Insect Thresholds

Janet Knodel and Patrick Beauzay

NDSU Extension Entomology

Robert Koch, University of Minnesota

NDSU | EXTENSION

Advanced Crop Advisers Workshop

February 11-12, 2025

IPM Definition

- "IPM is a <u>sustainable</u> approach to managing pests: by combining
- **biological,**
- **cultural,**
- **physical,**
- **and chemical tools**
- in ways that minimize economic, health, and environmental risks"

(Source: National IPM Network)

NDSU EXTENSION

PP863 (Revised)

NDSU photo

IPM BASICS

Integrated Pest Management in North Dakota Agriculture

Janet J. Knodel, Extension Entomologist
Patrick Beauzay, State IPM Coordinator and Research Specialist
Andrew Friskop, Extenion Plant Pathologist, Cereal Crops
Samuel Markell, Extension Plant Pathologist, Broadleaf Crops

What is IPM?

Integrated pest management (IPM) is an integral part of North Dakota's agriculture. IPM is a program to manage pests that combines a number of strategies to reduce pest risks while protecting the environment, wildlife and people. The goal of IPM in agriculture is to produce safe, abundant and affordable food, feed and fiber. The target pests generally are weeds, insects, and disease-causing organisms such as fungi, bacteria, viruses and nematodes.

IPM Strategies

IPM incorporates several pest management strategies to maintain crop profitability, minimize pest populations, and minimize environmental and health impacts. Approaches are aimed at preventing the pest from occurring in an area, using avoidance techniques to minimize the chance of pest development, monitoring for pests in the field, identifying pests properly, assessing pest populations and determining economic threshold levels, and using pest management strategies to mitigate economic crop loss. The following strategies may be used in various combinations to accomplish these goals:

Cultural Strategies

- **Using good crop rotations** between cereal and broadleaf crops, because these different crops often have dissimilar pests and crop rotation breaks the life cycle of pests. For example, planting a nonhost crop such as wheat or barley after soybean can significantly reduce egg levels of soybean cyst nematodes.
- **Choosing planting dates that may minimize risk** of certain pests, such as later fall plantings of winter wheat, to reduce the risk of wheat streak mosaic virus.
- **Using sanitation techniques** to remove debris from the field or removing cull piles of diseased potatoes that may harbor diseases or insect pests.
- **Planting pest-free seed**, such as certified seed that is free of seed-borne diseases and weed seed.
- **Planting trap crops**, such as a field margin of a susceptible variety or host crop that concentrates a pest in the trap area. This can result in treating a smaller area with a pesticide. For example, a susceptible chemically preferred variety of hard red spring wheat can be planted around the field edges for wheat stem sawfly.
- **Adjusting harvest date** to minimize crop damage, such as harvesting early to minimize damage from alfalfa weevil.

Host Plant Resistance

- **Selecting varieties with resistance** to various pests, such as resistant varieties of hard red spring wheat for leaf rust.

Mechanical Strategies

- **Cultivation** may be used to reduce weed pressure.
- **Hand weeding** may be used to reduce weed populations or individual weeds.
- **Screens or physical barriers** often are used in home gardening and landscaping but seldom in commercial agriculture.
- **Tillage practices** may be used to bury or expose pests or pest-infested residue.

Physical Strategies

- **Heat**, such as burning of residues or soil pasteurization.
- **Cold and dry storage** prevents the development of mold and insects.

NDSU EXTENSION

North Dakota State University, Fargo, ND
Revised June 2018

Principles of Integrated Pest Management

1. Identify: Know your foe and know your friend and know its life cycle

2. Scout: Have to know what is out there before making management decisions

3. Integrate: Employ different sustainable strategies to manage pests instead of relying on one unsustainable approach

Lady Beetle
(Predator)

Spotted cucumber beetle
(Pest)

IPM Toolbox

Pest Identification

Pest Monitoring

Economic Thresholds

Predictive Models

Prevention

Cultural Control

Host Plant Resistance

Biological Control

Chemical Control

Intervention

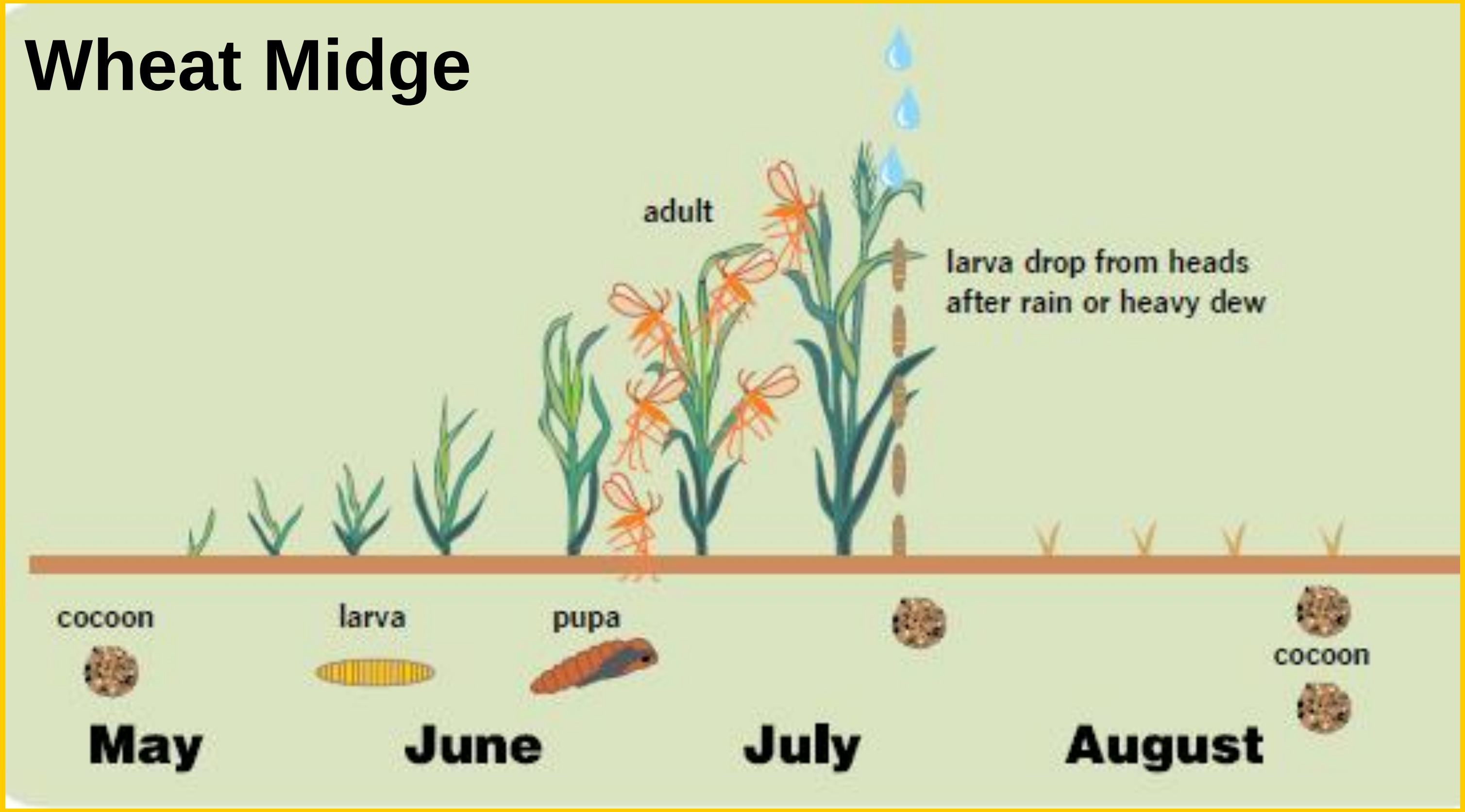
Toxicity

Pest Identification

- **First step in pest management**
- **Misidentification can lead to unnecessary pesticide applications with human health or environmental consequences OR crop failure**

Pest Biology

- **Pest life cycles**
- **Injurious life stages**
- **Crop growth stages**
  - **Susceptible?**
- **Interaction between pests and cropping systems**



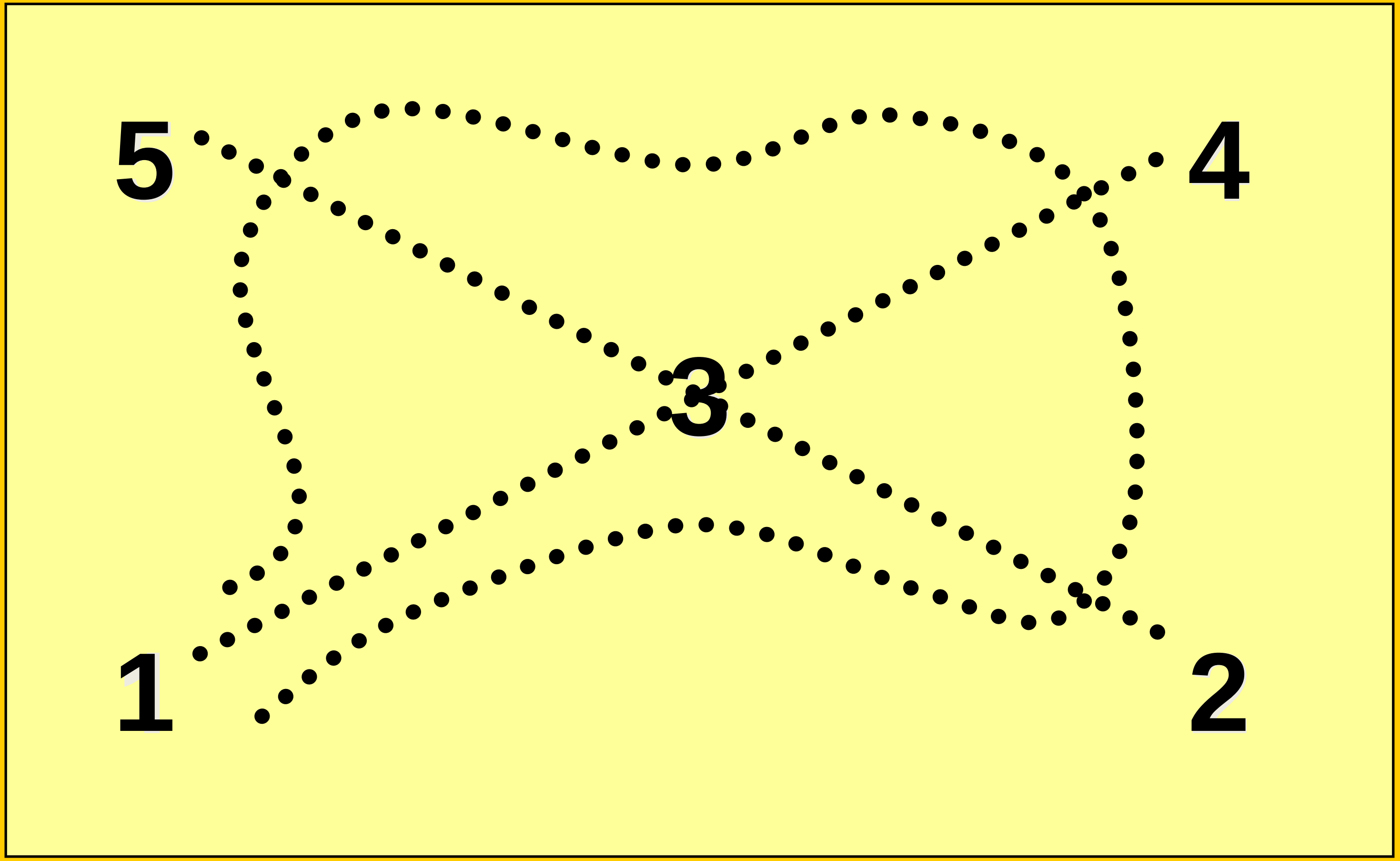
NDSU | EXTENSION

Pest Scouting / Monitoring

- **Need to know what pests are present and when they will become an economic problem**
- **MANY different monitoring methods**
  - **Some general (sweep net)**
  - **Some specific (pheromone traps)**

Field Sampling Patterns

- Sample all areas of the field
- Select plants at random



NDSU | EXTENSION

Using Insect Degree Days

- Time scouting activities
- Predict biological events

. . . Eliminate unnecessary scouting, avoid missing injurious pest populations, improve management decisions.

Chemical Control - Insecticides

- **Know your pests and use appropriate products and rates**
- **USE ECONOMIC THRESHOLDS!**
- **If more than one application is necessary, rotate modes of action**
- **Insecticides are not a "Silver Bullet"**

Insecticide Resistance

Pyrethroids

Chemical Control Costs Money

- Insecticide product costs
  - What pest am I managing?
  - What rate should I use?
- Application costs
  - Ground or air?
  - Equipment costs
  - Fuel costs
  - Labor wages
  - Wear and tear, repair, depreciation, unforeseen costs
- Total costs in $/acre

Photos by Howard F. Schwartz, Colorado State University, Bugwood.org

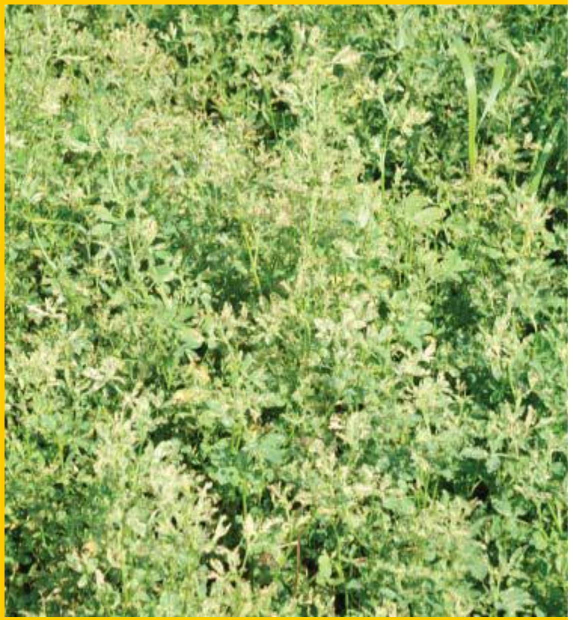
Why Use Economic Thresholds?

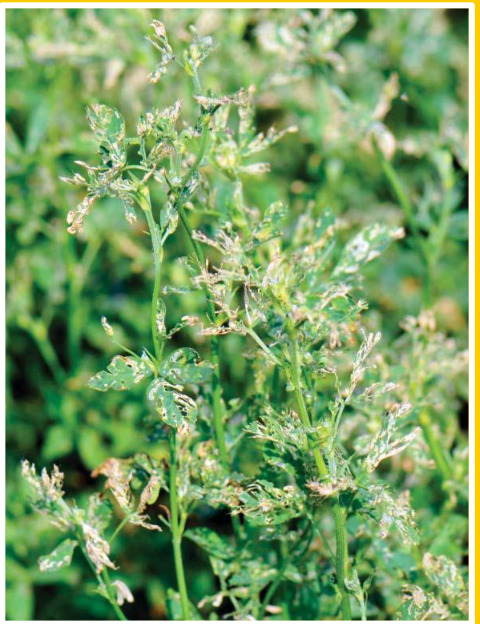
- **$ Cost savings** – economic justification
  - Reduce insecticide resistance when E.T. is used
- **Human health – reduce worker exposure**
  - Handling, loading, mixing, application and cleanup are all inherently dangerous
- **Reduce environmental impact**
  - Reduce or eliminate off-target movement
  - Conserve beneficial insects including pollinators
- **Sustainability and stewardship**
  - Helps prevent development of insecticide resistance in target and non-target pests

Should I Spray?

Nominal Threshold

- A <u>nominal threshold</u> is an estimated value from entomologist best experiences
  - Used when the relationship between an insect pest and an crop yield has not been measured experimentally
- Alfalfa weevil – 30% defoliation





Insect Injury & Damage

Leaf injury

- Affects host physiology

Damage

- Loss of host utility
- Yield quantity / quality

(Courtesy of Dr. Ian MacRae, Crookston campus, UMN)

Damage Boundary & Gain Threshold

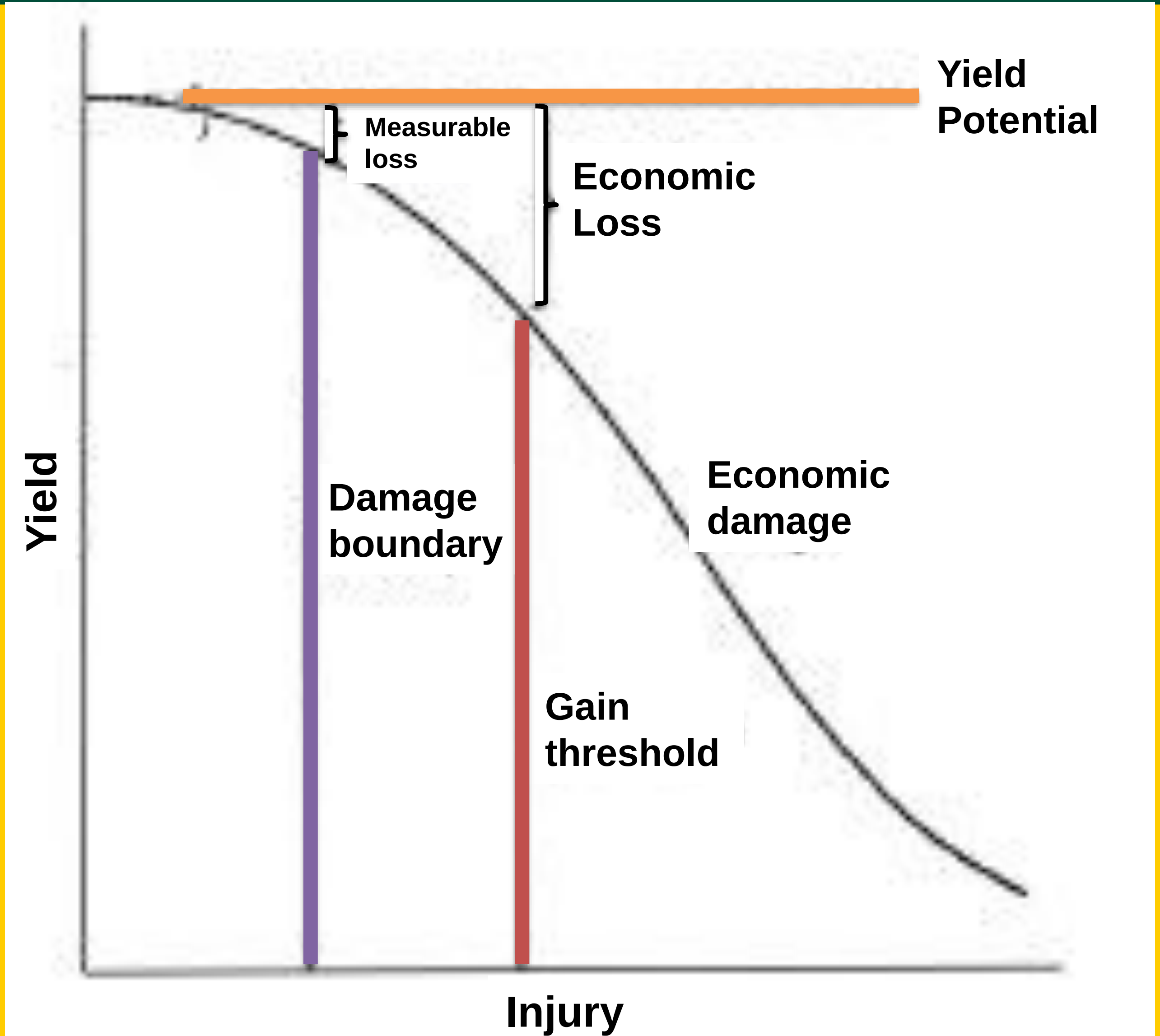
- **Damage Boundary** is the lowest point of injury where damage can be measured
  - No injury level below the damage boundary merits control

(Courtesy of Dr. Ian MacRae, Crookston campus, UMN)

Damage Boundary & Gain Threshold

- **Gain Threshold** is the beginning point of economic damage
- Expressed in bushels/acre
  - Management costs = $10/acre
  - Crop market value = $2/bushel
- $Bushels/acre = \frac{Management\ costs\ (\$/acre)}{Market\ value\ (\$/bushel)}$ = 5 bushel/acre to cause yield loss
- Reached before the economic damage
  - Measurable loss of host utility – yield quantity / quality

Graph showing relationships between the damage boundary and gain threshold



(From Pedigo and Rice 2009)

NDSU EXTENSION

Economic Decision Levels - Research

- **Economic Injury Level (EIL)**
  - **the minimum pest population density that will cause economic loss (break even point)**
  - **Expressed as # insects per plant, # insects per square foot (or square yard, etc.)**
- **Economic Threshold (ET)**
  - **A level of pest populations that triggers a management action**
  - **Implies a certain level of pests CAN BE tolerated**
  - **Integrates plant value and management costs**

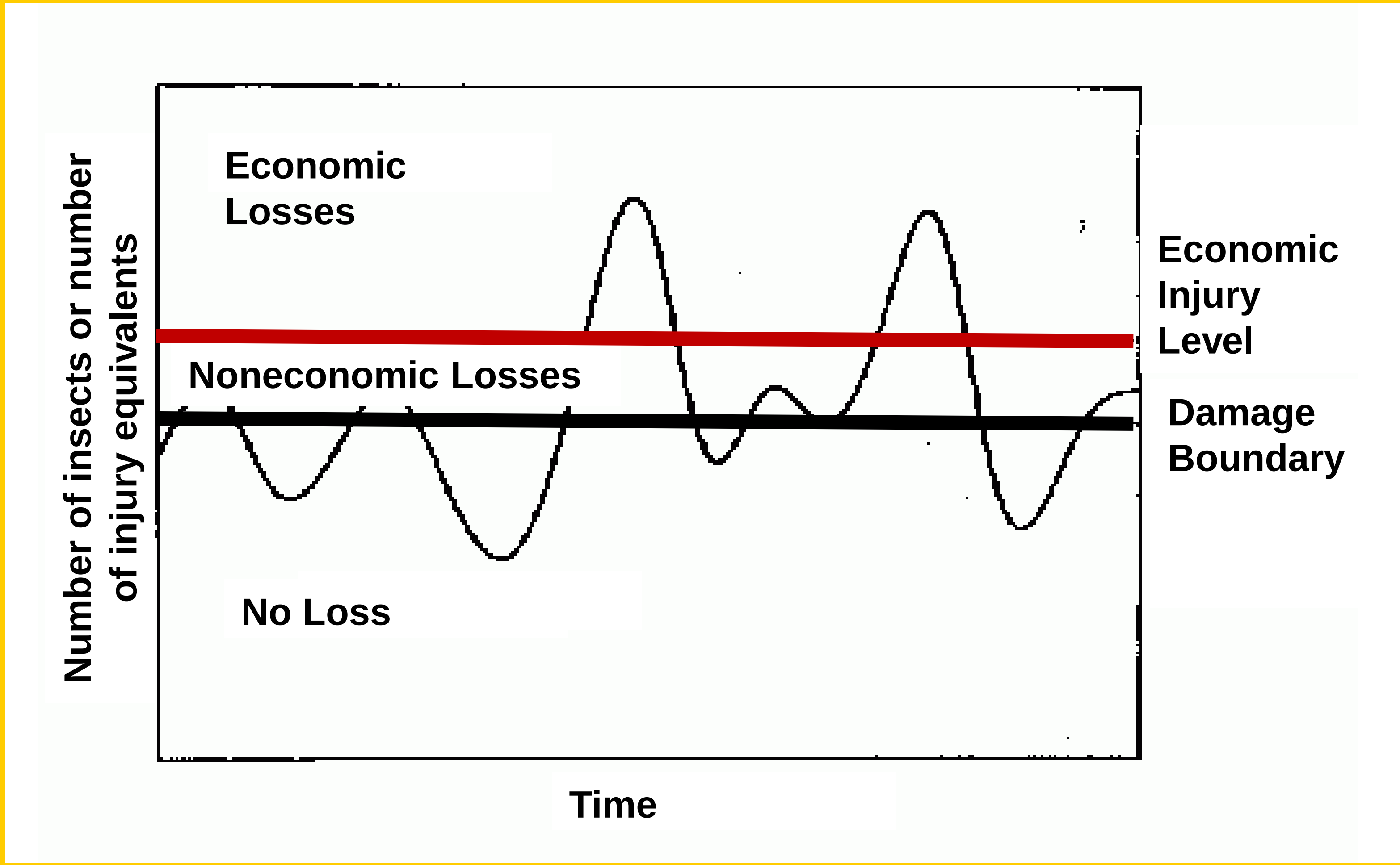
Economic Injury Level

$$EIL = \frac{C}{V \cdot I \cdot D \cdot K}$$

C = cost of management
V = value of crop
I = injury
D = damage
K = percent control

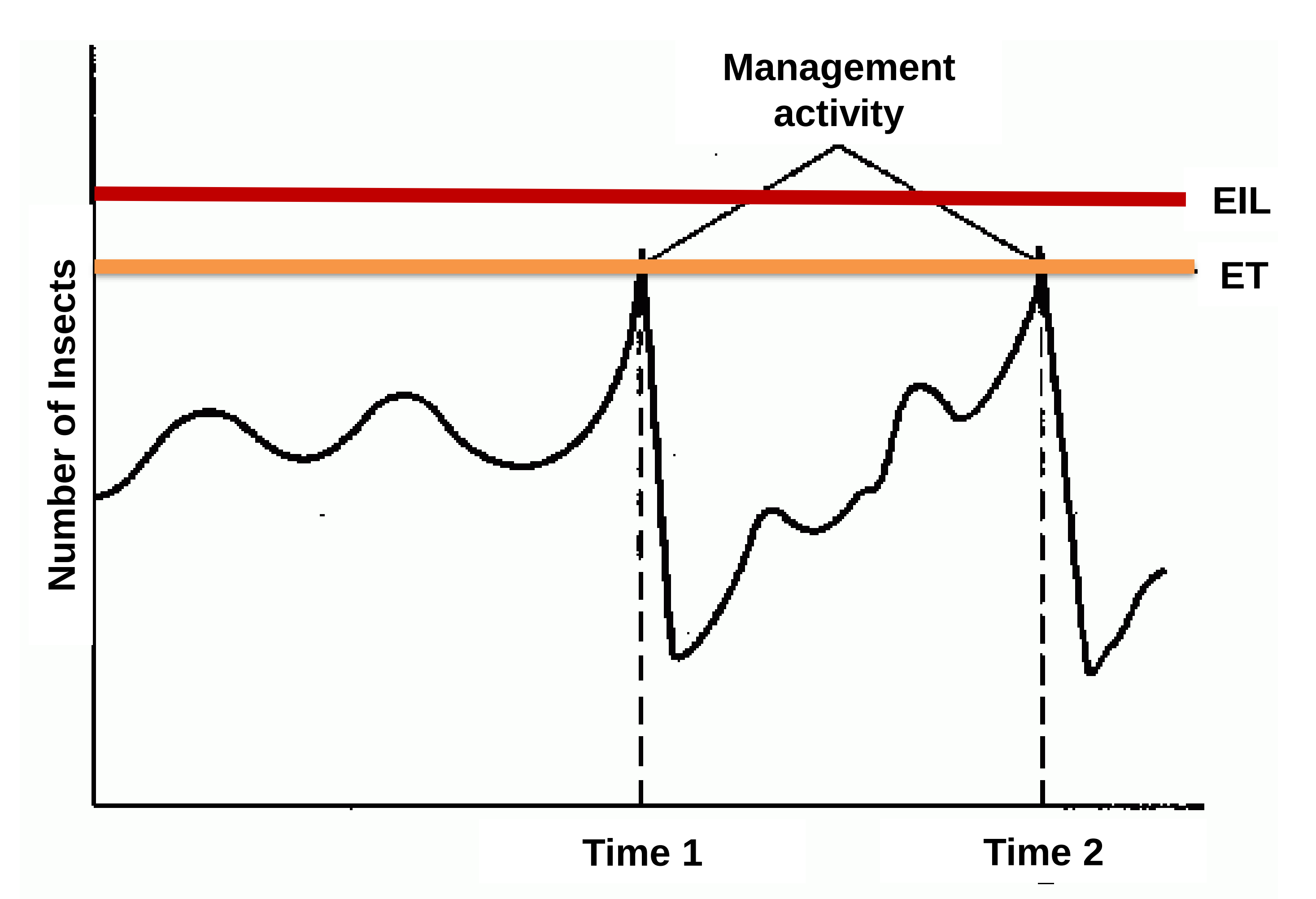
Damage Boundary and EIL

- Area below Damage Boundary represents no noticeable yield loss and control measures are not necessary
- Area between EIL and Damage Boundary highlights importance of monitoring pest levels to intervene before significant damage occurs
- EIL helps farmers when to implement control measures based on economic viability

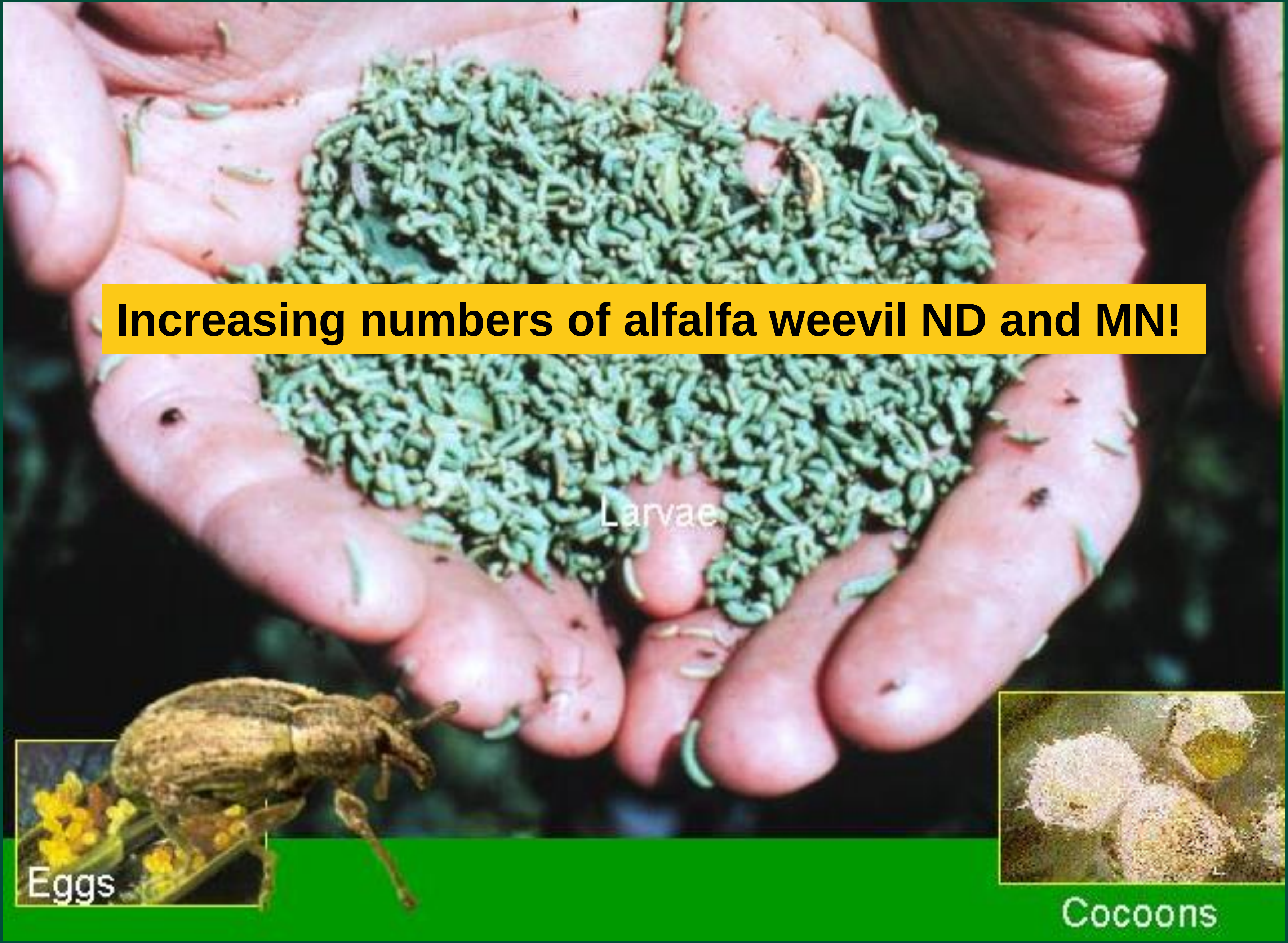


Economic Threshold

- ET set below EIL
- Gives producers time to respond



Increasing numbers of alfalfa weevil ND and MN!



Economic Injury Level

Joseph Berger, bugwood.org

Plant Growth Stage (Height)	Treatment Cost	Crop Value ($/ton)						Management Decision
		$50	$75	$100	$125	$150	$175	
		Number of Alfalfa Weevil Larvae per Stem						
50% bud or greater								Cut early
Early bud (>20 Inches)	$7/acre $8/acre $9/acre $10/acre $11/acre $12/acre	4.0						Cut early, or use a short PHI/PGI product
Late vegetative (16 to 20 Inches)	$7/acre $8/acre $9/acre $10/acre $11/acre $12/acre							Use a short to mid-PHI/PGI product
Midvegetative (10 to 15 Inches)	$7/acre $8/acre $9/acre $10/acre $11/acre $12/acre							Use a long-residual product

NDSU

Economic Injury Level

Joseph Berger, bugwood.org

Plant Growth Stage (Height)	Treatment Cost	Crop Value ($/ton)						Management Decision
		$50	$75	$100	$125	$150	$175	
		Number of Alfalfa Weevil Larvae per Stem						
50% bud or greater								Cut early
Early bud (>20 inches)	$7/acre $8/acre $9/acre $10/acre $11/acre $12/acre	4.0 4.6 5.2 5.8 6.3 6.9						Cut early, or use a short PHI/PGI product
Late vegetative (16 to 20 inches)	$7/acre $8/acre $9/acre $10/acre $11/acre $12/acre							Use a short to mid-PHI/PGI product
Midvegetative (10 to 15 inches)	$7/acre $8/acre $9/acre $10/acre $11/acre $12/acre							Use a long-residual product

NDSU

Economic Injury Level

Joseph Berger, bugwood.org

Plant Growth Stage (Height)	Treatment Cost	Crop Value ($/ton) $50	$75	$100	$125	$150	$175	Management Decision
		Number of Alfalfa Weevil Larvae per Stem						
50% bud or greater								Cut early
Early bud (>20 inches)	$7/acre $8/acre $9/acre $10/acre $11/acre $12/acre	4.0	2.7	2.0	1.6	1.3	1.2	Cut early, or use a short PHI/PGI product
Late vegetative (16 to 20 inches)	$7/acre $8/acre $9/acre $10/acre $11/acre $12/acre							Use a short to mid-PHI/PGI product
Midvegetative (10 to 15 inches)	$7/acre $8/acre $9/acre $10/acre $11/acre $12/acre							Use a long-residual product

NDSU

Economic Injury Level

Joseph Berger, bugwood.org

Plant Growth Stage (Height)	Treatment Cost	Crop Value ($/ton)						Management Decision
		$50	$75	$100	$125	$150	$175	
		Number of Alfalfa Weevil Larvae per Stem						
50% bud or greater								Cut early
Early bud (>20 inches)	$7/acre	4.0	2.7	2.0	1.6	1.3	1.2	Cut early, or use a short PHI/PGI product
	$8/acre	4.6	3.1	2.3	1.8	1.5	1.3	
	$9/acre	5.2	3.5	2.6	2.1	1.7	1.5	
	$10/acre	5.8	3.8	2.9	2.3	1.9	1.6	
	$11/acre	6.3	4.2	3.2	2.5	2.1	1.8	
	$12/acre	6.9	4.6	3.5	2.8	2.3	2.0	
Late vegetative (16 to 20 inches)	$7/acre	3.8	2.4	1.8	1.4	1.1	0.9	Use a short to mid-PHI/PGI product
	$8/acre	4.4	2.8	2.1	1.6	1.3	1.1	
	$9/acre	4.9	3.2	2.4	1.8	1.5	1.2	
	$10/acre	5.5	3.6	2.6	2.1	1.7	1.4	
	$11/acre	6.1	4.0	2.9	2.3	1.9	1.6	
	$12/acre	6.7	4.4	3.2	2.5	2.1	1.7	
Midvegetative (10 to 15 inches)	$7/acre	3.6	2.2	1.5	1.1	0.9	0.7	Use a long-residual product
	$8/acre	4.1	2.6	1.8	1.4	1.1	0.8	
	$9/acre	4.7	3.0	2.1	1.6	1.2	1.0	
	$10/acre	5.3	3.4	2.4	1.8	1.4	1.2	
	$11/acre	5.9	3.7	2.7	2.1	1.6	1.3	
	$12/acre	6.4	4.1	3.0	2.3	1.8	1.5	

NDSU

Alfalfa Weevil

30-Stem Sampling Method

- Using Bucket
  - Select 30 stems from 5 locations
  - Count total number of stems sampled
  - Count total number of larvae counted
  - Measure height of alfalfa at the sampling site
  - Determine average # of larvae/stem and average plant height in field

Figure 9. Alfalfa weevil larvae collected during 30-stem sampling method using a white bucket

(Patrick Beauzay, NDSU)

Factors Affecting Economic Thresholds

Red Sunflower Seed Weevil on Oil Sunflowers

- **Cost of the insecticide treatment per acre**
- **Market price of crop in dollars**
- **Plant population per acre**
- **Developed and verified through research**

$$\text{Threshold (Weevils per head)} = \frac{\text{Cost of Insecticide Treatment}}{(\text{Market Price} \times 21.5)(0.000022 \times \text{Plant Population} + 0.18)}$$

Factors Affecting Economic Thresholds

Red Sunflower Seed Weevil on Oil Sunflowers

Table 1. Economic Threshold for Oilseed Sunflowers - Number of adult red sunflower seed weevil per head when the cost of control equals $18.00 per acre ($6.00 for insecticide and $12 for aerial application costs).

Market Price	Sunflower Plants per Acre (x 1,000)									
$ per lb	16	17	18	19	20	21	22	23	24	25
0.18	11.7									
0.19										
0.20										
0.21										
0.22										

Table 2. Economic Threshold for Oilseed Sunflowers - Number of adult red sunflower seed weevil per head when the cost of control equals $20.00 per acre ($8.00 for insecticide and $12 for aerial application costs).

Market Price	Sunflower Plants per Acre (x 1,000)									
$ per lb	16	17	18	19	20	21	22	23	24	25
0.18										
0.19										
0.20										
0.21										
0.22										

Factors Affecting Economic Thresholds

Red Sunflower Seed Weevil on Oil Sunflowers

Table 1. Economic Threshold for Oilseed Sunflowers - Number of adult red sunflower seed weevil per head when the cost of control equals $18.00 per acre ($6.00 for insecticide and $12 for aerial application costs).

Market Price	Sunflower Plants per Acre (x 1,000)									
$ per lb	16	17	18	19	20	21	22	23	24	25
0.18	11.7									
0.19	11.1									
0.20	10.6									
0.21	10.2									
0.22	9.8									

Table 2. Economic Threshold for Oilseed Sunflowers - Number of adult red sunflower seed weevil per head when the cost of control equals $20.00 per acre ($8.00 for insecticide and $12 for aerial application costs).

Market Price	Sunflower Plants per Acre (x 1,000)									
$ per lb	16	17	18	19	20	21	22	23	24	25
0.18										
0.19										
0.20										
0.21										
0.22										

Factors Affecting Economic Thresholds

Red Sunflower Seed Weevil on Oil Sunflowers

Table 1. Economic Threshold for Oilseed Sunflowers - Number of adult red sunflower seed weevil per head when the cost of control equals $18.00 per acre ($6.00 for insecticide and $12 for aerial application costs).										
Market Price	Sunflower Plants per Acre (x 1,000)									
$ per lb	16	17	18	19	20	21	22	23	24	25
0.18	11.7	11.1	10.5	10.0	9.6	9.1	8.8	8.4	8.1	7.8
0.19	11.1	10.5	10.0	9.5	9.1	8.7	8.3	8.0	7.7	7.4
0.20	10.6	10.1	9.6	9.1	8.7	8.3	8.0	7.6	7.3	7.1
0.21	10.2	9.6	9.1	8.7	8.3	7.9	7.6	7.3	7.0	6.8
0.22	9.8	9.2	8.8	8.3	8.0	7.6	7.3	7.0	6.7	6.5

Table 2. Economic Threshold for Oilseed Sunflowers - Number of adult red sunflower seed weevil per head when the cost of control equals $20.00 per acre ($8.00 for insecticide and $12 for aerial application costs).										
Market Price	Sunflower Plants per Acre (x 1,000)									
$ per lb	16	17	18	19	20	21	22	23	24	25
0.18										
0.19										
0.20										
0.21										
0.22										

Factors Affecting Economic Thresholds

Red Sunflower Seed Weevil on Oil Sunflowers

Table 1. Economic Threshold for Oilseed Sunflowers - Number of adult red sunflower seed weevil per head when the cost of control equals $18.00 per acre ($6.00 for insecticide and $12 for aerial application costs).

Market Price	Sunflower Plants per Acre (x 1,000)									
$ per lb	16	17	18	19	20	21	22	23	24	25
0.18	11.7	11.1	10.5	10.0	9.6	9.1	8.8	8.4	8.1	7.8
0.19	11.1	10.5	10.0	9.5	9.1	8.7	8.3	8.0	7.7	7.4
0.20	10.6	10.1	9.6	9.1	8.7	8.3	8.0	7.6	7.3	7.1
0.21	10.2	9.6	9.1	8.7	8.3	7.9	7.6	7.3	7.0	6.8
0.22	9.8	9.2	8.8	8.3	8.0	7.6	7.3	7.0	6.7	6.5

Table 2. Economic Threshold for Oilseed Sunflowers - Number of adult red sunflower seed weevil per head when the cost of control equals $20.00 per acre ($8.00 for insecticide and $12 for aerial application costs).

Market Price	Sunflower Plants per Acre (x 1,000)									
$ per lb	16	17	18	19	20	21	22	23	24	25
0.18	13.0	12.3	11.7	11.1	10.6	10.2	9.7	9.4	9.0	8.7
0.19	12.4	11.7	11.1	10.6	10.1	9.7	9.3	8.9	8.6	8.2
0.20	11.8	11.2	10.6	10.1	9.7	9.2	8.8	8.5	8.2	7.9
0.21	11.3	10.7	10.2	9.7	9.2	8.8	8.5	8.1	7.8	7.5
0.22	10.8	10.3	9.7	9.3	8.8	8.5	8.1	7.8	7.5	7.2

Red Sunflower Seed Weevil

Economic Thresholds Used in 2024

2024 RSSW Economic Threshold (average # weevils per head)

Oilseed sunflower at 18 cents per lb:

22,000 to 18,000 plants per acre

$18 insecticide cost per acre – 9-11 weevils per head

$20 insecticide cost per acre – 10-12 weevils per head

Confection sunflowers:

1 weevil per head

Early bloom stage sunflower.
Photo courtesy of Hans Kandel, former NDSU Extension Broadleaf Agronomist.

Red sunflower seed weevil on R2 bud stage sunflower.
Photo courtesy of Marc Michaelson, former IPM scout.

Economic Thresholds – Barley Thrips

- Based on calculated EIL for a single insect pest
- Developed and verified through research

$$\text{Barley thrips/stem} = \frac{\text{Management costs (\$/acre)}}{\text{Market value (\$/bushel)}} \div 0.4$$

$$\frac{\$8/\text{acre}}{\$4/\text{bushel}} \div 0.4 = 5 \text{ Thrips/stem}$$

$$\frac{\$8/\text{acre}}{\$2/\text{bushel}} \div 0.4 =$$

$$\frac{\$12/\text{acre}}{\$2/\text{bushel}} \div 0.4 =$$

Economic Thresholds – Barley Thrips

- Based on calculated EIL for a single insect pest
- Developed and verified through research

$$\text{Barley thrips/stem} = \frac{\text{Management costs (\$/acre)}}{\text{Market value (\$/bushel)}} \div 0.4$$

$$\frac{\$8/\text{acre}}{\$4/\text{bushel}} \div 0.4 = 5\ \text{Thrips/stem}$$

$$\frac{\$8/\text{acre}}{\$2/\text{bushel}} \div 0.4 = 10\ \text{Thrips/stem}$$

$$\frac{\$12/\text{acre}}{\$2/\text{bushel}} \div 0.4 =$$

Economic Thresholds – Barley Thrips

- Based on calculated EIL for a single insect pest
- Developed and verified through research

$$\text{Barley thrips/stem} = \frac{\text{Management costs (\$/acre)}}{\text{Market value (\$/bushel)}} \div 0.4$$

$$\frac{\$8/\text{acre}}{\$4/\text{bushel}} \div 0.4 = 5\ \text{Thrips/stem}$$

$$\frac{\$8/\text{acre}}{\$2/\text{bushel}} \div 0.4 = 10\ \text{Thrips/stem}$$

$$\frac{\$12/\text{acre}}{\$2/\text{bushel}} \div 0.4 = 15\ \text{Thrips/stem}$$

E.T. for Insect Trapping

- **Monitoring adult corn rootworm (western & northern) beetle activity**
  - **Sticky traps: 6-12 yellow (Pherocon AM yellow sticky traps)**
  - **Corn pollination - August**
- **Record total number of beetles from all traps and divide by total number of traps, then divide by total number of days in field**


Photo: P. Beauzay,

NDSU EXTENSION

E.T. for Insect Trapping

- **E.T. = Two or more beetles**
  - Either species or any combination of the two species
  - High corn rootworm populations is expected next year
  - Implement corn rootworm management tool next year to protect the crop

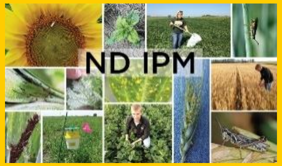
Wheat Midge Pheromone Trap

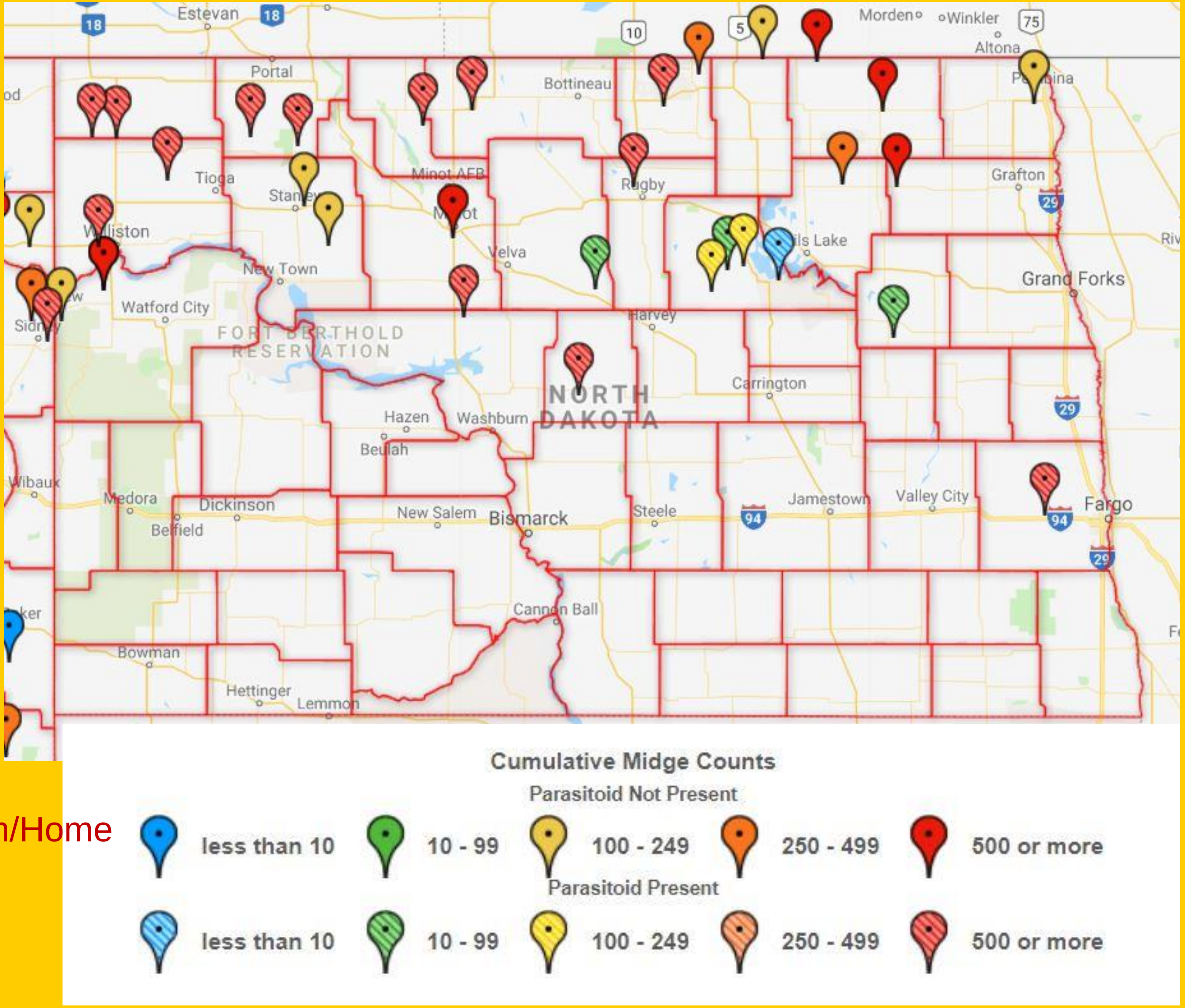
- **Scentry LP Delta with sticky trap liners**
- **Place traps in field during heading (wheat head height)**
- **Three traps per 160 acres**
- **Examine every 1-2 days**
- **Threshold = >10 captured males per trap indicate NEED TO SCOUT FIELDS**
- **Available for $7.20/ trap unit (trap + pheromone)**
- **Great Lake IPM (source of insect trap supplies)**

  http://www.greatlakesipm.com/

Wheat Midge Trap Bottom

Pheromone Trapping for Wheat Midge and Parasitoid in North Dakota





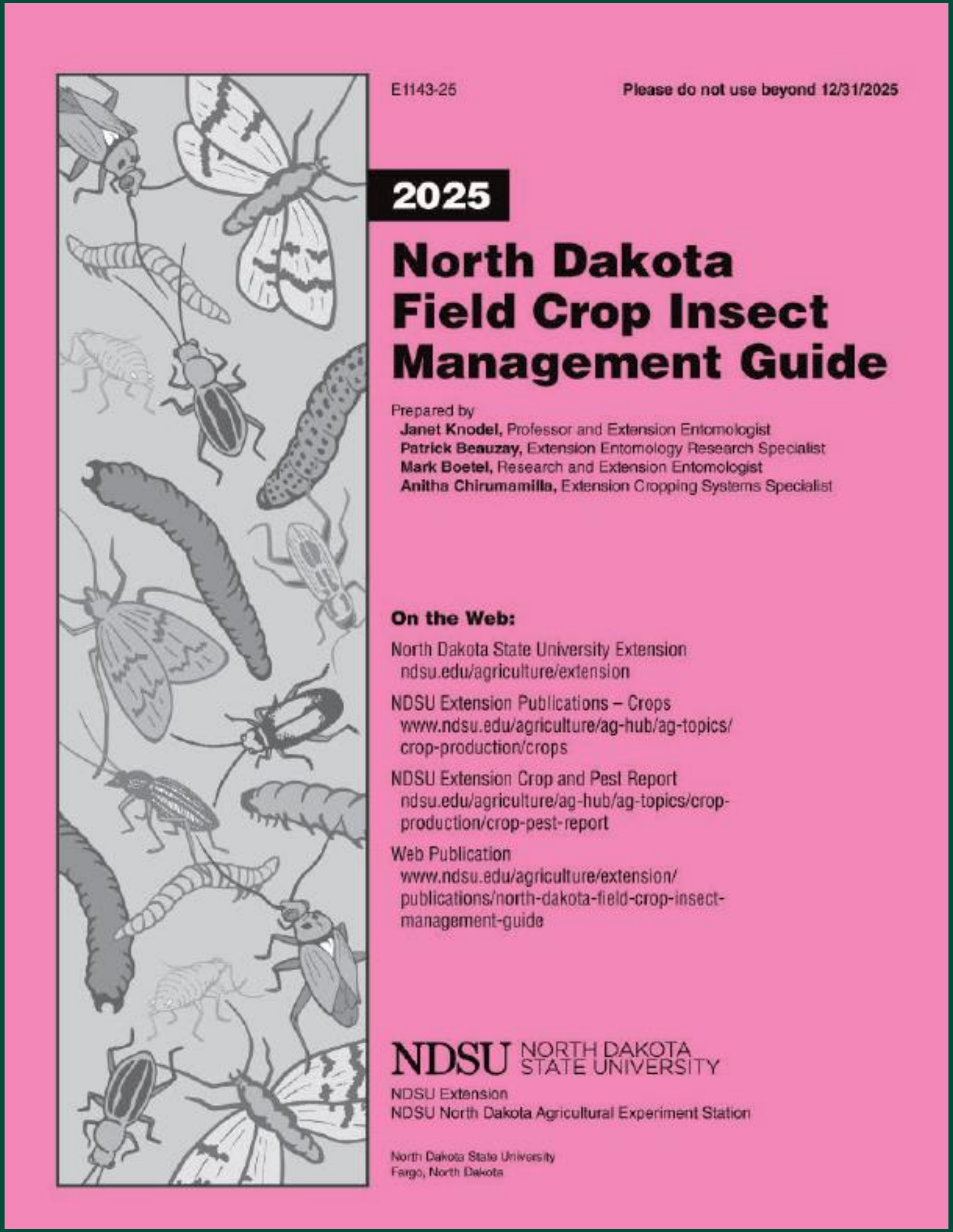
PestWeb
Montana State University
https://pestweb.montana.edu/Owbm/Home

United States Department of Agriculture
National Institute of Food and Agriculture

Insecticides and Mode of Actions

Crop – Dry Bean

Always Read and Follow Labels.


E1143-25 Please do not use beyond 12/31/2025

2025

North Dakota Field Crop Insect Management Guide

Prepared by
Janet Knodel, Professor and Extension Entomologist
Patrick Beauzay, Extension Entomology Research Specialist
Mark Boetel, Research and Extension Entomologist
Anitha Chirumamilla, Extension Cropping Systems Specialist

On the Web:

North Dakota State University Extension
ndsu.edu/agriculture/extension

NDSU Extension Publications – Crops
www.ndsu.edu/agriculture/ag-hub/ag-topics/crop-production/crops

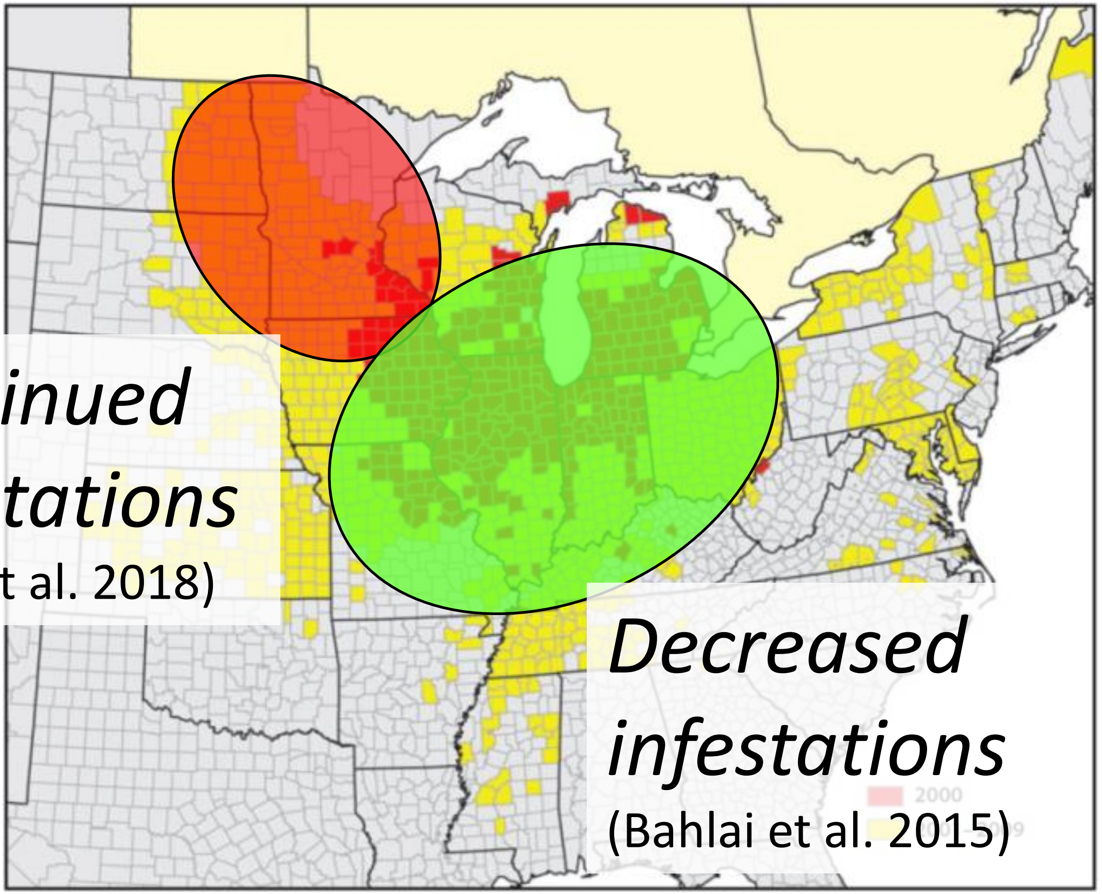
NDSU Extension Crop and Pest Report
ndsu.edu/agriculture/ag-hub/ag-topics/crop-production/crop-pest-report

Web Publication
www.ndsu.edu/agriculture/extension/publications/north-dakota-field-crop-insect-management-guide

NDSU NORTH DAKOTA STATE UNIVERSITY
NDSU Extension
NDSU North Dakota Agricultural Experiment Station

North Dakota State University
Fargo, North Dakota

Soybean aphid



Continued infestations
(Koch et al. 2018)

Decreased infestations
(Bahlai et al. 2015)

Reproducing machines

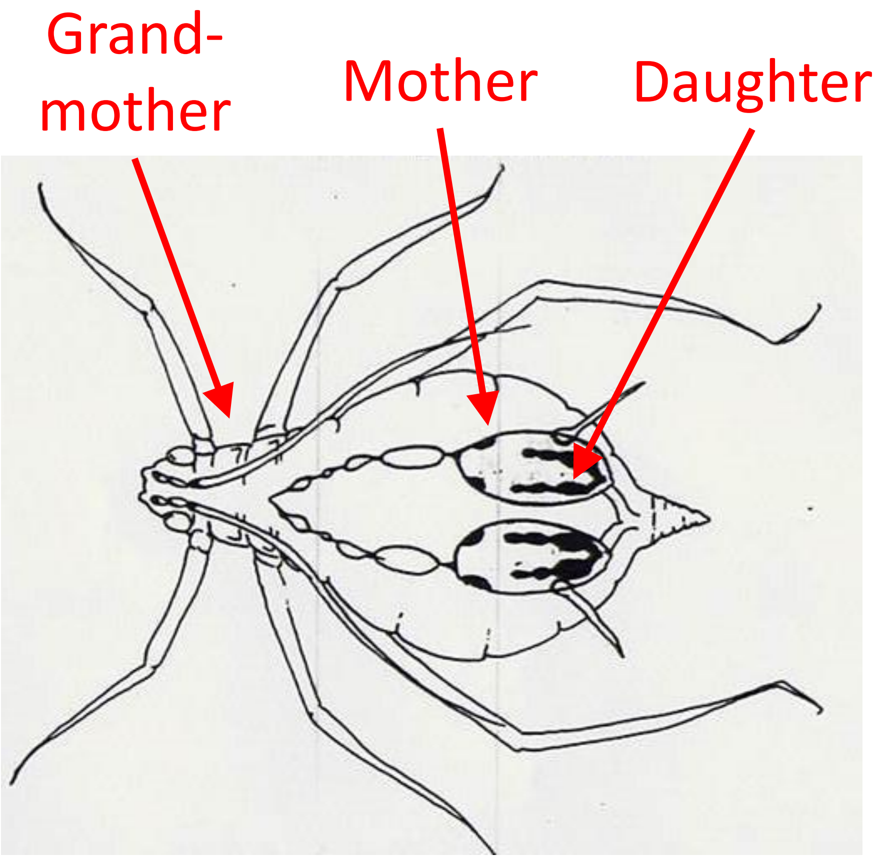
- Parthenogenesis
  - Females cloning themselves

Reproducing machines

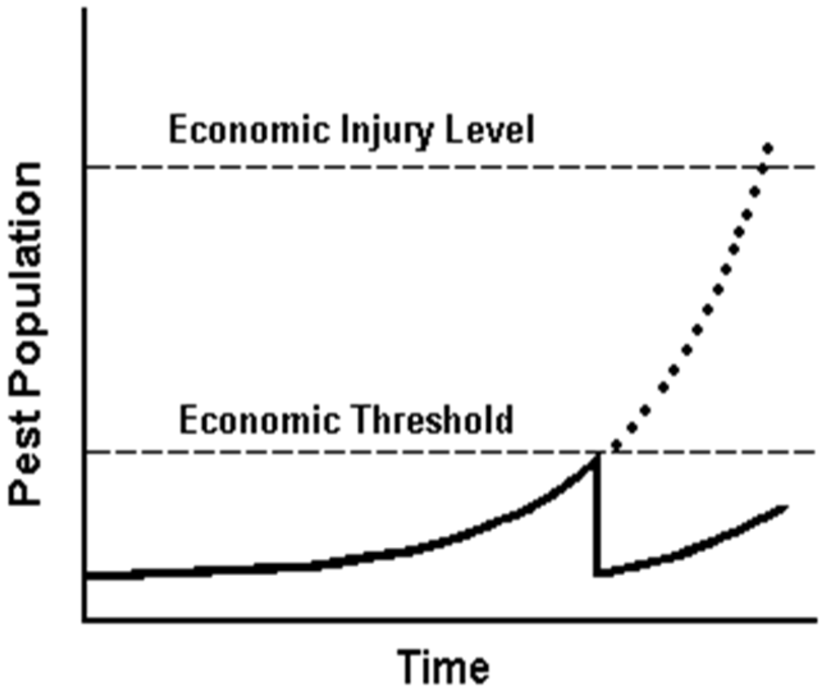
- Parthenogenesis
  - Females cloning themselves
- Live birth

Reproducing machines

- Parthenogenesis
  - Females cloning themselves
- Live birth
- Telescoping generations

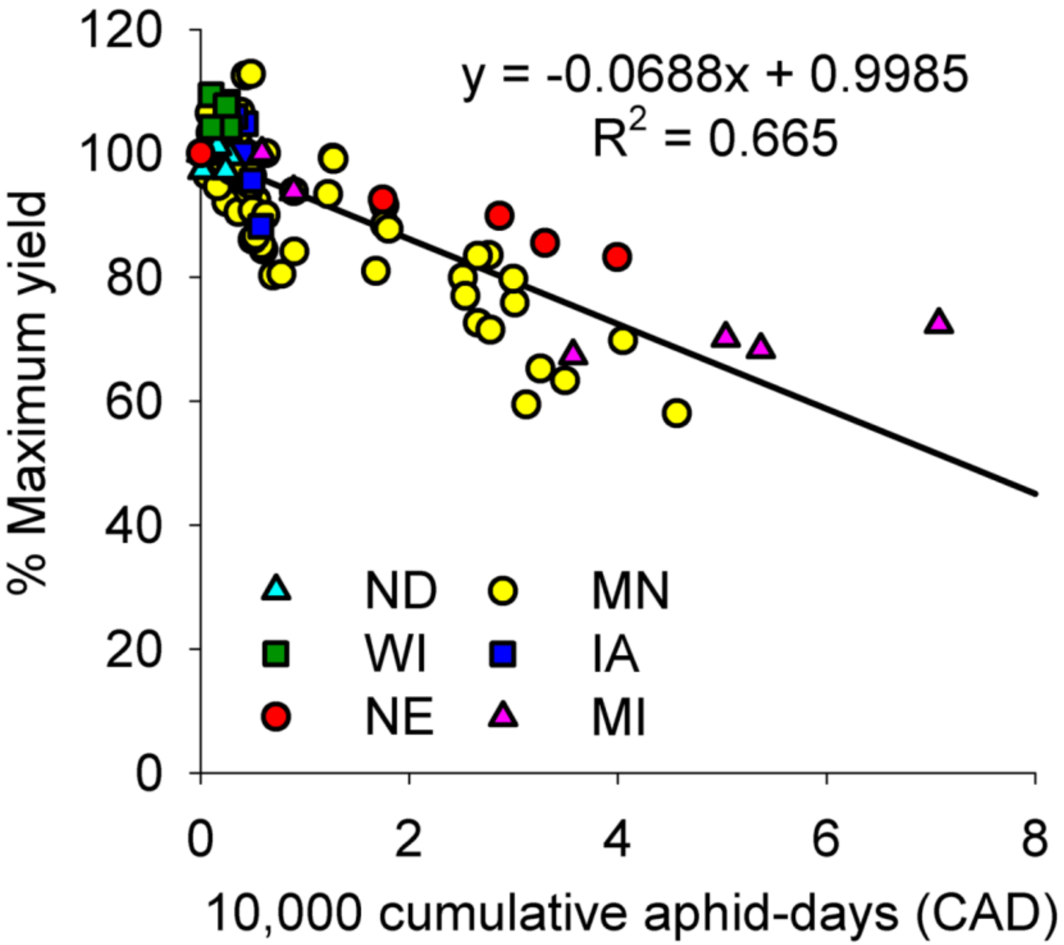


EIL & ET for soybean aphid



250 aphids/ plant

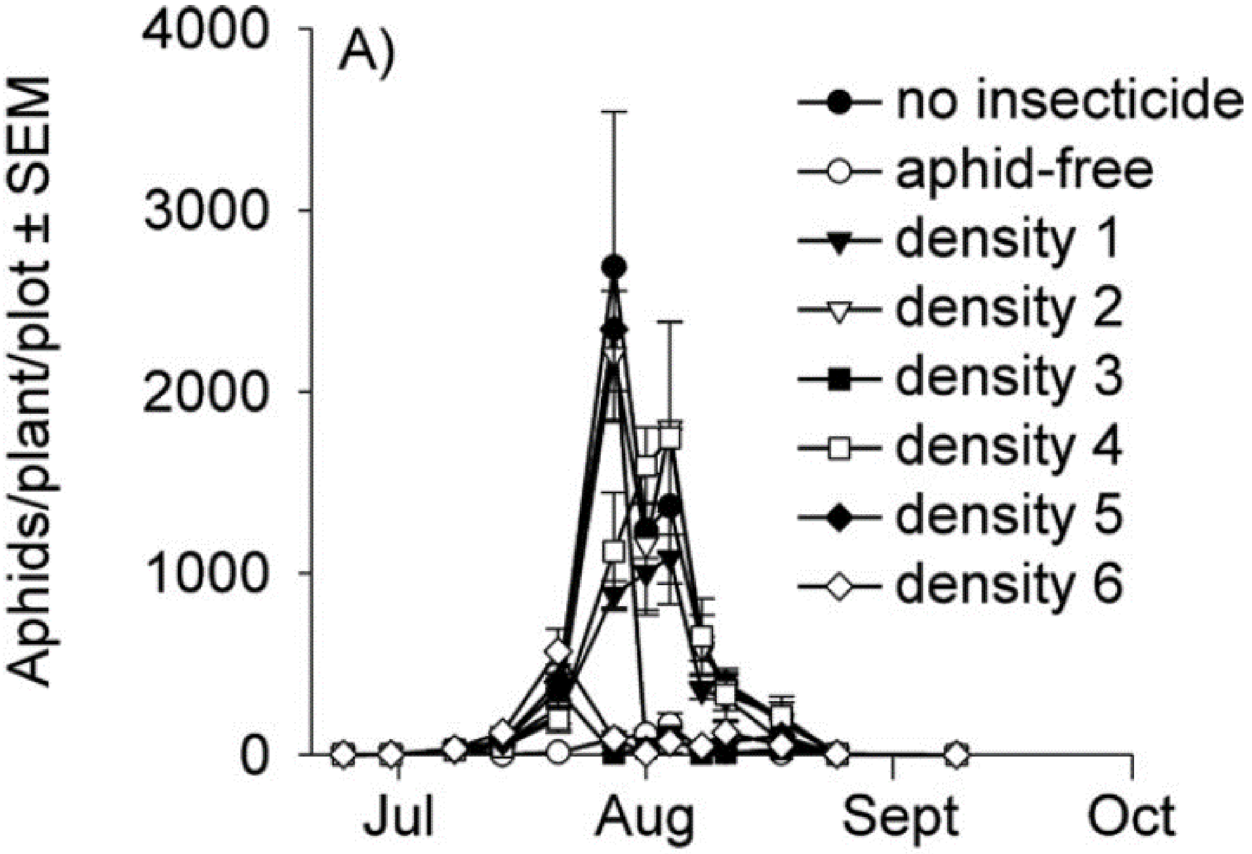
EIL & ET for soybean aphid



Ragsdale et al. 2007

EIL & ET for soybean aphid

- Population doubling times
  - 6.8 d (2.7-13.4 d)



Ragsdale et al. 2007

EIL & ET for soybean aphid

- Biology
  - Injury: 6.88% yield loss per 10,000 CAD
    - Assumed linear
- Economics
  - Control costs: $6.64 - $13.33 per acre
  - Market price: $5.50 - $6.50 per bushel
  - Yield Potential: 30 - 60 bushels per acre

Ragsdale et al. 2007

Control costs
$6.64-
13.33/ac

Market price
$5.50-
6.50/bu

Yield
30-60 bu/ac

Cost of control ($/ha)[a]	Market price ($/ton)[b]	Yield potential (ton/ha)[c]
16.41	202.09	2.02
		2.69
		3.36
		4.04
	220.46	2.02
		2.69
		3.36
		4.04
	238.83	2.02
		2.69
		3.36
		4.04
24.51	202.09	2.02
		2.69
		3.36
		4.04
	220.46	2.02
		2.69
		3.36
		4.04
	238.83	2.02
		2.69
		3.36
		4.04
32.94	202.09	2.02
		2.69
		3.36
		4.04
	220.46	2.02
		2.69
		3.36
		4.04
	238.83	2.02
		2.69
		3.36
		4.04
		Mean

Ragsdale et al. 2007

Control costs
$6.64-
13.33/ac

Market price
$5.50-
6.50/bu

Yield
30-60 bu/ac

EIL
(CAD)

Cost of control ($/ha)[a]	Market price ($/ton)[b]	Yield potential (ton/ha)[c]	EIL: cumulative aphid-days
16.41	202.09	2.02	5,649
		2.69	4,188
		3.36	3,309
		4.04	2,715
	220.46	2.02	5,160
		2.69	3,821
		3.36	3,015
		4.04	2,471
	238.83	2.02	4,747
		2.69	3,510
		3.36	2,766
		4.04	2,264
24.51	202.09	2.02	8,546
		2.69	6,363
		3.36	5,051
		4.04	4,164
	220.46	2.02	7,816
		2.69	5,815
		3.36	4,611
		4.04	3,798
	238.83	2.02	7,198
		2.69	5,350
		3.36	4,240
		4.04	3,489
32.94	202.09	2.02	11,561
		2.69	8,627
		3.36	6,863
		4.04	5,671
	220.46	2.02	9,696
		2.69	7,890
		3.36	6,273
		4.04	5,180
	238.83	2.02	8,933
		2.69	7,266
		3.36	5,773
		4.04	4,765
		Mean	5,563

Average 5,563

Ragsdale et al. 2007

Control costs
$6.64-13.33/ac

Market price
$5.50-6.50/bu

Yield
30-60 bu/ac

Cost of control ($/ha)[a]	Market price ($/ton)[b]	Yield potential (ton/ha)[c]	EIL: cumulative aphid-days	EIL: aphids per plant
16.41	202.09	2.02	5,649	684
		2.69	4,188	507
		3.36	3,309	401
		4.04	2,715	329
	220.46	2.02	5,160	625
		2.69	3,821	463
		3.36	3,015	366
		4.04	2,471	300
	238.83	2.02	4,747	575
		2.69	3,510	425
		3.36	2,766	335
		4.04	2,264	275
24.51	202.09	2.02	8,546	1,035
		2.69	6,363	771
		3.36	5,051	612
		4.04	4,164	504
	220.46	2.02	7,816	946
		2.69	5,815	704
		3.36	4,611	559
		4.04	3,798	460
	238.83	2.02	7,198	871
		2.69	5,350	648
		3.36	4,240	514
		4.04	3,489	423
32.94	202.09	2.02	11,561	1,399
		2.69	8,627	1,044
		3.36	6,863	831
		4.04	5,671	687
	220.46	2.02	9,696	1,174
		2.69	7,890	955
		3.36	6,273	760
		4.04	5,180	627
	238.83	2.02	8,933	1,081
		2.69	7,266	880
		3.36	5,773	699
		4.04	4,765	577
		Mean	5,563	674

	EIL (CAD)	EIL (aphids /plant)
Average	5,563	674

Ragsdale et al. 2007

Control costs
$6.64-13.33/ac

Market price
$5.50-6.50/bu

Yield
30-60 bu/ac

EIL (CAD)

EIL (aphids /plant)

ETs (1-7 d lead)

Cost of control ($/ha)[a]	Market price ($/ton)[b]	Yield potential (ton/ha)[c]	EIL: cumulative aphid-days	EIL: aphids per plant	ET with different lead times (d):			
					1	3	5	7
16.41	202.09	2.02	5,649	684	601	465	359	278
		2.69	4,188	507	446	345	266	206
		3.36	3,309	401	353	272	211	163
		4.04	2,715	329	289	224	173	134
	220.46	2.02	5,160	625	549	425	328	254
		2.69	3,821	463	407	314	243	188
		3.36	3,015	366	321	248	192	148
		4.04	2,471	300	263	204	157	122
	238.83	2.02	4,747	575	505	391	302	233
		2.69	3,510	425	374	289	223	173
		3.36	2,766	335	295	228	176	136
		4.04	2,264	275	241	187	144	111
24.51	202.09	2.02	8,546	1,035	909	703	543	420
		2.69	6,363	771	677	523	404	313
		3.36	5,051	612	538	416	321	248
		4.04	4,164	504	443	343	265	205
	220.46	2.02	7,816	946	832	643	497	384
		2.69	5,815	704	619	478	370	286
		3.36	4,611	559	491	379	293	227
		4.04	3,798	460	405	313	242	187
	238.83	2.02	7,198	871	766	592	457	353
		2.69	5,350	648	570	440	340	263
		3.36	4,240	514	452	349	270	208
		4.04	3,489	423	372	287	222	172
32.94	202.09	2.02	11,561	1,399	1,230	950	734	567
		2.69	8,627	1,044	918	709	548	424
		3.36	6,863	831	730	564	436	337
		4.04	5,671	687	604	467	360	279
	220.46	2.02	9,696	1,174	1,032	797	616	476
		2.69	7,890	955	840	649	501	387
		3.36	6,273	760	668	516	399	308
		4.04	5,180	627	552	426	329	254
	238.83	2.02	8,933	1,081	951	735	568	439
		2.69	7,266	880	773	598	462	357
		3.36	5,773	699	615	475	367	284
		4.04	4,765	577	507	392	303	234
		Mean	5,563	674	592	458	354	273

Average 5,563 674 273 → 250

Ragsdale et al. 2007

EIL (CAD)

EIL (aphids /plant)

ETs (1-7 d lead)

Control costs $6.64-13.33/ac

Market price $5.50-6.50/bu

Yield 30-60 bu/ac

Cost of control ($/ha)[a]	Market price ($/ton)[b]	Yield potential (ton/ha)[c]	EIL: cumulative aphid-days	EIL: aphids per plant	ET with different lead times (d): 1	3	5	7
16.41	202.09	2.02	5,649	684	601	465	359	278
		2.69	4,188	507	446	345	266	206
		3.36	3,309	401	353	272	211	163
		4.04	2,715	329	289	224	173	134
	220.46	2.02	5,160	625	549	425	328	254
		2.69	3,821	463	407	314	243	188
		3.36	3,015	366	321	248	192	148
		4.04	2,471	300	263	204	157	122
	238.83	2.02	4,747	575	505	391	302	233
		2.69	3,510	425	374	289	223	173
		3.36	2,766	335	295	228	176	136
		4.04	2,264	275	241	187	144	111
24.51	202.09	2.02	8,546	1,035	909	703	543	420
		2.69	6,363	771	677	523	404	313
		3.36	5,051	612	538	416	321	248
		4.04	4,164	504	443	343	265	205
	220.46	2.02	7,816	946	832	643	497	384
		2.69	5,815	704	619	478	370	286
		3.36	4,611	559	491	379	293	227
		4.04	3,798	460	405	313	242	187
	238.83	2.02	7,198	871	766	592	457	353
		2.69	5,350	648	570	440	340	263
		3.36	4,240	514	452	349	270	208
		4.04	3,489	423	372	287	222	172
32.94	202.09	2.02	11,561	1,399	1,230	950	734	567
		2.69	8,627	1,044	918	709	548	424
		3.36	6,863	831	730	564	436	337
		4.04	5,671	687	604	467	360	279
	220.46	2.02	9,696	1,174	1,032	797	616	476
		2.69	7,890	955	840	649	501	387
		3.36	6,273	760	668	516	399	308
		4.04	5,180	627	552	426	329	254
	238.83	2.02	8,933	1,081	951	735	568	439
		2.69	7,266	880	773	598	462	357
		3.36	5,773	699	615	475	367	284
		4.04	4,765	577	507	392	303	234
		Mean	5,563	674	592	458	354	273

Average 5,563 674 273 → 250

Ragsdale et al. 2007

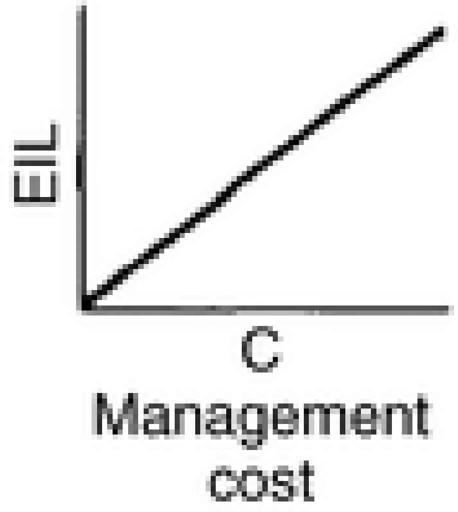
Control costs
$6.64-13.33/ac

Market price
$5.50-6.50/bu

Yield
30-60 bu/ac

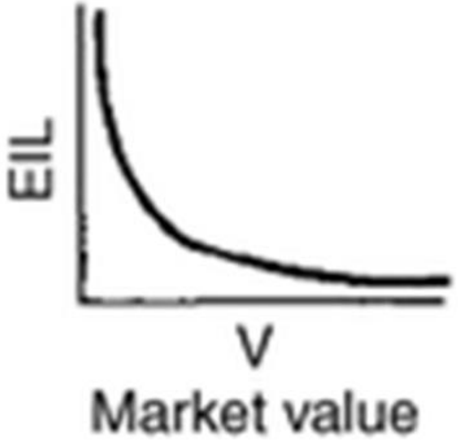
Q) What happens to EIL if control cost decreases?

A) EIL decreases.



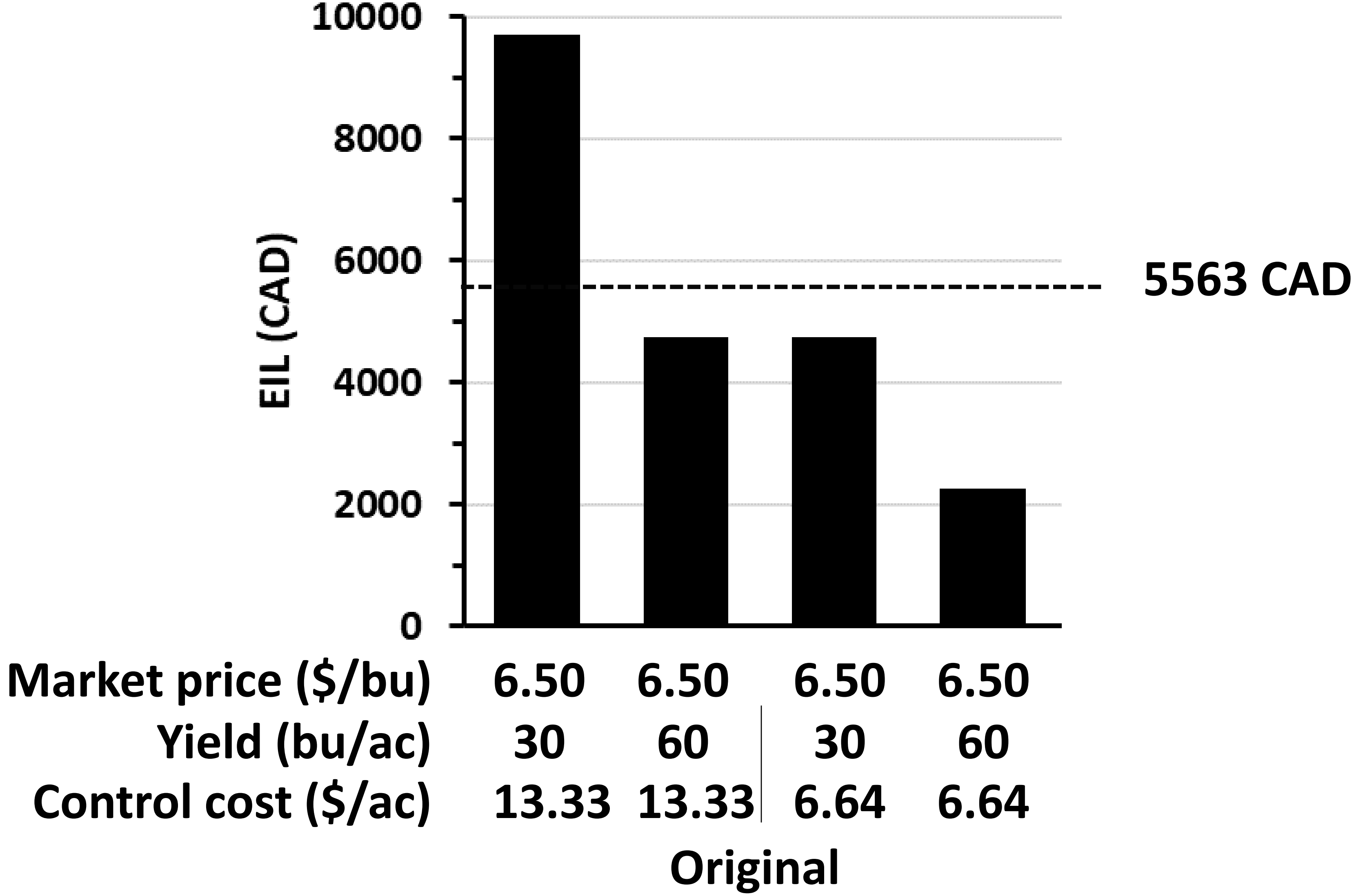
Q) What happens to EIL if market price increases?

A) EIL decreases.



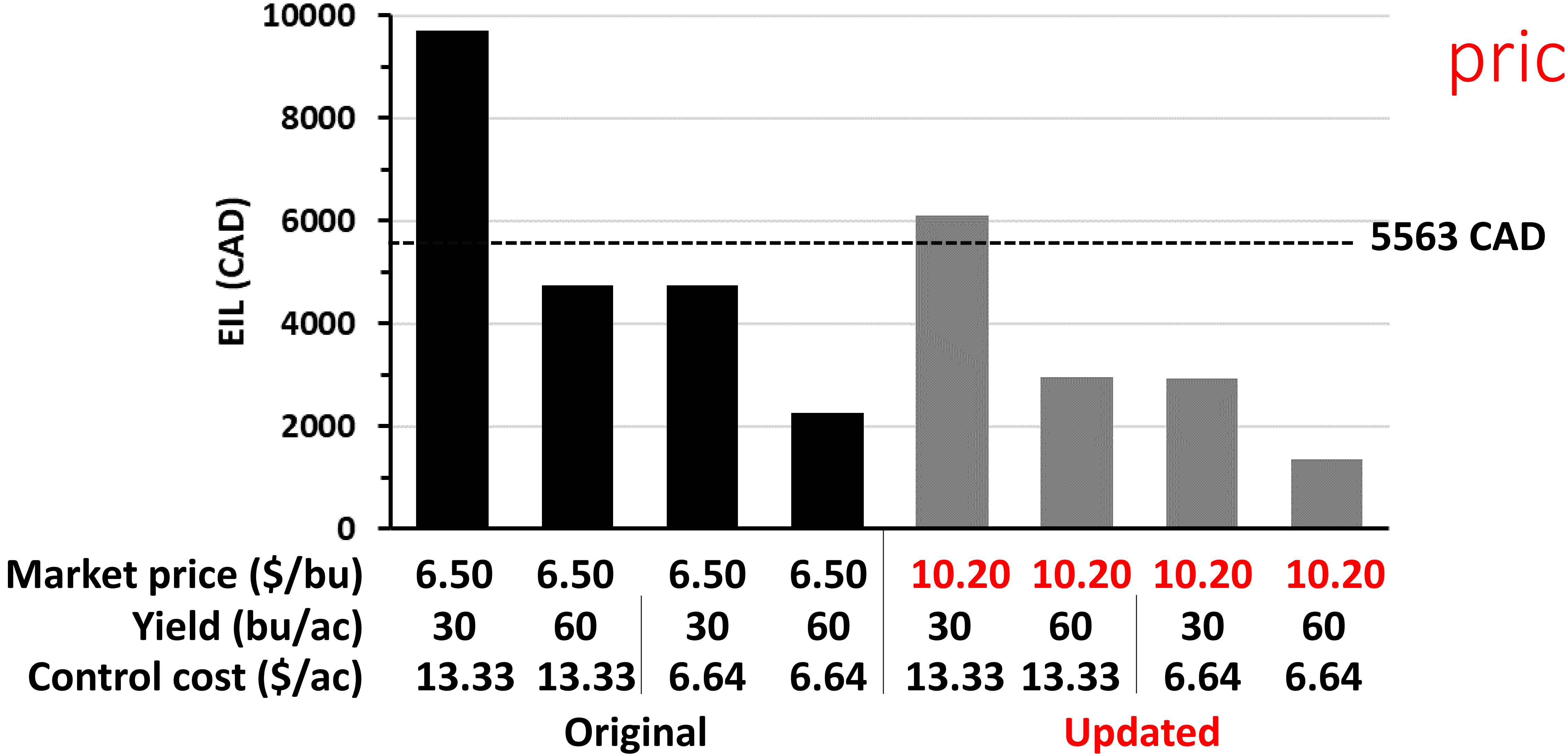
Pedigo & Rice 2009

EIL & ET for soybean aphid

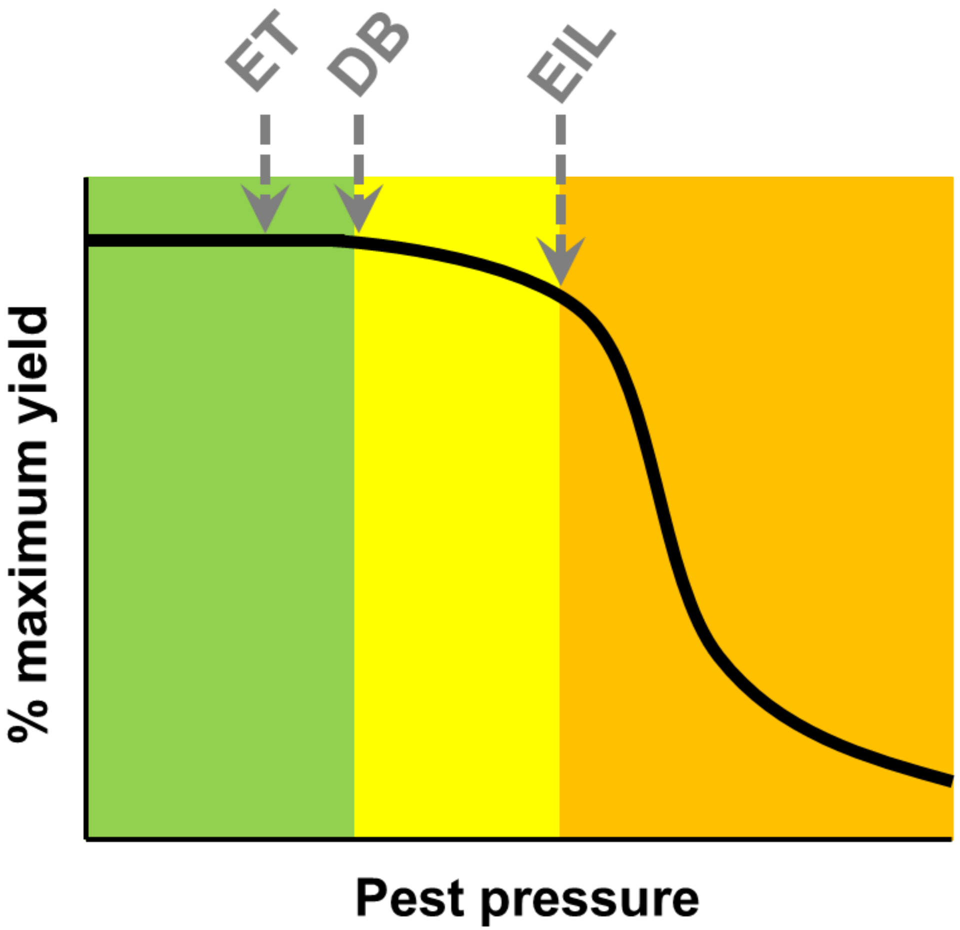


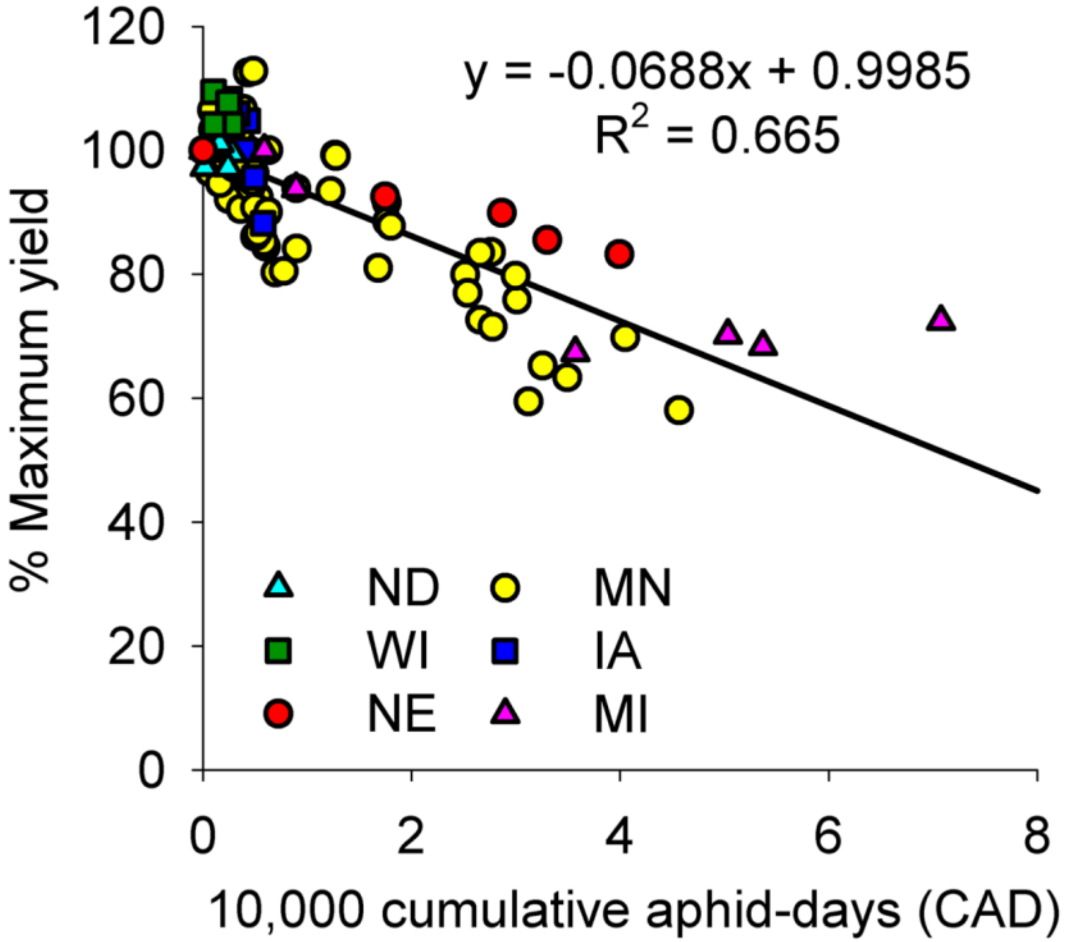
EIL & ET for soybean aphid

Increased market price



Actual biology

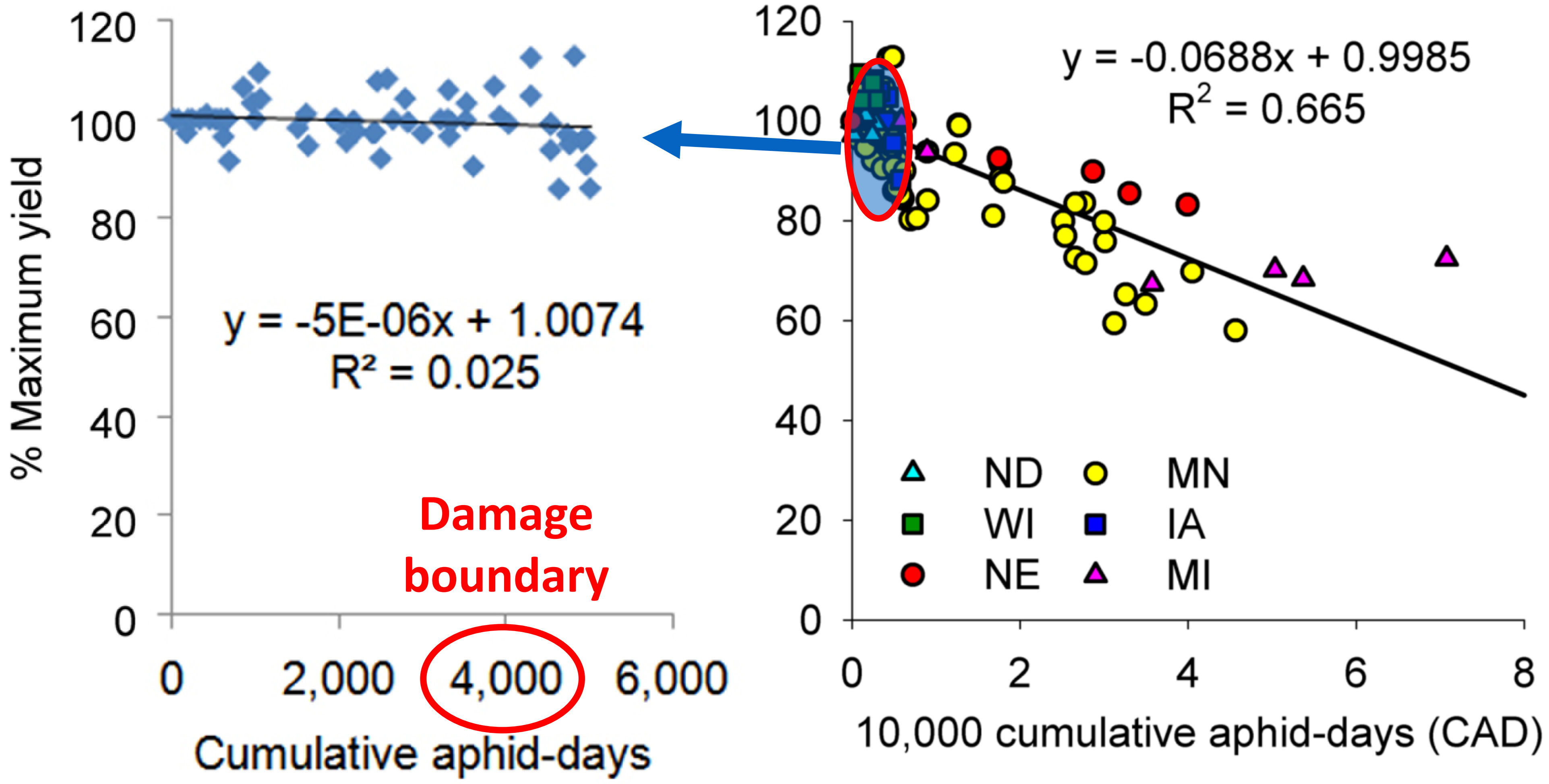




Non-linear relationship

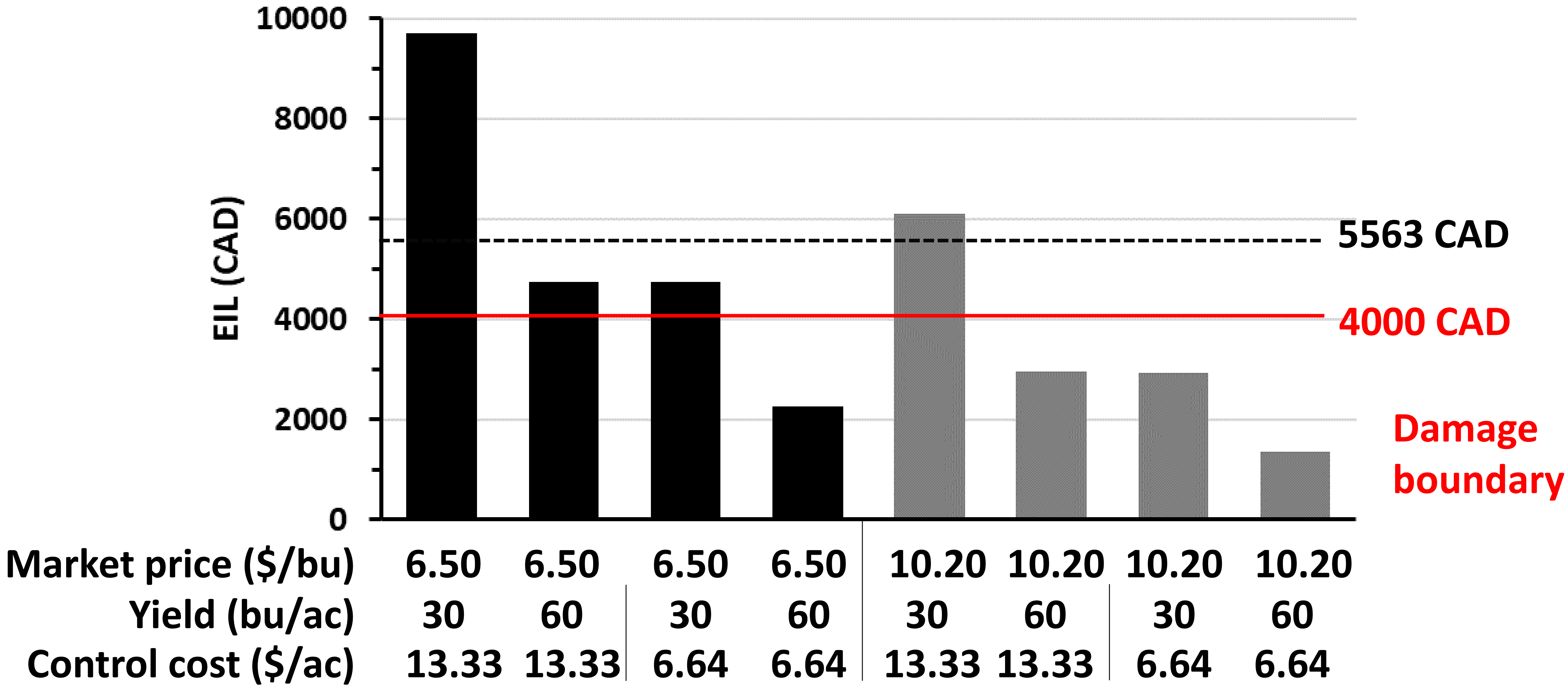
Damage boundary (DB) = pest pressure causing measurable yield loss

Actual biology



Ragsdale et al. 2007 & Koch et al. 2016

EIL, ET & DB for soybean aphid



EIL, ET & DB for soybean aphid

EIL (CAD)	EIL (aphids/plant)	ET (aphids/plant)
5,563	674	273 (250)

DB (CAD)	DB (aphids/plant)	Lowest ET (aphids/plant)
4,000	484	196

EIL, ET & DB for soybean aphid

Plant Health Progress ♦ 2016 ♦ 17:265-269 http://dx.doi.org/10.1094/PHP-RV-16-0061

Plant Health Review

Biology and Economics of Recommendations for Insecticide-Based Management of Soybean Aphid

Robert L. Koch, Department of Entomology, University of Minnesota, Saint Paul 55108; **Bruce D. Potter,** Southwest Research and Outreach Center, University of Minnesota, Lamberton 56152; **Phillip A. Glogoza,** University of Minnesota Extension, Moorhead 56560; **Erin W. Hodgson,** Department of Entomology, Iowa State University, Ames 50011; **Christian H. Krupke,** Department of Entomology, Purdue University, West Lafayette, IN 47907; **John F. Tooker,** Department of Entomology, Penn State University, University Park 16802; **Christina D. DiFonzo,** Department of Entomology, Michigan State University, East Lansing 48824; **Andrew P. Michel** and **Kelley J. Tilmon,** Department of Entomology, The Ohio State University, Wooster 44691; **Travis J. Prochaska,** North Central Research Extension Center, North Dakota State University Extension, Minot 58701; **Janet J. Knodel,** Department of Plant Pathology, North Dakota State University, Fargo 58102; **Robert J. Wright,** Department of Entomology, University of Nebraska-Lincoln 68583; **Thomas E. Hunt,** Department of Entomology, University of Nebraska-Lincoln, Concord 68728; **Bryan Jensen,** Integrated Pest Management, University of Wisconsin, Madison 53706; **Adam J. Varenhorst,** Agronomy, Horticulture, and Plant Science Department, South Dakota State University, Brookings 57006; **Brian P. McCornack,** Department of Entomology, Kansas State University, Manhattan 66506; **Kelly A. Estes** and **Joseph L. Spencer,** Illinois Natural History Survey, University of Illinois, Champaign 61820

Accepted for publication 13 December 2016

ABSTRACT

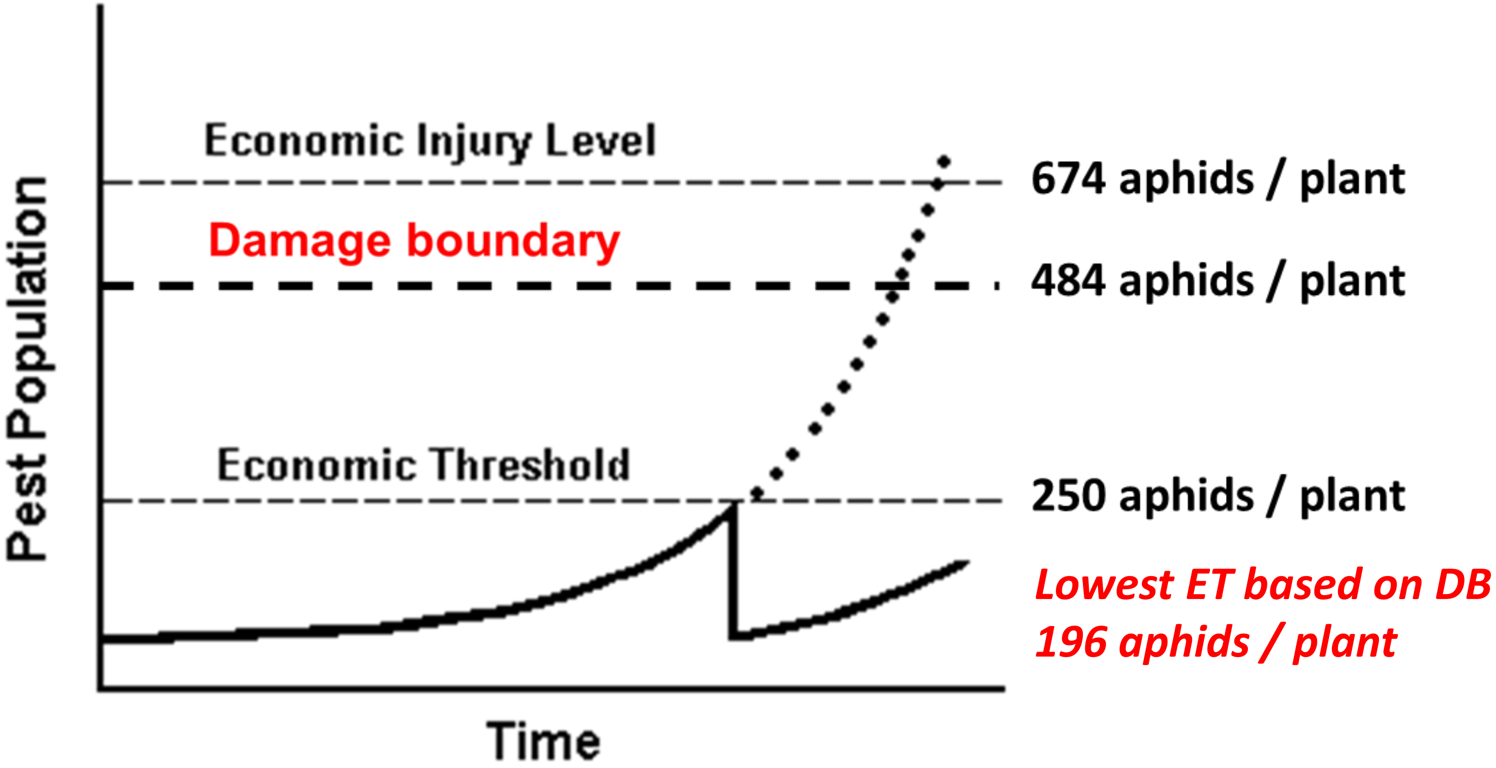
Soybean aphid, *Aphis glycines* Matsumura, remains the key insect pest of soybean, *Glycine max* (L.) Merrill, in the north-central United States. Management of this pest has relied primarily on scouting and application of foliar insecticides based on an economic threshold (ET) of 250 aphids per plant. This review explains why this ET remains valid for soybean aphid management, despite changes in crop value and input costs. In particular, we review how soybean aphid impacts soybean yield, the role of biology and economics in recommendations for soybean aphid management, and the short and long-term consequences of inappropriately timed insecticide applications.

INTRODUCTION

The soybean aphid, *Aphis glycines* Matsumura (Fig. 1), was first detected in the United States in 2000. Prior to the invasion by this pest, insecticide applications to soybean, *Glycine max* (L.) Merrill, in the north-central United States were rare (USDA-NASS 1999), but during the last region-wide outbreak in 2005, millions of acres were treated for soybean aphid (USDA-NASS 2005). Although outbreaks are less common in some states since the mid-2000s (Bahlai et al. 2015), soybean aphid is still the key insect pest of soybean in this region (Hurley and Mitchell 2014). In North America, a tremendous amount of research and observational data have been generated on soybean aphid since its initial detection, and tools and knowledge now exist for effective management of this pest (Hodgson et al. 2012, Ragsdale et al. 2004; Ragsdale et al. 2011; Tilmon et al. 2011).

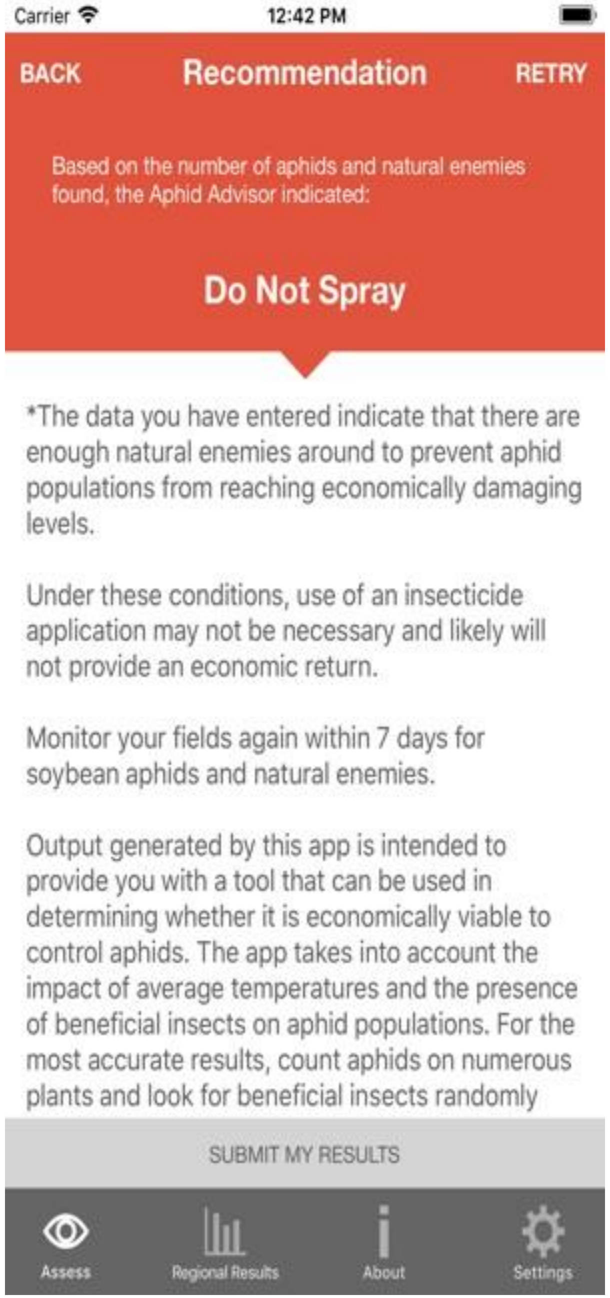
Soybean aphid management recommendations, including the economic threshold (Ragsdale et al. 2007), developed by land-grant universities are based on replicated research evaluated by other agricultural scientists (i.e., peer-reviewed) before publication and dissemination. These recommendations take into consideration pest biology as well as effectiveness and short- and long-term economic and environmental implications of management tactics. Economic conditions (e.g., crop and input prices) have changed since publication of soybean aphid management recommendations (Ragsdale et al. 2007; Tilmon et al. 2011). Here, we present a research-based review updating what is known about soybean aphid, including the potential effects on yield and cost-effective management for this pest.

FIGURE 1
Soybean aphid colony on soybean (photo by A. Varenhorst).



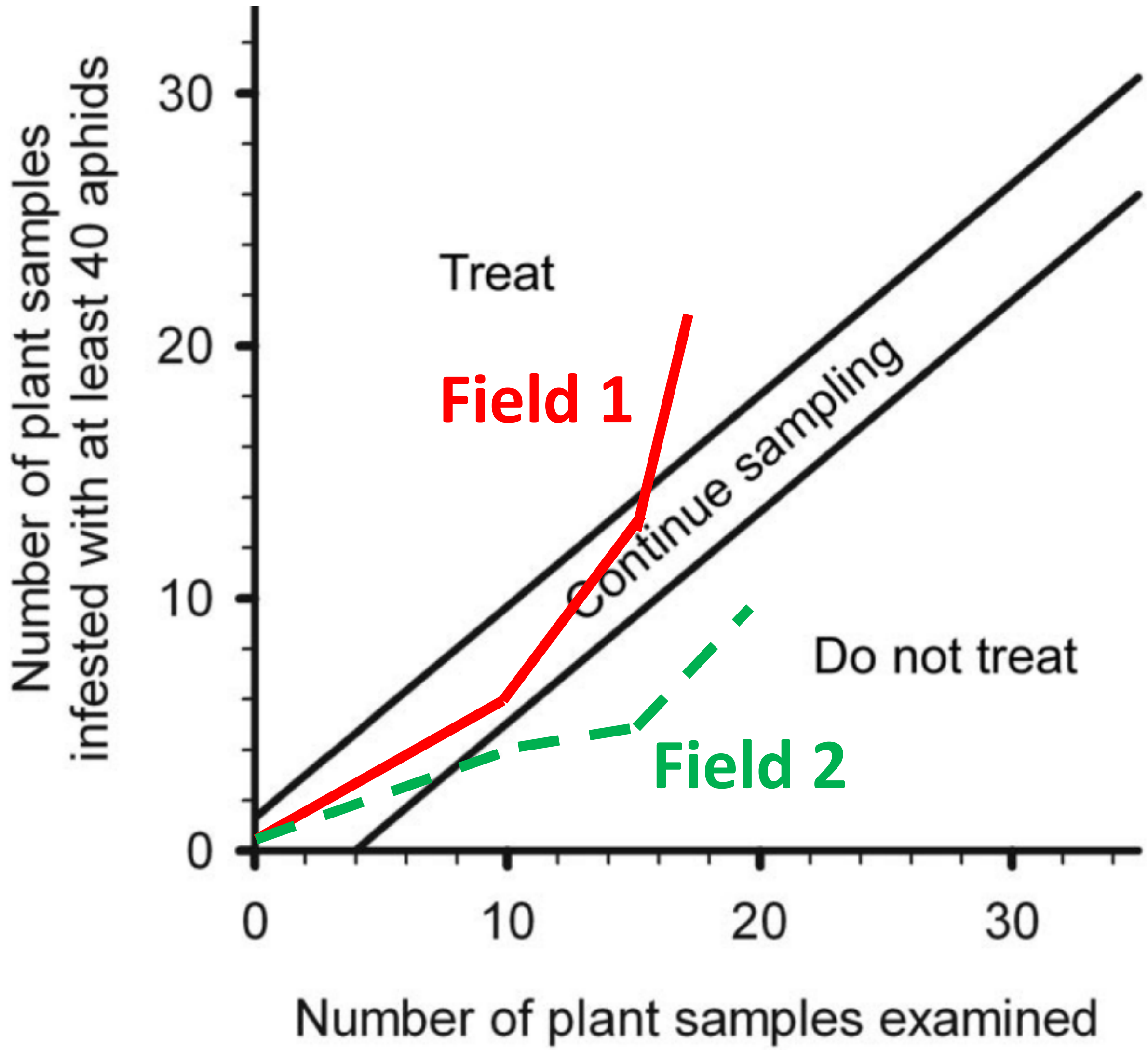
Aphid advisor app

- Example of potential advancements
- ET modified to account for natural enemies
- Developed in Canada
- Not validated in US
- Not recommended in ND or MN



“Speed scouting” for soybean aphid

- Binomial sequential sampling
- Tally threshold
  - Infested: >40 aphids
  - Uninfested: <40 aphids
- 11-31 plants to make decision



Hodgson et al. 2004

Speed Scouting for Soybean Aphid

For blank forms and an interactive example, go to *www.soybeanaphid.info*

Directions for Speed Scouting:

1. Go to a plant at random and start counting aphids. If less than 40 aphids are on the ENTIRE plant, mark a minus [-] for that non-infested plant. If you reach 40 aphids, STOP COUNTING (this is the speedy part!) and mark a plus [+] for that infested plant.

2. Walk 30 rows or paces at random to find the next plant. Repeat Step #1 until 11 plants are sampled in different areas of the field. Total the number of infested plants [+] to make a treatment decision.

3. If you must 'CONTINUE SAMPLING' (7-10 plants with a [+]), sample 5 more plants and use the new total number of plants to make a decision.

4. If no decision is reached, sample additional sets of 5 plants until 31 plants are sampled. Remember, always use the total number of infested plants [+] to make a decision. If no decision can be made after sampling 31 plants, resample the same field in 3-4 days.

5. A 'TREAT' decision must be confirmed a second time 3-4 days later. If confirmed, apply an insecticide in 3-4 days.

Field Location: ______________________

Average Plant Stage: ______________________

Date: ______________________

Treatment Decision: ______________________

Field Notes: ______________________

____

____

____

Remember: *Use [+] or [-] notations for each plant sampled.*

— = < 40 aphids/ plant ('non-infested')
+ = ≥ 40 aphids/ plant ('infested')

Remember: *If you have to continue sampling, add the previous number of infested plants [+] to the next 5-plant count to make a treatment decision.*

Plants sampled		DO NOT TREAT, resample in 7-10 days	CONTINUE SAMPLING 5 more plants	TREAT, confirm again in 3-4 days
___ 1 ___ 2 ___ 3 ___ 4 ___ 5 ___ 6 ___ 7 ___ 8 ___ 9 ___ 10 ___ 11 ▶	☐ ▶	6 or less	7 to 10	11
___ 12 ___ 13 ___ 14 ___ 15 ___ 16 ▶ ___ + ___	☐ ▶	10 or less	11 to 14	15 or more
___ 17 ___ 18 ___ 19 ___ 20 ___ 21 ▶ ___ + ___	☐ ▶	14 or less	15 to 18	19 or more
___ 22 ___ 23 ___ 24 ___ 25 ___ 26 ▶ ___ + ___	☐ ▶	18 or less	19 to 22	23 or more
___ 27 ___ 28 ___ 29 ___ 30 ___ 31 ▶ ___ + ___	☐ ▶	22 or less	23 to 26, *Stop sampling! Return in 3-4 days.*	27 or more

“Speed scouting” for soybean aphid

- Quick: ~10 minutes per field
- Accurate: 79% of fields had same decision as 250/plant threshold
- Conservative: 21% of fields treated early
- Simple: Less detailed information for decision making

Hodgson et al. 2007

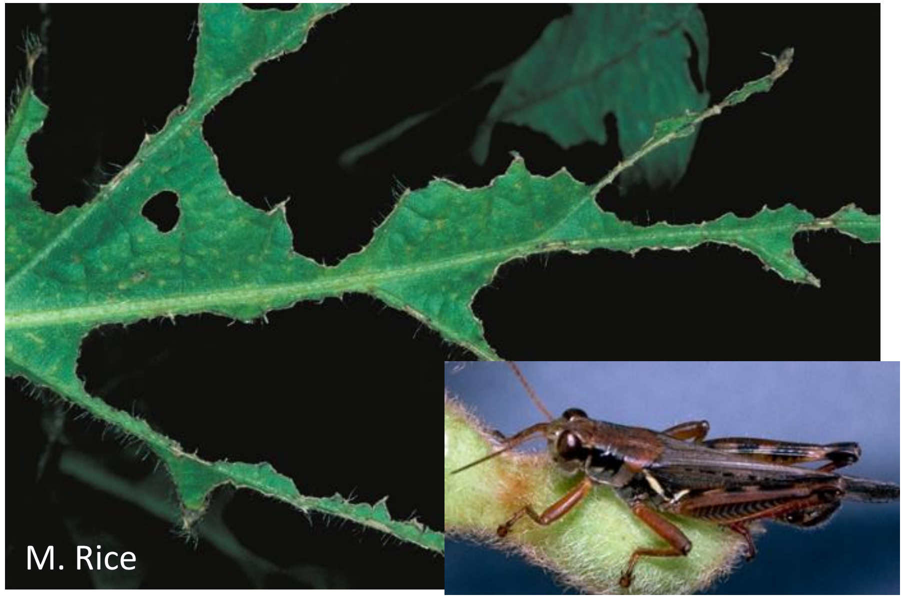
Summary: soybean aphid

- Make decisions based on some estimate of pest population
- Aphids/plant threshold
  - EIL & ET can change
  - DB sets floor (lowest value)
  - 250/plant still conservative
- Speed scouting
  - Quick, accurate, conservative

Defoliation


J. Obermeyer

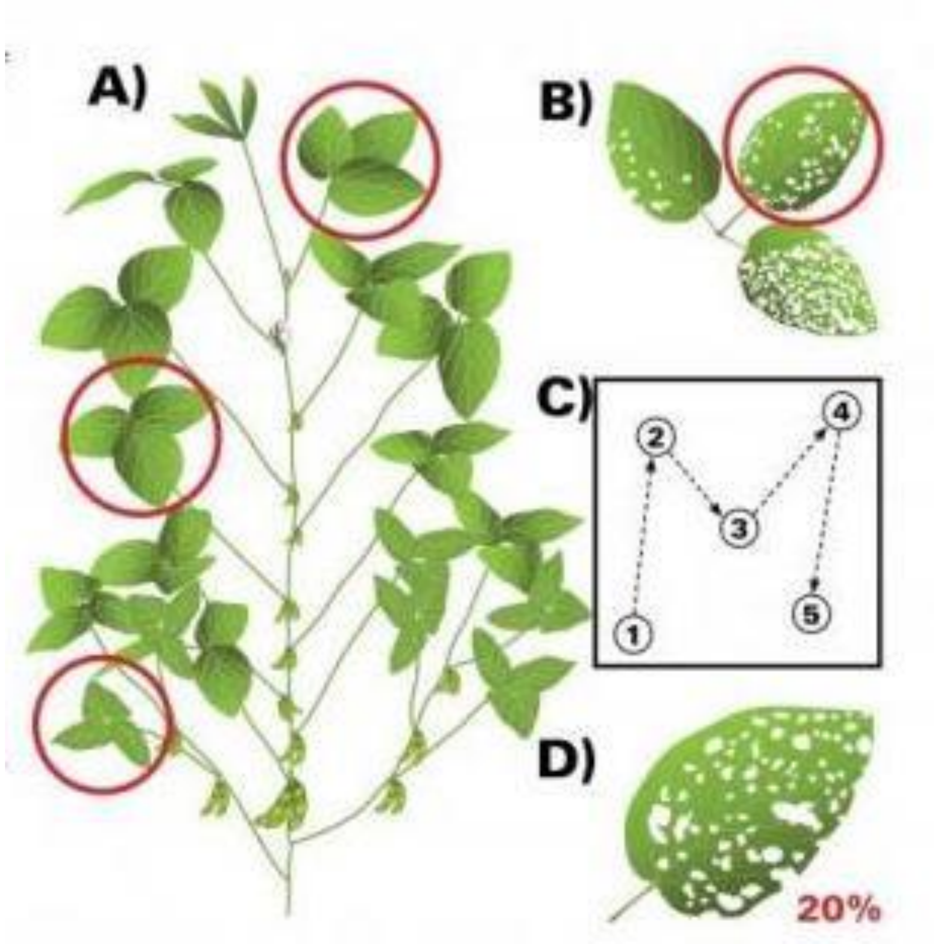

Purdue.edu


M. Rice


illinois.edu

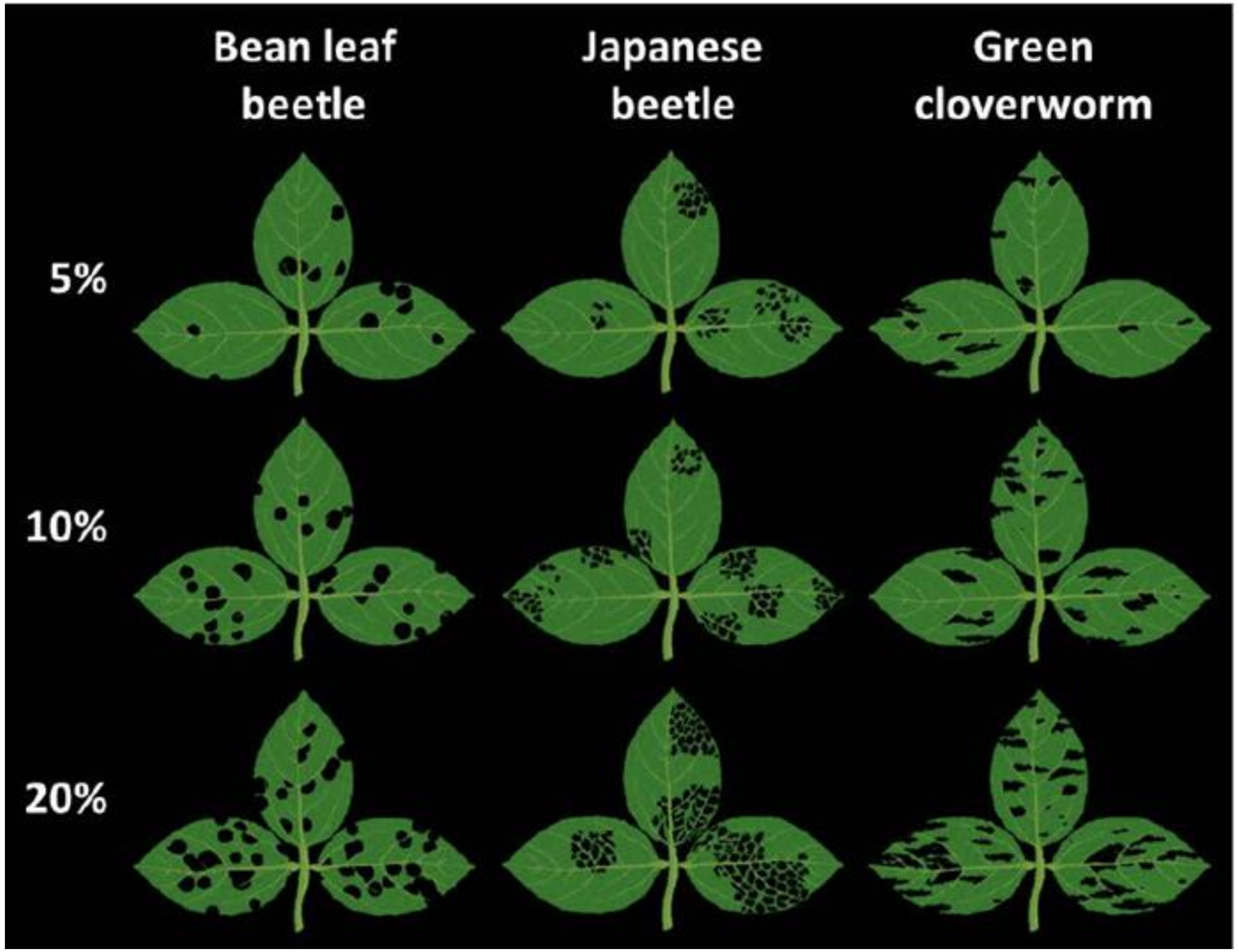
Estimating defoliation

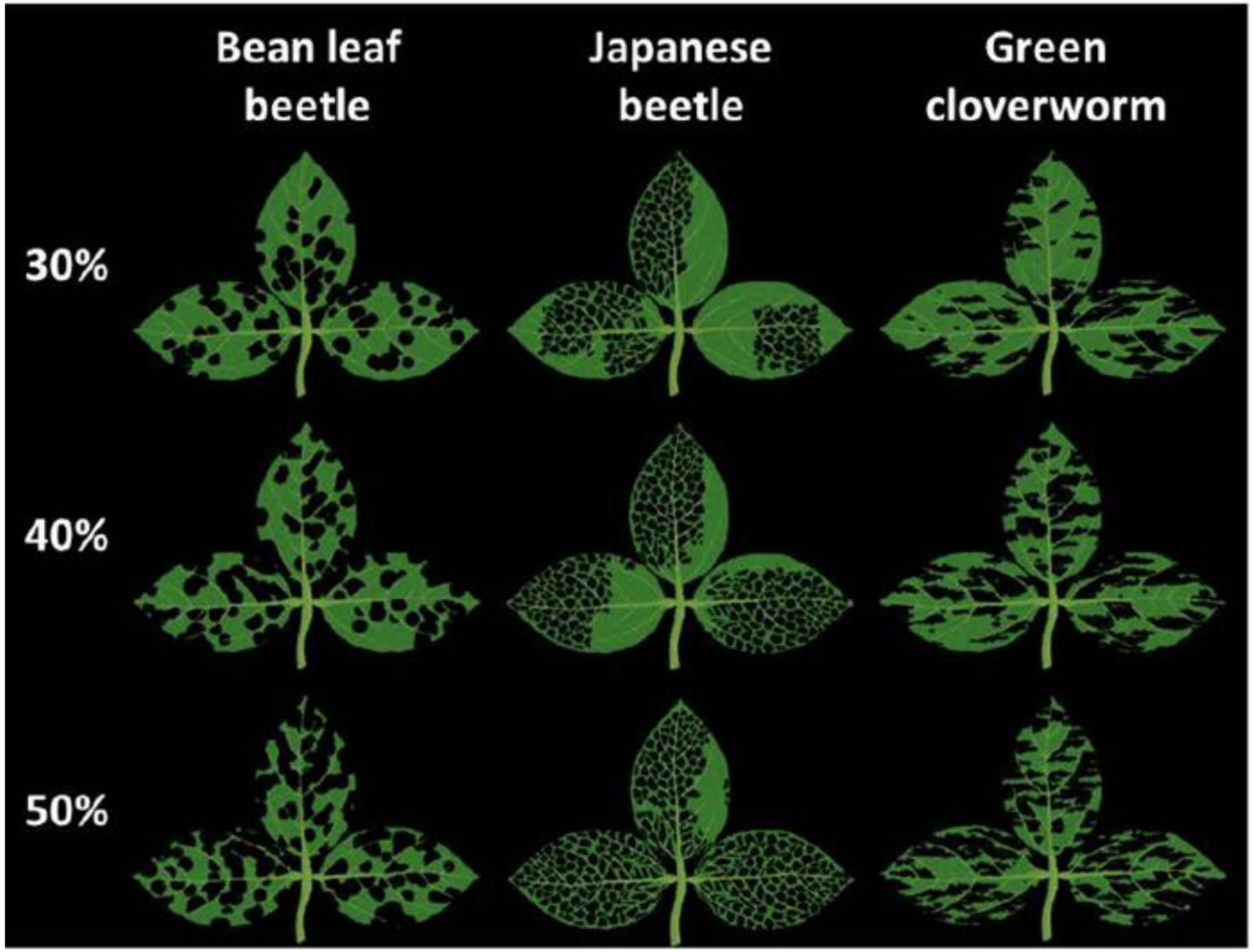
- Select plants from multiple locations throughout field
- Select top, mid & bottom leaf from each plant
- Estimate defoliation per leaf
- Calculate average canopy-level defoliation



Hodgson 2022

Estimating defoliation

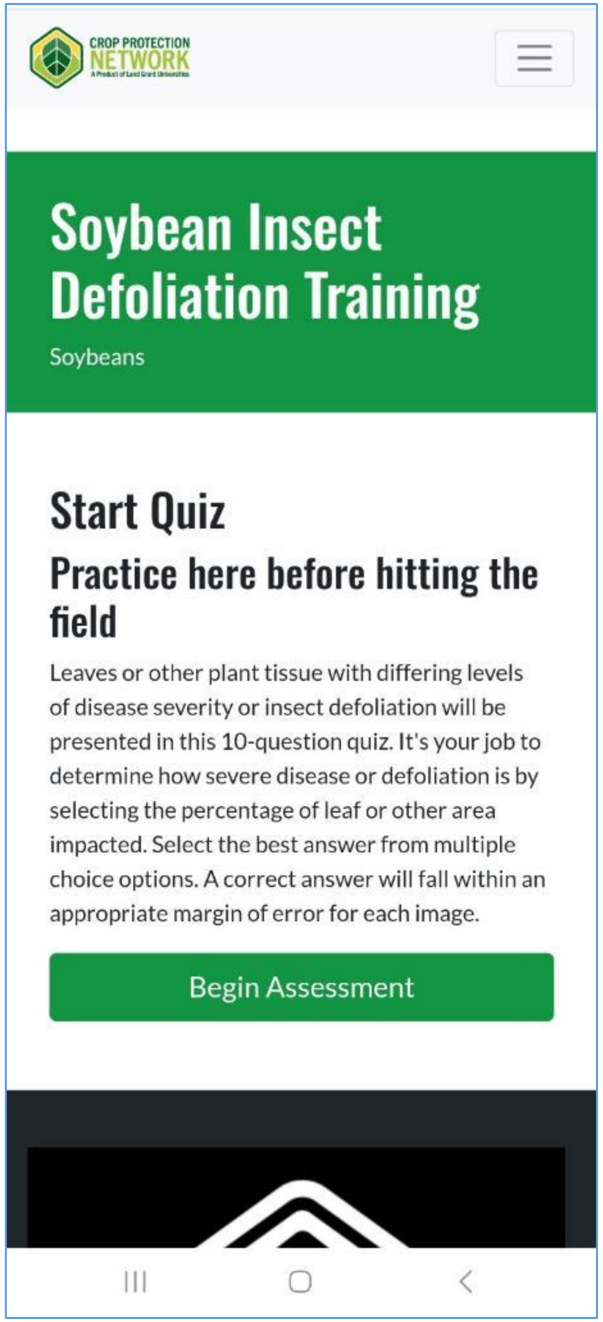


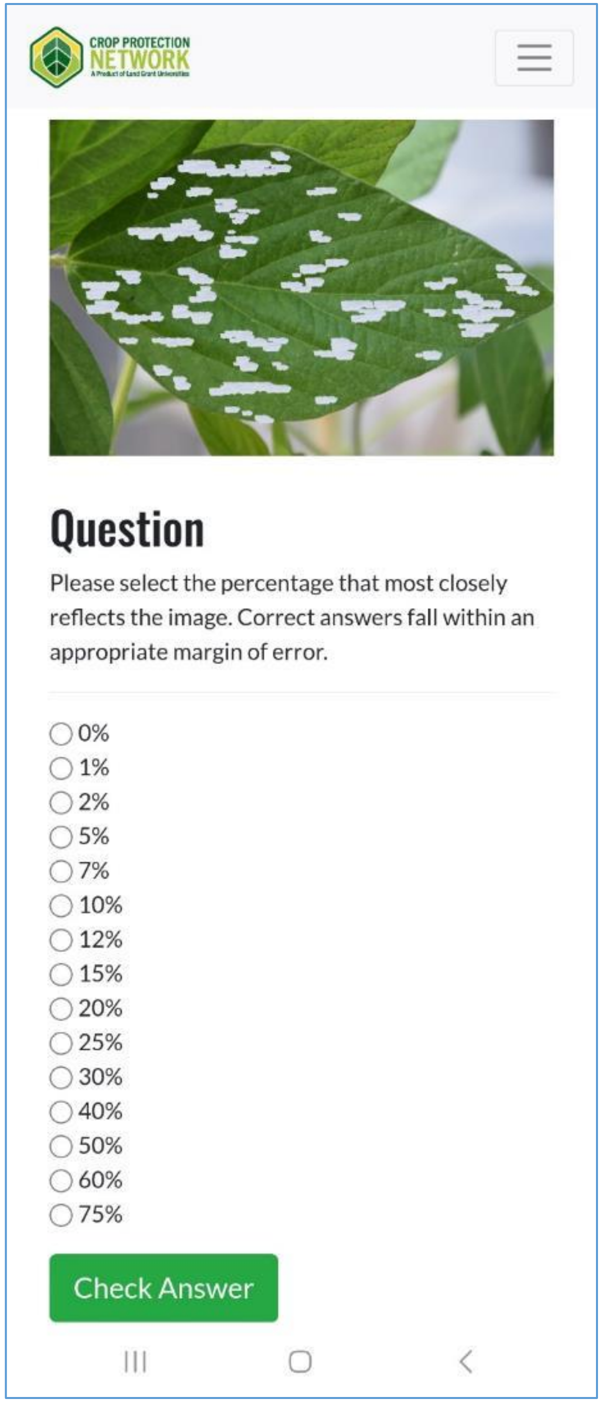


DefoliationPro software

Estimating defoliation

- Train your eye
- Crop Protection Network
  - “Soybean insect defoliation training”
  - “Corn insect defoliation training”





Quiz

CROP PROTECTION NETWORK
A Product of Land Grant Universities

ABOUT RESOURCES PUBLICATIONS TOOLS WATCH & LISTEN NEWS & MEDIA

Soybean Insect Defoliation Training

Soybeans

Back

Question

Please select the percentage that most closely reflects the image. Correct answers fall within an appropriate margin of error.

- 0%
- 1%
- 2%
- 5%
- 7%
- 10%
- 12%
- 15%
- 20%
- 25%
- 30%
- 40%
- 50%
- 60%
- 75%

Check Answer

29%

Quiz

CROP PROTECTION NETWORK
A Product of Land Grant Universities

ABOUT RESOURCES PUBLICATIONS TOOLS WATCH & LISTEN NEWS & MEDIA

Soybean Insect Defoliation Training

Soybeans

Back

Question

Please select the percentage that most closely reflects the image. Correct answers fall within an appropriate margin of error.

- 0%
- 1%
- 2%
- 5%
- 7%
- 10%
- 12%
- 15%
- 20%
- 25%
- 30%
- 40%
- 50%
- 60%
- 75%

Check Answer

18%

Quiz

CROP PROTECTION NETWORK
A Product of Land Grant Universities

ABOUT | RESOURCES | PUBLICATIONS | TOOLS | WATCH & LISTEN | NEWS & MEDIA

Soybean Insect Defoliation Training

Soybeans

Back

Question

Please select the percentage that most closely reflects the image. Correct answers fall within an appropriate margin of error.

- 0%
- 1%
- 2%
- 5%
- 7%
- 10%
- 12%
- 15%
- 20%
- 25%
- 30%
- 40%
- 50%
- 60%
- 75%

Check Answer

58%

Quiz

CROP PROTECTION NETWORK
A Product of Land Grant Universities

ABOUT RESOURCES PUBLICATIONS TOOLS WATCH & LISTEN NEWS & MEDIA

Soybean Insect Defoliation Training

Soybeans

Back

Question

Please select the percentage that most closely reflects the image. Correct answers fall within an appropriate margin of error.

- 0%
- 1%
- 2%
- 5%
- 7%
- 10%
- 12%
- 15%
- 20%
- 25%
- 30%
- 40%
- 50%
- 60%
- 75%

Check Answer

7%

Quiz

CROP PROTECTION NETWORK
A Product of Land Grant Universities

ABOUT RESOURCES PUBLICATIONS TOOLS WATCH & LISTEN NEWS & MEDIA

Soybean Insect Defoliation Training

Soybeans

Back

Question

Please select the percentage that most closely reflects the image. Correct answers fall within an appropriate margin of error.

- 0%
- 1%
- 2%
- 5%
- 7%
- 10%
- 12%
- 15%
- 20%
- 25%
- 30%
- 40%
- 50%
- 60%
- 75%

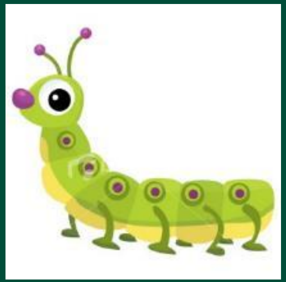
Check Answer

27%

Defoliation thresholds – U of MN

- Consider all defoliators
- Estimate % defoliation over <u>entire</u> canopy
- Threshold
  - 30% pre-bloom
  - 20% bloom to pod fill
  - Pest/s still present

Economic Threshold
Foliage-feeding Caterpillars



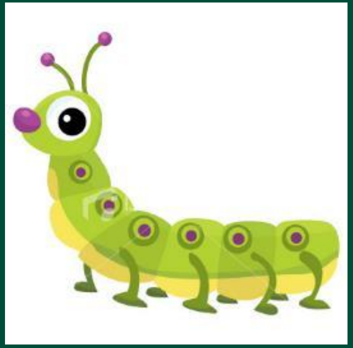
- Defoliation
  - 30% vegetative stages
  - 20% bloom R1 to early seed R5
  - 10% full seed R6
- 30% equivalent to:

10-15 larvae per foot of row

NDSU | EXTENSION

Would you spray this field?

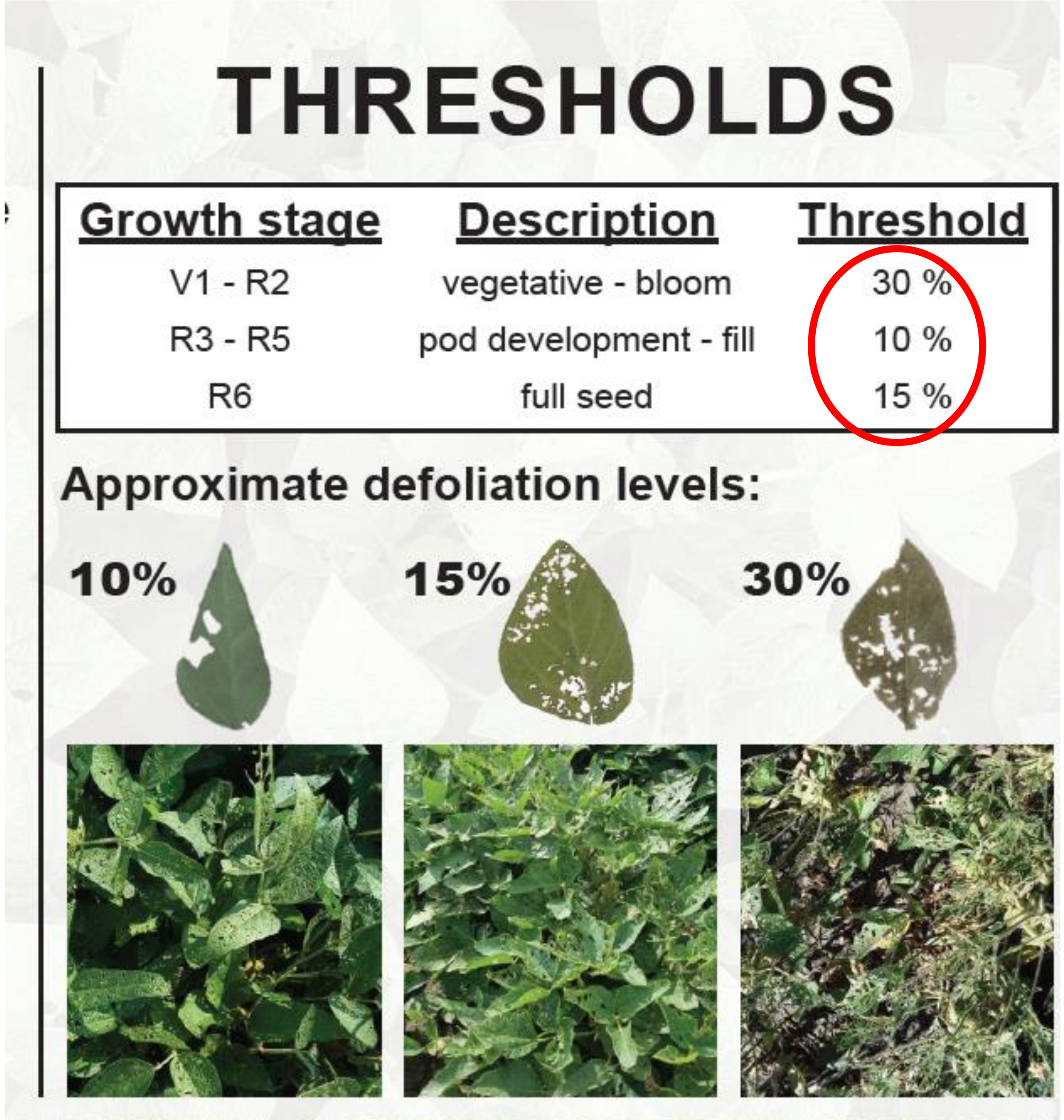
Photo by: V. Calles Torrez



Source:
Bruce Potter, UMN

Lower threshold?

- Not recommended by UMN or NDSU Extension
- Change based on data from Mississippi with MG IV soybean (Owen et al. 2013)
- Not validated in northern states



THRESHOLDS

Growth stage	Description	Threshold
V1 - R2	vegetative - bloom	30 %
R3 - R5	pod development - fill	10 %
R6	full seed	15 %

Approximate defoliation levels:

Excerpt from NCSRP handout

Summary

- Soybean aphid (250 aphids / plant)
  - Objective (calculated) ET, but used as subjective (nominal) ET…still conservative
  - EIL & ET can be adjusted, but damage boundary sets minimum
    - Lowest reasonable threshold (196 aphids / plant)
  - Speed scouting is an alternative
- Defoliation (30% & 20%)
  - Nominal threshold
  - Whole canopy estimates of defoliation