The optimal time frame for treating biodeteriorated plaster remains unclear. The next step would be further experiments focused on antifungal treatment trials.

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MICROBIAL DYNAMICS AND BIOLOGICAL ACTIVITY IN SHELL-EXPLOSION-DAMAGED SOILS

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Abstract. The full-scale Russian invasion of Ukraine has severely disrupted soil ecosystems and microbial communities. This study evaluated phytobacterial remediation of shell-explosion-damaged soil near Bakhmut using microbial bioformulations, white clover (*Trifolium repens*), and *Rhizobium leguminosarum* bv. *trifolii* 320b. After 60 days, nitrogen-fixing, phosphate-mobilising, amylolytic, ammonifying, and pedotrophic microorganisms increased, whereas oligotrophic and cellulolytic populations declined. The strongest increases were observed for phosphate-mobilising microorganisms (2.2–5.2-fold). Overall, remediation promoted functional restructuring of the soil microbiome and recovery of nutrient cycling and biological soil fertility.
Keywords: soil microbiota, military impact, microbial abundance, bioformulations.

The full-scale Russian invasion of Ukraine has resulted in substantial degradation of soil ecosystems through mechanical disturbance, chemical contamination, and disruption of microbial communities (Solokha et al., 2024). Explosive residues, including TNT, RDX, and HMX, may persist in soils, exert toxic effects, and alter the structure and functional activity of soil microbial communities (Corredor et al., 2024). While the physicochemical impacts of warfare are increasingly recognised, alterations in soil microbiome structure and function remain insufficiently understood. Given the essential role of microorganisms in nutrient cycling, soil organic matter turnover, fertility, and ecosystem functioning (Sokol et al., 2022), restoration of microbial communities represents an important component of post-war soil rehabilitation. Therefore, this study aimed to assess microbial dynamics and biological activity in soils affected by shell explosions and to evaluate microbial bioformulations as a biotechnological approach for accelerating their ecological recovery.

The study was conducted under vegetation conditions using soil collected from an artillery shell crater near Bakhmut (Donetsk region, Ukraine); unaffected soil sampled 50 m

from the crater served as the control. Remediation treatments included microbial bioformulations developed at the D. K. Zabolotny Institute of Microbiology and Virology, NAS of Ukraine, BioStymix Standard®, and white clover (*Trifolium repens* cv. Rivendell) used as a phytoremediator. Clover seeds were inoculated with *Rhizobium leguminosarum* bv. *trifolii* 320b. Soil samples were collected after 60 days of plant growth. The abundance of major ecological-functional microbial groups and microbial ecological indices were determined as described previously (Biliavska et al., 2024). Microbial abundance was expressed as CFU g^{-1} of absolutely dry soil, while ecological indices were calculated from ratios of microbial counts on selective culture media.

Combined application of microbial bioformulations and white-clover-based phytoremediation induced a pronounced restructuring of the soil microbial community, with the strongest effects observed in functional groups involved in nitrogen cycling, phosphorus mobilisation, and organic matter transformation.

Oligonitrotrophic and nitrogen-fixing microorganisms increased by approximately 20 % after Ultrachyst® + *Streptomyces violaceus* IMV Ac-5027 treatment and by up to 1.7-fold when combined with white clover and additional bioformulations. This response likely reflects improved rhizosphere conditions and greater availability of root-derived carbon substrates, while *Rhizobium leguminosarum* bv. *trifolii* 320b may have further promoted recovery of biological nitrogen cycling.

Phosphate-mobilising microorganisms increased 2.2–5.2-fold following bioformulation treatments, indicating enhanced microbial phosphorus solubilisation. Amylolytic microorganisms increased 1.5–2.3-fold, likely reflecting intensified utilisation of root-derived carbohydrates. These changes suggest activation of phosphorus mobilisation and carbon turnover, representing an early stage of functional recovery of nutrient cycling in the remediated soil.

Ammonifying microorganisms increased by 2.5- to 3.3-fold, with the highest abundance observed in soil planted with inoculated white clover. This response may reflect intensified decomposition of organic nitrogen compounds generated by root turnover, microbial biomass, and rhizodeposition.

Pedotrophic microorganisms increased after 60 days, indicating enhanced nutrient availability and rhizosphere activation. In contrast, oligotrophic populations generally declined, except after seed inoculation alone, where their abundance increased by 37.6 %. This shift likely reflects the development of more copiotrophic conditions and a transition from a stress-affected microbial community toward a more metabolically active system. Under such conditions, slow-growing oligotrophs may have been competitively displaced by rapidly proliferating pedotrophic and ammonifying populations. Cellulolytic microorganisms decreased 2.0–4.8-fold after combined remediation, likely reflecting a functional shift toward microbial groups utilising more readily available carbon substrates.

The mineralisation–immobilisation index remained low across all treatments (0.10–0.23), indicating a predominance of nitrogen immobilisation. We hypothesise that active microbial growth following remediation increased microbial demand for available nitrogen, resulting in temporary incorporation of mineral nitrogen into microbial biomass. Such immobilisation may represent a transitional stage of soil recovery in which nutrients are retained within the microbial pool and subsequently become available through biomass turnover.

Overall, the microbial response suggests that phytobacterial remediation didn`t merely increase total microbial abundance but induced a functional reorganisation of the soil microbiome. The observed enrichment of nitrogen-fixing, phosphate-mobilising, ammonifying, amylolytic, and pedotrophic microorganisms, together with the decline of oligotrophic, fungal, and cellulolytic groups, supports the hypothesis that remediation shifted the

microbial community toward a more nutrient-responsive and rhizosphere-driven functional state. This restructuring may constitute an important mechanism underlying the restoration of nutrient cycling and biological fertility in contaminated soils.

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FUNCTIONAL PROPERTIES OF *ARTHROBACTER* SP. E35 – AN ENDOPHYTE OF THE *DESCHAMPSIA ANTARCTICA*: PSYCHROTOLERANCE, METAL RESISTANCE, AND SYNTHESIS OF AUXIN-LIKE COMPOUNDS

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Abstract. A psychrotolerant strain of the bacterium *Arthrobacter* sp. E35 was isolated from the endosphere of the Antarctic plant *Deschampsia antarctica* (King George Island). Based on the nucleotide sequence of the 16S rRNA gene (GenBank: OR899264.1), the strain is most closely related to *Arthrobacter agilis* DSM 20550 (99.92 % identity). These bacteria are Gram-positive, aerobic, catalase-positive, nonmotile cocci that grow at temperatures ranges from +4 to +30 °C. The bacteria are resistant to heavy metal salts (Co^{2+}, Cu^{2+}, Fe^{2+} up to 2.0 mM; $Cr_2O_7^{2-}$, Mn^{2+} up to 1.0 mM; Cd^{2+} up to 0.4 mM) and can tolerate up to 2.5 % NaCl. The strain was found to effectively synthesize auxin-like compounds in a medium containing L-tryptophan; at 22 °C, phytohormone production was 5 times higher than at 28 °C (9.6 mg/g dry weight).
Keywords: auxins, *Arthrobacter* sp., *Deschampsia antarctica*, endophytes, heavy metals, wheat.

Introduction. Modern agriculture requires the development of environmentally safe biotechnological solutions to increase crop yields amid increasing abiotic stresses and global climate change. Of particular interest in this context are endophytic microorganisms, which colonize the internal tissues of plants and form close symbiotic relationships with them (Wippel, 2023). A unique source of stress-resistant bioagents is the endosphere of Antarctic vascular plants, which survive in extreme ecological niches characterized by low temperatures, high ultraviolet radiation, and a constant nutrient shortage (Iungin et al., 2024;