Fall armyworm herbivory affects silica accumulation in corn and rice

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Abstract

Plants, especially grasses, accumulate large amounts of silicon dioxide in their leaves. Silica deposition plays a role in defense against abiotic and biotic stresses including herbivores. This research determined the effect of the fall armyworm (FAW) herbivory in the accumulation of silica in corn and rice plants, as well as the effect of silica on the caterpillar mandible durability. Our results show that FAW feeding induces silica accumulation in rice but not in corn plants. Silica wears the FAW mandibles affecting its feeding ability; in response the FAW plastically modifies its morphology and development to feed on silica-containing plants.

Introduction

- **Silicon accumulation increases plant resistance to herbivorous insects**
  Among many other roles, silicon accumulation increases the abrasiveness of the plant leaves acting as a physical defense mechanism against phytophagous insects (1).

- **Herbivorous insects face diverse plant defense mechanisms**
  Insect herbivores adapt their morphology, physiology, development and behavior to counteract plant defenses (2).

- **Research questions**

1) Does insect feeding affect plant silica accumulation?
2) Does silica affects the herbivore feeding?
3) How do insects manage to feed on silica-containing plants?

- **Model system**
  Corn, rice and the polyphagous insect fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) (Fig. 1).

Fig. 1. Fall armyworm larva feeding on corn.

Objectives

This research determined:

1) The effect of fall armyworm herbivory on the accumulation of silica in corn and rice plants.
2) The effect of silica on the fall armyworm mandible wear.
3) The fall armyworm adaptations to feed on plants with high silica content.

Results and discussion

1. Fall armyworm feeding affects plant silica accumulation.

Rice and corn plants accumulate silica in the epidermis of their leaves and tips of trichomes (Fig. 2). Rice contain ~3 times more silica than corn.

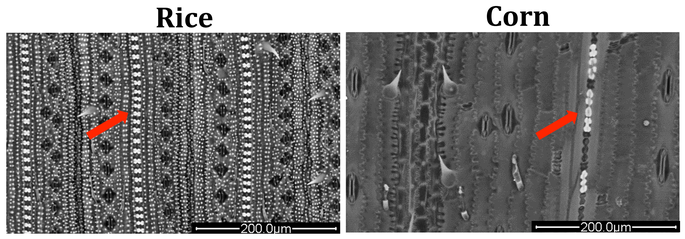

Fig. 2. Backscatter electron image of silica bodies in rice and corn leaves.

The mechanical damage caused by the fall armyworm feeding induces silica accumulation in rice plants by ~37.2 % compared with untreated controls.

Conversely, in corn, the deposition of silica is the same for insect-fed plants and for untreated controls, both are lower than mechanically damaged plants (Fig. 3).

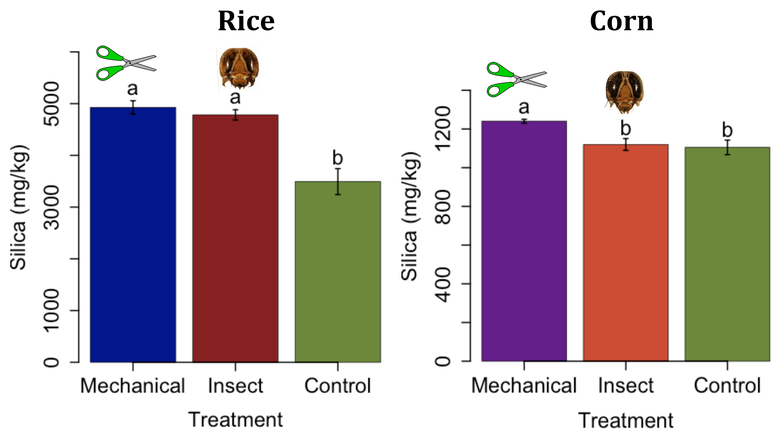

Fig. 3. Silica accumulation in rice (left) and corn (right) plants after mechanical damage and insect-feeding treatments. Different letters indicate significant differences among treatment means (P<0.05).

2. Silica accumulated in plant leaves wears the fall armyworm mandibles.

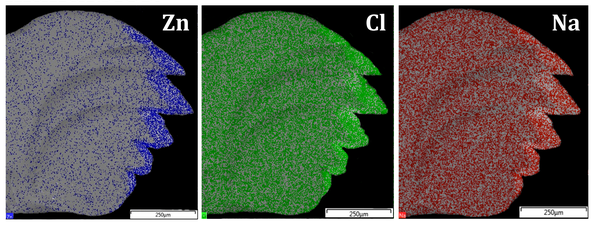

Fig. 4. X-ray mapping of Zn, Cl and Na of the FAW mandibles.

The FAW enhances the hardness of the cutting edges of its mandibles by incorporating minerals including zinc, chlorine and sodium (Fig. 4).

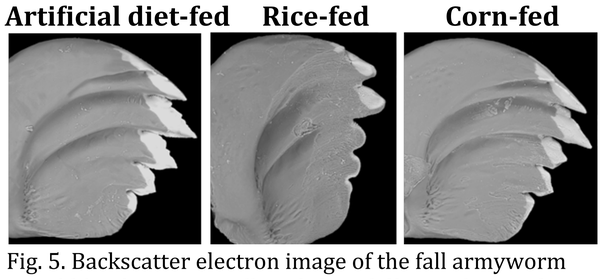

Fig. 5. Backscatter electron image of the fall armyworm mandibles from caterpillars fed on different diets. Whiter outer areas correspond to mineral-enriched regions.

Feeding on rice, a high silica-containing plant, destroys most of the mineralized area of the FAW mandibles (Fig. 5). Mandible wear hampers the caterpillar ability to feed on plant tissues.

3. The fall armyworm plastically modifies its morphology and development to feed on tough silica-containing plants.

When feeding on rice, the FAW undergoes an additional molt increasing the size of its mandibles and attached musculature (Fig. 6).

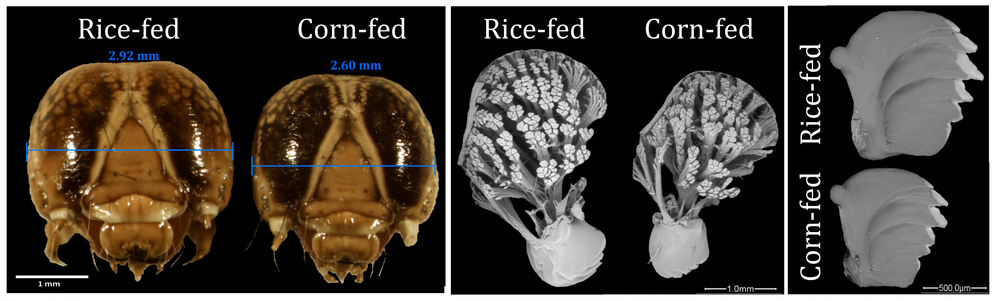

Fig. 6. Head capsule size (left), mandibular muscles (center), and mandible size (right) of the fall armyworm last instar caterpillars reared on rice and corn leaves.

Methods

- **Plants and insects**

We used the corn, *Zea mays* inbred line B73; and the rice, *Oryza sativa* japonica cultivar Nipponbare. The fall armyworm, *Spodoptera frugiperda* were obtained from a lab colony from the USDA-ARS in Gainesville Florida.

- **Effect of insect feeding on plant silica accumulation**

Rice and corn plants were exposed to FAW herbivory for 24 hours or mechanically damaged with scissors in a complete randomized design; the new regrowth tissues were used to quantify the amount of silica with the molybdenum yellow method (3).

- **Caterpillar mandible wear**

Mandible wear and mineral composition was determined by X-ray and scanning electron microscopy.

- **Statistical analysis**

We used ANOVA to test for differences of treatment means, followed by the Tukey test at α=0.05.

Significance

This is one of the first studies to explore the dynamic interplay between insect herbivores and silica accumulation in plants of economic importance.
Three of the most important crops for human kind are grasses (silica-accumulating plants); a better understanding on how silica enhances crop resistance against insect herbivores is of global importance.

Conclusions

- Silica accumulation is an inducible plant defense mechanism that causes wear on the insect mandibles and hampers their ability to feed on plant tissues.
- Insect herbivores are able to modify its development to feed on plants with high silica content.

Acknowledgments

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