Climate-Modulated Cadmium Phytoremediation: Biomass, Uptake, and Removal Efficiency of *Brassica napus*

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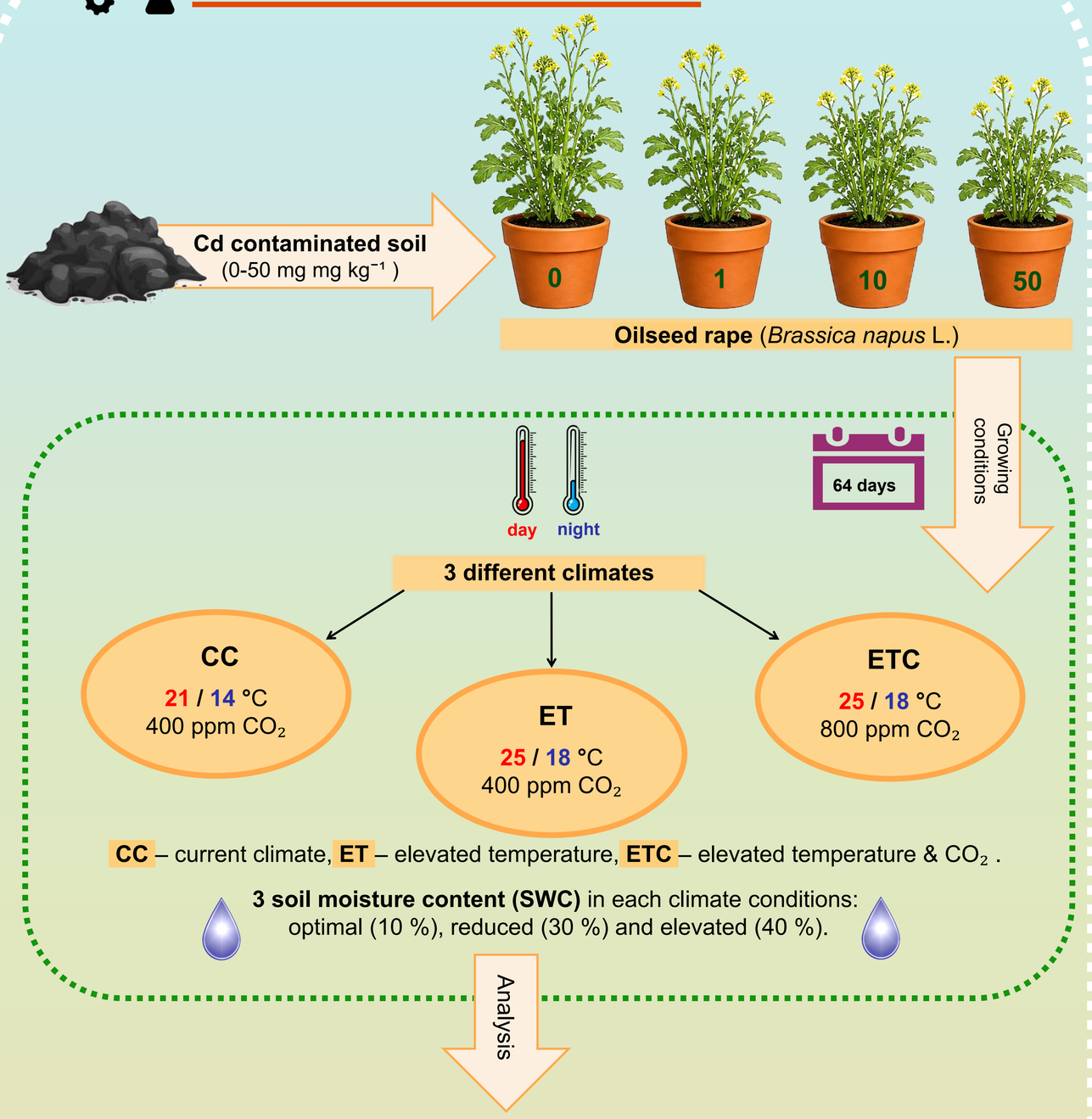
Introduction

➢Heavy metal (HM) contamination remains a critical environmental challenge, contributing to up to 35% of potentially contaminated sites throughout Europe. Phytoremediation is a promising bioremediation method for the restoration of contaminated sites by utilizing plants and posing no adverse effect to soil and environment. Using the energy plant oilseed rape it is possible to clean the soil while obtaining bioenergy at the same time.

➢Phytoremediation efficiency is influenced by several factors, including climatic conditions, soil properties, fertilizer application, and co-contaminants. As an in-situ technology, its effectiveness may be further affected by ongoing climate change.

➢This study aimed to analyze the effects of air temperature, CO_2 concentration, and soil water content (SWC) on the phytoremediation efficiency of Cd-contaminated soil using oilseed rape (*Brassica napus* L.).

Materials & methods



➢Plant growth parameters and tolerance to Cd contamination were assessed.

➢Efficiency of phytoremediation was calculated as the capacity of aboveground plant parts to remove Cd from the soil.

➢Cd concentrations were measured in soil and plants with PerkinElmer ® OptimaTM 8000 ICP-OES.

➢The statistical analysis was performed using Statistica software.

Results & discussions

- Cd soil concentration and analysed environmental parameters (SWC, climate) had a significant effect on *B. napus* biomass individually and in combination (Table 1). Plant biomass decreased with increasing Cd soil concentration in all treatments (R^2>0.12, p<0.05). **Climate conditions and SWC significantly modified plant response to soil Cd contamination.**

- BCF was significantly affected by SWC and climate and their interaction (Table 1). In almost all Cd treatments under different climate and SWC conditions BCFs were greater than 1 (Fig. 1B), indicating significant Cd uptake by *B. napus* and its suitability for phytoremediation.

- Cd soil concentration, SWC, climate and the interaction of these variables (Climate*Cd*SWC) had a significant effect on total DW and Cd removal rate (Table 1).

- Under CC, optimal SWC resulted in the best Cd removal efficiency with the fewest number of plant harvesting cycles. In all analyzed climates, reduced SWC extends cleaning time.

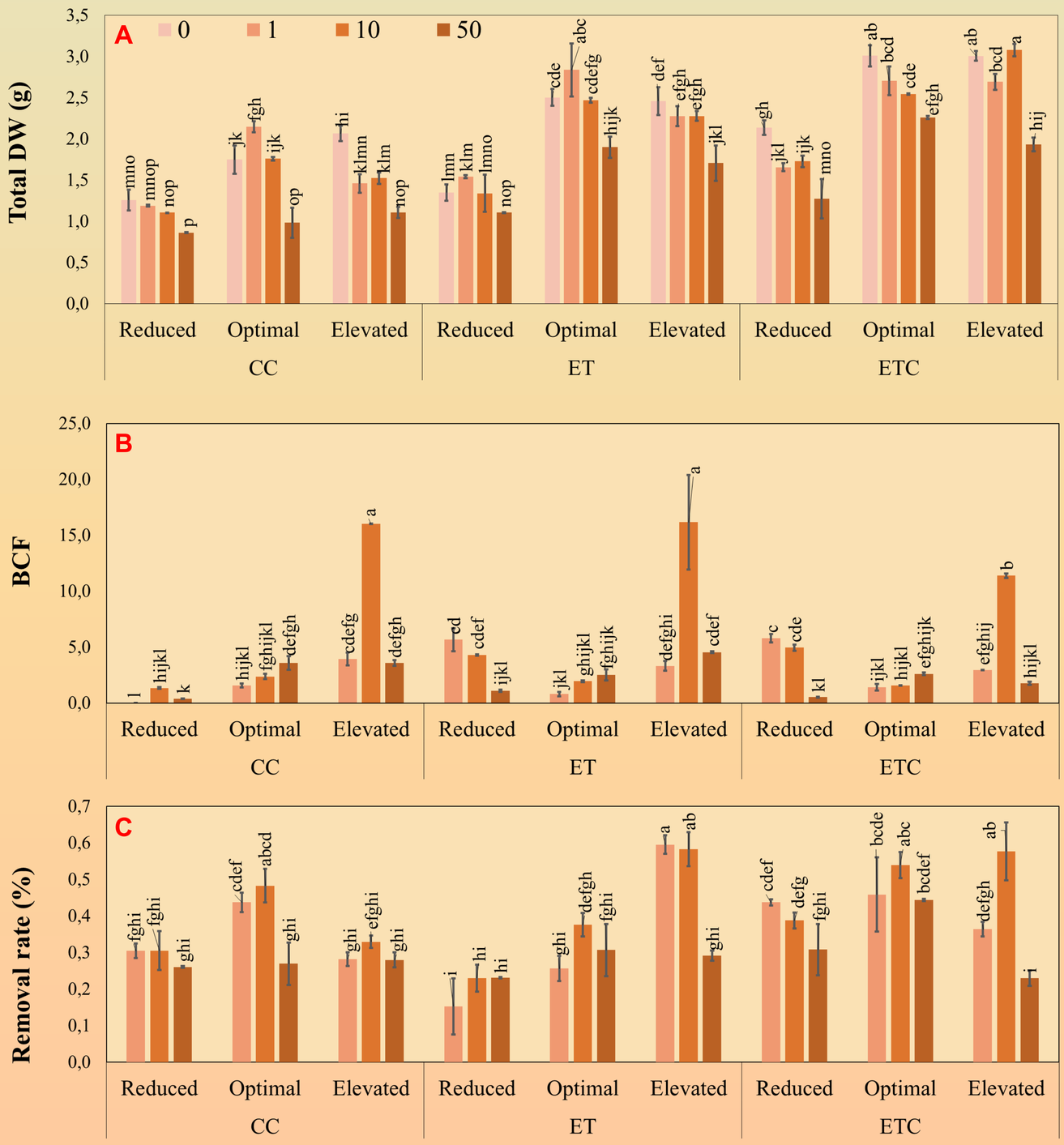


Fig. 1. *B. napus* grown in Cd polluted soil (0, 10, 10, 50 mg kg^{-1}) under different climate (**CC** – current climate, **ET** – elevated temperature, **ETC** – elevated temperature & CO_2) and SWC (reduced, optimal, elevated): total DW (**A**), Cd bioconcentration factor (BCF) (**B**) and removal rate (**C**). *Error bars represent standard errors (SE). Different letters indicate significant difference (p<0.05) among the treatments (LSD test).*

Table 1. Levels of significance of variance analysis (factorial ANOVA) of biomass, bioconcentration (BCF) and Cd removal rate in summer rape (*B. napus*) grown in Cd polluted soil under different climatic conditions (CC, ET, ETC) and SWC. * <0.05; ** <0.01; *** <0.001; **ns >** 0.05

	Environmental factors						
	Climate	**Cd**	**SWC**	**Climate*Cd**	**Climate*SWC**	**Cd*SWC**	**Climate*Cd*SWC**
Total DW	***	***	***	*	***	**	*
BCF	ns	***	***	n s	***	***	n s
Cd removal	***	***	***	n s	***	*	*

Concluding remarks

- ✓ Bioenergy plant *B. napus* was proved to be effective in remediating lightly to moderately Cd-contaminated soils under different climatic conditions and soil water content.
- ✓ Under CC conditions the best Cd removal efficiency requiring lowest number of harvesting cycles and accompanied by the highest possible bioenergy production could be achieved under optimal SWC.
- ✓ Elevated temperature and its combination with elevated CO_2 enhanced the phytoremediation efficiency of *B. napus* through increased plant biomass and Cd accumulation capacity. Nevertheless, positive effect of elevated temperature and CO_2 may be restricted by altered soil water content.
- ✓ SWC adjustment in response to climate change is critical for boosting phytoremediation capacity since it influences plant biomass development, heavy metal uptake.

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