Husk Extension and Corn Earworm Resistance in Organic Sweet Corn

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Background

Corn earworm (*Helicoverpa zea*) is an important pest for organic sweet corn growers. Earworm larvae feed on corn silks and ears, making the ears unmarketable. Organic growers have few earworm management options, and breeding for earworm resistance is one promising option for reducing the damage caused by corn earworm on organic farms. Two potential traits for increasing resistance to corn earworm are longer **husk extension** (extending further past the ear tip) and higher **maysin** (a flavonoid present in some corn silks that delays earworm larval development). We conducted two studies to assess the potential of husk length and/or maysin to improve sweet corn resistance to corn earworm. The first was a **selection experiment** for longer husk extension, and the second was a **factorial mating design** to test the effects of husk extension and maysin on earworm resistance.

Methods - Selection Experiment

Germplasm: A population was developed by intermating three inbreds with long, thick, tight husks (A684su, A685su, and A686su) by a high-quality parent (Super Sweet Jubilee Plus). This population was the basis of 116 full-sib families in Cycle 0 of the selection experiment.

Selection & Recombination Methods: We conducted three cycles of **full-sib recurrent selection** in 2014 to 2016, using the following methods for selection and recombination:

- **Evaluation:** ear length and husk extension past the ear tip
- **Selection criteria:** longest husk extension and minimum ear length of 16 cm
- **Selection pressure:** approximately 10% of families selected per cycle
- Ears from selected families self-pollinated in summer nursery and recombined in winter nursery to form new full-sib families

Evaluation Methods: We evaluated **gain from selection** in summer 2017 using a randomized complete block design (**RCBD**) with **4 replications** in **4 environments**, all planted at West Madison Agricultural Research Station (WMARS):

- 2 organic environments (one with a delayed planting date)
- 2 conventional environments (one with a delayed planting date)

We evaluated **single-row plots** of seven entries:

- Cycles 0-3 of the selection experiment
- Three commercial varieties identified in interviews with organic farmers as having some resistance to corn earworm

Plots were **artificially inoculated** with corn earworm eggs. Inoculated ears were evaluated for ear length, husk extension, number of earworm larvae, and amount of earworm damage using the Revised Centimeter Scale (see *Table 1*).

Data Analysis: Linear fixed effects models were used to model three dependent variables on a plot-mean basis:

1. Husk extension
2. Ear length
3. Corn earworm damage for successfully inoculated plants

Genotype, environment, and replication within environment were used as explanatory variables. Genotype-by-environment interaction was not significant in any of the models, and was therefore excluded.

Methods – Factorial Experiment

Germplasm: 12 inbreds were crossed using a factorial mating design, as follows:

- **7 male parents:** either maysin or non-maysin
- **5 female parents:** either short or long husk

Evaluation Methods: We evaluated husk extension, maysin content, and corn earworm damage in the summers of 2016 and 2017 using a randomized complete block design (**RCBD**), with **4 replications** in the following **6 environments:**

- 2 organic environments at Arlington Agricultural Research Station (AARS) (one with a delayed planting date) in 2016
- 2 organic environments at West Madison Agricultural Research Station (WMARS) (one with a delayed planting date) in 2016
- 2 conventional environments at West Madison Agricultural Research Station (WMARS) (in separate fields and one with a delayed planting date) in 2017

We evaluated **two-row plots** of 47 entries:

- The 35 possible hybrid combinations of the 7 males and 5 females
- The 12 inbred parents

One row in each plot was **artificially inoculated** with corn earworm eggs. Inoculated ears were evaluated for ear length, husk extension, number of earworm larvae, and amount of earworm damage using the Revised Centimeter Scale (see *Table 1*).

Silks were harvested from the second row in the plot and **analyzed for maysin content** using High Performance Liquid Chromatography (HPLC).

Data Analysis: Linear fixed effects models were used to model two dependent variables on a plot-mean basis:

1. Husk extension
2. Corn earworm damage for successfully inoculated plants

Environment, replication, male parent, and female parent were used as explanatory variables. All two-way interactions between environment, male, and female were significant in both models, and a three-way environment-by-male-by-female interaction (ExMxF) was significant in the husk extension model only. However, Spearman rank correlations indicated that this ExMxF interaction was due largely to differences in magnitude rather than rank. Therefore, it is possible to examine the differences between the hybrids as combinations of male and female parents.

Top Photo: Corn earworm has 6 larval instars. Adults oviposit on fresh corn silks, and newly hatched larvae crawl down the silk channel and into the ear.
Bottom Photo: Corn earworm larvae feed on the silks and kernels of sweet corn ears, causing significant economic damage for growers.

Figure 1: Mean husk extension by genotype in the selection experiment. Cycle 3 has significantly longer husk extension than other cycles, showing gain from selection.

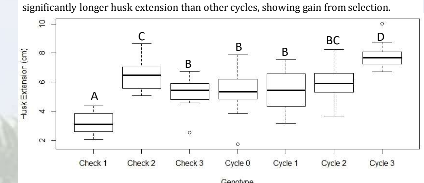


Figure 2: Mean ear length by genotype in the selection experiment. There is no significant difference between ear length in the selection cycles, indicating no change in ear length under selection for long husk extension.

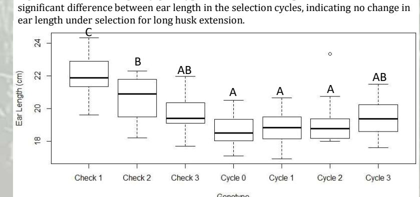
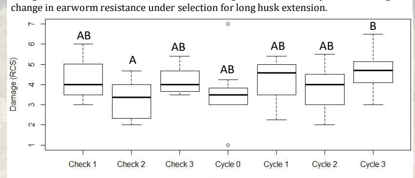


Figure 3: Mean earworm damage by genotype in the selection experiment. There is no significant difference between earworm damage in the selection cycles, indicating no change in earworm resistance under selection for long husk extension.



Left Photo: To artificially inoculate ears, corn earworm eggs were suspended in an agar solution and applied to the ears at fresh silking stage.
Right Photo: At harvest, ear length, husk extension, and extent of corn earworm damage were measured.

Table 1: Revised Centimeter Scale

Value	Description
0	No damage
1	Damage to silks only
2	Feeding up to 1cm beyond the ear tip
3	Feeding up to 2cm beyond the ear tip
> 4	Value increases by 1 for each additional centimeter of feeding beyond the tip of the ear

Results

Selection Experiment: Cycle 3 had significantly longer husk extension than Cycles 0-2, and there were no significant differences in ear length between the selection cycles, indicating successful selection for longer husk extension without selecting for shorter ears. Cycle 3 also had significantly longer husk extension than any of the commercial varieties evaluated (see *Figures 1* and *2*). However, there were no significant differences between the cycles in terms of corn earworm damage (see *Figure 3*).

Factorial Experiment: There were significant interactions between all factor combinations (i.e. male parents, female parents, and environment) for both husk extension and corn earworm damage. *Figure 4* shows that some parents produce progeny with consistently short husk extension (e.g. males Maysin3 and Maysin4 and female Ia453), while others have variable performance depending on the other parent (e.g. male We11401 and the three female long-husk parents). There were fewer significant differences between genotypes for corn earworm damage, but one of the short-husked parents (Ia5125) had progeny with significantly higher damage levels compared to most other genotypes. There is no obvious effect of maysin-containing genotypes on earworm resistance (see *Figure 5*).

Figure 4: Mean husk extension by genotype in the factorial experiment. Genotypes are grouped by female parent along the x-axis, and color coded by male parent; letters indicate significance at the 5% level for select groups with husks longer than other genotypes.

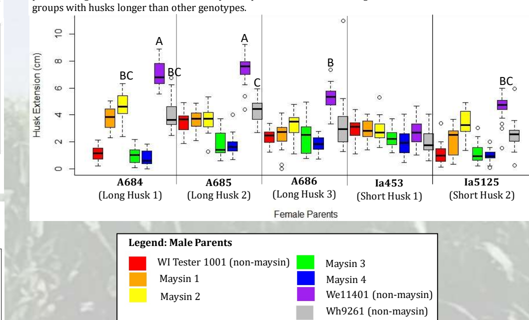
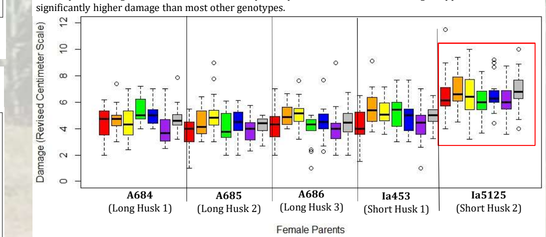


Figure 5: Mean earworm damage by genotype in the factorial experiment. Genotypes are grouped by female parent along the x-axis, and color coded by male parent. The red box indicates genotypes with significantly higher damage than most other genotypes.



Conclusions

Selection Experiment:

1. Selection successfully increased husk extension without decreasing ear length.
2. Increasing husk extension did not result in reduced earworm damage.

Factorial Experiment:

1. Interactions between parents play a significant role in determining husk extension.
2. One of the short-husked parents showed more earworm damage than others, indicating a possible role of husk extension in earworm resistance.

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