Henan Agricultural University

Heavy Metal and Nutrient Accumulation in Forage-Grain Ratoon Rice:

Implications for Food Safety and Health Risks

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Outline

1 Background & Significance

2 Experimental Design

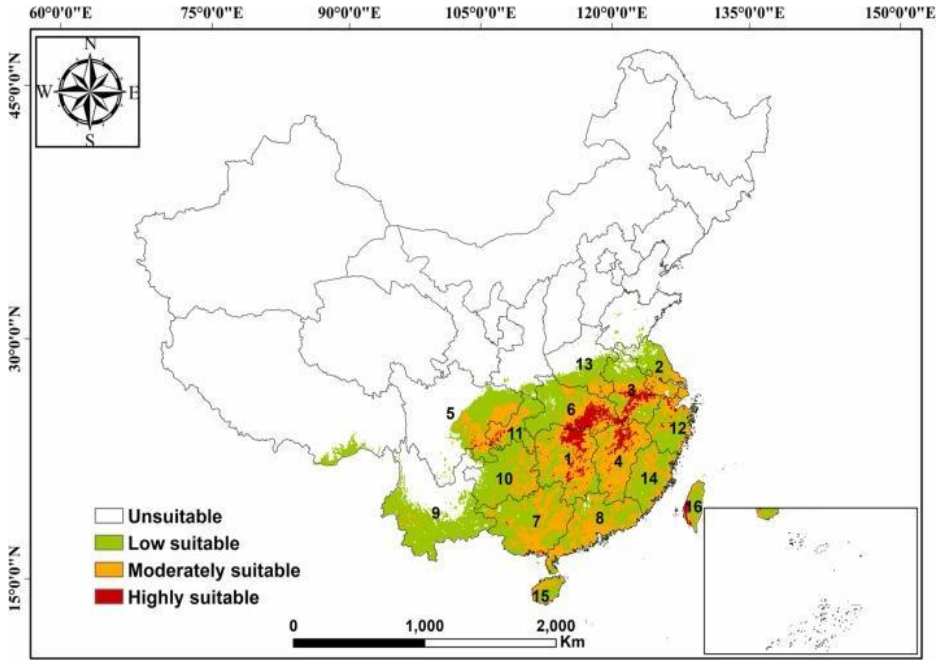
3 Workflow

4 Results

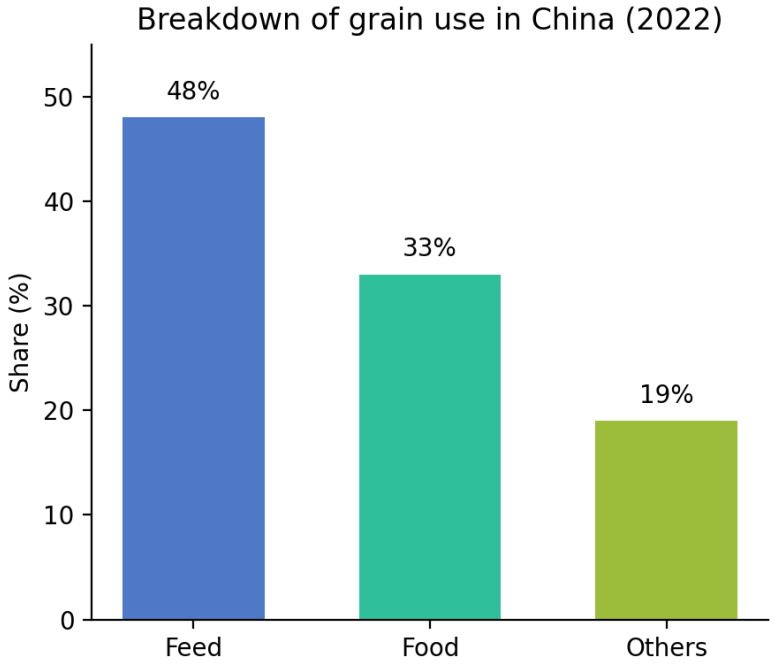
5 Conclusions

Why Promote Forage-Grain Ratoon Rice?

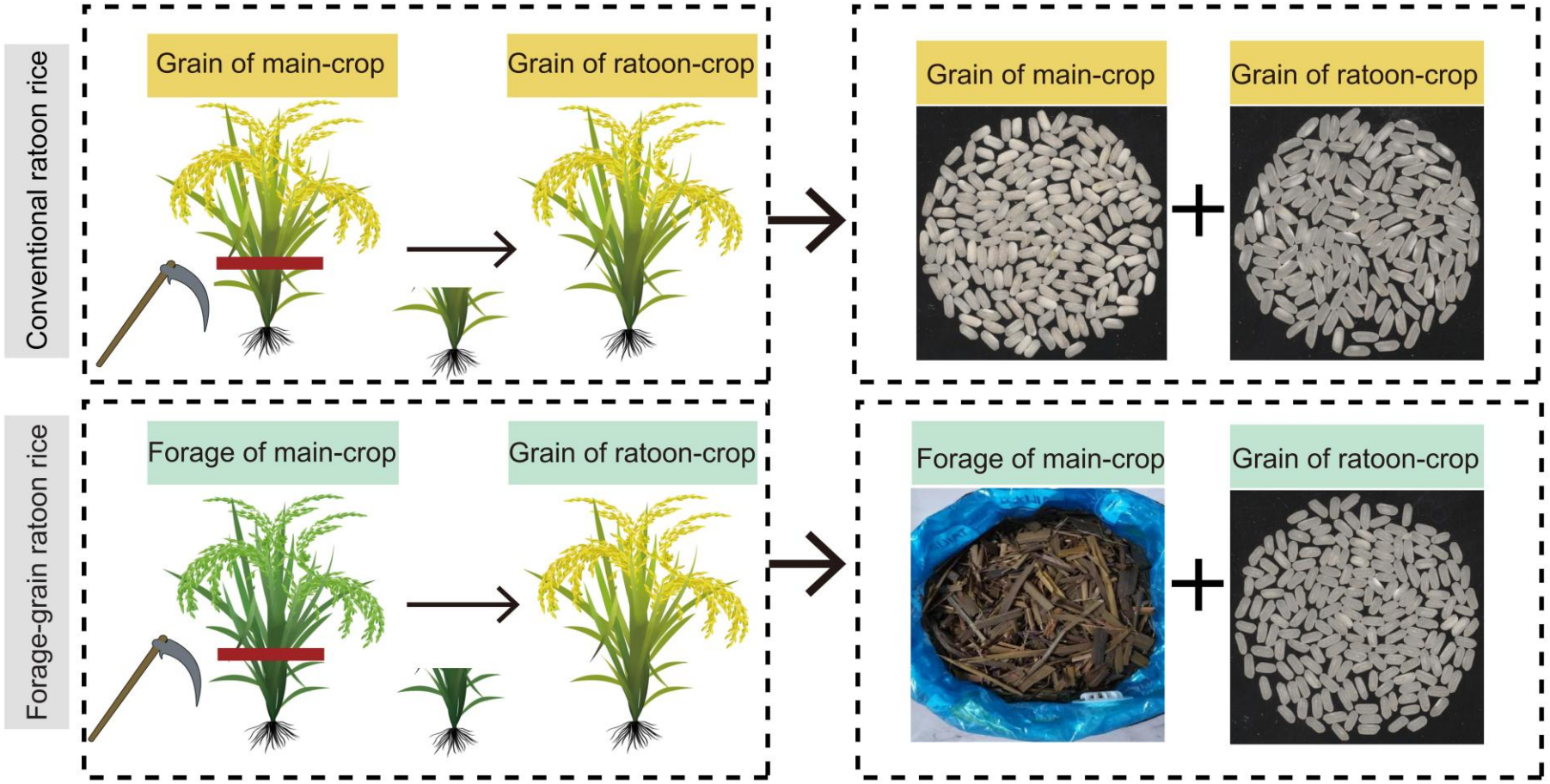
- China has **6 million hectares** suitable for ratoon rice, **mostly marginal land.**
- In 2022, **feed grain accounted for 48%** of total grain consumption in China.
- Ministry of Agriculture and Rural Affairs (MARA) launched the "**Increase Forage, Save Grain**" initiative.



(Peng et al., 2021)



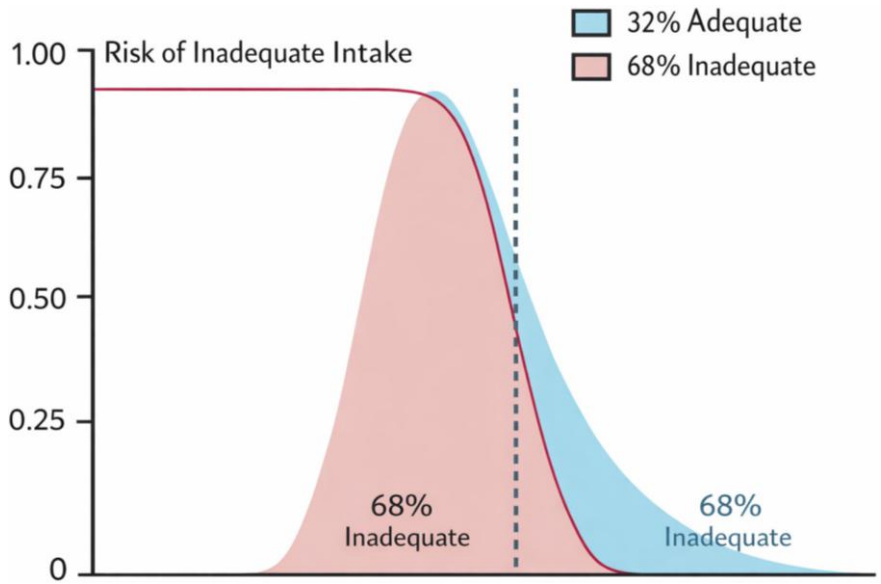
Pattern of Forage-Grain Ratoon Rice



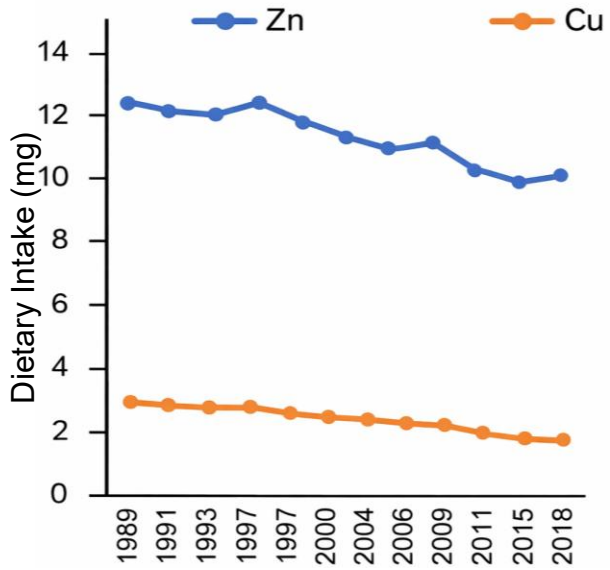
Forage-grain ratoon rice achieves dual production: forage of main crop and high-quality grain of ratoon crop.

Micronutrient Deficiency and Soil Pollution

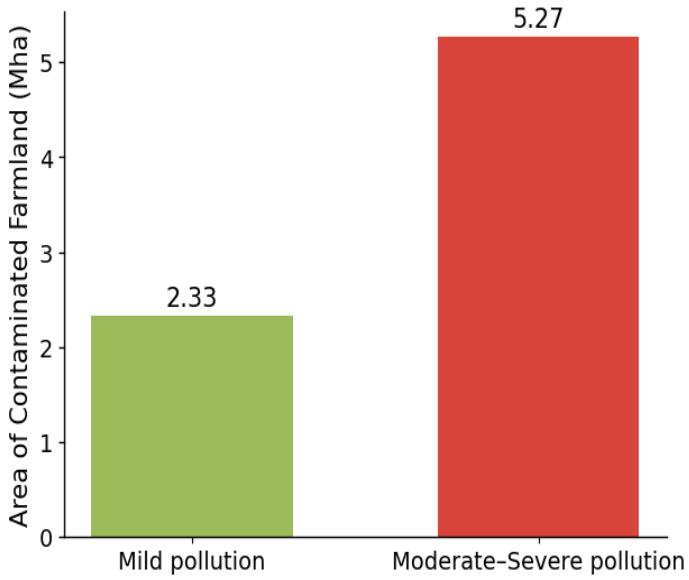
- **More than two-thirds** of the global population suffer from inadequate micronutrient intake.
- Dietary **Zn and Cu** intake in China has **declined continuously.**
- **Large areas of farmland** in southern China are affected by heavy metals.



(Simone Passarelli, et al. 2024)

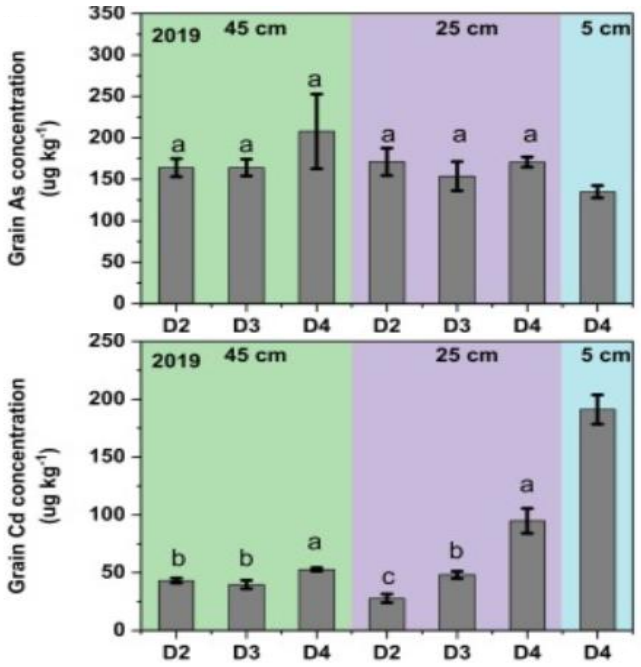


(Li, et al. 2023)

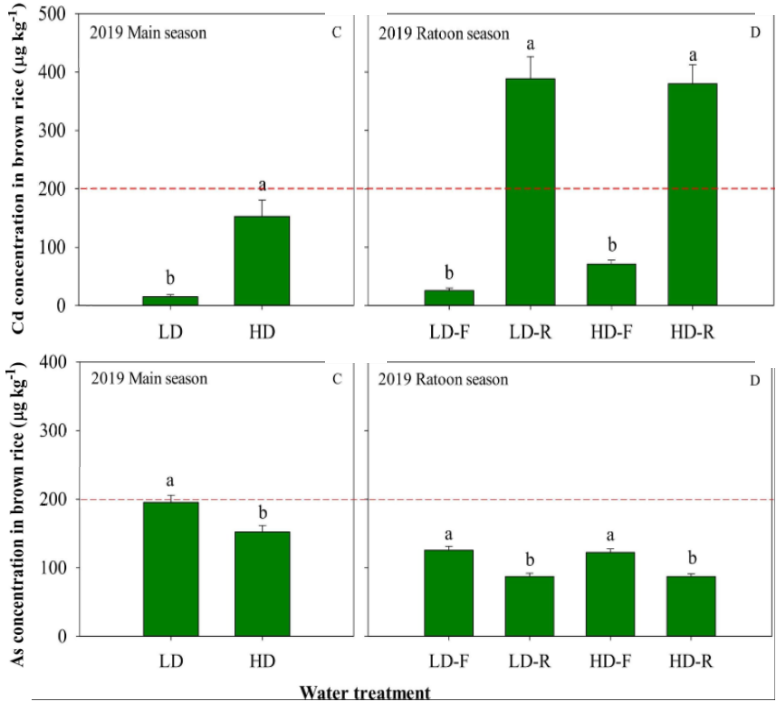


Agronomic Effects on Heavy Metals in Rice

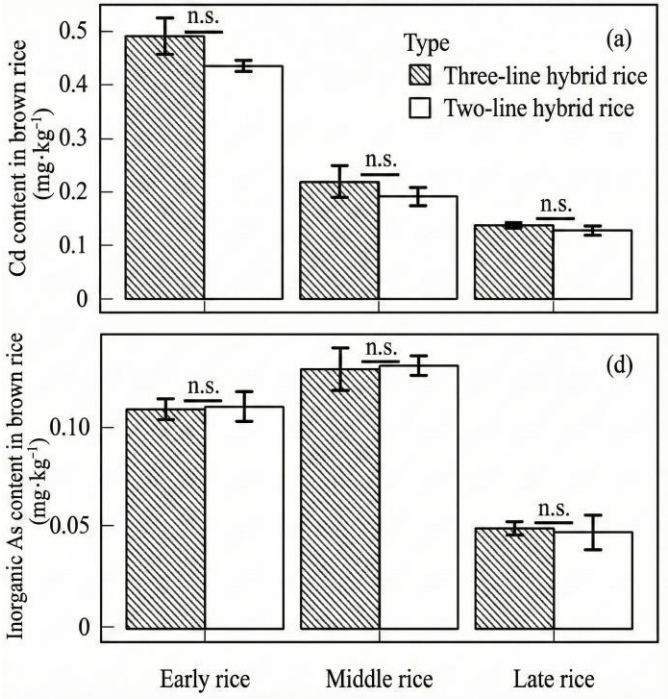
- **Higher cutting height** (45 cm) reduces Cd in ratoon rice.
- **Water regime** affects metal accumulation, ↑ Cd but ↓ As.
- **Varietal differences** are evident; three-line hybrids tend to accumulate more Cd.



(Yu, et al. 2023)



(Yang, et al. 2023)



(Lin, et al. 2018)

Research Significance

The timing of main-crop mowing determines yield and quality of forage-grain ratoon rice.

How does mowing stage affect metal accumulation?

- **Optimize cropping & management across ecological regions.**
- **Enhance the food safety and nutritional quality of rice.**

Experimental Design

Variety Screening Trial

Site: Site N

Varieties: 23

Representative varieties

Ecological Region Trial

Site: Site N, Site X, Site B

Varieties: LY6326 & TYXZ

Same Mowing Protocol

Cutting height: 25 cm

Mowing stages: Heading stage (HS), Milk-ripening stage (MS), Dry-ripening stage (DS), Full maturity stage (FS)

Site N

Site X

Site B

Workflow

A Sampling Design

4 mowing stages
HS, MS, DS, FS
23 varieties
3 ecological regions

B Measurements

Climate factors:
Accumulated temperature
Sunshine duration
Precipitation
Elements: Zn, Cu, As, Cd

C Assessment

Bioconcentration factor
Metal pollution index
Target hazard quotient
Total target hazard quotient
Index of nutritional quality

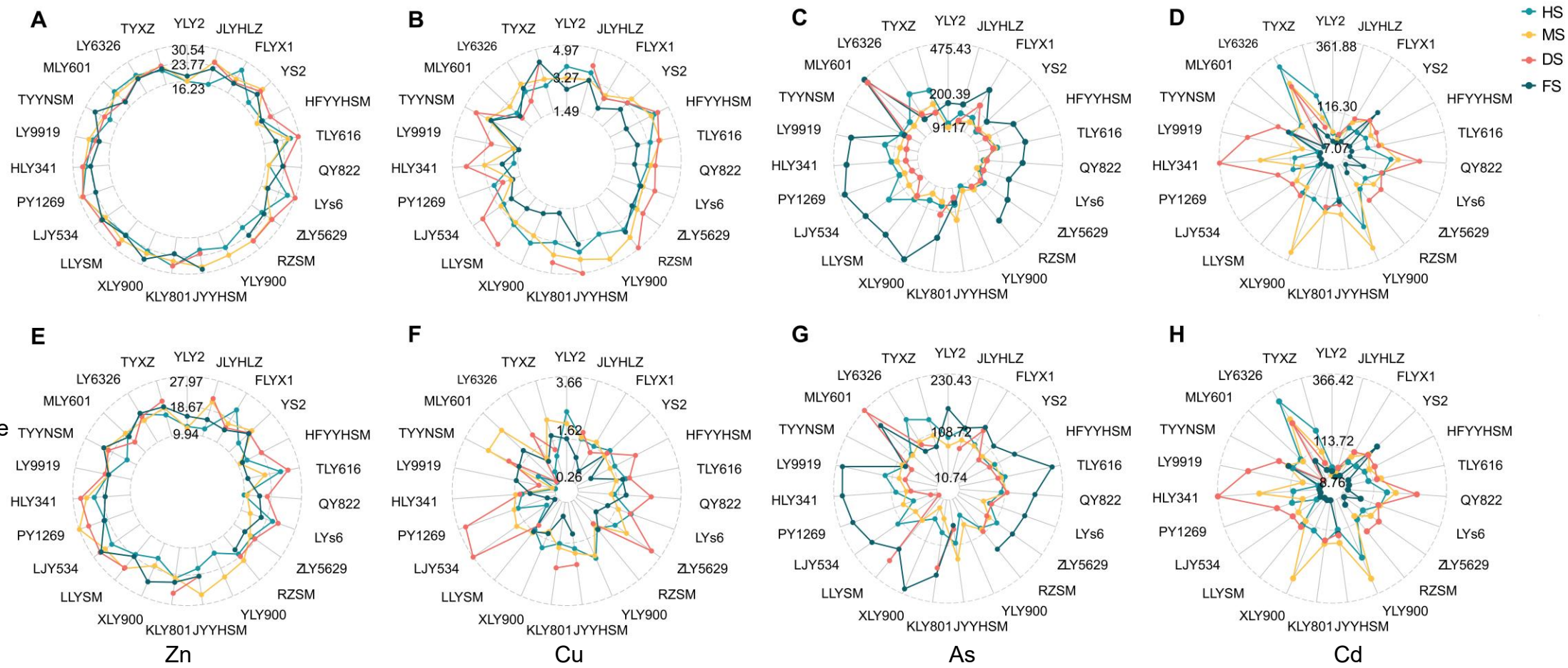
Goal: Improve the safety and nutritional quality of forage-grain ratoon rice production

Genotypic Variation & Mowing Stage Effects

- Metal concentrations varied widely across 23 varieties.
- Zn, Cu, and As levels were significantly higher in brown rice.
- As exceedances peaked at 17 (FS), while Cd remained 2–4 in early stages.

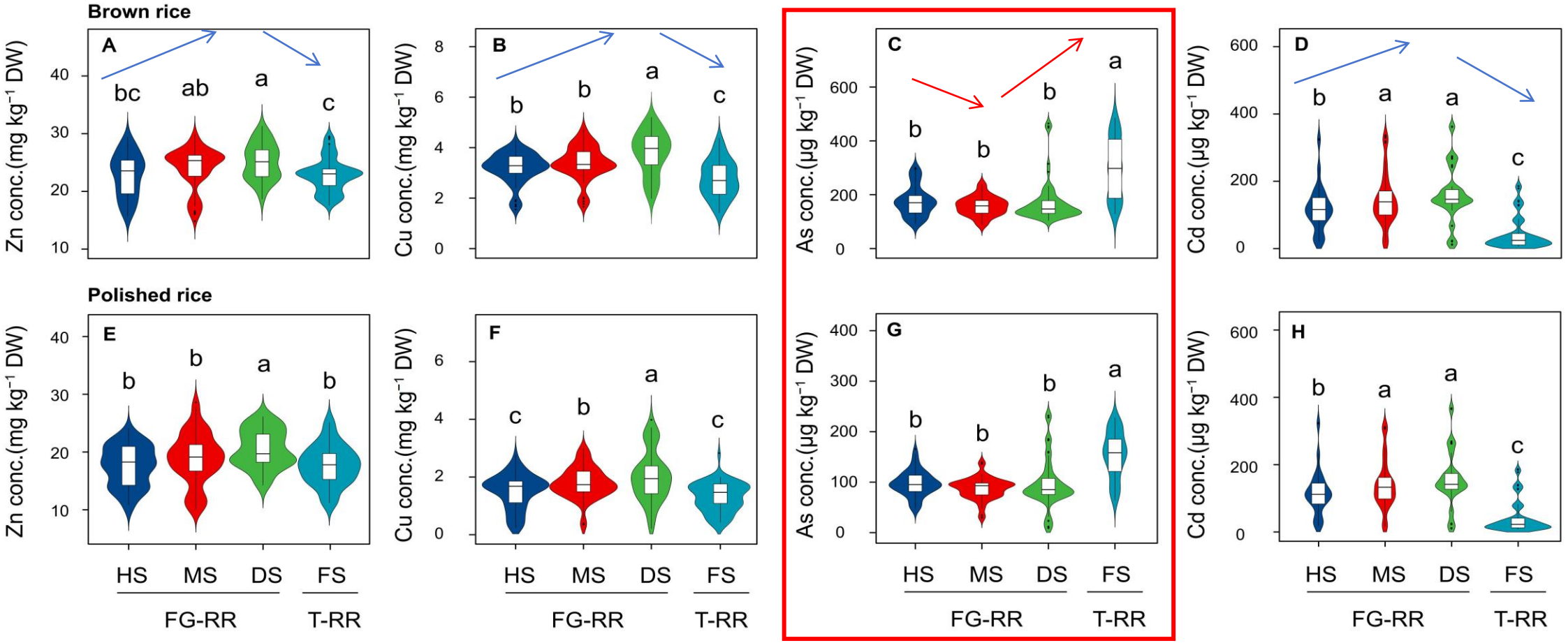
Brown rice

Polished rice



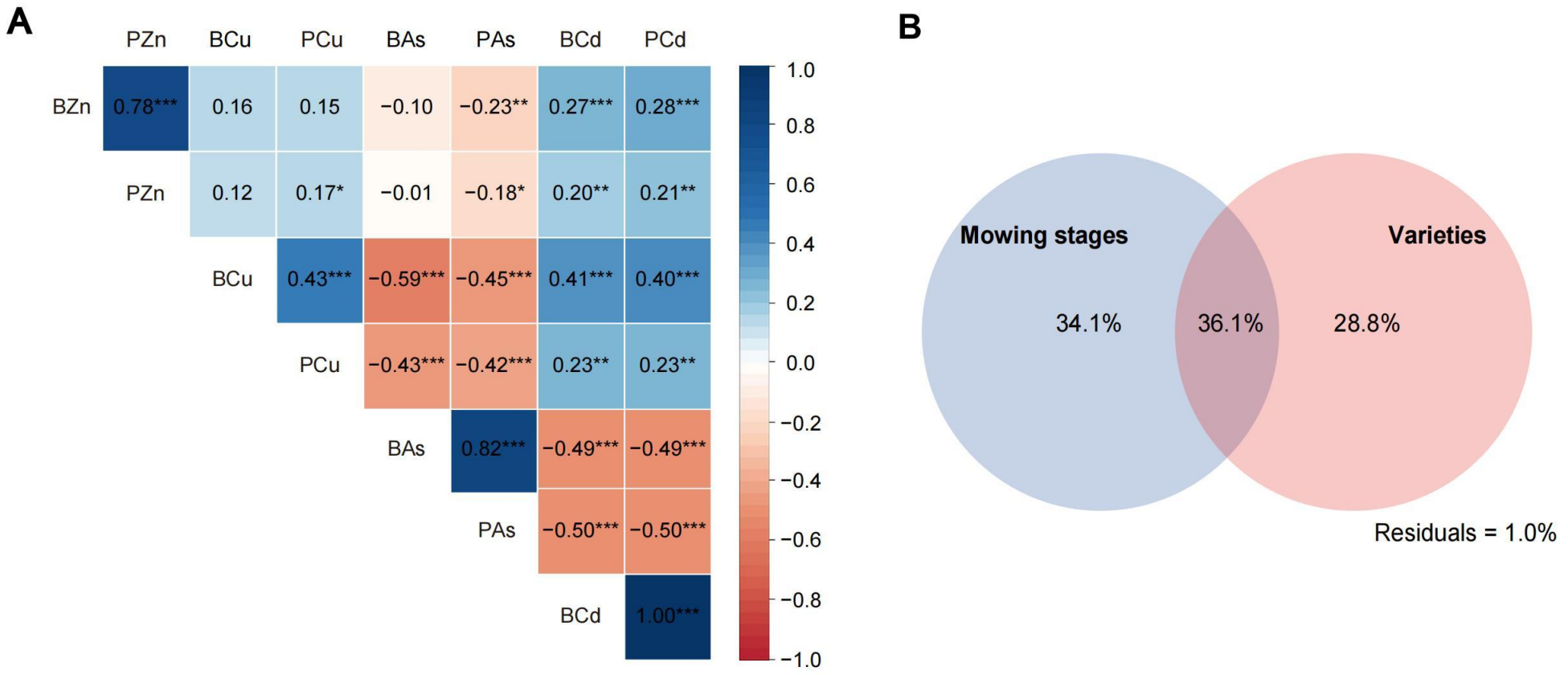
Impact of Mowing Stage on Metal Accumulation

- As the mowing stages delayed, Zn, Cu, and Cd concentrations in ratoon rice initially increased and then decreased.
- As showed the opposite trend.



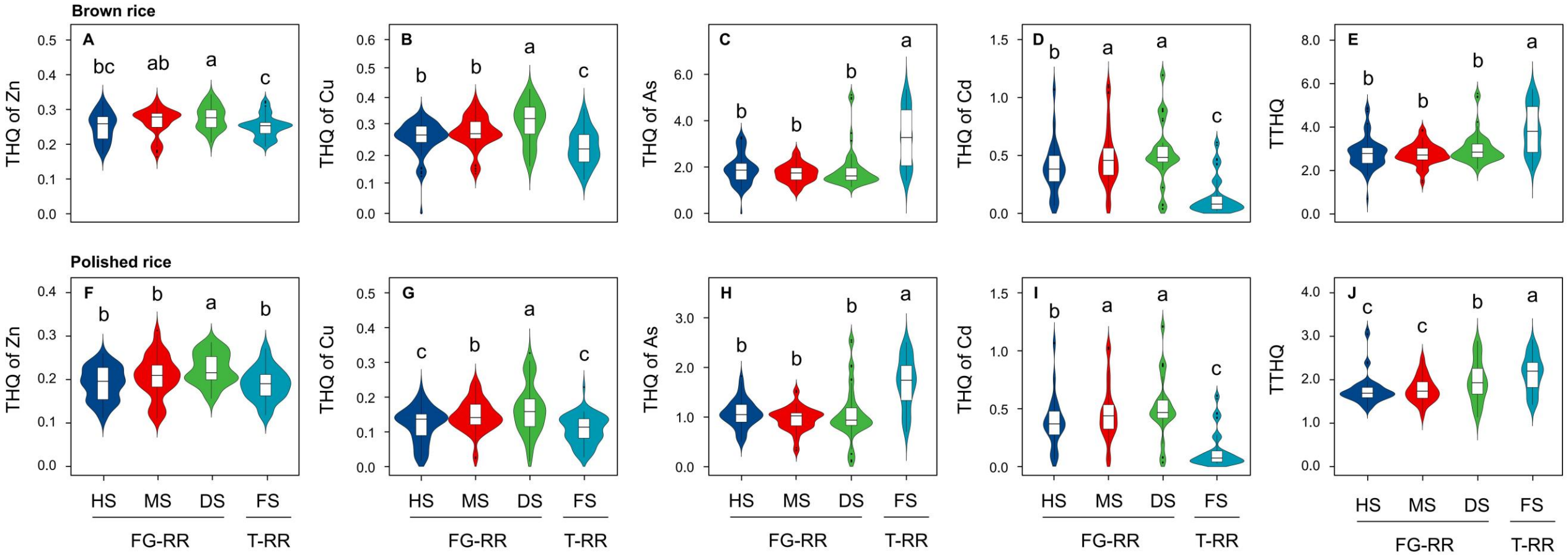
Correlations and PERMANOVA

- Zn was positively correlated with Cu and Cd, but negatively correlated with As in ratoon rice.
- Mowing stage and variety significantly affected metal levels in ratoon rice.



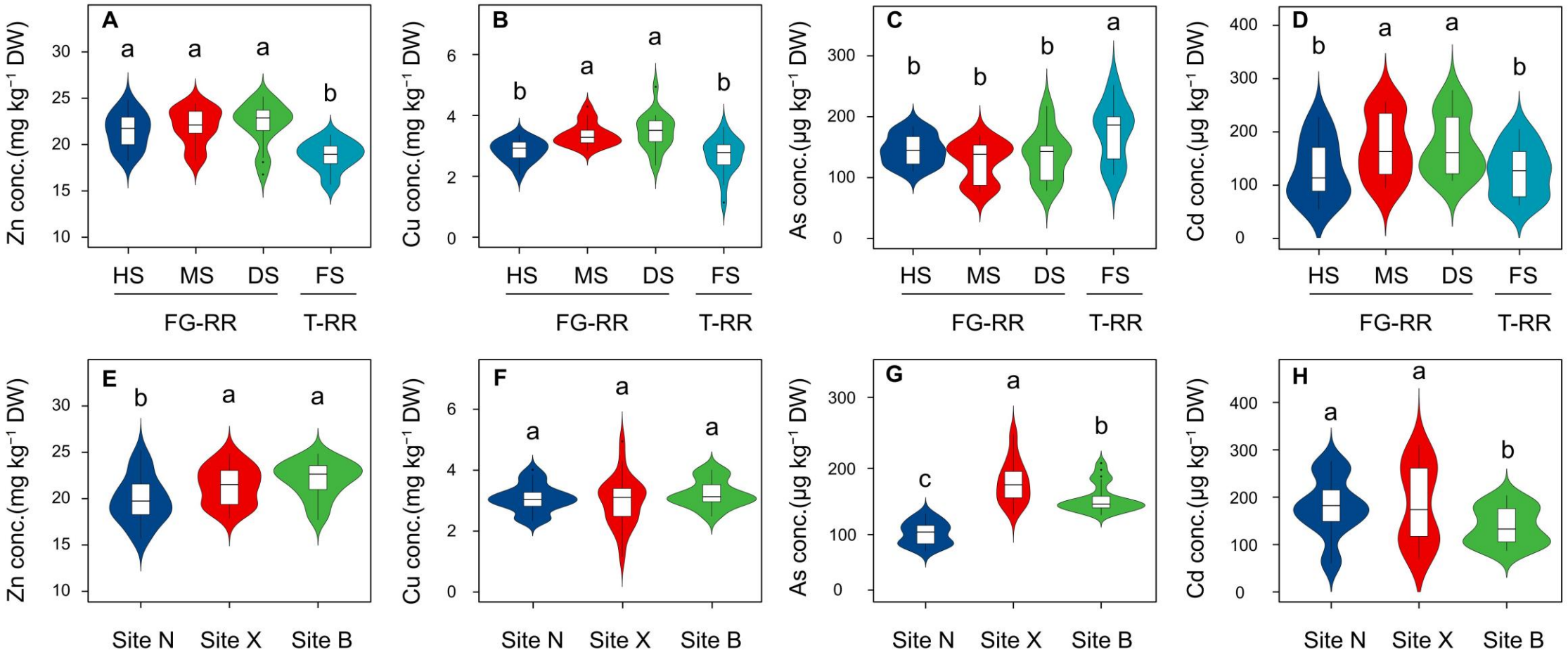
Mowing Stage Shifts THQ/TTHQ

- THQ trends generally mirror metal concentration patterns.
- FG-RR increased health risks for Zn, Cu, and Cd, but reduced As risk.
- Mowing at MS in FG-RR reduced TTHQ compared with T-RR.



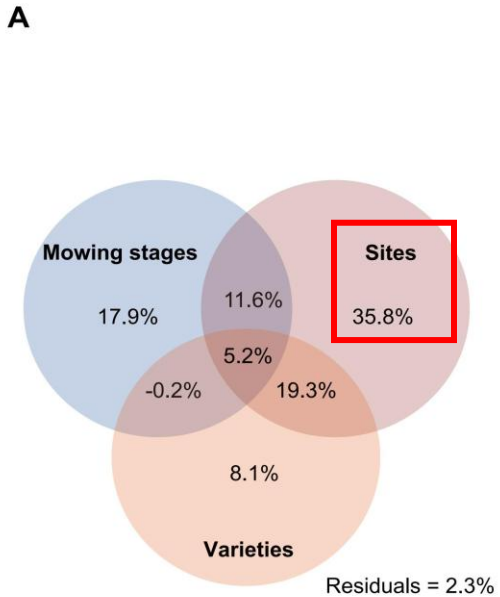
Effects of Mowing Stage Across Ecological Sites

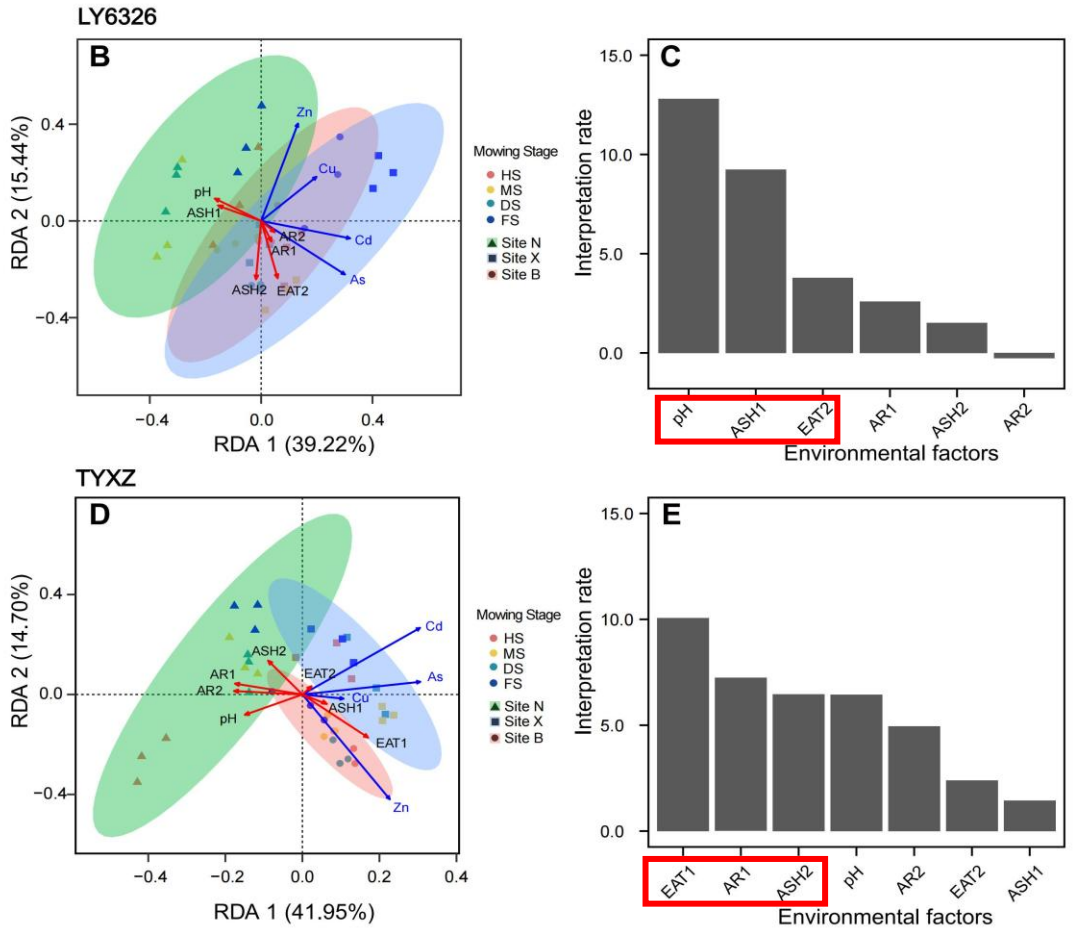
- In the ecological region trial, metal levels follow the same trends.
- Across different sites, grain Zn and As were lowest at Site N, Cd was lowest at Site B, while Cu did not differ among sites.



Environmental Drivers Across Sites

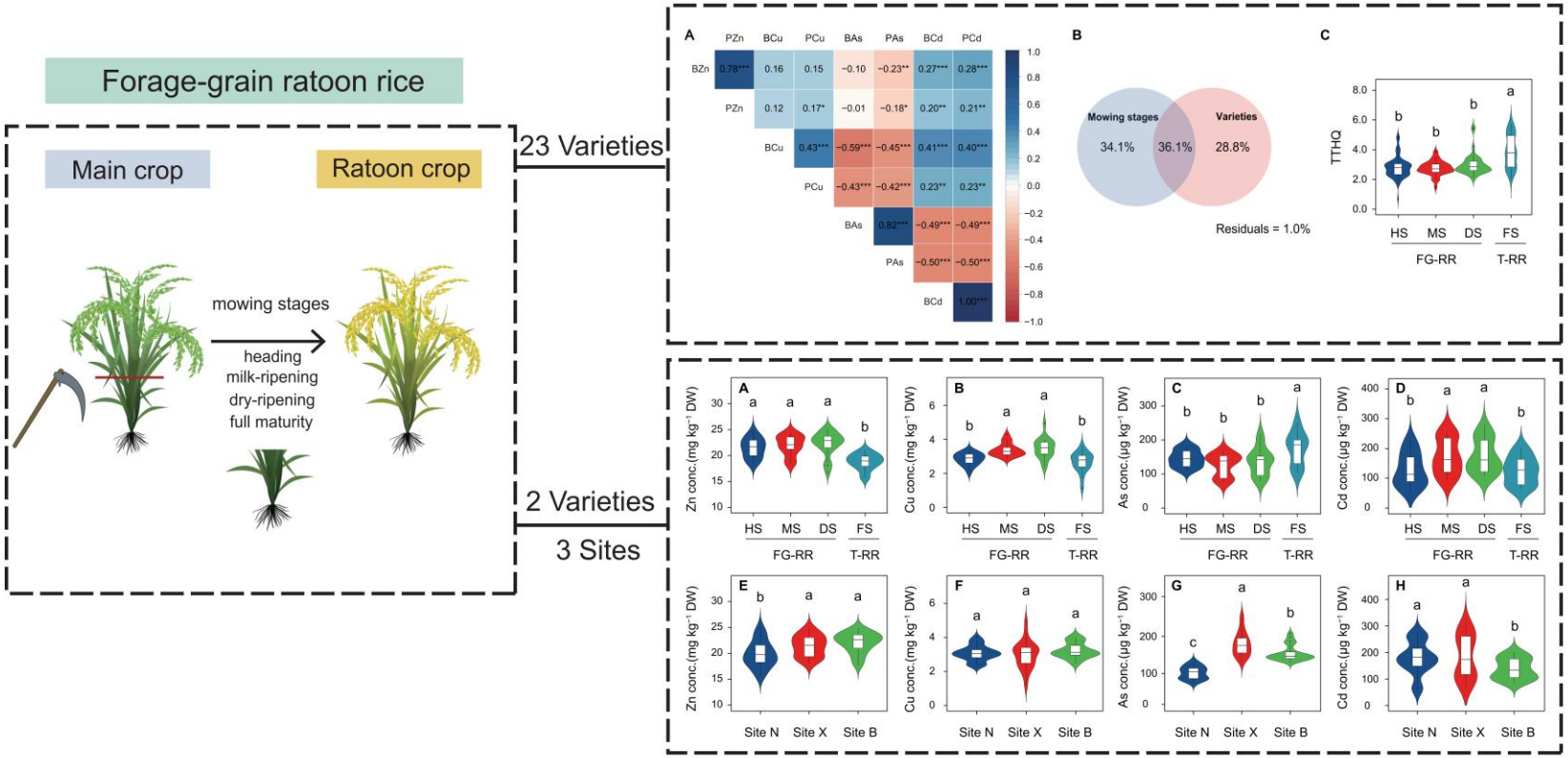
- Mowing stage and variety affected metal levels, site was the main factor.
- LY6326 was mainly driven by soil pH, ASH1, and EAT2, whereas TYXZ was mainly driven by EAT1, AR1, and ASH2.





Conclusions

- With the mowing stages delayed, Zn, Cu and Cd in ratoon rice initially increased and then decreased, while As showed the opposite trend.
- As was significantly and negatively correlated with Zn, Cu, and Cd levels.
- Forage-grain ratoon rice is a good source of Zn and Cu; mowing at the MS minimizes health risks.
- Site difference is the main factor, with significant environmental impacts.



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Thank you for your attention!

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