Threats to Food Security and Agricultural Economy from Increased Propagation Risk of Pathogens *Phytophthora* *spp.* and *Fusarium* *spp.* due to Climate Change

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Approach

• Scientific Background
  - Climate Change
  - Pathogens

• Direct Impacts on Farmers

• Local Resources

• Vermont Issue
Methods

- Professors
- NOFAVT
- Farmers
- Extension Services

- UVM library database

- Keywords: *Phytophthora capsici*, *Fusarium graminearum*, climate change, Vermont, meteorology, *Trichoderma viride*, mitigation, economic impacts, agriculture, crop loss, food security
Agricultural Economy in Vermont

FACTS

- 7,000 farms accounting for 17,000 Vermont jobs
- Final crop output of $107,401
- Agricultural sector output (including crops, animals, and services) of $338,465
- Net farm income of 2010 was $156,015 after paying farm employees, providing farm with proper equipment, etc.
- 3% of the average Vermonters diet consists of locally-grown food
- An increase to 10% would bring an additional $135 million dollars/year to the state economy
So What's the Problem?

A changing climate is increasing annual temperatures, and increasing precipitation events, creating many challenges for the Agricultural sector

Change in growing season length
Effect on crop loss and field productivity
Food Security is the availability and one’s access to food

Food Insecurity indicates reduced quality, variety, or desirability of diet, resulting in a fraction of the population suffering from hunger

14% of all Vermont Households are food insecure
6% of all Vermont Households are food insecure with hunger

These percentages rise with an increase in crop loss
USDA Measure of Food Security

High Food Security

Marginal Food Security

Low Food Security

Very Low Food Security
Hurricane Irene

Deposited a foot of rain as traveled along spine of Vermont's Green Mountains

Widespread flooding, erosion, and damage to crops and property

476 farms impacted
  7,200 acres of hay
  6,000 acres of corn
  1,750 acres of pasture
  1,400 acres of sugarbush
  600 acres of vegetables and fruits
  225 acres of soybeans

Total damage to 9100 acres losses by farms at $20 million total
Government and Agency Efforts

Vermont Farm Fund
Emergency Loan Program
Innovative Loan Program
Vermont Community Foundation's Farm Disaster Relief Fund
Northeast Organic Farming Association
USDA Risk Management Agency
Non Insured Crop Disaster Assistance Program
Emergency Conservation Program
Using climate data to determine expected future conditions and how they will affect disease spread:

- Research often focuses on one atmospheric event affecting pathogens & hosts
- Might be more useful to look at overarching climate trends that will define future growing seasons
- What are Vermont's expected future climate conditions?
- What are favorable conditions for *Fusarium* and *Phytophthora*?
- What are favorable conditions for host plants?

Climate Change and Plant Disease Management, Coakley et al.
http://www.heavypetal.ca/uploads/archived/tomato_LG.jpg
http://aesop.rutgers.edu/~horteng/hightunnel6.htm
Expected future climate of Vermont...

- More heavy precipitation events and less light ones
- Higher temperatures that will be more predictable in summer than in winter months

Coakley et al, 1999
By 2050 - average annual temperatures will be 3 to 4 degrees F higher (larger increases in winter than summer)

Winter temperatures in Vermont vary twice as much as summer temps.

Result = increasing length of growing season

Higher temperatures increase pathogen fecundity during reproductive stages
Increased Heavy Precipitation

- 15-20% increase in precipitation in Vermont in the past 50 years
- 67% increase in precipitation during heavy rainfall events in the Northeast
Increased CO$_2$ Levels

For 650,000 years, atmospheric CO$_2$ has never been above this line ... until now.
Increased CO$_2$ levels can:

- Increase leaf hardiness
  - creating more food for diseases, including blights like *Phytophthora capsici* and *Fusarium graminearum*; combined with increased humidity - better conditions for blight spread
  - or- increasing host resistance to pathogens (beneficial)

- Slow down litter decay. In combination with warmer winters, this would mean better survival for pathogens living on crop residue and higher initial inoculum ready to infect spring crops
Non-organic growers might have an easier time preparing for and dealing with blight...
Organic growers might have more difficulty finding solutions...

- But even for farmers that use fungicides, heavier precipitation in a changing climate will limit effectiveness of these chemicals.
- Need to watch out for increased use of chemicals due to precipitation wash-off and extended growing seasons.

http://www.youtube.com/watch?v=lV8UleIKvIA
Skip to 1:45 for this Northeasterner’s mitigation technique
http://www.eatlocalchallenge.com/2006/06/upick_ueat_ulo.html
Phytophthora capsici

Fungus Target? Table 1. LOTS OF VEGGIES ARE AT RISK. Most information is available on peppers and cucumbers

Damage? Can rot ANYTHING and EVERYTHING…root, stem, crown, fruit

(Northeast Vegetable and Strawberry Pest Identification Guide 2012)
Fruit Rot

(Northeast Vegetable and Strawberry Pest Identification Guide 2012)
Crown Rot

http://www.youtube.com/watch?v=RB2K7H8qKgA

(Northeast Vegetable and Strawberry Pest Identification Guide 2012)
Phytophthora capsici Blight

Total collapse of pumpkin crop in low areas of field infected with Phytophthora. NY
Phytophthora capsici blight
Life Cycle?
oospores (protected by a coating of b-glucan and cellulose)...
sporangia (hold 20-40 zoospores)...
zoospores (THEY CAN SWIM)...
sexual reproduction...
more oospores, etc. (Zitter 1989)
Range?
New Mexico in 1922
Outbreaks common in North Carolina, California, Florida, and Georgia
Starts to move to New Jersey and New York in 1940s
MOVIN’ ON UP! In Massachusetts, next step is Vermont!

Favorable conditions?
25-30°C (77-86°F)
wet/saturated soil (Zitter 1989)

Problem?
Climate Change = increased precipitation and warming = paradise for Phytophthora! (Petzoldt and Seaman 2006)
Moves via water…zoospores swim and other life cycle stages can detach from host plant and move when in contact with water = rain splash, irrigation, rain, etc. (Gevens et al. 2007)
Documented economic losses (Michigan) $300,000 dollars of pickling cucumbers and $40,000 of processing tomatoes (Hausbeck and Lamour 2004)

VIDEO…not as exciting as gasland…

http://veggies.msu.edu/Research/P.capsici_water1.AVI
Mitigation?
Mulching…no polyurethane (plastic) mulch without raised beds, or use straw or other substrates that will adsorb water to limit spread and rain splash

Irrigation…need well drained fields, watch out for contaminated irrigation water, irrigate sparingly, especially close to harvest

Bed structure…dome shaped beds to allow better water runoff

Fungicides…not proven to work effectively on their own…there are many isolates (genetic varieties) of Phytophthora so one fungicide may work in one region but not another

Using plant varieties that are genetically resistant…ex: Paladin (bell pepper)

Avoid contaminated soil, and practice preventative measures to avoid cross contamination (like with cooking)…wash equipment, shoes, etc. when on the farm…

(Ristaino and Johnston 1999 and University of Massachusetts Extension 2012)
Mitigation: Raised Beds
Influence of excess moisture on the occurrence of Phytophthora blight of pepper even on raised beds-result of irrigation main leak
“Phytophthora blight of cucurbits, caused by *Phytophthora capsici*, is the **most important disease** of cucurbits in Illinois. It occurs in cucurbit fields every year, causing **up to 100% crop loss**. Phytophthora blight of cucurbits is expected to occur widely in Illinois in 2009, as it is a **wet season**. The disease causes seedling death, crown infection, vine lesions, and fruit rot.”  

(http://ipm.illinois.edu/ifvn/volume15/frveg1509.html)

Not from a scientific paper, but observations from the field can be just as important, as with the concept of Traditional Ecological Knowledge (TEK)  

Hits close to home for me, and I have no doubt that it could become a major problem in Vermont
Fusarium graminearum

- Causes Fusarium Head Blight
- Infects wheat and barley
- Reduce grain quality, decrease yields, produces mycotoxins with human and animal health impacts
Symptoms
Range

- World-wide, re-emergence in past twenty years.

Favorable Conditions

- If wet, humid weather and temperatures ranging from ~ 65- 85°F, seven days prior to anthesis.
- Timing of rainfall affects incidence more rather than the amount of rainfall at anthesis.
- Weather leading up to anthesis is most determining factor.

Problem

- Over winters in residues left on the field
- More likely to get infected at anthesis (flowering).

http://www.wheatscab.psu.edu/riskTool_2011.html
Fusarium Head Blight Disease Cycle

Courtesy A. Schilder and G. Bergstrom
Mycotoxins

- Produces deoxynivalenol (DON) and zearalenone

- In animals it can cause losses of productivity, reduced weight gain and immunosuppression

- NOEL= .1 mg/kg of body weight per day

- In Humans it can cause nausea, vomiting, headache and fever.
<table>
<thead>
<tr>
<th>FDA Advisory Levels for DON (parts per million)</th>
<th>End-Use Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ppm</td>
<td>Finished grain products for human consumption</td>
</tr>
<tr>
<td></td>
<td>Grain and grain by-products destined for swine and other animal species (except cattle and chickens); not to exceed 20% of the diet for swine, and not to exceed 40% for other animal species.</td>
</tr>
<tr>
<td>10 ppm</td>
<td>Grain and grain by-products for ruminating beef and feedlot cattle older than 4 months and for chickens; not to exceed 50% of the diet.</td>
</tr>
</tbody>
</table>
Mitigation of *Fusarium graminearum*: Farming Practices

- Clear residue after each season
- Planting dates
- Resistant Varieties

- Mulching
- Irrigation
- Bed structure
- Cover crops
Mitigation of *Fusarium graminearum*: Altering Soil Conditions

- High pH value
- High clay content
- Large amount of organic matter
- Antagonistic bacteria
- Actinomycetes
Mitigation of *Fusarium graminearum*: Fungicides

- Issue of field conditions
- Propagation materials and dip-treating
- Constantly introduced and removed from the market
- Increase in pathogens = increase in application
Mitigation of *Fusarium graminearum*: Genetic Modification

- Controversial
- Studies with traits from wheat
- Faster responses to challenge pathogen
Mitigation of *Fusarium graminearum*: Biocontrol Agents

- Environmentally-friendly
- *Trichoderma* spp
- *Trichoderma harzianum*
- Enhance germination, grain yields
- Non-pathogenic *Fusarium oxysporum*
- Induced systemic resistance
Current Mitigation: resource intensive and short term

Goal: long-term solution options that are focused on community and information collection and dispersal

Task Force:
generate a database of *P. capsici* and *Fusarium* outbreaks

create a model to predict future spread and infestation rates throughout the Northeast

community outreach through farming extension programs

regular visits to farms to monitor and receive reports from farmers on *P. capsici* and *Fusarium* outbreaks

phone hotline, email system, and discussion forum

Also:
Collect data on about formations and characteristics of farming landscape that would be of high risk to pathogen infection in precipitation or flood events

implement sustainable soft-engineering features
Climate Matching Tools

“Climate-based model of habitat suitability”

- Match Climates (compares climate of multiple locations to look for similarities)
- or -
- Compare Locations (predict possible distributions of species using current climate data)

Limitations:
- Uses climate as main and sometimes only predictor of species distribution
- No current climate matching system incorporates extreme events, based on averages

http://www.climatemodel.com/climex.htm
http://www.nappfast.org/ASPRM%20web/presentations/Kriticos.pdf