Early-season flooding for insect pest control

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A century of flooding

• **1911**: the WSCGA annual meeting minutes detail the use of flooding to control “miller moths.”

• **The rub**: growers need to strike a balance between pest suppression and crop loss due to flooding injury.

• **Our objective**: document the degree of pest suppression and plant damage associated with a 30-40 hour spring flood, applied as close to bloom as possible
Hypotheses

• **Black-headed fireworm** (BHFW) and **cranberry fruitworm** (CFW) populations will be suppressed by the floods, such that densities will be equivalent to unflooded, sprayed beds.

• **Sparganothis** populations (Sparg) will not be suppressed (based on past lab data).

• **Vines will be “set back”** by the floods (based on years of observation by growers).
Large-scale field study initiated

- 46 beds across 11 Wisconsin marshes
- Replicated by site: 23 pairs of flooded/non-flooded beds
- 3 varieties: *Ben Lear*, *Stevens*, and *GH1*
Phenological stage: 90-95% roughneck (early hooking at bed edges)
Complete submergence
Flood timing needed to be as late as possible (to allow BHFW eggs to hatch)

Site-specific DD accumulations ranged from 514 to 759 DDs (mean: 580 DDs)
## Critical dates and DD totals

<table>
<thead>
<tr>
<th>Site</th>
<th>BL</th>
<th>ST</th>
<th>GH1</th>
<th>Water up</th>
<th>Drained</th>
<th>Duration</th>
<th>BHFW DD s</th>
<th>GDDs</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>5/30/2011</td>
<td>6/1/2011</td>
<td>46</td>
<td>418</td>
<td>594</td>
</tr>
<tr>
<td>8</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>6/1/2011</td>
<td>6/2/2011</td>
<td>42</td>
<td>466</td>
<td>650</td>
</tr>
<tr>
<td>Total/Ave</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>37.5</td>
<td>418.81</td>
</tr>
</tbody>
</table>
Field sampling methods

- Water sampling
  - Dissolved $O_2$
  - Temperature
  - Turbidity
  - pH
  - Hardness

- Insect sampling
  - Sweeps
  - Pheromone trapping
  - Berry collections
  - Dvac’ing
  - “Trash” collections

- Plant sampling
  - Chlorophyll
  - Upright lengths
  - Hooks
  - Flowers
  - Harvest
Flood durations ranged from 31 to 48 hours—temperature and dissolved O₂ were measured at start/end of floods
# Wisconsin floodwater characteristics

<table>
<thead>
<tr>
<th></th>
<th>Initial</th>
<th>Final</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>17.90 (64.2°F)</td>
<td>18.64 (65.4°F)</td>
<td>0.066</td>
</tr>
<tr>
<td>DO (ppm)</td>
<td>8.18</td>
<td>7.70</td>
<td>0.048</td>
</tr>
<tr>
<td>DO (% saturation)</td>
<td>86.20</td>
<td>81.81</td>
<td>0.140</td>
</tr>
</tbody>
</table>

Cool, well-oxygenated water flooded the marshes. Cool, oxygenated water drained out, but outflow was significantly less oxygenated than inflow.
Initial

Initial temperature vs. Initial DO ppm

Initial DO ppm = 10.414 - (0.124 * Init temp)
R² = 0.238    P < 0.001

Final

Final DO vs. Final Temp

Final DO ppm = 11.426 - (0.200 * Final temp)
R² = 0.163    P = 0.005
(Some beds consumed more \( \text{O}_2 \) than others)
Insect sampling

sweeps
pheromone trapping
berry scoring
Black-headed fireworm (BHFW): sweeps Week 1 post-flood

<table>
<thead>
<tr>
<th></th>
<th>Flooded</th>
<th>Non-flooded</th>
</tr>
</thead>
<tbody>
<tr>
<td>BHFW larvae (mean per bed)</td>
<td>0</td>
<td>40</td>
</tr>
</tbody>
</table>

NS
BHFW: sweeps
Week 2

Black-headed fireworm

BHFW larvae (mean per bed)

Flooded Non-flooded

NS
Pheromone-based trapping

Black-headed fireworm

Mean no. BHFW adults (per cranberry bed)

**

Flooded Non-flooded
Sparganothis: sweeps
Week 1

Sparganothis fruitworm

<table>
<thead>
<tr>
<th></th>
<th>Flooded</th>
<th>Non-flooded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean per bed</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Sparganothis: sweeps

Week 2

Sparganothis

NS

Sparg larvae (mean per bed)

Flooded
Non-flooded
Pheromone-based trapping

Sparganothis fruitworm

Mean no. cranberries (per 200 berries)

- Flooded
- Non-flooded

NS
Cranberry fruitworm

Mean no. CFW adults (per cranberry bed)

Pheromone-based trapping
CFW Berry-scoring: 200 fruit/bed
Cranberry fruitworm (CFW)

Flooded - Non-flooded
Mean no. cranberries (per 200 berries)

<table>
<thead>
<tr>
<th></th>
<th>Flooded</th>
<th>Non-flooded</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFW present</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Damaged by CFW</td>
<td>4</td>
<td>8</td>
</tr>
</tbody>
</table>

NS
Plant sampling
Early-season:

<table>
<thead>
<tr>
<th>Week</th>
<th>Measurement</th>
<th>Flooded</th>
<th>Non-flooded</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week 1:</td>
<td>Chlorophyll (SPAD)</td>
<td>9.40</td>
<td>10.84</td>
<td>0.029</td>
</tr>
<tr>
<td>Week 2:</td>
<td>Upright lengths (mm)</td>
<td>45.36</td>
<td>46.65</td>
<td>0.342</td>
</tr>
<tr>
<td>Week 3:</td>
<td>Hooks/upright</td>
<td>2.58</td>
<td>2.72</td>
<td>0.420</td>
</tr>
<tr>
<td>Week 4:</td>
<td>Hooks + Flowers/upright</td>
<td>3.83</td>
<td>4.16</td>
<td>0.016*</td>
</tr>
</tbody>
</table>
Variety: $P < 0.001$
Flood: $P < 0.001$
Var x Flood: $P = 0.487$
Greenhouse experiments:
What is the submergence tolerance of cranberries?
Potting up overwintered sods
<table>
<thead>
<tr>
<th>Duration</th>
<th>Cold</th>
<th>Warm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 hours</td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>48 hours</td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>96 hours</td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
</tr>
</tbody>
</table>
Dissolved O$_2$

Variety

<table>
<thead>
<tr>
<th></th>
<th>Cold</th>
<th>Warm</th>
</tr>
</thead>
<tbody>
<tr>
<td>GH1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dissolved Oxygen (% saturated)

Cold

Warm
Dissolved Oxygen (% saturated)

- GH1
- S1
- BL

Varieties: GH1, S1, BL

Temperature: Cold, Warm

Dissolved Oxygen ( % saturated )

0 20 40 60 80 100

GH1: Cold 80\%, Warm 70\%
S1: Cold 100\%, Warm 80\%
BL: Cold 40\%, Warm 30\%
Upright length at 7 DAT

Temperature

Variety

Duraction: Cold regime

variety
Hooks per upright at 49 DAT

Temperature

Variety

GH1  ST  BL

0.0  0.2  0.4  0.6  0.8  1.0  1.2  1.4  1.6  1.8

Cold  Warm

*

Duration: Cold regime

Variety

GH1  ST  BL

0 hrs.  48 hrs.  96 hrs.

**
Dissolved Oxygen (% saturated)

Variety

GH1  ST  BL

Cold  Warm

Dissolved Oxygen (°C saturated)

0  20  40  60  80  100

Variety
What did we learn?

1) **GH1 & Stevens**: no effect at 48 or 96 hrs of flooding
2) **BL**: negatively affected at 48 and 96 hrs of flooding
3) **BL**: dissolved oxygen half that of **GH1** and **Stevens**

<table>
<thead>
<tr>
<th>Conclusion</th>
<th>New question</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>In cold water, dissolved oxygen level—rather than duration of flood—determines effects on plant.</em></td>
<td><em>Does age of bed affect oxygen levels in flood water?</em></td>
</tr>
</tbody>
</table>
Harvest
## Harvest weight (grams/ft.²)

<table>
<thead>
<tr>
<th></th>
<th>Flooded</th>
<th>Non-flooded</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total weight (g/ft²):</td>
<td>204.3</td>
<td>203.0</td>
<td>0.934</td>
</tr>
<tr>
<td>Berry count (per ft²):</td>
<td>151.5</td>
<td>153.1</td>
<td>0.900</td>
</tr>
<tr>
<td>Per-berry weight</td>
<td>1.34</td>
<td>1.32</td>
<td>0.541</td>
</tr>
</tbody>
</table>
Harvest breakdown

Harvest weight

Mean harvestable crop (gram/sq. ft)

Variety

ST
GH1
BL
Overall

Flooded
No Flood
Harvest breakdown

Harvest weight

Mean harvestable crop (gram/sq. ft)

Variety:
- ST
- GH1
- BL
- Overall

Condition:
- Flooded
- No Flood

Berry count

Berries / sq.ft.

Variety:
- ST
- GH1
- BL
- Overall

Condition:
- Flooded
- No Flood
Does the plant compensate for early-season stresses?

### Early-season

- **ST**
- **BL**
- **GH1**

### Late-season

**ST**

- Flooded
- No Flood

**GH1**

- Flooded
- No Flood

**BL**

- Flooded
- No Flood
Does the plant compensate for early-season stresses?

Hawker & Stang (1985)
Conclusions: 2011 field work

Floodwaters:

• Wisconsin’s spring floodwaters are cool and well-oxygenated.

• After 30+ hours of flooding, floodwaters warm up and lose oxygen (likely via plant/microbial respiration).
Conclusions: 2011 field work

Insects:

• BHFW in flooded beds was hit hard.
• Sparg and CFW were not significantly reduced.
• Interesting trend with CFW infestation.
Conclusions: 2011 field work

**Plants:**

- Flooded beds endured stress.
  - reduced chlorophyll (immediate effect)
  - slower growth (early-season upright length)
  - reduced flowers/upright (4 weeks post-flood)

- Harvest data suggest flooding stress was minimal by Sept/Oct.
  - Overall, no significant effect of flooding on crop

**Economics:**

- Can a prolonged (30+ hrs) spring flood replace 1-2 pre-bloom sprays?
Wisconsin cranberry entomology

• WI cranberry grower-cooperators
• Cranberry consultants
## Harvest weight (grams/ft.²)

<table>
<thead>
<tr>
<th></th>
<th>Flooded (g)</th>
<th>Non-flooded (g)</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall:</td>
<td>204.3</td>
<td>203.0</td>
<td>0.934</td>
</tr>
<tr>
<td>Ben Lear</td>
<td>165.6</td>
<td>183.6</td>
<td>0.742</td>
</tr>
<tr>
<td>Stevens</td>
<td>237.8</td>
<td>209.7</td>
<td>0.180</td>
</tr>
<tr>
<td>GH1</td>
<td>179.7</td>
<td>222.6</td>
<td>0.101</td>
</tr>
</tbody>
</table>
## Individual berry weight (grams/berry)

<table>
<thead>
<tr>
<th></th>
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<th>Non-flooded</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall:</td>
<td>1.34</td>
<td>1.32</td>
<td>0.541</td>
</tr>
<tr>
<td>Ben Lear</td>
<td>1.20</td>
<td>1.07</td>
<td>0.182</td>
</tr>
<tr>
<td>Stevens</td>
<td>1.41</td>
<td>1.46</td>
<td>0.059</td>
</tr>
<tr>
<td>GH1</td>
<td>1.32</td>
<td>1.25</td>
<td>0.558</td>
</tr>
</tbody>
</table>
## Berry count (berries/ft.²)

<table>
<thead>
<tr>
<th></th>
<th>Flooded</th>
<th>Non-flooded</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall:</strong></td>
<td>151.5</td>
<td>153.1</td>
<td>0.900</td>
</tr>
<tr>
<td><em>Ben Lear</em></td>
<td>135.9</td>
<td>164.4</td>
<td>0.486</td>
</tr>
<tr>
<td><em>Stevens</em></td>
<td>169.7</td>
<td>143.8</td>
<td>0.106</td>
</tr>
<tr>
<td><em>GH1</em></td>
<td>137.2</td>
<td>177.2</td>
<td>0.067</td>
</tr>
</tbody>
</table>