Development of near real-time weather-based insect pest forecasting system for Alberta

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Introduction

• Insect Pest Management: A key issue

• Effective implementation of Pest Management Strategies:
  – Time of occurrence of key pest stages
  – Knowledge of pest phenology

• Weather-based Pest Phenology Models:
  – Can predict pest development
  – Use of Near-Real Time (NRT) Weather data provides greater precision in the prediction
Alberta Pest Modeling Project

- The project brings two disciplines together
  - Pest Management
  - Agro-meteorology and modeling

- **Project Partners:**
  - Alberta Agriculture and Forestry
    - Engineering and Agroclimatic Services Branch
    - 170+ AF standard weather stations plus ~230 provincial stations
  - Alberta Canola Producers Commission (ACPC)

- **Approach:** Integrating NRT quality controlled weather data with pests and crops phenology data
The Alberta Agriculture Weather Station Network

- Owns and operates 170 + standard Near Real Time weather stations,

- Have developed and implemented a NRT weather data quality program and reporting (via ACIS),

- Also makes use of 230+ other provincial NRT reporting weather stations data

- Developed a weather based operational agricultural risk management models that support AF programs (Drought, irrigation, crop Insurance, crop report, grass fire, weather based pest prediction)
The Alberta year round soil water and energy balance model outputs

Daily:
- Crop phenology
- Evapotranspiration
- Soil moisture (spring wheat, pasture)
- Snow accumulation
- Drought indices
- Grass fire indices
- .................
Project Objectives

1. The project aims to develop and implement a provincial near real time (NRT) weather-based crop insect-pest monitoring/prediction model for producers and industry stakeholders.

2. Development and implementation of on-farm weather monitoring systems to collect NRT weather data parameters.

3. Extensive phenology surveys for the target pest species with data collection with respect to crop hosts and natural enemies.

4. Integration of tritrophic pest models with soil water and energy balance model.

5. Development of web-based decision support system for pest management in Alberta.
In the weather based pest prediction modeling: the project looks beyond the traditional use of daily degree-days accumulation – much into the pest/insect physiological time.
Project Objectives

- On-site NRT weather monitoring
- Improved Insect Phenology Monitoring
- Improvement of current models
Phenology Models: Potential Applications

Forewarning of Pest Occurrence

Pest Prediction Models

Timing of Control Strategies

Chemical Control
- Spray window

Biological Control
- Pest-Natural Enemy Synchronization

Other IPM Tools
- Seeding date, resistant varieties

Decision Support

Pest-Agroecosystem interactions and local phenology
Project Components

Literature Component
- Pest Bioecology
- Existing Models
- Management tactics
- Pest phenology
- Diapause Needs
- Sampling strategies

Field Component
- 2014, 2015, 2016
- Trap based monitoring
- Field Surveys
- Sampling Strategies

Weather Component
- ACIS weather data
- Portable weather stations

Lab Component
- Survey Sample sorting
- Staging
- Data Entry
- Soil Core Processing

Model Component
- GDD Based Insect Phenology Models
- Data Processing
- SAS Coding
- Model testing and Validation

Existing Pest Management tactics
Cropping Systems

• Canola
• Wheat
• Alfalfa
Insect Species

- **Bertha Armyworm:**
  - Yield losses in amounts of $14 million
  - Costs for insecticidal applications amounted to $3.4 million

- **Wheat Midge:**
  - Yield losses of over $30 million CAD
  - Degradation of kernel quality

- **Alfalfa Weevil:**
  - 60-100% losses and defoliation of first cutting
Insect-Crop-Natural Enemy Interactions

- **Bathyplectus curculionis**
- **Macroglenes penetrans**
- **Banchus flavescens**

- Alfalfa Weevil System
- Wheat Midge System
- Bertha Armyworm
Study Area

Bertha Armyworm: 20 Sites

Wheat Midge: 25 Sites

Alfalfa weevil: 15 Sites
Pest Project: Weather Component

- **2014-2016:**
  - *Six weather stations: hourly weather data*
  - Two stations for each model insect species

![Diagram showing weather components]

- **Temperature**
- **R.H.**
- **Soil Temperature**
- **Solar Radiation**
- **Wind Speed**

- Irrigated Site
- Dryland Site
- Central Alberta + South
- Central Alberta + Peace
- Mainly South Alberta
Weather Station Site Selection

• On-site weather monitoring

• Proximity to ACIS network stations

• Comparison between on-site field data and nearby sites
On-site Weather Monitoring

Portable Weather Station

Hobo-based Weather Station
Modeling Thresholds

• **Wheat Midge:**
  – Post-diapause development: $6^0$ C (soil temp vs. Air temp)
  – Larval development: $8.9^0$ C (air temp)

• **Alfalfa weevil:**
  – Two different thresholds: $8^0$ C and $10^0$ C
  – $10^0$ C works the best

• **Bertha armyworm:**
  – $7^0$ C
How does onsite weather compare with surrounding network stations?

**Comparison of Temperature**

\[ y = 1.0329x + 0.9408 \]

\[ R^2 = 0.9883 \]

**Comparison of Relative Humidity**

\[ y = 0.7756x + 5.9743 \]

\[ R^2 = 0.7385 \]
Comparison of R.H. and Precipitation

- **Graph 1:** Comparison of R.H. and Precipitation over the period from 1-May to 12-Jun. The graph shows the daily precipitation at two sites: Pest Station and Bow Island IMCN, along with the difference in humidities.

- **Graph 2:** Average daily precipitation at Pest Station (Precip + Irrigation) and the difference in the humidities at two sites, expressed as a percentage. The data is available from 29-Apr to 10-Jun.

- **Key:**
  - Pest Station
  - Bow Island IMCN
  - Difference in Humidities
  - Average Daily Precipitation (ml)
  - Difference in the Humidities at two sites (Expressed as %)

- **Dates:**
  - 1-May to 12-Jun
  - 29-Apr to 10-Jun
Bertha Armyworm
Wheat Midge Life Cycle

Adults

Larvae

Overwintering Stage

Cocoons

Spring emerged larvae

Post-diapause larvae
Alfalfa Weevil
Pest Project: Crop Phenology Component

Location: Flagstaff County, Erions Field
Week of: 27 June-1 July 2016

Field ID: Pest_Erions _Wheat2016

Crop Type: Wheat (dry)

Sampled by: Justina Nibourg

LLD: NW-11-40-13w4

Date picture taken: 29 June 2016

Crop Growth Stage: Heading
Existing Monitoring Systems: Wheat Midge

Wheat Midge:

• **Pheromone trap counts**
  – Setup at June 20- observations reported weekly for two weeks during peak adult activity

• **Fall soil sampling:**
  • Soil cores to estimate numbers/m² of midge cocoons to predict fields with midge activity next year
Fall Sampling: Tool for next year

Prediction for next season based on soil sampling results

Use of nominal threshold values to risk and identify hot-spot

A great tool to find areas with midge infestation but not a predictive tool
Pheromone Trap Counts: Current Season

- Weekly trap counts reported from province
- Provide emergence pattern for ONLY MALES and no information on females
- Peak male activity is considered to coincide with female activity but exact female activity is not known

Pic: Pheromone traps in the field
Current Knowledge Gaps: Wheat Midge Model

• What parameters are not known?
  – Female oviposition activity of wheat midge
  – Activity of overwintered larvae
  – Beginning and end of male and female flight patterns
  – Active oviposition period window
  – Initiation of egg hatch and peak larval activity in the field
  – Emergence and activity of natural enemy: *M. penetrans*
How did we address this gap?

• We refined existing protocols to include sampling on:
  – Postdiapause larvae
  – Emergence and activity of both MALES AND FEMALES
  – Sampling of eggs
  – Sampling of larvae, identification of instars
  – Identification of crop stages for wheat
  – Sampling of natural enemy activity
Wheat Midge Phenology

Site Pairing

Wheat of current year
Wheat past year-canola current year

Emergence Traps
Pheromone Traps
Yellow sticky Traps
Quarter section – Wheat in 2016
Location- Lavoy, AB

Emergence traps
Pheromone traps
Yellow sticky traps

N ↑

2015 Wheat

50 m

2016 Wheat

Portable Weather Station

50 m

54 m
How the improved sampling filled the knowledge gap?

**Lavoy, AB-2015**

- Mean No. Midge/Trap/Week
- Sampling Date
- 10% Emergence
- 50% Emergence
- 90% Emergence

**Falher, AB-2015**

- Mean No. of Midges/Card
- Critical Window for Oviposition
- Site 1 Portable Station
- Site 2 (Hobo)
- site3 (Hobo)

**Males**
- Site 1 Portable Station
- Site 2 (Hobo)

**Females**
- Males
- Females

**Sampling Date**
- 15-Jun
- 22-Jun
- 29-Jun
- 6-Jul
- 13-Jul
- 20-Jul
- 27-Jul
- 3-Aug
- 10-Aug
- 17-Aug
- 24-Aug
- 25-May
- 8-Jun
- 15-Jun
- 22-Jun
- 29-Jun
- 6-Jul
- 13-Jul
- 20-Jul
- 27-Jul
- 3-Aug
- 10-Aug
- 17-Aug
- 24-Aug
Understanding Critical Events

Mean No. of Midges/Card vs. Sampling Date

- Males
- Females
- Pheromone-Males ONLY
- Parasitoid

Sampling Date:
- 25-May
- 1-Jun
- 8-Jun
- 15-Jun
- 22-Jun
- 29-Jun
- 6-Jul
- 13-Jul
- 20-Jul
- 27-Jul
- 3-Aug
- 10-Aug
- 17-Aug
- 24-Aug

Critical Events:
- Wheat Midge
- Natural Enemy
- Midge Eggs
Wheat Midge Phenology: Precipitation has a role in predicting adult emergence patterns

Rainfall Effect on Post-Diapause Larvae

\[ y = 3.4286x - 19.286 \]
\[ R^2 = 0.7726 \]
Soil Temperatures influence post-diapause development

\[ y = 0.242x + 12.458 \]

\[ R^2 = 0.6626 \]

Efect of soil temperatures between 1 May-30 June on post diapause development
Wheat Midge Emergence: Yellow Sticky Card based monitoring

Better approach over using pheromone traps: data on both males and females
Wheat Midge Larval Activity Patterns at Lavoy, AB in 2015 in a dryland spring wheat field

Larval development: 303-580 Degree Days at 8.9º C
Alfalfa Weevil: Current Approach

- Monitoring typically initiated in mid to late May, with increasing frequency of scouting in June as the crop develops.
- Following threshold’s used:

<table>
<thead>
<tr>
<th>Stage or event</th>
<th>Degree days (Base 9°C)*</th>
<th>Weevil activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg hatch</td>
<td>155-167</td>
<td></td>
</tr>
<tr>
<td>Instar 1</td>
<td>176-206</td>
<td>Light leaf feeding</td>
</tr>
<tr>
<td>Instar 2</td>
<td>218-243</td>
<td>Major leaf feeding</td>
</tr>
<tr>
<td>Instar 3</td>
<td>260-280</td>
<td></td>
</tr>
<tr>
<td>Instar 4</td>
<td>306-331</td>
<td></td>
</tr>
</tbody>
</table>

*Peak alfalfa weevil developmental times from Harcourt (1981) and Beazay et al. (2013)
Alfalfa Weevil: Current Knowledge Gaps

• How early does the adult emergence occur?

• When does oviposition start, for how long and when does first larva appear?

• Does phenology differ between seed and forage purpose crops or do management practices influence AW occurrence?

• How well is parasitoid activity synchronized with larval activity?
Alfalfa Weevil: How did we bridge knowledge gap?

• Early scouting for adults (starting from April 1)
• Improved protocol for egg sampling (this stage is missing)
• Improved monitoring of larval activity: beginning, peak, end
• Continued scouting in second cut crop and recording of larvae until end of August
• Monitoring of teneral adults
Alfalfa Weevil Phenology: Stettler, AB

Sampled early

Stettler-Site 1 (Portable Station)

- Adults/sweep
- Egg
- Larve-small
- Larvae-Big

Sampled Late

Stettler-Site 2 (Hobo Station)

- Adults/sweep
- Egg
- Larve-small
- Larvae-Big
Alfalfa Weevil Development

Larval activity continues after first cut

Sampling Date

Average Individuals/Sample

- Adults/sweep
- Egg
- Larve-small
- Larvae-Big

First Cut
Alfalfa Weevil: Observed vs. Theoretical
Bertha Armyworm: Adult Trap Captures between 2012-2014

The graph shows average adult captures of bertha armyworm in pheromone traps in three counties in Alberta with data from 35 townships in each county over a four year period from 2012-2014.

Collapse of bertha armyworm adult populations indicate declining phase of an outbreak cycle.

(Picture Courtesy: Shelley Barkley, CDC South, Brooks)
Modeling Component

- Will involve insect phenology modeling in response to weather parameters (R.H, precipitation, temperature, wind speed, solar radiation etc.)
  - GDD and crop phenology ongoing
  - Stage structured insect developmental modeling
Model validation

• Model validation: comparing field developmental requirements with lab based theoretical requirements
**Wheat Midge Status**

**Week of: July 7-15**

**Observed Life Cycle of Wheat Midge**

- **Eggs**
- **Larvae**
- **Cocoons (inside soil)**
- **Cocoons (inside soil)**
- **Pupae (on soil surface)**
- **Adults**

**Stages currently being observed**

**Picture Courtesy: Shelley Barkley, Government of Alberta**

**July 7-July 15**

**Add STAGES**
- Overwintering cocoons in soil
- Termination of diapause
- Post-diapause development and pupae
- Onset of adult emergence
- 10% adult emergence
- 50% adult emergence
- 100% adult emergence
- 0-214
- 225-450
- 477-700
- 700-900
- 900-1200
- 1200-1600
- 1600-2000

**Map:** Wheat Midge Life Stages and Accumulated Degree Day (ADD) since April 1 requirement, for development using 6°C base temperature

**Regions:** Peace Region, Northern Region, Central Region, Southern Region

**Color Code:**
- Red: Overwintering cocoons in soil
- Orange: Termination of diapause
- Yellow: Post-diapause development and pupae
- Green: Onset of adult emergence
- Dark Green: 10% adult emergence
- Medium Green: 50% adult emergence
- Light Green: 100% adult emergence
Life Cycle of Alfalfa Weevil

Week of: July 7, -July 15, 2016

Overwintered Adults

Natural enemy activity

Stages currently being observed

Early Instars

Late Instars

Teneral Adults

Overwintering

Adults

Eggs

May

June

July

August

April

Alfalfa Weevil Status

Alfalfa Weevil Life Stages and Accumulated Degree Day (ADD) since April 1 requirement, for Development using 10 C base temperature

July 07, 2016

ADD Life Stage (Feeding Activity)

0 - 100 Adult's active and feeding

100 - 200 Early instar larvae

200 - 300 Onset of late instars

300 - 400 Onset of teneral adults

400 - 500 Peak Emergence of teneral adults (no eggs laid)

Peace Region

Northern Region

Southern Region

Picture Courtesy: Shelley Barkley, Government of Alberta
Pest Project: Progress

• Two field seasons of data collection

• 65+ sites sampled for the insect models

• On-site monitoring for weather parameters at 16 sites: 6 full weather stations + 10 hobo stations

• Improvement in insect phenology protocols
Our work

• 2100 yellow sticky cards
• 1200 White sticky cards
• 1200 emergence trap cards
• 3000+ wheat heads
• 500 soil samples across Alberta
Pest Project: End Goal

• Development of provincially applicable pest models based on NRT weather data

• Model validation and development of web-based decision support system for producers, industry and pest managers

• Potential for collaborations for expertise development in designing decision support systems
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