Host Plant Resistance to Wheat Stem Sawfly in Barley

Buddhi B. Achhami

PhD Candidate - Ecology and Environmental Sciences
Department of Land Resources and Environmental Sciences

MONTANA STATE UNIVERSITY
Overview of the presentation

- Life cycle of *Cephus cinctus*
- Economic loss and distribution of *Cephus cinctus*
- Management tactics for *Cephus cinctus*
  - Host plant resistance
- Materials and methods
- Results
  - Infestation in barley cultivars
  - Larval mortality in barley cultivars
- Ongoing activities
Life cycle of *Cephus cinctus*

- **Spring**: Eggs
- **Summer**: Feeding larvae and frass
- **Fall and Winter**: Larva in diapause
- **Stems cut by larvae**
Economic losses and distribution of Cephus cinctus

Lost plant vigor, accelerated senescence, and yield loss

- **Economic loss**: direct loss is caused by reducing photosynthetic rate (Macedo et al. 2005)
- Up to 30% potential loss at harvest (Delaney et al. 2010)

- Stem cutting by larvae at harvest makes it difficult to recover grains.
- Overall losses of 44-80 million USD per year in Montana.

(Bekkerman, 2014; Bekkerman and Weaver, 2018)
Cephus cinctus management tactics

- **Cultural control**: Tilling field to expose diapausing larvae to predators and freezing temperature, crop rotations
- **Chemical control**: Thimet®
- **Biological control**:
  - **Parasitoids**: Bracon cephi and B. lissogaster
  - **Predator**: Phyllobaenus dubius
- **Host plant resistance**: solid stem wheat

Photos credit: RKD Peterson, Ag NDSU
Host plant resistance

i) **Antixenosis (non-preference):** host plant characteristics that interfere with the ability to infest.

ii) **Antibiosis:** host plant characteristics that reduce growth or survival of the feeding stage(s) of the insect.

iii) **Tolerance:** the ability of plant that can grow and reproduce even after insect damage.

(Prenter, 1951)
**Overall goal**
To develop barley as a useful tool for Cephus cinctus management in wheat and barley cropping systems

**Objectives**

i) To assess WSS infestation and stem cutting across a set of barley cultivars

ii) To assess WSS larval survival rates

iii) To estimate the age-specific mortality

**Hypothesis**
Cultivars with greater host plant resistance receive fewer eggs, have greater larval mortality, and fewer cut stems.
## Materials and Methods

### Cultivar Class Use

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Class</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hockett</td>
<td>Two-row</td>
<td>Malt</td>
</tr>
<tr>
<td>Craft</td>
<td>Two-row</td>
<td>Malt</td>
</tr>
<tr>
<td>Lavina</td>
<td>Two-row</td>
<td>Forage</td>
</tr>
<tr>
<td>Haybet</td>
<td>Two-row</td>
<td>Forage</td>
</tr>
<tr>
<td>Haxby</td>
<td>Two-row</td>
<td>Feed</td>
</tr>
<tr>
<td>Champion</td>
<td>Two-row</td>
<td>Feed</td>
</tr>
<tr>
<td>Celebration</td>
<td>Six-row</td>
<td>Malt</td>
</tr>
<tr>
<td>Tradition</td>
<td>Six-row</td>
<td>Malt</td>
</tr>
</tbody>
</table>

**Design:** Randomized complete block

**Replication:** 3

**Plot size:** 1.8 m × 3.6 m

**Seed rate:** 9 gm/m²

**Planting date:** April 11, 14, and May 3rd

Experimental sites in Montana
Sampling

• First sampling: 59 days after seeding (Approximately 50% of plants have elongated stems).

• Three 0.3 m samples from each plot at weekly interval (Total nine subsequent weeks of sampling)

Dissected 35 primary stems from each bag of samples
Assessment of infestation and stem cutting

- Eggs
- Live larva
- Stubs
- Dead larva
- Live larva with hibernaculum in a stub
- Cut stems
Results
1. Assessment of infestation in barley

The image shows a bar chart with the following cultivars: Celebration, Champion, Craft, Haxby, Haybet, Hockett, Lavina, and Tradition.

The chart indicates the presence of eggs, larvae, or frass with different levels of infestation across the cultivars. The y-axis represents the percentage of infestation ± SE, while the x-axis lists the cultivars.
1.2 Mean number of eggs per stem

Cultivar

- Amsterdam_16
- Amsterdam_17
- Big Sandy_17

Mean number of egg ±SE

Cultivars:
- Celebration
- Champion
- Craft
- Haxby
- Haybet
- Hockett
- Lavina
- Tradition
1.3 Mean number of eggs per infested stem

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Amsterdam_16</th>
<th>Amsterdam_17</th>
<th>Big Sandy_17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Celebration</td>
<td>1.3</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Champion</td>
<td>1.3</td>
<td>1.7</td>
<td>1.6</td>
</tr>
<tr>
<td>Craft</td>
<td>1.4</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>Haxby</td>
<td>1.4</td>
<td>1.6</td>
<td>1.7</td>
</tr>
<tr>
<td>Haybet</td>
<td>2.3</td>
<td>2.9</td>
<td>2.7</td>
</tr>
<tr>
<td>Hockett</td>
<td>2.3</td>
<td>2.9</td>
<td>2.7</td>
</tr>
<tr>
<td>Lavina</td>
<td>1.3</td>
<td>1.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Tradition</td>
<td>1.3</td>
<td>1.7</td>
<td>1.5</td>
</tr>
</tbody>
</table>
1.4 Assessment of cut stems in infested plants

- Amsterdam_16
- Amsterdam_17
- Big Sandy_17

Cut stem percent ± SE

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Amsterdam_16</th>
<th>Amsterdam_17</th>
<th>Big Sandy_17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Celebration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Champion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Craft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haxby</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haybet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hockett</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lavina</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tradition</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary: Assessment of infestation and cut stems in barley

- Mean infestation in Celebration, Craft, Lavina, and Tradition had the lowest (~40-45%); Champion, Haxby, and Haybet had moderate (~55%), Hockett had the highest (~65%).

- Average number of eggs per stem was 0.2 to 0.8, with 1 to 2.4 eggs per infested stem.

- Mean cut stem in Craft was ~8%, Celebration, Champion, Haxby, Lavina, and Tradition was ~15%, in Haybet was 25%, and the highest was 30% in Hockett.
2. Mortality of WSS larvae

Methodology

- Dissected 105 stems per plot for each cultivar at each location.
- Categorized larval mortality into four groups:
  1) Host plant resistance (plant factor)
  2) Unknown factor
  3) Cannibalism
  4) Parasitism
2. Estimation of age-specific mortality

- Allow to estimate the age-specific mortality rate and associated morality factor in absence or presence of other mortality factors.

- M-DEC (Davis et al. 2011) was used to calculate probability of mortality of one mortality factor in absence of other factor (= also called irreplaceable mortality).

- Summer, pre-flight period, and post flight periods were chosen to assess mortality.

<table>
<thead>
<tr>
<th>Celebration</th>
<th>Life stage (x)</th>
<th>Number of individual live at x (lx)</th>
<th>Total number of death in x (dx)</th>
<th>Cannibalism (1x)</th>
<th>Cannibalism (2x)</th>
<th>Plant Factors (3x)</th>
<th>Parasitoid (4x)</th>
<th>Unknown (5x)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Egg</td>
<td>264</td>
<td>146</td>
<td>146</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Larva I</td>
<td>556</td>
<td>293</td>
<td>0</td>
<td>90</td>
<td>180</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Larva IV</td>
<td>542</td>
<td>404</td>
<td>0</td>
<td>14</td>
<td>315</td>
<td>14</td>
<td>61</td>
</tr>
</tbody>
</table>
2.1 Irreplaceable mortality of summer larvae

The diagram shows the irreplaceable mortality of summer larvae across different cultivars, categorized into Cannibalism, Unknown factor, Parasitoid, and Plant factor. Each bar represents the percentage ± SE for each cultivar, with specific mortality factors indicated by different colors: red for Parasitoid, orange for Unknown factor, purple for Cannibalism, and black for Plant factor. The cultivars include Celebration, Champion, Craft, Haxby, Haybet, Hockett, Lavina, and Tradition.
2.2 Post diapause larval status (from 2016 plots)

WSS status in pre-flight period, Amsterdam (April 2017)

- **Alive**
- **Dead Unknown**
- **Parasitism**

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Celebration</th>
<th>Champion</th>
<th>Craft</th>
<th>Haxby</th>
<th>Haybet</th>
<th>Hockett</th>
<th>Lavina</th>
<th>Tradition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alive</td>
<td>10</td>
<td>15</td>
<td>5</td>
<td>20</td>
<td>15</td>
<td>20</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Dead_Unknown</td>
<td>5</td>
<td>10</td>
<td>2</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Parasitism</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>5</td>
</tr>
</tbody>
</table>

**Stubs**

**Dead larvae and stubs**

**Pupae and stubs**
Post flight period (July 2017)

WSS status in post-flight period Amsterdam (July 2017)

Number of larva or adult

- **Alive**
- **Parasitism**
- **Dead_unknown**

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Alive</th>
<th>Parasitism</th>
<th>Dead_unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Celebration</td>
<td>60</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Champion</td>
<td>30</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Craft</td>
<td>20</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Haxby</td>
<td>15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Haybet</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Hockett</td>
<td>10</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Lavina</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Tradition</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Summary: Estimation of age-specific mortality

- Irreplaceable mortality due to plant factor(s) was the greatest percent followed by unknown factor, cannibalism, and the parasitism in summer larvae.

- Survival rate of overwintered WSS larvae and emergence of adults was the highest in Hockett and the lowest in Craft.

Hypothesis

Cultivars with greater host plant resistance receive fewer eggs, have greater larval mortality, and fewer cut stems.
Works in progress

Behavioral (antixenosis) study
i) Oviposition
ii) Y-tube olfactometer
iii) Volatile collection

Molecular analysis of antibiosis
i) Tissue collected from infested and uninfested barley plants will be used for comparison.
Acknowledgements

Committee members
David K. Weaver
Gadi V. P. Reddy
Robert K. Peterson
Jamie Sherman

Wheat stem sawfly lab members
Ben Fisher
Chris Caron
Megan Hofland
Alexander Gaffke
Rekha Bhandari
Norma Irish
Katelyn Thornton

Undergraduate laboratory staff

Funding

Growers
M. Flikkema
L. Edwards
Questions ?