into the *microgreens* cultivation system using two approaches: seed inoculation and substrate inoculation. High-throughput next-generation sequencing (NGS) on the Illumina MiSeq platform was used to assess bacterial colonization efficiency and spatial distribution within the microgreens. Furthermore, we analyzed shifts in the microbial community structure forming the microgreens holobiont in response to inoculation. The study allowed us to determine which inoculation strategy was more effective and how the introduction of *B. megaterium* B107/23 influenced the native microbiome of microgreens.

Acknowledgments

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FTIR spectroscopy in the identification of functional groups in lignocellulosic biomass

Biedrzycka A., Boguta P., Bulak P.

Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4 str, Lublin 20-290, Poland, e-mail: a.biedrzycka@ipan.lublin.pl

Plant biomass is a renewable, widely available, and low-cost natural resource with significant potential for production of new, valuable products. Its structure is based on three main components: cellulose, hemicellulose, and lignin. Cellulose and hemicellulose are rich in hydroxyl (-OH) groups, while hemicellulose also contains small amounts of carboxyl (-COOH) and acetyl groups. Lignin, in contrast, is characterized by a complex network of aromatic rings bearing methoxy (-OCH_3) and phenolic (-OH) substituents.

The current high level of economic development and growing population may lead to an imbalance in the natural environment, particularly in the soil. The progressive degradation of soils is contributing to the intensification of works on developing solutions to the problem of poor soil quality and low content of organic carbon. An interesting aspect is the possibility of reprocessing plant biomass to obtain artificial humic acids. Their effect in soil could mimic those of natural humic acids, including improvement of water retention, availability of nutrients for plants, and microbial activity.

This study highlights the importance of accurately characterizing the chemical composition of plant biomass using FTIR as a key element in optimizing artificial humification processes. Based on the spectra, it was found that wood samples (oak, spruce, pine, willow) are characterized by a high content of lignin. Straw samples (corn, miscanthus, wheat, rye) have a lower content of aromatic lignin and more hemicellulose and amorphous cellulose. According to FTIR spectra, oak has the highest lignin content and the most complex chemical profile among the wood samples. Willow and spruce show intermediate characteristics, e.g., lower aromatic peaks. Furthermore, miscanthus straw differs from other herbaceous plants. It has a more orderly cellulose structure and a certain proportion of aromatic lignin. An interesting aspect is also the presence of bands below 500 cm^{-1} in straw, which may indicate the presence of mineral components, e.g., silica.

The FTIR spectra showed significant differences in chemical composition between wood and straw biomass, especially in terms of the content of functional groups associated with lignin, cellulose, and hemicelluloses. This difference may be important when selecting the appropriate raw material for processes leading to the development of artificial humic acids. The results provide a valuable basis for optimizing the artificial humification processes.

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From one drop to the successive falling drops

Bielak K., Beczek M., Bieganowski A.

Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, Lublin, Poland, e-mail: kgibala@ipan.lublin.pl

Soil is a very important component of many ecosystems, but as a non-renewable natural resource of the Earth it may be subjected to various degradation processes. The reasons for degradation depend on many different factors, which can be categorized as chemical, physical and biological. One of the types of physical degradation is water erosion. One of the first stages of water erosion is splash. This process is initiated when water drops hit the soil surface during rainfall and results in the detachment and ejection of splashed material. As a consequence, this could lead to the loss of soil material e.g. in streams and rivers. The other effect is the breakdown of soil aggregates by impacting drops influencing the soil structure.

So far, single-drop splash or rainfall induced splash has been studied under natural or simulated conditions. There are very few studies describing the initial phase of rainfall and it is impact on soil and water splash. Subsequent drops falling on the soil can eject more soil material. Measurements of splashed mass are important in the context of the transport of pollutants and pathogenic microorganisms during splash events. The aim of the research is to show how subsequent drops affect the soil during the splash phenomenon. Understanding how drops fall onto the surface is important because each drop changes the properties of the soil where it lands. Subsequent drops may eject more soil particles, which may contribute to the extended surface deformation, compared to a single drop.

The study focused on measuring the mass transferred by successive drops. Water drops equal 5.2 mm in diameter fell onto the soil samples from a height of 3 m. They fell one by one within a range of 1 to 50 drops. The collected material in splash cup was weighed on a laboratory scale to determine its total mass. The splash cup was then dried and reweighed to determine the mass of the solid phase (soil), and the difference between the measured values was used to determine the mass of the liquid phase.

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The impact of the green herbicide – nonanoic acid on methanotrophic bacteria

Furtak A.[1], Bilokinna A.[2], Szafranek-Nakonieczna A.[3], Skrzypek T.[3], Zięba E.[3], Bieganowski A.[1], Pytlak A.[1]

[1] *Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, 20-290, Lublin, Poland, e-mail: a.furtak@ipan.lublin.pl, a.bieganowski@ipan.lublin.pl, a.pytlak@ipan.lublin.pl*

[2] *Department of Microbiology, Institute of Soil Science and Plant Cultivation — State Research Institute, Czartoryskich 8, 24-100 Puławy, Poland, e-mail: a.bilokinna@iung.pulawy.pl*

[3] *The John Paul II Catholic University of Lublin, Konstantynów 1I, 20-708, Lublin, Poland, e-mail: anna.szafranek-nakonieczna@kul.pl, tomasz.skrzypek@kul.pl, emil.zieba@kul.pl*

As the use of synthetic pesticides increases, green alternatives are gaining momentum. One such substance is a natural medium-chain fatty acid – nonanoic acid (often referred to as pelargonic acid, PA). PA is commonly used as a non-specific herbicide due to its ability to disrupt cellular walls and membranes. It is used in both organic and conventional systems, for example in vineyards, sunflower fields and cornfields. As a fatty acid PA is considered as easily biodegradable with no residual activity. However, due to its non-specific, membrane-disrupting mechanism of action, this pesticide may affect the biological process of methane (CH_4) oxidation, known as methanotrophy. In terms of greenhouse potential, CH_4 is second only to carbon dioxide, and it contributes to approximately 20% of the greenhouse effect. Reducing CH_4 emissions (from e.g. agriculture) is an effective way to mitigate global warming. Methanotrophy is a membrane-dependent process, and by disrupting cellular membranes, PA may affect the responsible bacteria that involved in the process, thereby reducing their effectiveness in CH_4 fixation. In view of the accelerating global warming and increasing chemicalisation of agriculture, it is necessary to investigate the impact of herbicides that are considered environmentally safe on the soil methanotrophy.

The main objective of this study is to highlight the impact of nonanoic acid on the methane oxidation rate of soil-delivered methanotrophs under *in vitro* conditions. Particular attention is paid to the analysis of methanotroph cell count, community structure, and methanotroph cell physiology response to PA exposure.

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Effect of biochar from digestate on the wettability of Abruptic Luvisol soil

Gryta A., Skic K., Boguta P.

[1] *Instytut Agrofizyki im. Bohdana Dobrzańskiego Polskiej Akademii Nauk, ul. Doświadczalna 4, 20-290 Lublin*

Wettability is a key property of organic material surfaces, such as biochar, which is used to improve soil quality. It depends on adhesion forces—interactions between liquid molecules and the solid surface—and cohesive forces, which are interactions within the liquid itself. A common parameter to describe the wetting behaviour is the contact angle. This is the angle formed between the tangent to a droplet's outline and the surface of the material being tested. Measuring the contact angle with water allows us to determine whether a material is hydrophobic or hydrophilic. A water droplet spreads out on a hydrophilic surface, resulting in a low contact angle, while it contracts on a hydrophobic surface, leading to a high contact angle (Bachmann et al., 2000; Zemifra and Milanovskiy, 2015).

The materials used for the study were mixtures prepared from Abruptic Luvisol (degraded Podzolic soil from weakly loamy sand) and biochars produced from digestate at temperatures of 300°C, 450°C, and 600°C. The dynamics of contact angle changes were assessed using a Krüss DSA100 apparatus, which took photographs or videos of a droplet on a smooth material surface. Measurements were performed in replicates under stable temperature conditions.

Adding biochar produced at 300°C significantly increased the contact angles of the soil-biochar mixtures. Conversely, the addition of biochar produced at 450°C did no change in contact angle, despite its relatively high value. Generally, the contact angle of the soil decreases as the proportion of biochar produced at 600°C increases.

From these results, it can be concluded that the effects of biochars produced at different pyrolysis temperatures (300, 450, and 600°C) vary depending on the soil characteristics and the specific properties of each biochar type. This information provides valuable insights into the potential applications of biochars to improve soil physicochemical properties, including wettability. This parameter is vital for various processes, such as the movement of soil solutions, infiltration, evaporation, erosion, humification rate, and the transfer of nutrients essential for plant growth.

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A new OpenFOAM solver implementing film flow mechanism for accurate unsaturated hydraulic conductivity calculations

Kozyra M., Lamorski K., Sławiński C.

Institute of Agrophysics PAS, Doświadczalna 4, 20-290 Lublin, e-mail: m.kozyra@ipan.lublin.pl

Water transport in porous media is an environmental and engineering phenomenon of fundamental importance, governing numerous natural and technical processes such as soil water retention, plant water uptake, and groundwater recharge. This process is mathematically described by Richards' equation, which primarily depends on soil water content and soil water potential. Despite its long-standing use and continuous refinement, the conventional form of Richards' equation predominantly considers water transport in the form of bulk liquid water, and when necessary, water vapor, particularly under extremely dry conditions. However, over the years, both soil water retention curve models and unsaturated hydraulic conductivity models have generally neglected the contribution of the film water phenomenon — a thin layer of water adhering to soil particle surfaces that can significantly influence hydraulic properties in the dry range of the soil water potential spectrum.

Our recent research, conducted on a wide variety of soil types, demonstrates that an accurate description of unsaturated hydraulic conductivity, especially at relatively low soil water potentials (around –10 m H_2O), requires explicit incorporation of the film flow mechanism into the mathematical formulation of water transport. Without accounting for this process, numerical simulations of soil drying often fail to reach the threshold potential of –10 m H_2O, indicating a limitation in current modeling approaches.

To address this issue, a new OpenFOAM-based solver has been developed that extends Richards' equation by incorporating the film flow mechanism. The solver has been thoroughly tested on a dataset of 450 soil samples representing diverse textural and structural characteristics. The results confirm that the inclusion of film flow substantially improves the model's ability to simulate drying processes and predict UHC values under low water potential conditions. This advancement offers a more physically consistent framework for modeling unsaturated water transport in porous media and provides a reliable tool for future research and environmental engineering applications.

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Immobilization of metals and metalloids in soil modified with activated carbon and polymers

Kukowska S.[1], Nowicki P.[2], Turski M.[1], Komaniecka I.[3], Szewczuk-Karpisz K.[1]

[1] *Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, 20–290, Lublin, Poland, e-mail: s.kukowska@ipan.lublin.pl; m.turski@ipan.lublin.pl; k.szewczuk.karpisz@ipan.lublin.pl*

[2] *Department of Applied Chemistry, Faculty of Chemistry, Adam Mickiewicz University in Poznań, Uniwersytetu Poznańskiego 8, 61-614 Poznań, Poland, piotr.nowicki@amu.edu.pl*

[3] *Department of Genetics and Microbiology, Institute of Biological Sciences, Maria Curie-Sklodowska University, 20-033 Lublin, Poland; iwona.komaniecka@mail.umcs.pl*

The mobility of heavy metals and metalloids in soil is a serious environmental problem, as these elements can migrate to groundwater, enter the food chain, and threaten both ecosystem and human health (Pusz et al. 2024). Therefore, developing effective methods to immobilize these hazardous species in the soil environment is of great importance. Application of activated carbons and polymers, which can simultaneously improve soil quality and reduce contaminant bioavailability, seems to be a promisig approach.

In this study, the impact of activated carbon produced from orange peels using a microwave furnace on Haplic Luvisol (HL) was examined. Two types of ionic polyacrylamides were applied as soil modifiers: cationic polyacrylamide (CtPAM) and anionic polyacrylamide (AnPAM). Copper (Cu) and arsenic (As) were used as metal and metalloid contaminants, respectively. The activated carbon addition had a positive impact on the soil adsorption capacity due to well-developed surface texture. The addition of polymers further enhanced this capacity by promoting electrostatic interactions and complexation processes. The adsorption of Cu and As was completely different after soil modification. For example, in the HL + OFM800 + AnPAM + Cu system, the sorption capacity increased up to 5.8 times, compared to the unmodified system.

The obtained results demonstrate that the proposed modification shows strong potential for the remediation of contaminated soils, particularly in areas affected by industrial or agricultural pollution.

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An effect of the onion cell wall polysaccharides and plant nutrients on the germination of vegetable seeds

Marciniak M., Cieśla J., Nosalewicz A., Zdunek A.

Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, 20-290 Lublin, Poland, e-mail: m.marciniak@ipan.lublin.pl

Plants need nutrients to grow and develop properly. We are constantly looking for ways to provide nutrients to plants in an environmentally safe way. Polysaccharides obtained from plants are an example of a natural and safe material that has already found applications in various industries and may be such a carrier.

The aim of the study was to investigate the effect of solutions of various onion cell wall polysaccharides and ionic forms of plant nutrients on the germination process of two selected plants.

Polysaccharides were extracted from the cell wall of onion bulb of the Karmen variety. Two plants with different allelopathic effects of onion were selected – red beet (*Beta vulgaris* L.) and common bean (*Phaseolus vulgaris* L.). The seeds of these plants were added to salt solutions containing nutrients (nitrogen, phosphorus, potassium, calcium, magnesium and sulphur). The experiment was conducted in a growth chamber KK 700 (Pol-Eko, Poland) under constant conditions (humidity, temperature and lighting time) appropriate for the growth of each plant. Changes were observed and documented daily. After 14 days, the germination percentage was calculated and the germinated parts of the seeds (roots, stems and leaves) were weighed. The kinetics of changes in seed growth phases were also examined.

Differences in the growth of plant seeds were observed depending on the type of polysaccharide and ions present. Further research is planned to explore the efficiency of nutrient supply to plants.

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From sharks to bacteria: Computational modeling of photosynthesis

Pfennig T.[1,§], Nakielski A.[2,†], Axmann I.[2], Matuszyńska A.[1]

[1]*Computational Life Science, Department of Biology, RWTH Aachen, Worringerweg 1, 52074 Aachen, Germany, e-mail: anna.matuszynska@cpbl.rwth-aachen.de*

[2]*Institute for Synthetic Microbiology, Biology Department, Heinrich Heine University Düsseldorf, 40225, Düsseldorf, Germany, e-mail: axmann@hhu.de*

Computational biology is now integral to life sciences, yet its practice remains opaque to many early-career researchers: What do we actually do? How does one start? I will start with a pragmatic view of careers at this interface, tracing my route from studying mathematics in Gdańsk, to pharmacology in Scotland, to finally establish an independent computational research lab in Germany, where we study biological processes such as photosynthesis, arguably the most important biochemical process on Earth.

Photosynthesis sustains agricultural productivity, global food systems and a wide range of biotechnological processes. Its regulation emerges from interactions spanning photophysics, metabolism and cellular resource allocation. Experimental studies resolve parts of this landscape; they rarely integrate them. I will illustrate how mechanistic and hybrid mechanistic–data-driven models developed in a tight collaboration with experimental groups, provide a quantitative framework that links processes across scales: from electron transport and proton-motive force to carbon partitioning and growth, enabling hypothesis-driven design rather than empirical iteration.

We developed a dynamic, mathematical model that couples light harvest, redox poise and metabolic flux with environmental drivers (Pfennig *et al.*, 2024). This integration exposes control points that are otherwise obscured, including kinetic and energetic bottlenecks and trade-offs between photoprotection, ATP/NADPH balance and biosynthetic demand. Using this framework, we examined production of high-value terpenoids in photosynthetic bacteria, focusing on squalene, historically obtained from shark liver. We show how model-guided optimisation can identify theoretical optima for squalene productivity, specify regimes where overexpression is counterproductive owing to electron economy constraints, and prioritise interventions that shift yields without compromising robustness.

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§ *Currently at: Leibniz Institute of Plant Genetics and Crop Plant Research (IPK), Corrensstraße 3, Seeland, OT D-06466 Gatersleben, Germany, pfennig@ipk-gatersleben.de*
† *Currently at: Phyowelt GreenTechnologies GmbH, Cologne, Germany, a.nakielski@phytowelt.com*

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PsbS protein and zeaxanthin in non-photochemical quenching regulation under fluctuating light and drought

Okoń K.[1], M. Zubik-Duda M.[2], Nosalewicz A.[1]

[1] *Department of Soil and Plant System, Institute of Agrophysics, Polish Academy of Sciences, Lublin, Poland, e-mail: k.okon@ipan.lublin.pl, a.nosalewicz@ipan.lublin.pl*

[2] *Department of Biophysics, Institute of Physics, Maria Curie-Sklodowska University, Lublin, Poland, e-mail: monika.zubik-duda@mail.umcs.pl*

Plant growth conditions are highly variable in terms of light intensity and are frequently affected by intermittent periods of water scarcity. Efficient light utilization in photosynthesis depends on the plant’s ability to flexibly respond to dynamic environmental conditions - enhancing light energy use at low irradiance while preventing overexcitation of the photosynthetic apparatus under excessive light (Niyogi et al., 2005; Murchie and Ruban 2020).

This study aimed to assess the impact of light quantity and quality on the induction of photoprotective mechanisms under optimal and limited water availability. Wild-type *Arabidopsis thaliana* and mutants impaired in non-photochemical quenching (NPQ) mechanisms (lack of violaxanthin de-epoxidase or PsbS protein) were grown under both optimnaly-watered and drought conditions and exposed to constant or fluctuating light (FL) regimes. Chlorophyll fluorescence were measured by Imaging PAM Maxi (Walz), content of photosynthetic pigments was assessed by HPLC (Shimadzu).

Under combined FL and drought stress (DS), wild-type plants exhibited zeaxanthin (Zx) accumulation comparable to that observed under constant high light (HL). This response was significantly reduced in the absence of the PsbS protein, indicating its role in promoting Zx accumulation under these conditions. Both PsbS and Zx were synergistically required to induce high levels of energy-dependent quenching (qE) under FL and to minimize photoinhibitory quenching (qI) under drought combined with HL.

Overall, our findings highlight the crucial synergistic action of PsbS and Zx in enabling effective photoprotection when plants face the combined and dynamic challenges of fluctuating light and water deficit.

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Role of natural organic matter in the environmental persistence of bisphenol A

Paolella G.[1,2], Fabbricino M.[1], Locascio A.[2], Boguta P.[3]

[1]Department of Civil, Architectural and Environmental Engineering, University of Naples Federico II, via Claudio 21, 80125 Naples, Italy

[2]Department of Biology and Evolution of Marine Organisms, Stazione Zoologica Anton Dohrn, Villa Comunale 1, 80121 Naples, Italy

[3]Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4 st., 20-290 Lublin, Poland

Bisphenol A (BPA) is an emerging contaminant and endocrine-disrupting compound ubiquitously detected in natural environments. Its occurrence in fresh and marine waters, soils, and sediments poses increasing risks to both environmental and human health (Boahen et al., 2025). Understanding the mechanisms that control the fate of BPA is crucial for elaborating an accurate risk assessment and effective remediation strategies. Among the various factors, natural organic matter (NOM) plays a key role due to its ability to interact with organic pollutants, altering their speciation, mobility and bioavailability (Yi et al., 2022). However, the molecular mechanisms underlying BPA/NOM interactions remain poorly understood.

This work aims to elucidate the interactions between BPA and NOMs from wastewater treatment plant effluent organic matter (EfOM) and from marine natural organic matter (MNOM). Both NOM samples were characterized using different spectroscopy techniques and proton release analyses to assess their structural and functional properties. Subsequently, the interactions between BPA and EfOM/MNOM were investigated. The obtained results reveal that EfOM forms stable complexes with BPA through multiple mechanisms, mainly hydrogen bonding involving hydroxyl and carboxylic groups. In contrast, MNOM displayed low reactivity with the emerging contaminant. Overall, EfOM and MNOM show distinct but complementary behaviors toward BPA, governed by their structural features and metal-binding properties. These findings highlight the importance of metal-organic associations in controlling BPA complexation and suggest that NOM/BPA may persist through conventional wastewater treatments, contributing to its long-term environmental stability. In fact, the persistence of the complexes has direct implications for agricultural environments. Wastewater effluents and EfOM-containing bio-solids are reused for irrigation and soil improvement (Fito and Van Hulle, 2021), introducing BPA into agroecosystems. The strong association of BPA with EfOM may increase its accumulation and stability in soils receiving treated wastewater of sludge, affecting soil organic matter dynamics, microbial activity, nutrient cycling, and even plant uptake. These processes may contribute to the long-term retention of BPA in the soil environment and its potential transfer into the food chain. Therefore, understanding the interactions between BPA and NOM is essential not only for the aquatic systems, but also for safeguarding soil health, crop productivity, and sustainable agricultural management.

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Rheological investigation and printability analysis of low-methoxyl pectin-based bio-ink for 3D printed constructs

Puzhakkara V.A., Chibrikov V. ,Bandyopadhyay S., Cybulska J., Zdunek A.

Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, 20-290 Lublin, Poland, e-mail: a.zdunek@ipan.lublin.pl

The three dimensional bioprinting has been emerged as a versatile technic for biofabrication of biomimetic structures that are useful in biomedical and food technology. Pectin, an anionic heteropolysaccaride, is getting popular as a bio-ink due to its shear-thinning and tunable rheological properties [1]. Although pectin shows great potential as bio-ink, it is still unexplored to some extent. Since low methoxyl (LM) pectin forms ionic gel in the presence of cations,[2] this study reveals the printability of LM pectin with calcium chloride as a crosslinker. The chemical and structural characteristics of the commercial pectin were comprehensively analysed. Monosaccharide composition was determined using gas chromatography equipped with a flame ionization detector (GC–FID), whereas the degree of methylation was quantified using high-performance liquid chromatography (HPLC). The hydrodynamic radius of the pectin molecules was measured using size-exclusion chromatography coupled with multi-angle light scattering (SEC-MALS). In addition, the galacturonic acid content was assessed with a continuous flow analyser based on a colorimetric assay, and nanoscale morphology was examined using atomic force microscopy (AFM). Various bio-ink formulations were developed by altering the concentrations of LM pectin and calcium chloride, in aquous solution after which rheological properties were analyed. Meshes, lines, and cylindrical structures were subsequently printed and analysed using image analysis and mechanical compression testing. The shape retention properties of both printed lines and grids were evaluated as a uniformity factor, pore factor and perimeter coefficient [3], followed by statistical analysis of a data obtained. Compression tests provided additional insight into the mechanical performance of the constructs, evaluating parameters such as the secant modulus, Young's modulus, and work to limit.The printability of each formulation was evaluated at three different pneumatic pressures under a constant printing speed, and the results were compared.

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Effect of combined climate change factors on soil CH_4 uptake in grasslands

Rafalska A., Walkiewicz A.

Institute of Agrophysics, Polish Academy of Sciences, e-mail: adrianna.rafalska@ipan.lublin.pl

Anthropogenic activities are the primary cause of increased greenhouse gas emissions into the atmosphere. Methane (CH_4), one of the most potent greenhouse gases, has a global warming potential 27–30 times higher than that of CO_2, making it particularly important in studies of climate change [1]. Soils are the only known biological sink for CH_4 due to the presence of methanotrophs—microorganisms capable of oxidizing CH_4—which makes them a key component of strategies to mitigate methane emissions [2]. Grasslands cover ~40% of the Earth's land surface [3], and CH_4 oxidation in their soils represents a critical element of the global greenhouse gas balance. Well-aerated grassland soils enhance methanotroph activity and are expected to remain CH_4 sinks under future climate scenarios, although their efficiency may decline under warming and drought [4].

Most existing studies focus on single environmental drivers such as temperature, precipitation, elevated CO_2, or nitrogen deposition. However, these factors rarely act independently in nature, and their interactions can substantially alter the magnitude and direction of CH_4 fluxes. Research exploring the combined influence of multiple drivers remains limited, hindering a full understanding of these complex relationships.

In this review, we analyzed data from 17 studies that conducted multi-factor experiments. Five main combinations were identified: warming + altered precipitation, warming + elevated CO_2, elevated CO_2 + variations in soil moisture, soil nitrogen + variations in precipitation, and soil nitrogen + elevated CO_2.

The results reveal that interactions among climate drivers are often non-additive, exhibiting synergistic, antagonistic, or even direction-reversing effects (e.g., shifting soils from CH_4 sinks to sources). Warming combined with drought generally enhances CH_4 uptake by improving gas diffusion and oxygen availability, whereas warming with increased precipitation suppresses oxidation. Elevated CO_2 typically increases soil moisture through improved plant water-use efficiency, counteracting warming-induced drying, but under extreme moisture conditions may either enhance or inhibit CH_4 uptake depending on soil texture and methanotroph community composition. Nitrogen addition further complicates these interactions, as increased N deposition can reduce CH_4 uptake by inhibiting methanotroph activity through NH_4^+ and NO_3^-, with outcomes depending on precipitation, plant uptake, and microbial adaptation.

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Impact of post-harvest maturity on molecular and conformational properties of native pectin fractions from apple pomace

Sainul Abidh K.M., Cybulska J., Chibrikov V., Fila K., Zdunek A.

Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, 20-290 Lublin, Poland, e-mail: j.cybulska@ipan.lublin.pl

Pectin is a plant-derived polysaccharide that is abundant in the cell wall and middle lamella of plants. This study investigated the influence of post-harvest maturity on the molecular and conformational properties of water-, chelator-, and dilute alkali-soluble pectin fractions (WSP, CSP, DASP) extracted from Golden Delicious apple pomace, evaluated at three stages: optimum harvest (S1), after six months of cold storage at 4°C (S2), and twelve days of shelf life (S3). Total pectin yield relative to the dried pomace decreased with post-harvest maturity. Enzymatic depolymerization and solubilization with maturity stage were evident from the increase in galacturonic acid (GalA) content and decrease in arabinose (Ara) and galactose (Gal) content in all three fractions [1,2]. A decline in both degree of methylation (DM) and acetylation (DAc) with maturity stage was observed by high-performance liquid chromatography (HPLC). AFM showed WSP and CSP were aggregated at S1 and S3 but chain-like at S2, while DASP was chain-like at all stages. Chain length distribution of smooth and hairy regions showed a decreasing trend with maturity. The branching extent of pectin was also decreased with postharvest maturity. Persistence length analysis indicated flexible characteristics of the pectin fraction, which increased with later maturity stages. Analysis of molecular parameters and chain conformation using size exclusion chromatography coupled with multi-angle laser light scattering (SEC-MALLS) aligns well with AFM results. This work could lead to optimization of pectin characteristics for real-life applications in the food, pharmaceutical, and cosmetic fields.

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Agricultural waste-derived biochars and their modification in the context of the removal of silver nanoparticles from aqueous media

Sama D.K., Szewczuk-Karpisz K.

Institute of Agrophysics, Polish Academy of Sciences, email: d.kwayela-sama@ipan.lublin.pl

The increased utilization of silver nanoparticles (AgNPs) in consumer and industrial applications, in the aspect of crop protection, textiles, medicine, and cosmetic products, has resulted in continuous release of the pollutant in the environment, posing ecological and human health risks. As a result of AgNPs' toxicity, size, and nature, it can disrupt microbial communities, impair plant growth, and bioaccumulate in the food chain (Islam et al., 2024). The use of biochar (BC) to remove this pollutant offers a sustainable and eco-friendly approach. But sometimes this material (BC) possesses inadequate physiochemical properties to suit its specific application (An et al., 2023). The aim of this study was to modify BC from corncob (C) and rapeseed pomace (R) with ammonium hydroxide (NH_4OH) and examine its adsorption capacity towards AgNPs.

The production and modification of the produced BC with ammonium hydroxide has been described by Sama et al. (2025). Chemical reduction method was used to synthesize 200 ppm of AgNPs. The described method is a slightly modified version explained by Zielinska et al. (2009) and Tomczyk et al. (2024). Adsorption and desorption of AgNPs on the selected solids was conducted in a batch experiment in deionized water with 0.001 M $CaCl_2$ used as the supporting electrolyte. The concentration of AgNPs in the solution was measured with the use of a UV-Vis spectrophotometer at a wavelength of 437 nm. Dosage effect, pH effect, concentration effect, and kinetic effect were examined.

The obtained results indicated that the modification of BC with NH_4OH increased its adsorption capacity by 15.73% and 7.13% for corncob- and rapeseed-derived BC, respectively. The biomasses recorded the highest adsorption capacity towards AgNPs. It was observed pH did not affect the adsorption capacity of the different adsorbents relative to the selected pollutant. As the dosage of adsorbent increased, the adsorption of AgNPs increased as well. Regarding desorption, the biomasses had the highest degree of adsorbate released back into the environment, followed by the biochars, and the least from NH_4OH-modified materials. Both NH_4OH-modified BCs exhibited optimum immobilisation and stability of AgNPs in the environment when compared to their BC counterparts, with NH_4OH-modified C recording the highest. From the results, we can boldly conclude that NH_4OH modification of corncob and rapeseed BC enhanced the environmental removal of AgNPs.

Keywords: agricultural waste, biochar modification, environmental remediation, nanoparticles

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The seasonal resilience of soil microbial communities and functional profiles is strengthened by intercropping

Sisodia P.[1], Gryta A.[1], Siegieda D.[1], Panek J.[1], Oszust K.[1], Pylak M.[1], Mącik M.[1], Feledyn-Szewczyk B.[2], Pathan S.I.[3], Pietramellara G.[3], Frąc M.[1]

[1]Institute of Agrophysics, Polish Academy of Sciences, Lublin, Poland, e-mail: p.sisodia@ipan.lublin.pl, m.frac@ipan.lublin.pl

[2]Institute of Soil Science and Plant Cultivation – State Research Institute, Pulawy, Poland

[3]Department of Agriculture, Food, Environment and Forestry, University of Florence, Italy

Soil microbes drive the hidden processes that sustain plant growth, nutrient cycling, and soil health. Yet we still know relatively little about how their activity and community structure change across the growing season under different farming systems. In this study, we explored how intercropping and agriculture production system shape microbial dynamics in spring wheat fields intercropped with red clover (II) red clover and grasses (OI), versus wheat monocropping (CM, IM, OM), focusing on conventional (CM), integrated (IM, II), and organic (OM, OI) production systems. Soil samples were collected across four crop growth stages to capture seasonal changes in microbial enzyme activity, metabolic potential, and community structure.

Enzymatic activities exhibited substantial seasonal changes with clear system effects, particularly during late summer. Dehydrogenase (an indicator of overall microbial respiration) was significantly highest in II during late summer (T4). β-glucosidase tracked carbon turnover: CM led early season (T0), while II was highest at T4, suggesting a late-season shift in C-cycling potential towards intercropped soils. Acid phosphatase peaked earlier in CM (T0-T2), whereas alkaline phosphatase rose sharply in II at T4, together implying system-specific strategies for P mineralization across the season. Protease and Urease showed no significant difference over time.

Biolog ECO profiles aligned with these patterns: intercropped soils (II) maintained more balanced and efficient substrate use, whereas CM exhibited signs of metabolic stress. Bacterial community data (16s, KEGG, PICRUSt2) showed that IM and II were enriched in Verrucomicrobia, linked to decomposition of complex residues. Notably, II was also enriched for the xenobiotic-degradation pathway, consistent with a more resilient microbiome. Fungal analyses (ITS1, FUNGuild) indicated higher representation of beneficial guilds (saprotrophs and symbiotrophs) under intercropping, supporting nutrient cycling and plant–microbe mutualisms.

Overall, II concentrates microbial functional advantages, elevating respiration, carbon-degrading enzymes, and late-season phosphatase activity, while fostering balanced metabolism and beneficial microbial guilds. These coordinated responses highlight intercropping as a robust strategy to enhance soil function and agroecosystem resilience across the season.

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The influence of bacterial exopolymers on the biochemical composition of microalgae cells

Szymańska M., Krzemińska I.

Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, 20-290 Lublin, Poland, e-mail: mrszymanska@ipan.lublin.pl

Due to their ability to carry out photosynthesis, green algae play an important role in the environment (You et al., 2021). The physiological processes of green algae occurring in the natural environment may be affected by their interactions with bacteria. These interactions mainly involve the exchange of chemical compounds and genes (Zhou et al., 2022), and the transport of substances between cells is facilitated by extracellular polymers (exopolymers, EPS).

The aim of the study was to investigate the influence of bacterial exopolymers on the metabolic profile of unicellular green algae.

The algae were cultivated in BG11 liquid medium with addition of bacterial EPS. The cultures were illuminated with a 16-hour light/8-hour dark cycle, subjected to orbital shaking, and aerated with sterile air. The growth of the microalgae was monitored using spectrophotometric measurements of optical density and gravimetric determination of the dry biomass. After the culture reached the stationary phase of growth, the microalgal biomass was analysed for determination of: carbohydrate content using the anthrone method, protein content using the Bradford method, lipid content using the modified Bligh and Dyer method and photosynthetic pigment content.

The determination of metabolite content in unicellular algal cells revealed that bacterial exopolymers influence the biochemical composition of the studied microalgae. Furthermore, the quantitative composition of metabolites in the cells depended on the type and concentration of bacterial exopolymer.

Acknowledgments

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Multidimensional benefits of agroforestry in the face of climate change

Walkiewicz A., Rafalska A., Jaromin-Gleń K., Mazur R.

Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, 20-290 Lublin, Poland, e-mail: a.walkiewicz@ipan.lublin.pl

Agroforestry is defined as 'agriculture with trees' (CIFOR-ICRAF) which combines woody perennials, crops, and livestock within the same unit of land (Abebaw et al. 2025). Due to numerous economic, social, and environmental benefits, agroforestry is included in various strategies of the EU, such as the EU's Common Agricultural Policy, Biodiversity Strategy for 2030, and EU Forest Strategy for 2030. Interactions between trees and other agricultural components occur from the field to the landscape level.

Trees enhance sequestering atmospheric carbon, mobilize water and nutrients from deeper soil layers, enhance above- and belowground biodiversity, increase soil organic matter and carbon stocks, regulate microclimatic conditions, supply fodder and habitat for livestock, diversify agricultural production systems, and strengthen the resilience of agroecosystems (CIFOR-ICRAF; Rolo et al. 2023). Due to their numerous environmental benefits, agroforestry systems play a special role in climate change adaptation and mitigation (Abebaw et al. 2025). By improving soil fertility, structure, and moisture retention, these systems enhance soil health, maintains biodiversity, may reduce greenhouse gas (GHG) emission and control soil erosion.

Systematic field measurements are carried out to assess the impact of trees on soil conditions and GHG fluxes. Our research so far has shown that the presence of trees in a perennial pasture reduced nitrous oxide emissions and increased methane oxidation by regulating soil conditions, particularly by decreasing bulk density, which determines the water-air relations and influences soil microorganisms. In addition to pasture, the study also included the impact of field shelterbelts on soil GHG emissions from fertilized crop fields.

Due to the multidimensional benefits of agroforestry, its implementation and maintenance in agricultural landscapes are of particular importance for strategies aimed at addressing climate change.

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Optimization of the cultivation conditions of antagonistic organisms used in the biopreparation against bull's eye rot in apples

Zawadzka K. , Oszust K., Gryta A., Panek J., Pylak M., Frąc M.

Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, 20-290 Lublin, e-mail: k.zawadzka@ipan.lublin.pl, k.oszust@ipan.lublin.pl

Biopreparations based on antagonistic microorganisms are gaining importance in agriculture, particularly in plant disease protection. In response to the need to develop an effective and eco-friendly control agent against bull's eye rot (BER) caused by fungi of the genus *Neofabraea* (syn. *Phlyctema*, *Pezicula*), the APPAT(f)REE biopreparation containing carefully selected antagonistic strains of *Bacillus velezensis* and *Trichoderma koningiopsis* was developed.

This study aimed to optimize the cultivation conditions of selected isolates of *Bacillus velezensis* and *Trichoderma koningiopsis*, to maximize biomass production and sporulation.

Bacterial strains B134/22, B233/22, and B267/22 were cultured in several stages in a liquid mineral medium containing three different additions of ammonium nitrate and glucose. Spore induction was then performed, which included testing different culture conditions: reducing pH to 4.5 by adding concentrated lactic acid, introducing salinity using 2% KCl and 5% KCl, and a control without changing culture conditions. After incubation, the cultures were also pasteurized at 80°C to determine the number of spores formed. The selected *Trichoderma koningiopsis* isolate G779/22 was cultured on apple juice yeast extract (AJYE) medium using four different apple source modifications. Additionally, variants of the agar medium modification were prepared with three additive options, including yeast extract and ammonium nitrate.

The most significant growth of the bacteria was noted when the medium contained 5 g dm^{-3} of ammonium nitrate and 30 g dm^{-3} of glucose to increase the concentration of B134/22 and 10 g dm^{-3} of glucose to increase the concentration of B233/22 and B267/22, respectively. It was demonstrated that the addition of 5% KCl to the B134/22 and B267/22 cultures resulted in improved spore formation. The addition of 2% KCl to the B233/22 culture has the most positive effect on spore formation. *Trichoderma koningiopsis* G779/22 isolate exhibited the most significant growth in AJYE medium modified with apple purée and supplemented with 1% yeast extract.

Optimizing culture media for strain growth is a key aspect in the development of microbial biopreparations. This enables the selection of appropriate nutrients and culture conditions to achieve the fastest possible growth of microorganisms, which in turn enhances their antagonistic properties and minimizes biopreparation production costs.

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