COMPARATIVE ANALYSIS OF PHYTOACCUMULATION ABILITIES OF SEVERAL CROP PLANTS UNDER COMBINED HEAVY METAL CONTAMINATION

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Heavy metal contamination of agricultural soils has become a critical environmental issue, particularly in Ukraine, where military activities have caused significant soil pollution. In particular, huge amounts of heavy metals remain in the soil at the sites of military equipment combustion. Phytoremediation represents a cost-effective and environmentally friendly approach to soil decontamination, yet comparative data on crop species performance under combined metal stress remain scarce.

To conduct a pilot screening of eleven crop species common to Ukrainian agriculture for baseline metal tolerance and growth capacity under single and combined Pb^{2+}, Zn^{2+}, and Fe^{3+} contamination, as a first step toward identifying candidates worthy of further investigation for phytoremediation applications. As a supplementary objective, in silico optimization of the SpHMA2 metal transporter gene was carried out to adapt its sequence for subsequent GoldenGate cloning.

Eleven plant species were cultivated on Murashige-Skoog solid medium supplemented with individual and combined concentrations of Pb^{2+}, Zn^{2+}, and Fe^{3+}, starting at 500, 170 and 150 mg/L, respectively. These metal concentrations were selected because they represent the highest levels recorded at actual sites of military equipment combustion. Seed germination rate, vegetative growth, and linear dimensions were assessed. Heavy metal accumulation in roots and shoots was determined by spectrophotometric and atomic absorption spectrophotometric methods. Translocation factors (TF) were calculated to identify potential hyperaccumulators. Optimization of *SpHMA2* was performed using GeneOptimizer and Benchling software.

Combined metal contamination exhibited stronger phytotoxic effects than single-metal treatments. *Brassica napus* demonstrated the highest tolerance, maintaining germination efficiency above 88% across most Pb^{2+} and Zn^{2+}treatments, with TF values for Zn^{2+} reaching 17.1 at 42.5 mg/L. *Sorghum sudanense* in light-seeded form has also shown promising results, with TF for Pb^{2+} reaching 10.3. These findings align with published data: Abd-Elhady (2012) confirmed Sudan grass as an effective accumulator of Zn^{2+}, Cu^{2+}, and Pb^{2+}, while Angelova et al. (2017) and Szulc et al. (2014) demonstrated that *B. napus* maintains acceptable seed and oil quality even when grown on heavily contaminated soils, supporting its dual use for phytoremediation and biodiesel production. White clover and alfalfa exhibited moderate phytostabilization potential with TF < 1 for Pb^{2+}. Wheat, amaranth, and maize showed minimal or zero germination under combined contamination.

Brassica napus and *Sorghum sudanense* demonstrate the highest phytoremediation potential among the studied species and could be recommended for further trials on military-contaminated soils. The optimized *SpHMA2* sequence represents a foundation for generating transgenic *B. napus* lines with enhanced metal extraction capacity.