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Availability and Uptake of Potentially Toxic Elements by Rice as Influenced by Innovative Agronomic Techniques

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INTRODUCTION: State of Art

To cope with **climate change** and meet **organic product demand, Italian rice farms** are adopting new techniques like:

- **Green mulching and manuring** of cover crops (CCs) to reduce chemical imputs
- **Alternate Wetting and Drying (AWD)** to enhance water efficiency

Rice accumulates high concentrations of **potentially toxic elements** (**PTEs**), like arsenic (**As**) and cadmium (**Cd**), both type 1 carcinogens. Regulations have tightened limits for these PTEs with new Nickel (**Ni**) restrictions coming in 2026 [4,5].

In Continuous Flooded (CF) rice fields, the **drop in redox potential** (E_h), due to microbial degradation of organic matter, significantly alters PTEs mobility. This causes the **dissolution of iron oxides**, the major adsorption sites for PTEs, including iron plaque on rice roots [2].

Lower E_h increases As solubility, while more **aerobic conditions increase Cd** availability by inhibiting its precipitation with sulfide and hydroxide [1]. **Ni behavior** in the soil-rice system is **unclear** but likely depends on competition with Fe for plant absorption sites [3,6].

AIMS

To understand how **CCs** and **AWD** in Italian rice farms modulate soil PTEs dissolution and retention, and their uptake and accumulation by rice plants and grain, the following processs will be analyzed:

A) **CCs influence on PTEs immobilization and release** through **interactions with nutrient and organic carbon cycles**.
B) **Soil drying timing effects on PTEs mobility and bioavailability to rice during** the growing season.
C) Ni dynamics within the water-soil-plant system.

Milestones

Literature Review *&* ***ENR Database*** *Analysis Completed*

A) *Mesocosms Data on* ***CCs*** *collected and papers written*

C) Ni *knowledge expanded*

B) *Mesocosms Data on* ***AWD*** *collected and papers written*

Lab-experiment *& characterization analysis completed*

METHODS:

Field Scale

Analysis of ENR survey **database** (National Scale)

Mesocosms Scale

Effect of CCs

- **Different type of CCs and termination methods** in green mulching
- **Green mulching**, **manuring** and **traditional** practices.

Effect of AWD

- **Single drying during different critical phenological stages** of rice.
- **Single drying, AWD and CF.**

Lab Scale

Hydroponic/Pot Experiments in controlled condition isolating key variables

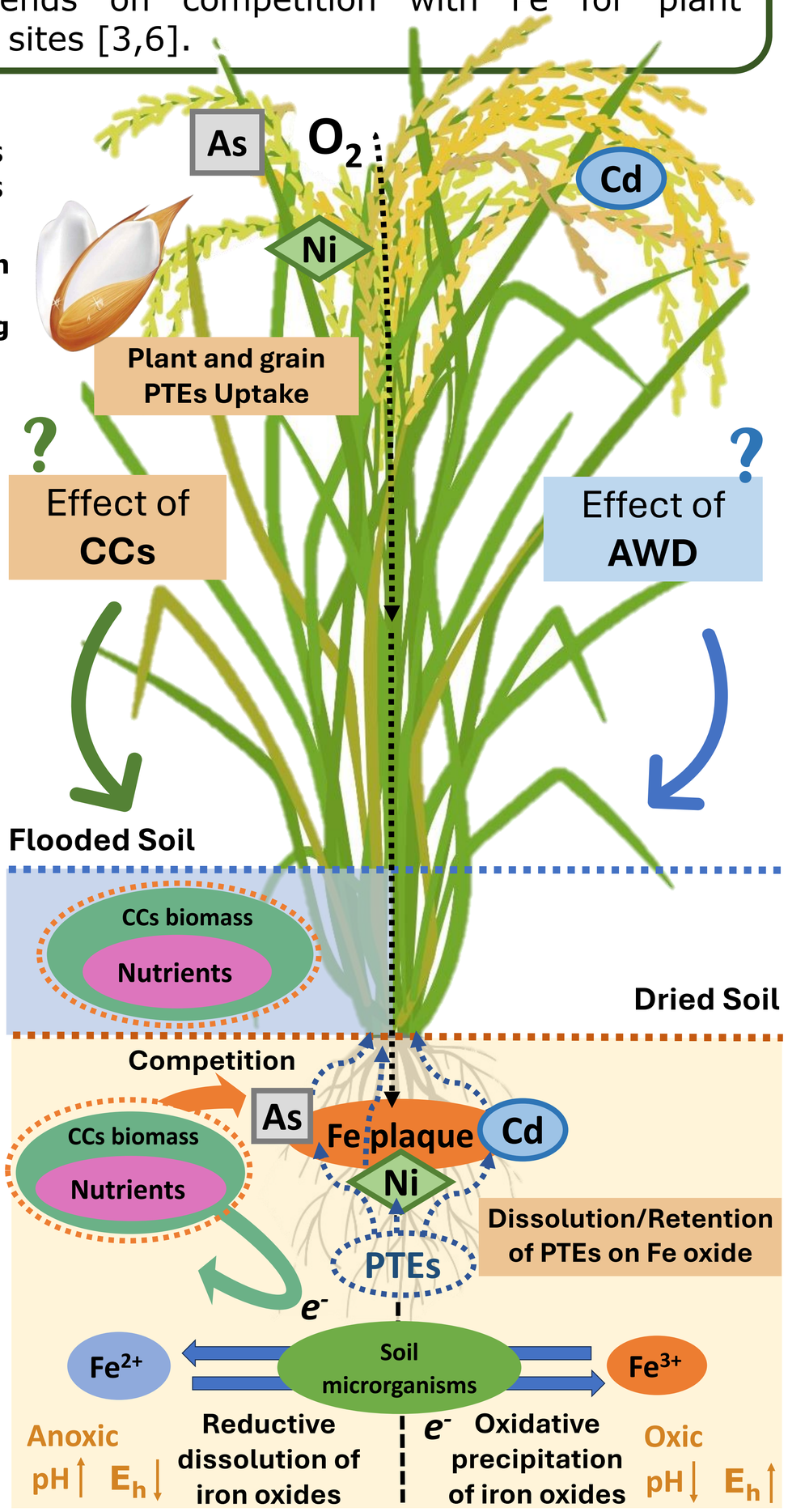
Insights for optimal water and organic management

Integrated water, soil and plant analysis in rice cycle *elemental analyzers, (HPLC-)ICP-MS/OES, UV-Vis*:

- Soil solution/water: As, Cd, Ni, DOC, Fe, P, NH_4^+
- Soil and plant tissues at 4 key phenological stages: concentrations, forms, and distribution of PTEs and nutrients.

Transcriptomic analysis: Expression of genes associated with PTEs uptake and transport.

Synchrotron analysis (*XRF, XAS, XANES*): elemental distribution maps and identification of PTEs adsorption mechanisms at the root surface.



EXPECTED RESULTS:

- **Effect of CCs**: understanding how **organic carbon and nutrient release** from CCs **modulates soil redox conditions** and the **biogeochemical dynamics of PTEs** will **help to improve organic farming practices for controlling PTEs concentrations in rice**.
- **Effect of AWD**: definition of **optimal drying periods** based on PTEs availability in the soil and the plant's response during critical phenological stages will enhance **water management, improving rice safety.**

References:

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[2] Han, R., Wang, Z., Wang, S., et al. (2023). Mitigating arsenic and cadmium accumulation in rice. Sci. Total Environ., 896, 165226.
[3] Harada et al. (2023). Temporal patterns of nickel transfer from soil to rice in terraced paddy fields affected by serpentinite. Sci. Total Environ.
[4] Regulation EU 2023/465 amending EC 1881/2006 on arsenic levels in foods.
[5] Regulation EU 2021/1323 amending EC 1881/2006 on cadmium levels in foodstuffs.
[6] Rinklebe, J., Shaheen, S.M. 2017. Redox chemistry of Ni in soils: Chemosphere, 179, 265-278.