Is one enough? Combining Rag genes improves aphid resistance in soybeans.

Matt O'Neal and Michael McCarville

Iowa State University

February 28, 2012

Soybean aphid impact

- Damage
  - Phloem feeding
  - Sooty mold
  - Transmits plant viruses

- 14%-50% yield reduction in Iowa
- Yield protected with insecticides
  - Scout, apply insecticide at 250 aphids/plant.
    - Ragsdale et al. 2007
    - Johnson et al. 2009

How valuable are aphid resistant soybeans?

- Outbreaks occurred in Iowa in:
  - 2001
  - 2003
  - 2005
  - 2007
  - 2008
  - 2009
  - 2011

7 of the last 11 years

Aphid resistance collaboration

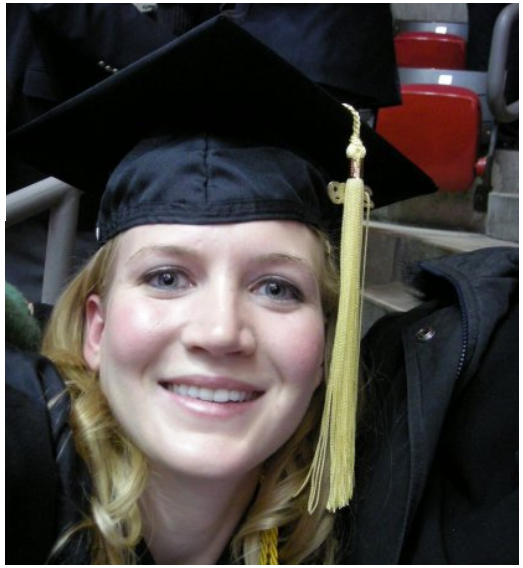
- Dr. Walter Fehr-Soybean Breeder, ISU
- Shaylyn Wiarda- Future Soybean Breeder, now at Purdue University

Iowa Soybean Association

EXPANDING OPPORTUNITIES. DELIVERING RESULTS.

NCSRP

NORTH CENTRAL SOYBEAN RESEARCH PROGRAM



How well does aphid resistance work?

- Wiarda, Fehr and O'Neal. 2012. **Soybean aphid development on soybean with *Rag1* alone, *Rag2* alone and both genes combined**. J. Econ. Entomol. 105: 252-258. DOI: http://dx.doi.org/10.1603/EC11020

- Four soybean genotypes
  rag1rag2 = Susceptible
  Rag1rag2 = *Rag1* alone
  rag1Rag2 = *Rag2* alone
  Rag1Rag2 = both genes combined

- The 'woodshed experiment'

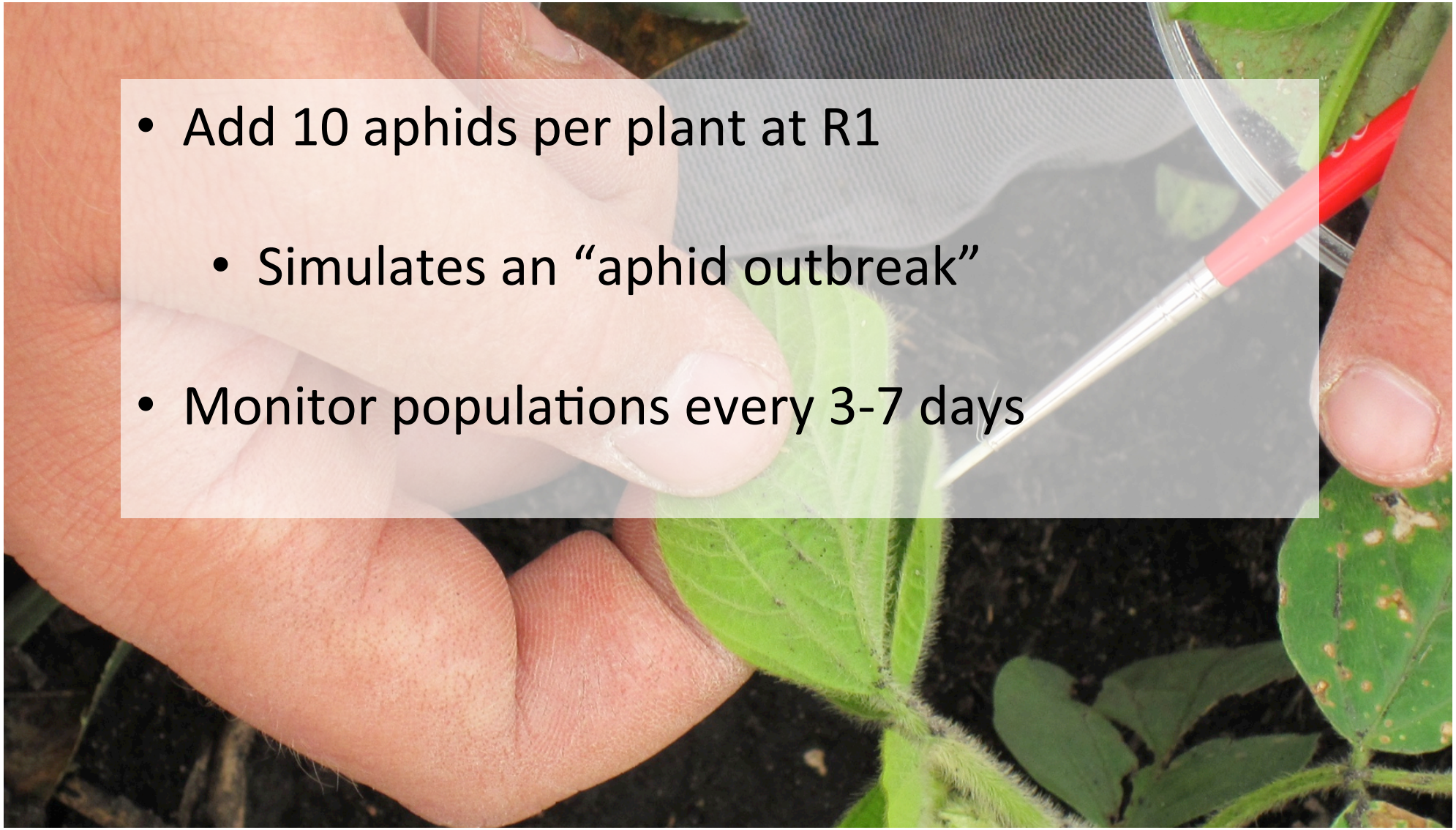
What happens when aphid resistance is taken behind “the woodshed”?

Wiarda et al. 2012 J. Econ. Entomology

The ‘woodsheds’

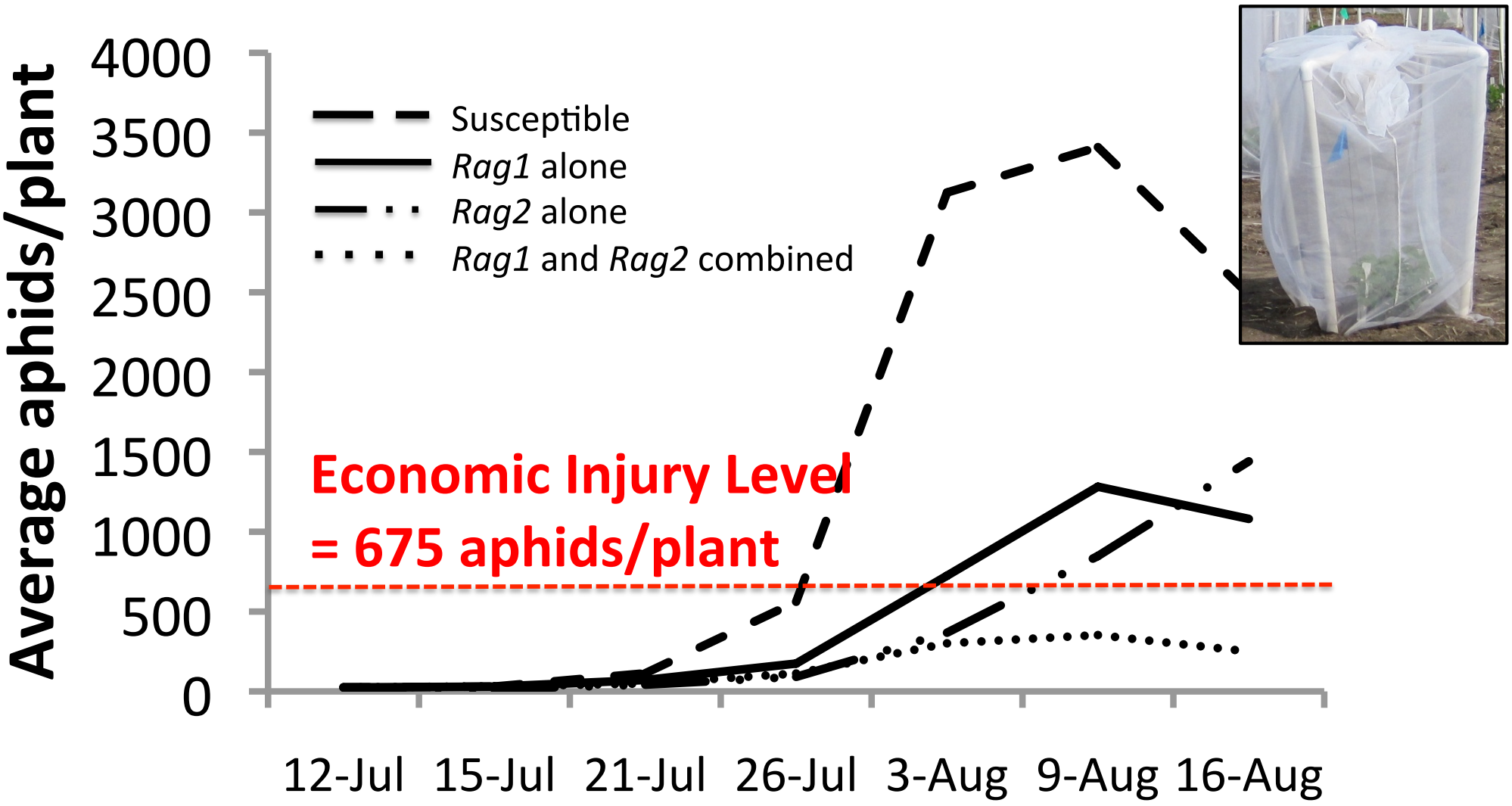
Plants artificially infested with aphids and caged to prevent predation (e.g. ladybeetles).

Aphids in the ‘woodshed’



- Add 10 aphids per plant at R1
  - Simulates an “aphid outbreak”
- Monitor populations every 3-7 days

Rag genes slow aphid population growth



Wiarda et al. 2012 J. Econ Entomology

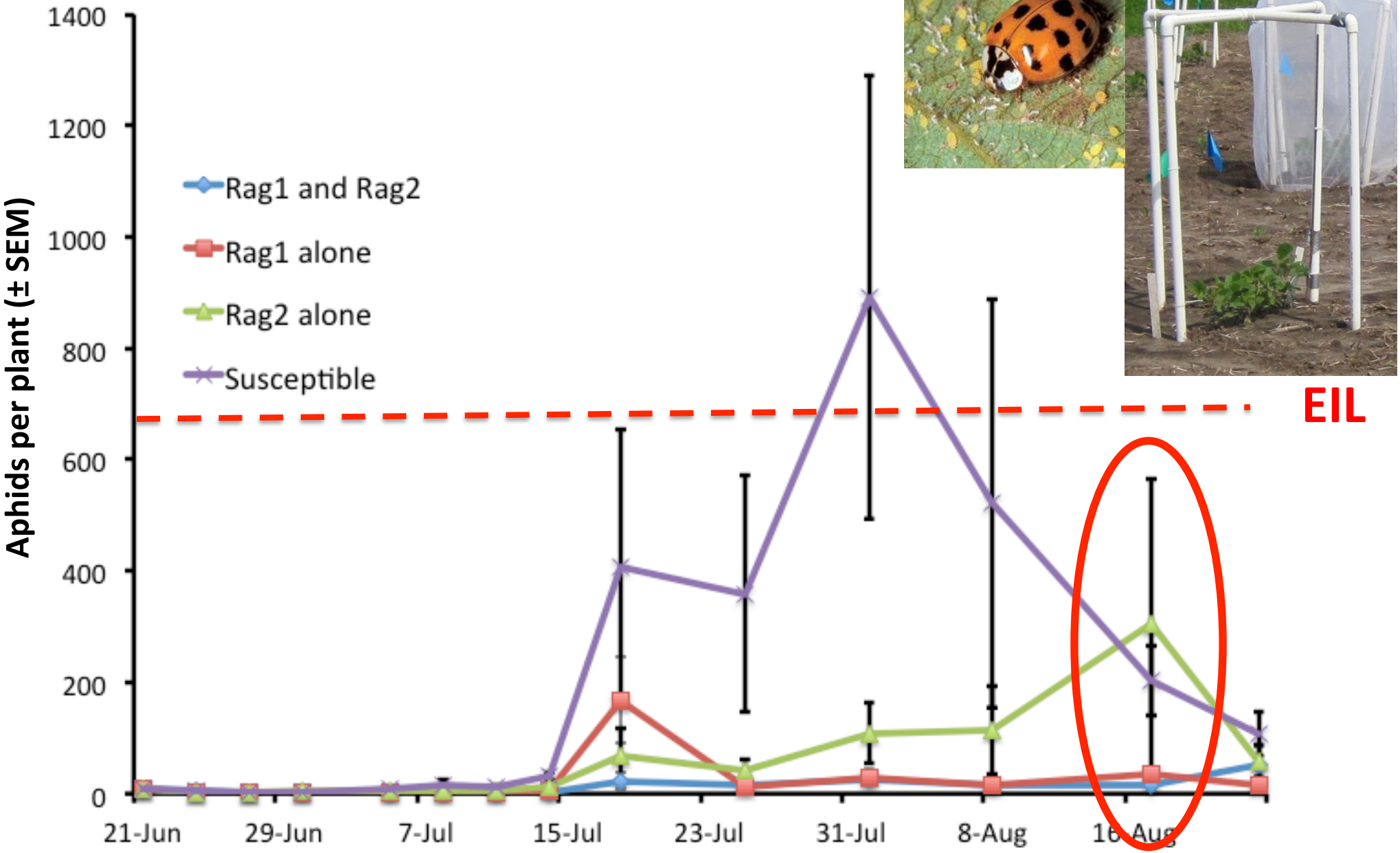
Conclusions from Wiarda et al. 2012. J. Econ. Entomol.

- Combining Rag1 and Rag2 **slowed** aphid population growth:
  - Even after multiple-infestations
  - In absence of predators

- Screening aphid resistance takes time.
  - Time = money

Why screen resistance all season long?

Why screen resistance all season long?

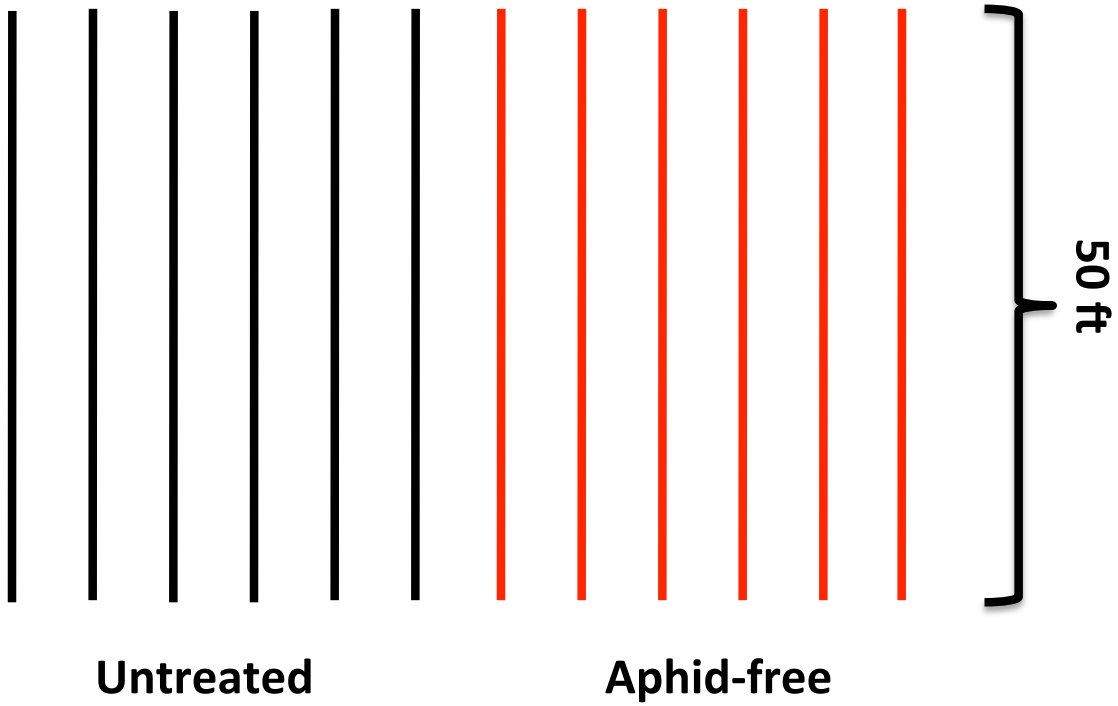


How well does the pyramid perform in multiple environments?

<u>University collaborators:</u>
Dr. Kelly Tilmon, SDSU
Dr. Bruce Potter, UM
Dr. Brian McCornack, KSU
Dr. Eileen Cullen, UW
Dr. John Tooker, PSU

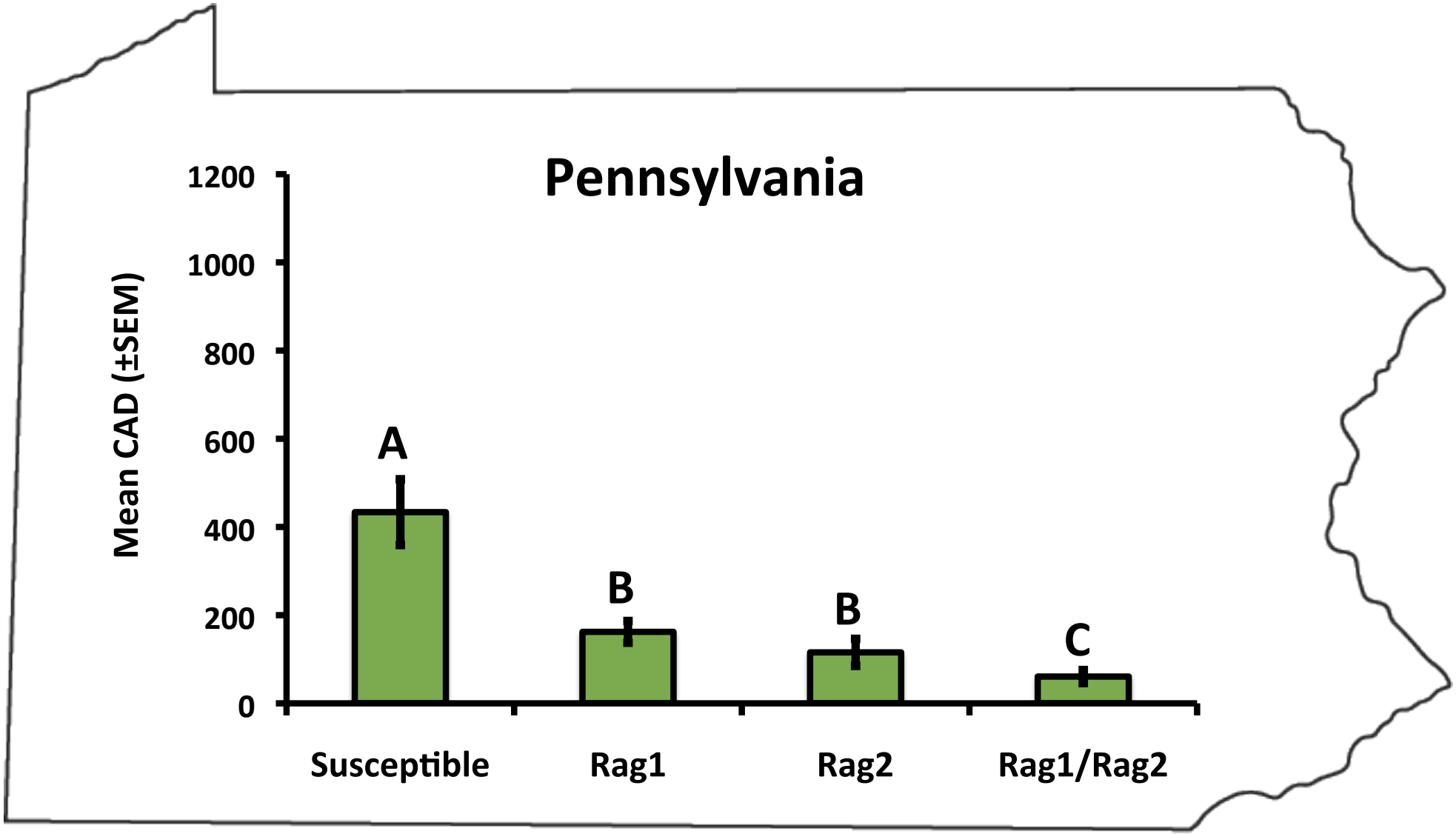
Multi-state experiment

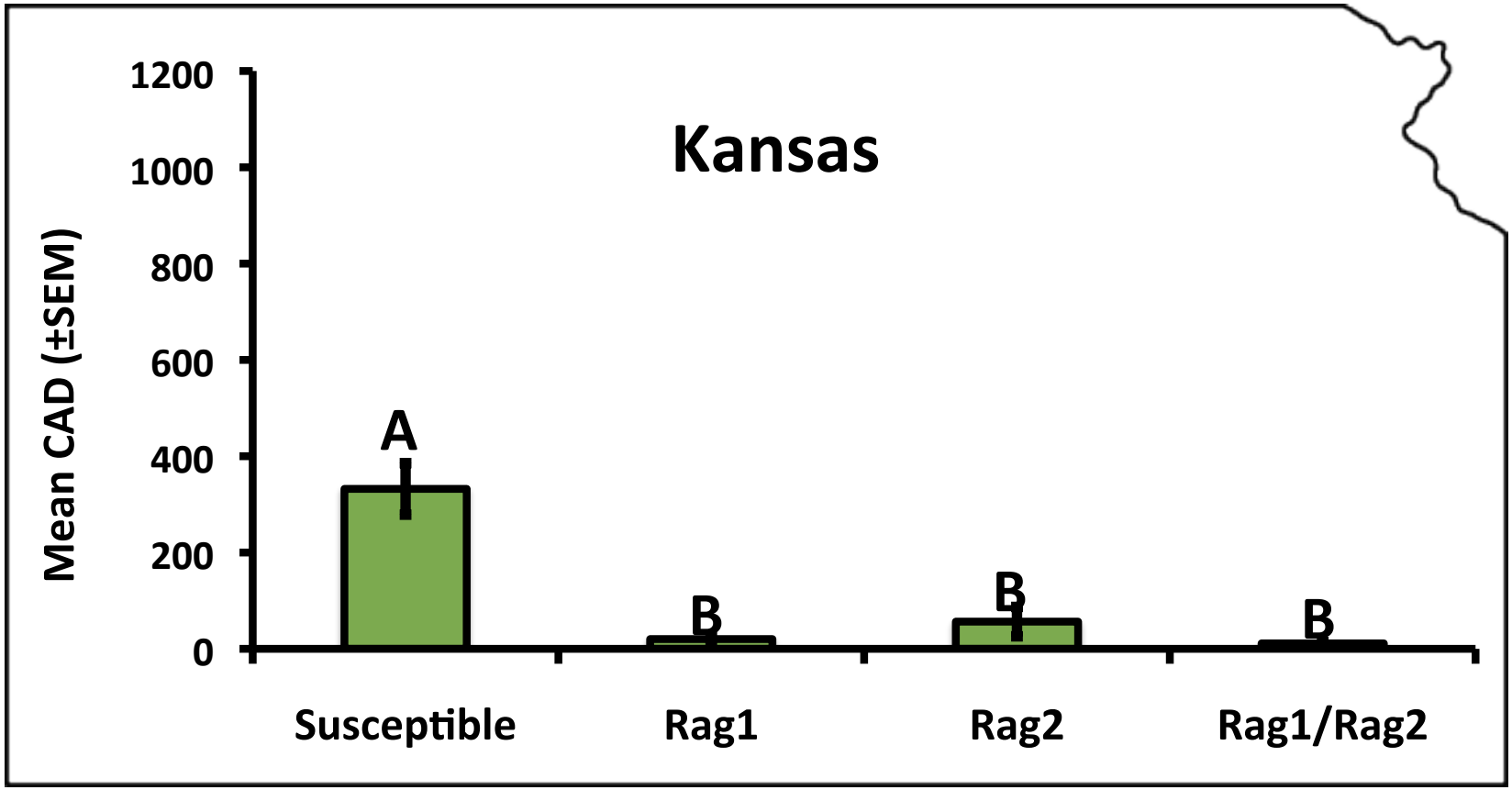
- Same 4 genotypes as Wiarda et al. 2012
  - Conducted during 2011
  - Grown without seed-applied or foliar-applied insecticide
  - Naturally occurring aphid populations
  - Split-plot = aphid density (untreated and aphid-free)

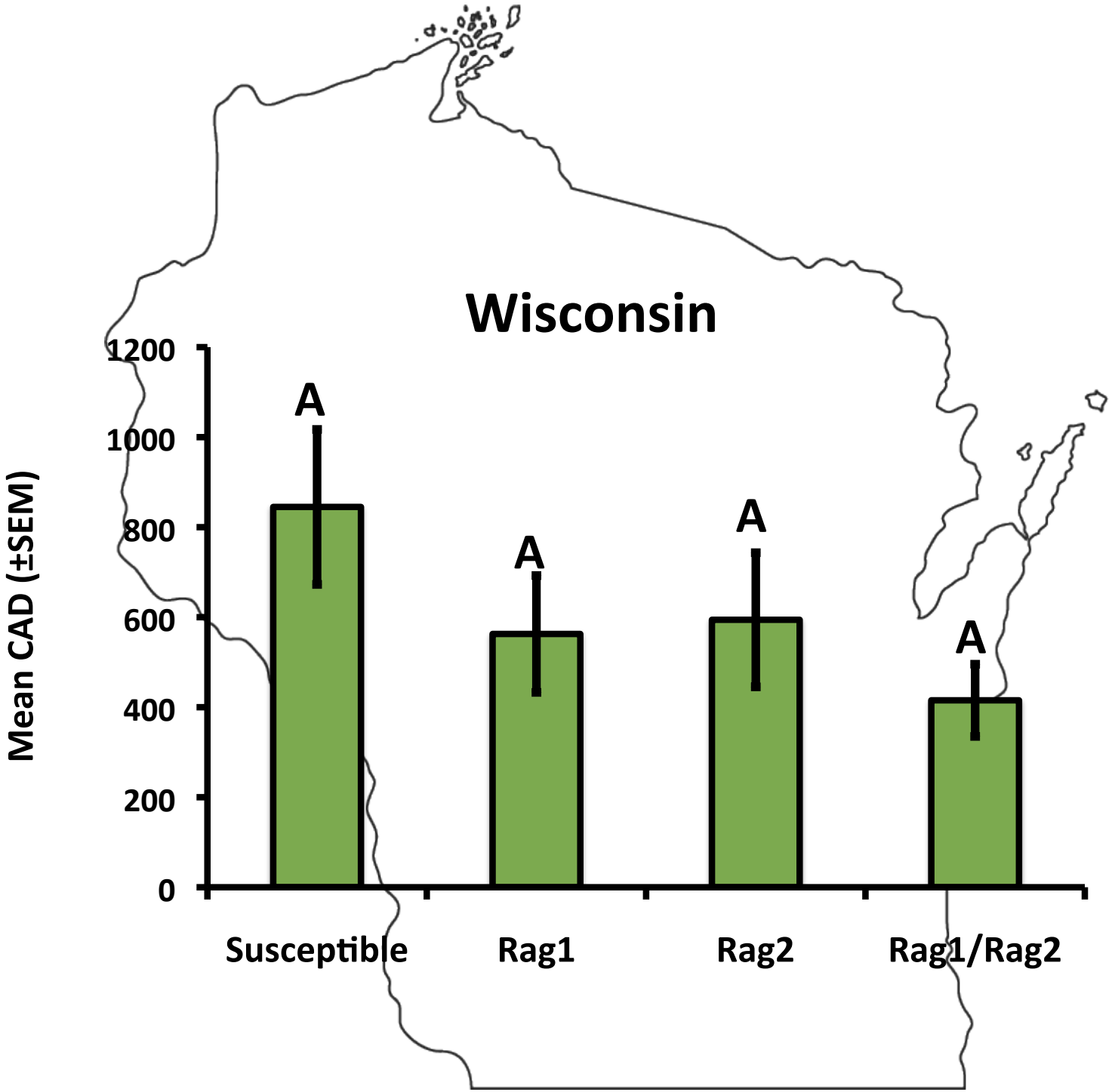


Low Aphid Population Locations

- Pennsylvania
- Kansas
- Wisconsin


Pennsylvania
Mean CAD (±SEM)
1200
1000
800
600
400
200
0
A
B
B
C
Susceptible
Rag1
Rag2
Rag1/Rag2


Kansas
Mean CAD (±SEM)
1200
1000
800
600
400
200
0
A
B
B
B
Susceptible
Rag1
Rag2
Rag1/Rag2

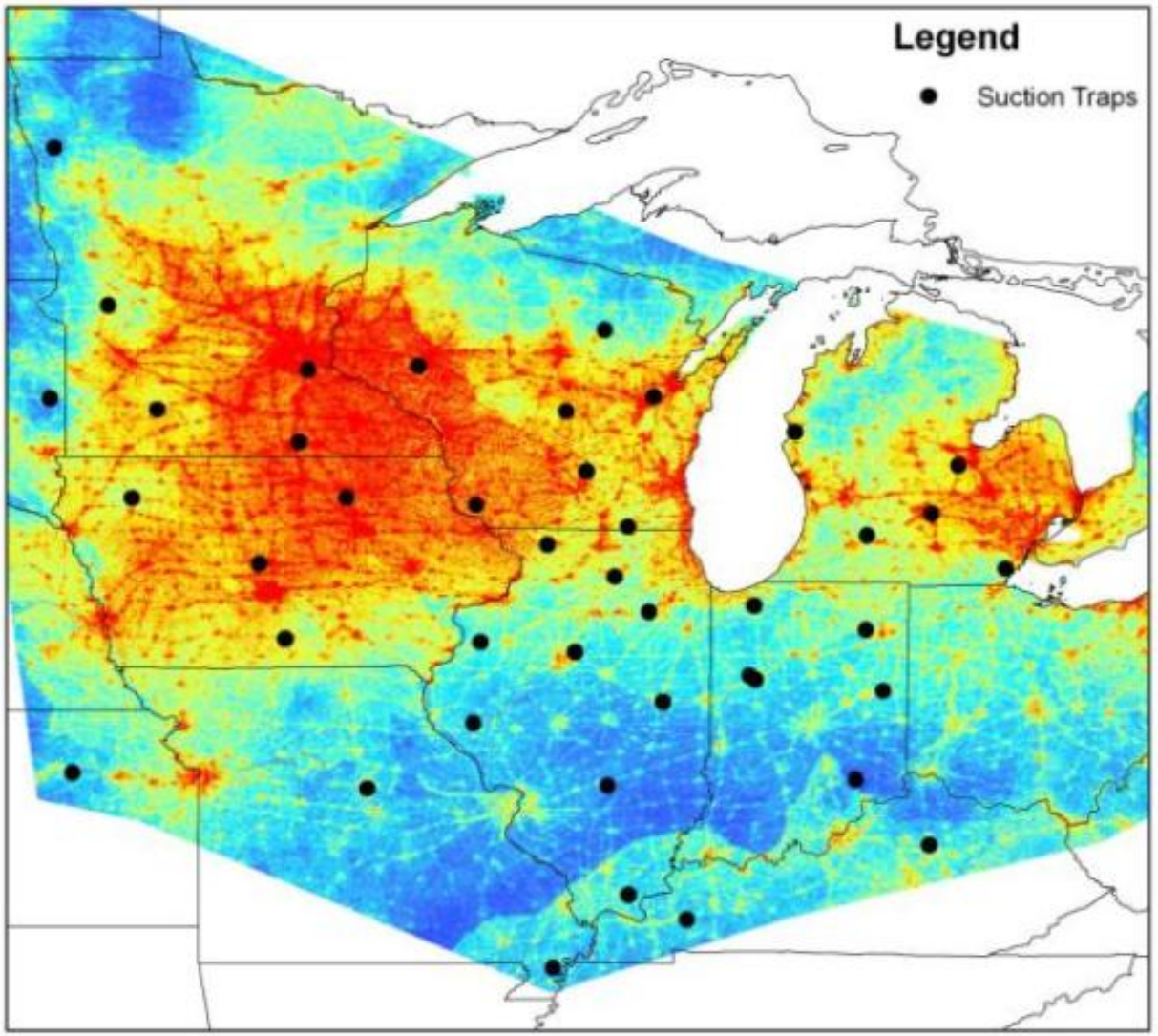

Wisconsin
Mean CAD (±SEM)
1200
1000
800
600
400
200
0
A
A
A
A
Susceptible
Rag1
Rag2
Rag1/Rag2

What's so special about Wisconsin?

Buckthorn probability map

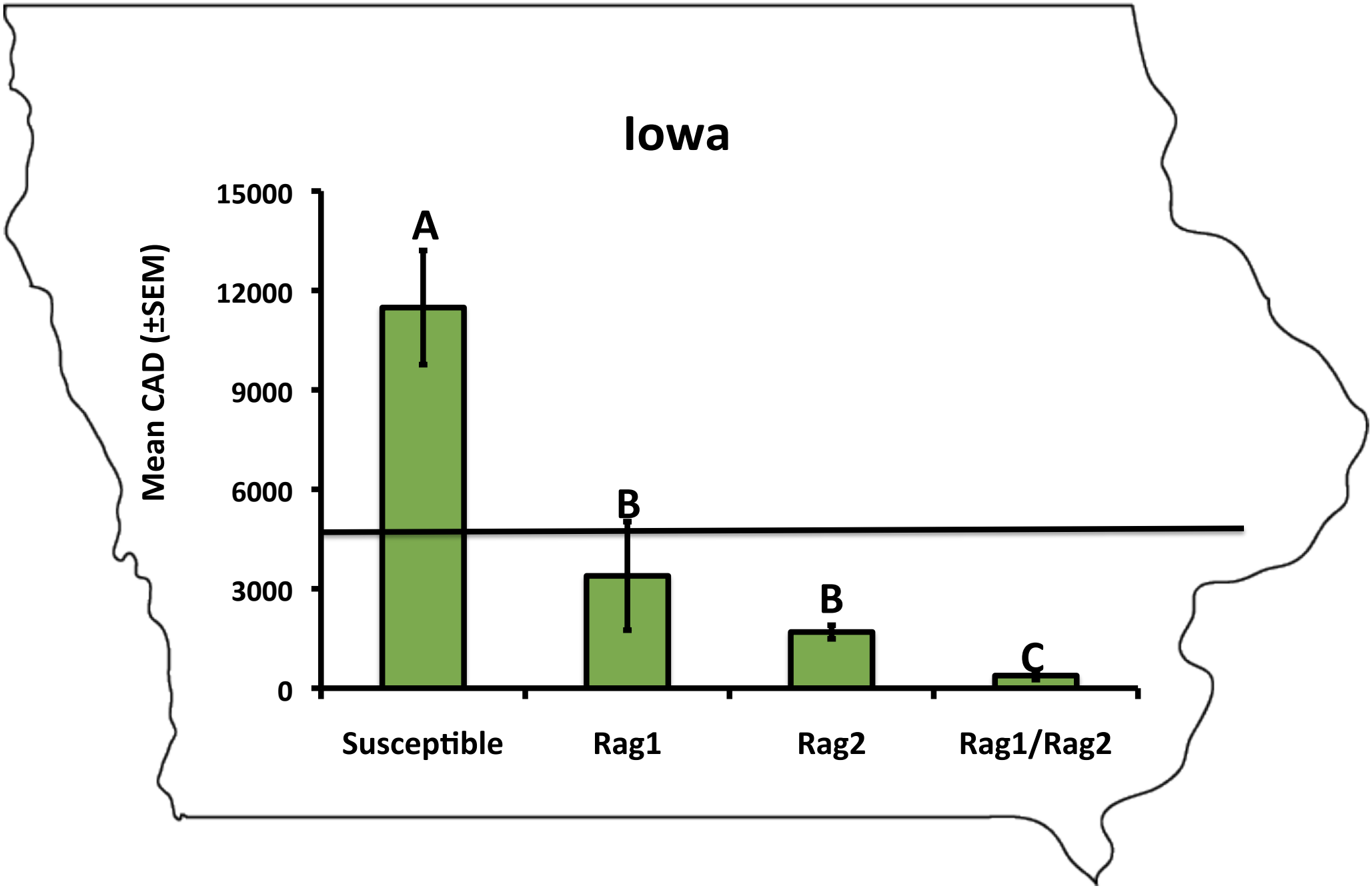
High buckthorn probability of occurrence

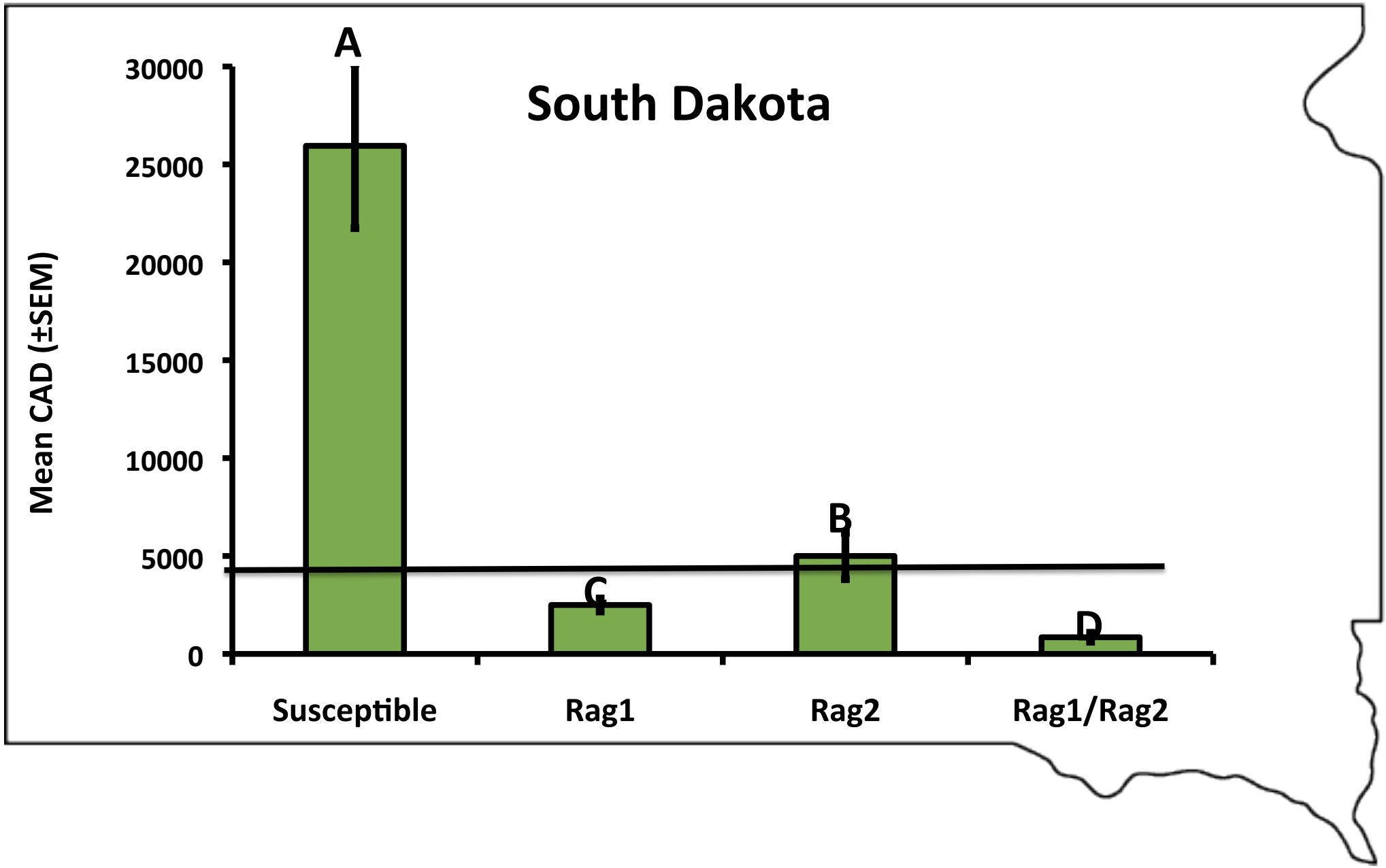
Low buckthorn probability of occurrence

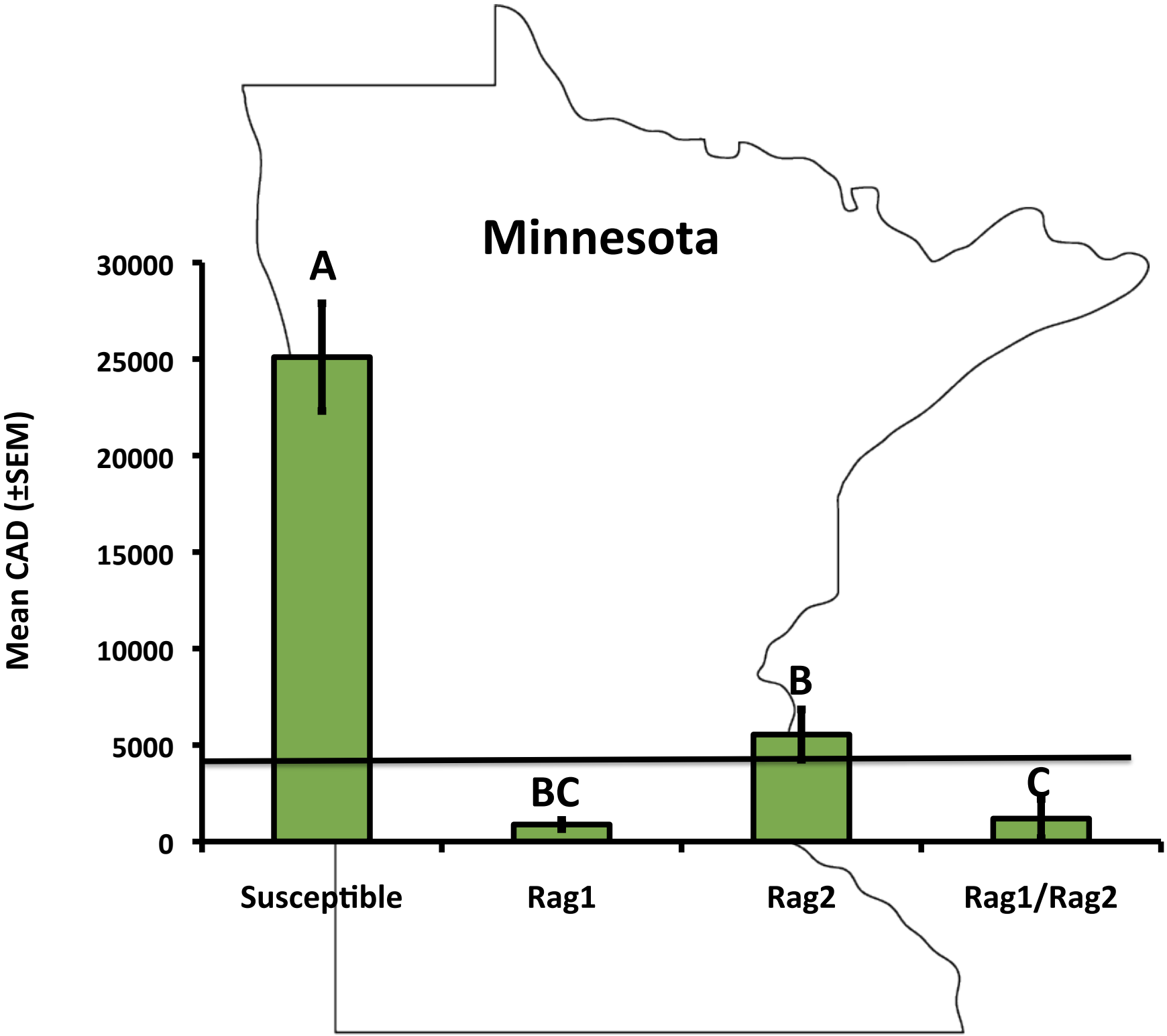


High Aphid Population Locations

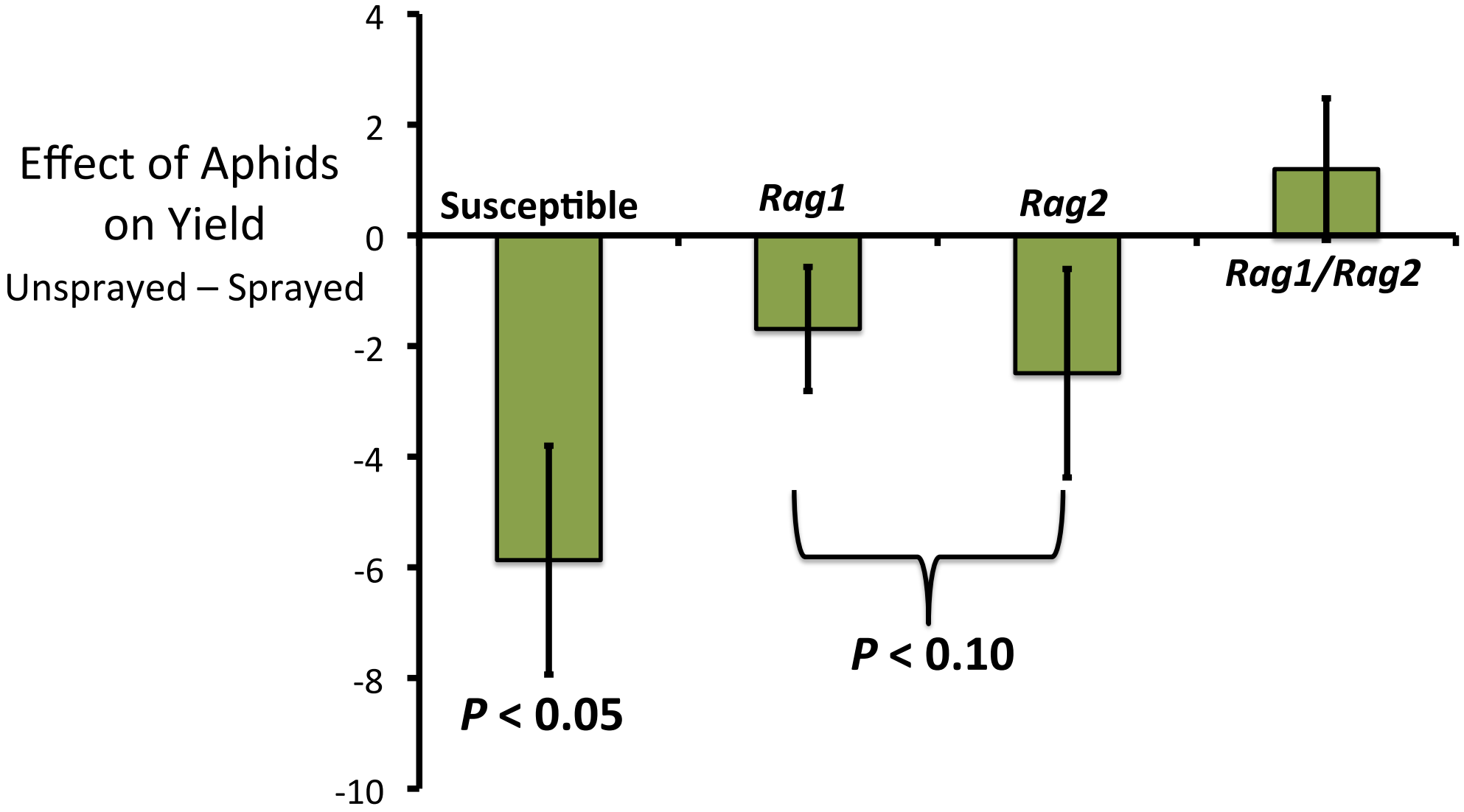
- Iowa
- South Dakota
- Minnesota


Iowa
Mean CAD (±SEM)
15000
12000
9000
6000
3000
0
A
B
B
C
Susceptible
Rag1
Rag2
Rag1/Rag2


South Dakota
Mean CAD (±SEM)
30000
25000
20000
15000
10000
5000
0
A
B
C
D
Susceptible
Rag1
Rag2
Rag1/Rag2


Minnesota
Mean CAD (±SEM)
30000
25000
20000
15000
10000
5000
0
A
BC
B
C
Susceptible
Rag1
Rag2
Rag1/Rag2

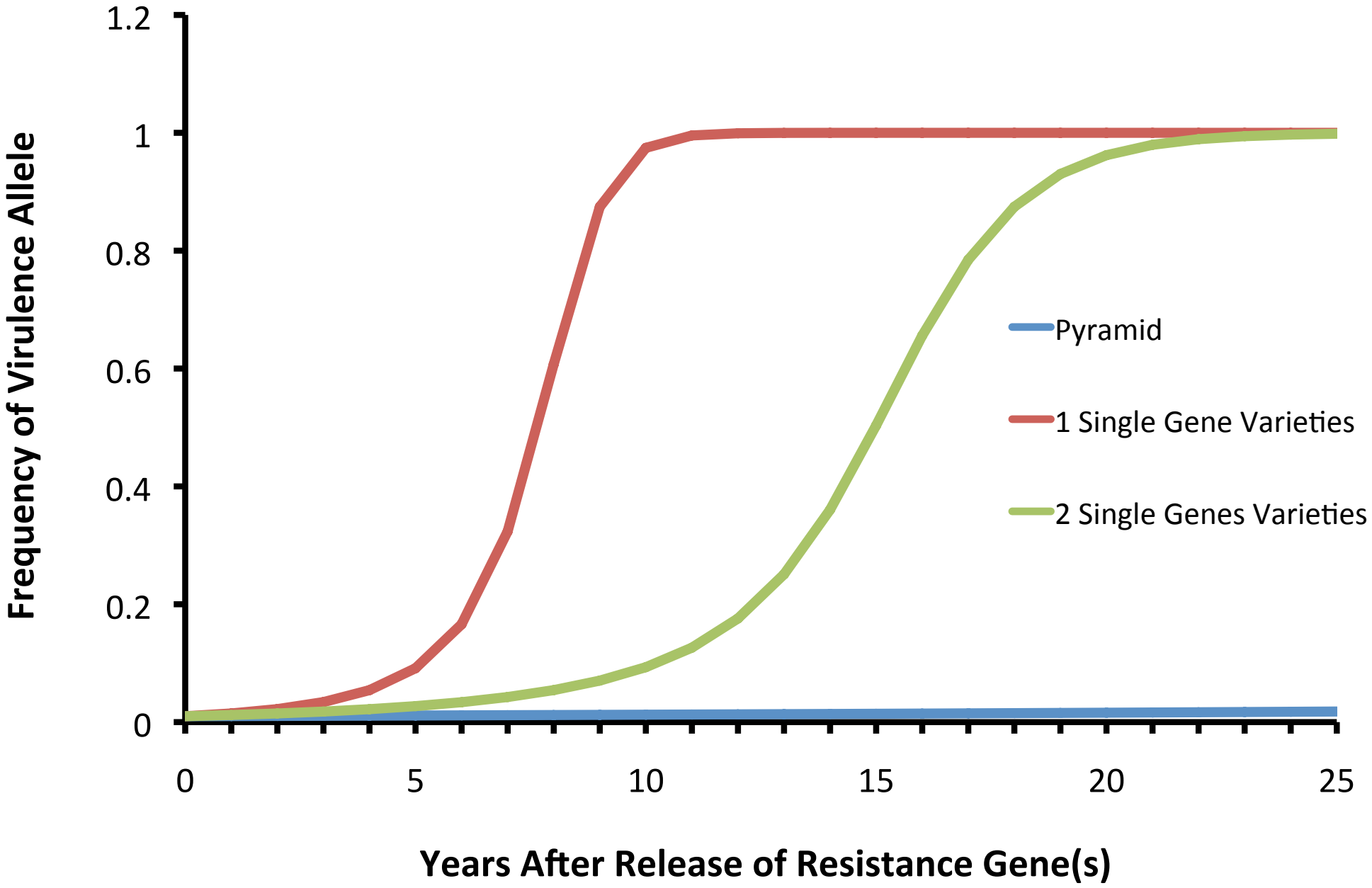
Aphid Resistance Protects Yield



How valuable are aphid resistant **pyramids**?

- Prevent aphid outbreaks without insecticides
- Work across the north central region
- Limit occurrence of biotypes
  - ½ of an insect resistance management (IRM) plan
    - Bates et al. Nature Biotechnology 2005
    - Pyramided traits combined with a refuge

IRM for *Rag* genes



Future for aphid resistant soybeans

- Provide farmers the 'freedom to operate' without soybean aphids.
- Greater commercial availability
- Improved IRM
  - Pyramids with varying forms of resistance
    - Combined antixenosis with antibiosis.
  - Is a refuge needed?
  - Are insecticides needed?

Soybean Aphid Management Evolves

2011 Soybean Aphid Insecticide Report

www.soybeanaphid.info

www.iasoybeans.com

Thanks to Our:

COLLABORATORS

KANSAS STATE

JACKRABBITS
SOUTH DAKOTA STATE UNIVERSITY

syngenta

FUNDING SOURCES

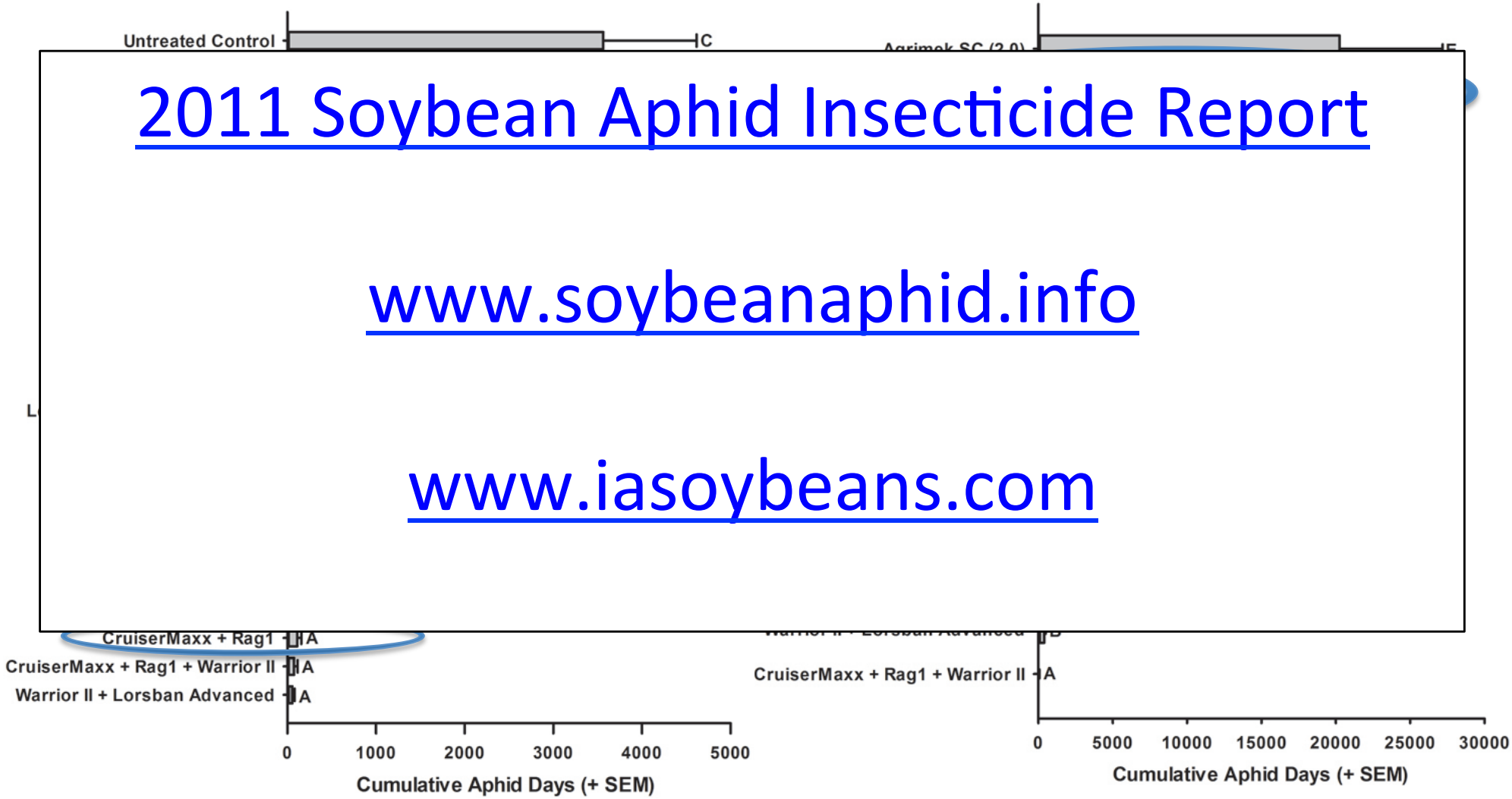
NCSRP
NORTH CENTRAL SOYBEAN RESEARCH PROGRAM

Iowa Soybean ASSOCIATION
EXPANDING OPPORTUNITIES. DELIVERING RESULTS.

Soybean Aphid Management Evolves

Nashua, Iowa

Sutherland, Iowa



[2011 Soybean Aphid Insecticide Report]

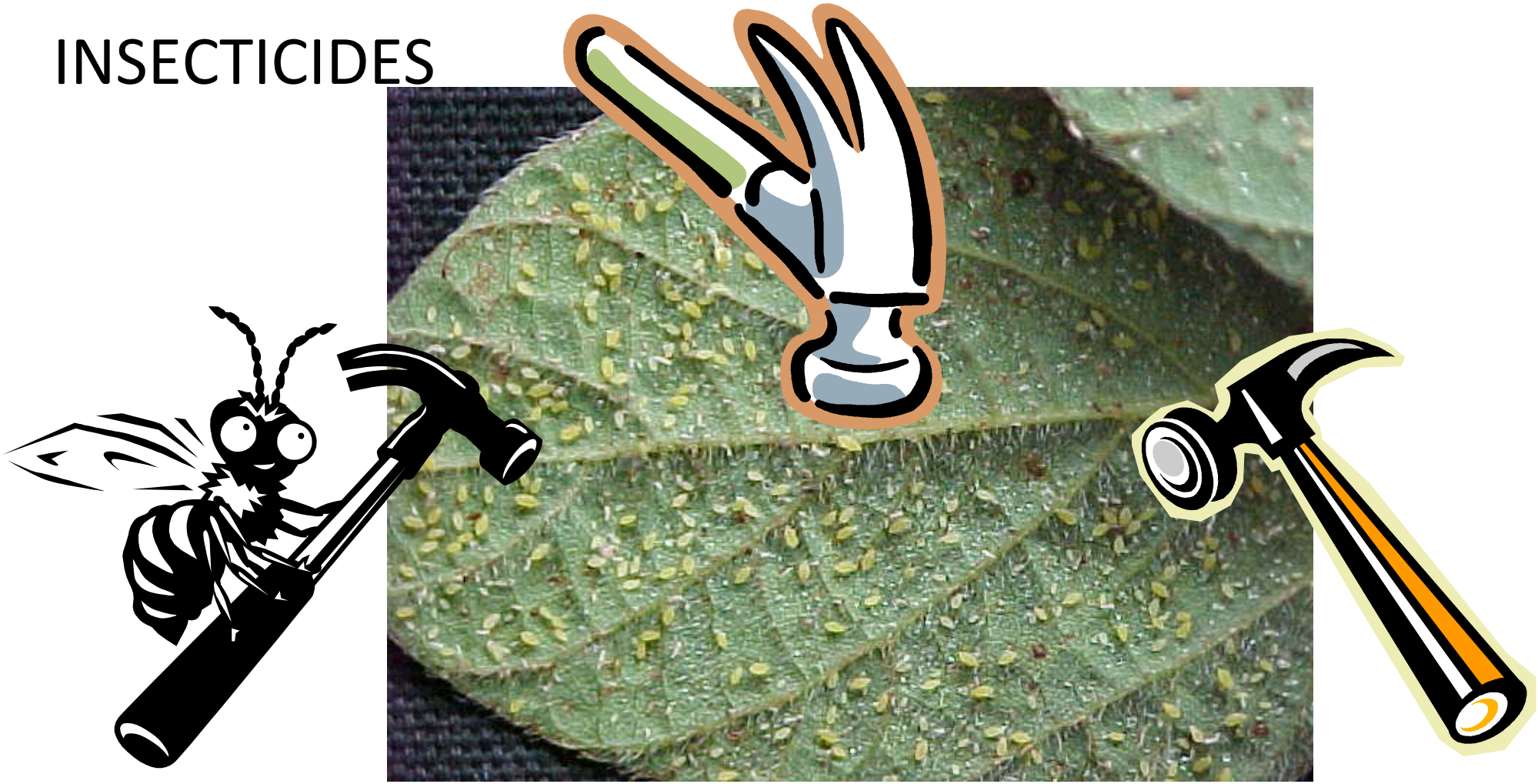
[www.soybeanaphid.info]

[www.iasoybeans.com]

120 cages with 4 soybean varieties and 5 aphid population levels

Soybean aphid management

INSECTICIDES

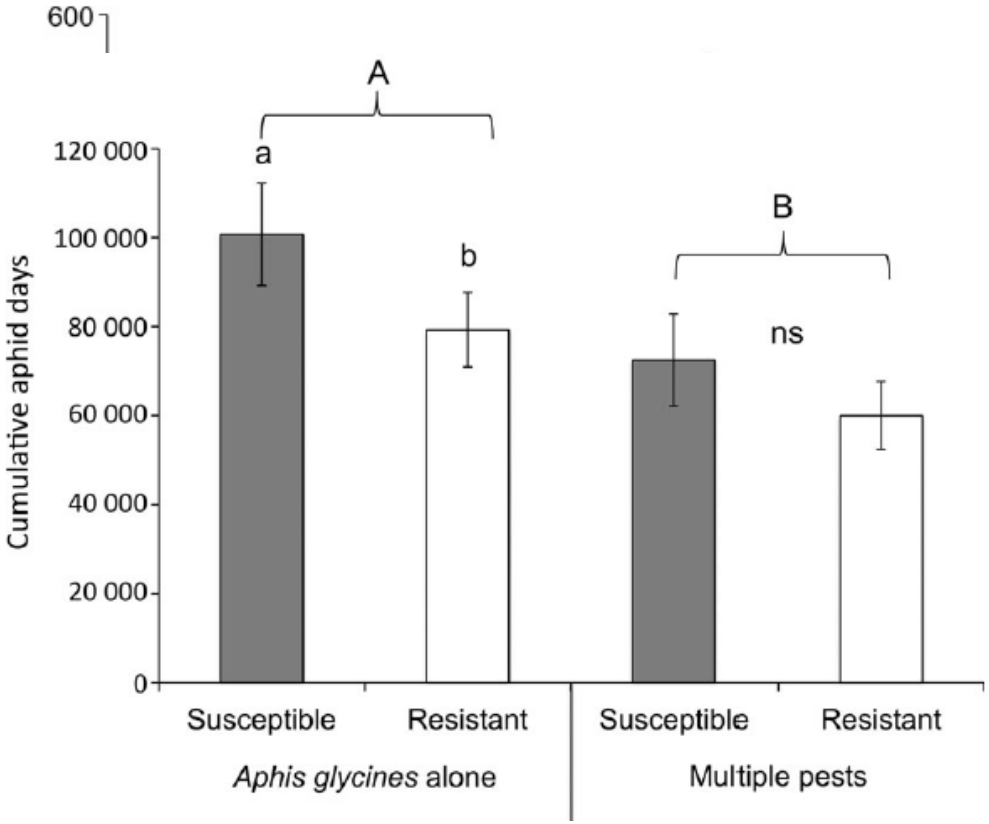


BIOLOGICAL CONTROL

HOST PLANT RESISTANCE

How valuable are Aphid Resistant Soybeans

- *Factors influencing farmer use:*
  - McCarville et al. 2012 Entomologia Experimentalis et Applicata. *In press.*



Key Findings

- co-infection of soybean w/ SBA & BSR increases SCN reproduction 5x
- Co-infection of soybean w/ SCN & BSR decreases SBA CAD 26%
- PI 88788 varieties decreased SBA CAD 20%

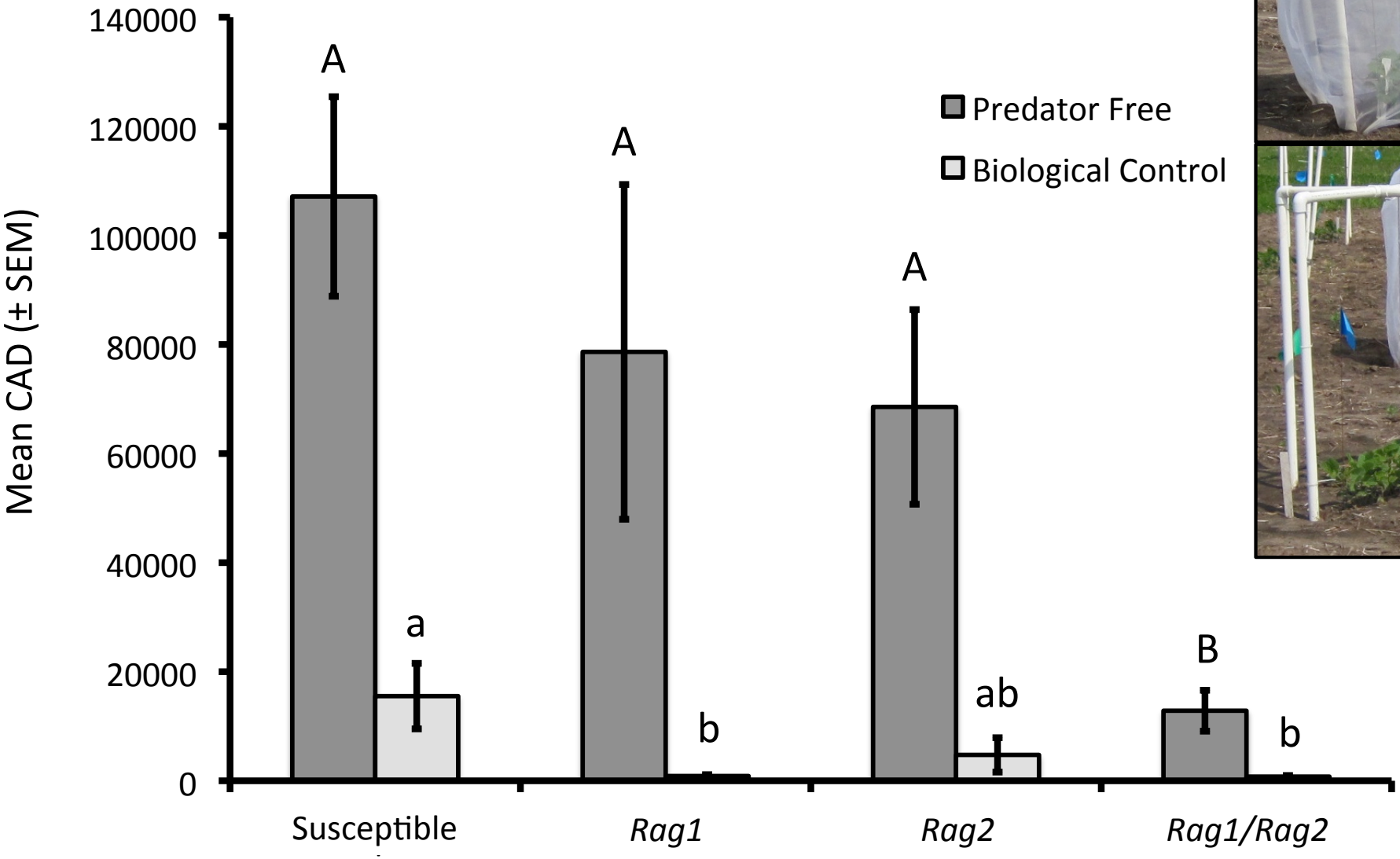
How valuable are Aphid Resistant Soybeans

- ***Future*** *factors influencing farmer use:*
  - Insecticide resistant soybean aphids.
  - Improvements in aphid resistant soybeans
    - Current commercial sources of resistance **are not** aphid free and may experience high populations.

How valuable are Aphid Resistant Soybeans

- *Factors influencing farmer use:*
  - Reduce risk of secondary pest outbreaks
    - Increase risk of spider mite outbreaks during drought and after insecticide applications.

Host Plant Resistance and Biological Control are Compatible



Is aphid resistance and biocontrol compatible?

Four varieties

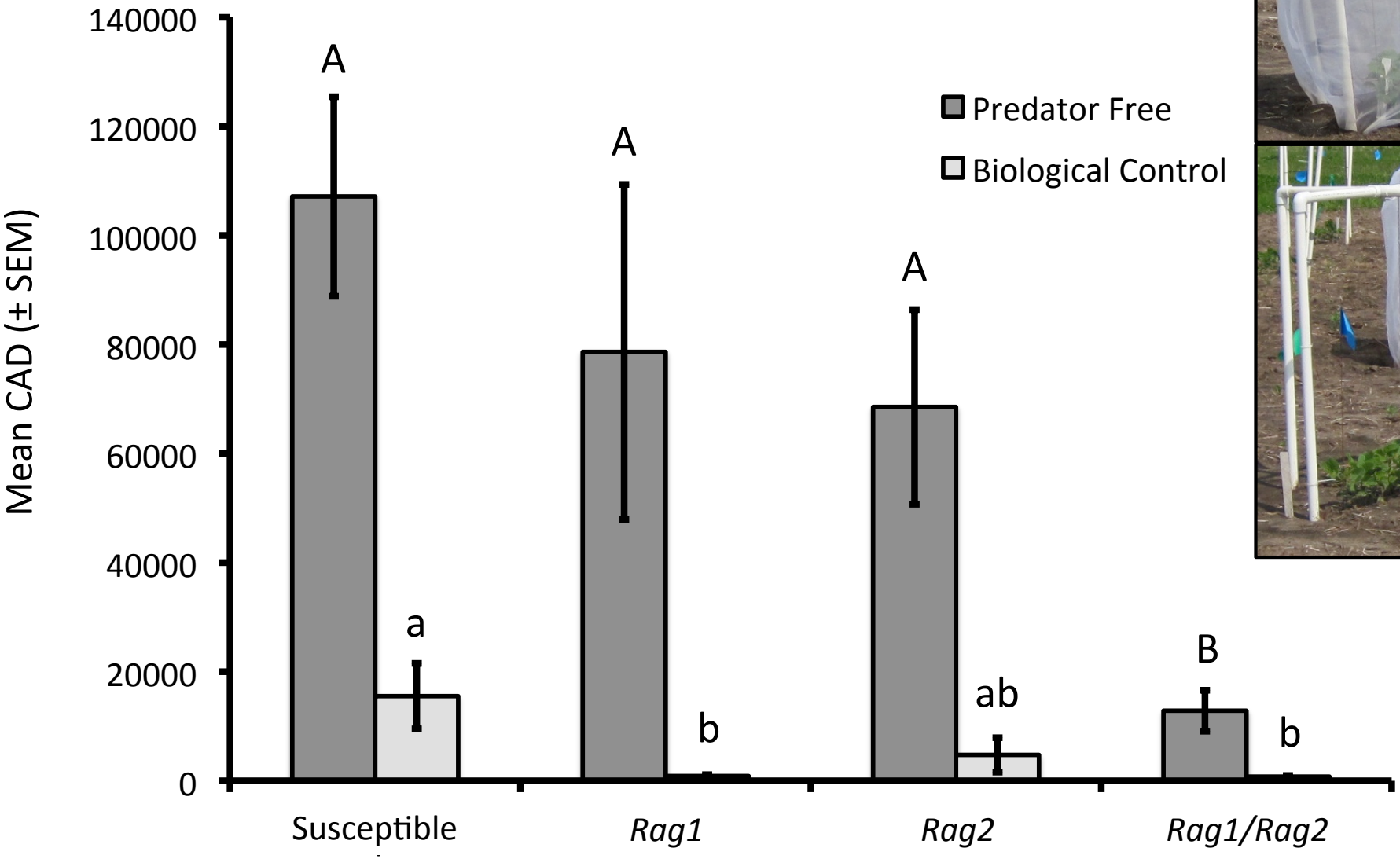
1. Aphid susceptible
2. *Rag1* alone
3. *Rag2* alone
4. Both genes combined

Three cage treatments

1. Caged without aphids = aphid free
2. Caged with aphids* = predator free
3. Uncaged with aphids = biocontrol

*10 aphids per plant at V3 stage

Host Plant Resistance and Biological Control are Compatible



Estimating yield loss from aphids

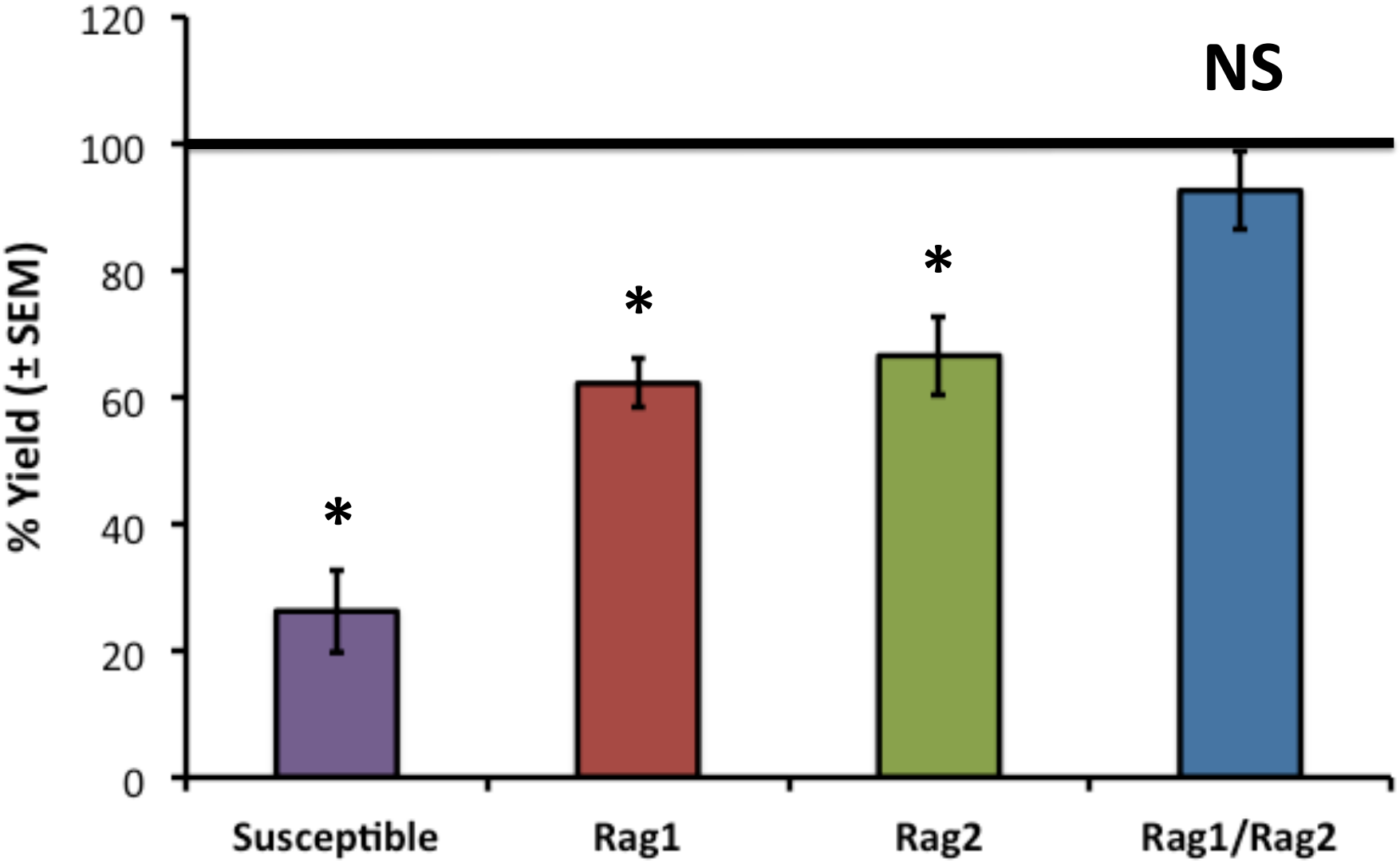
Predator Free Cages

Aphid Free Cages

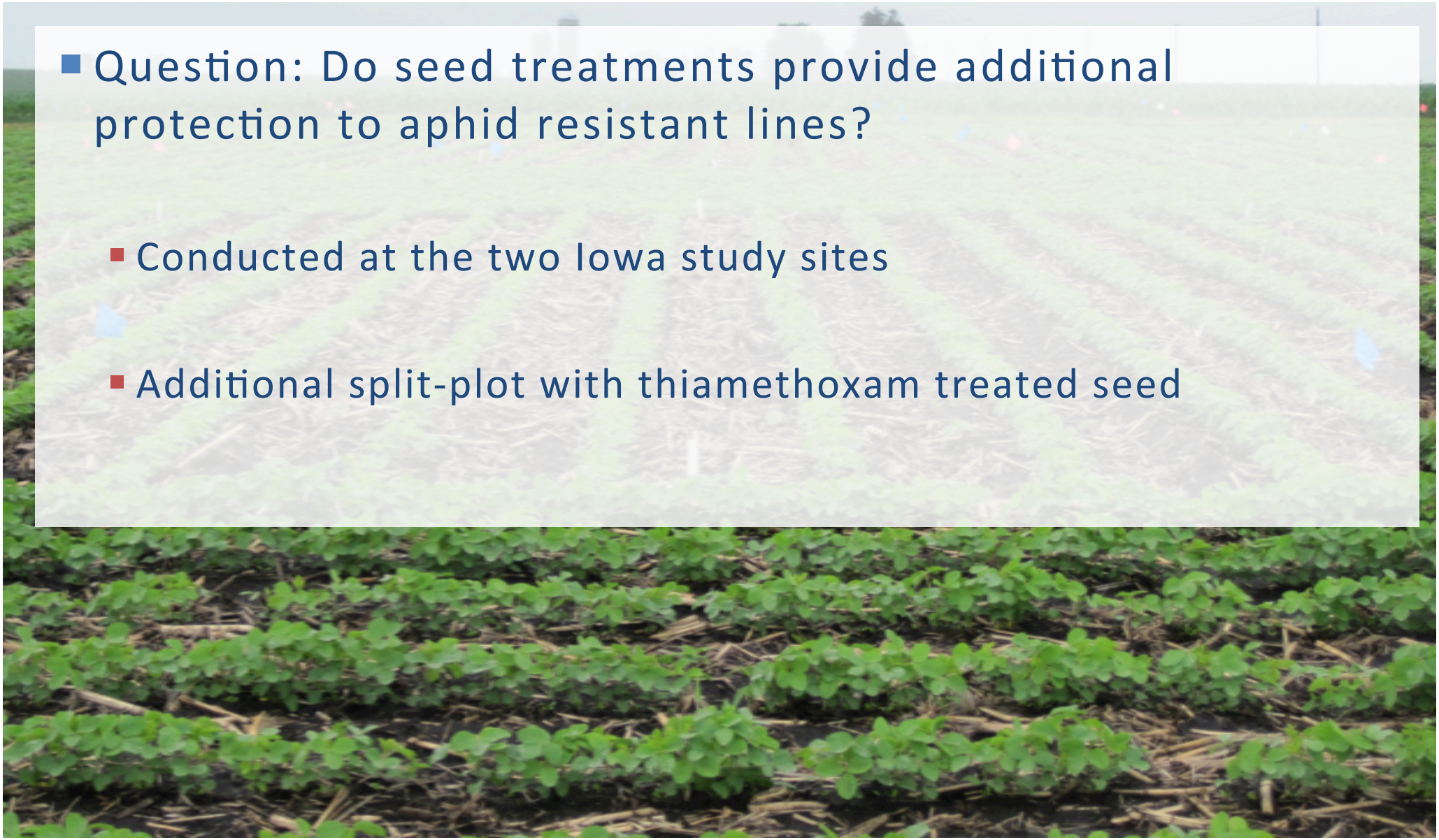
= % Yield

6 replicates of each cage

The Pyramid Prevents Yield Loss in the Absence of Predation



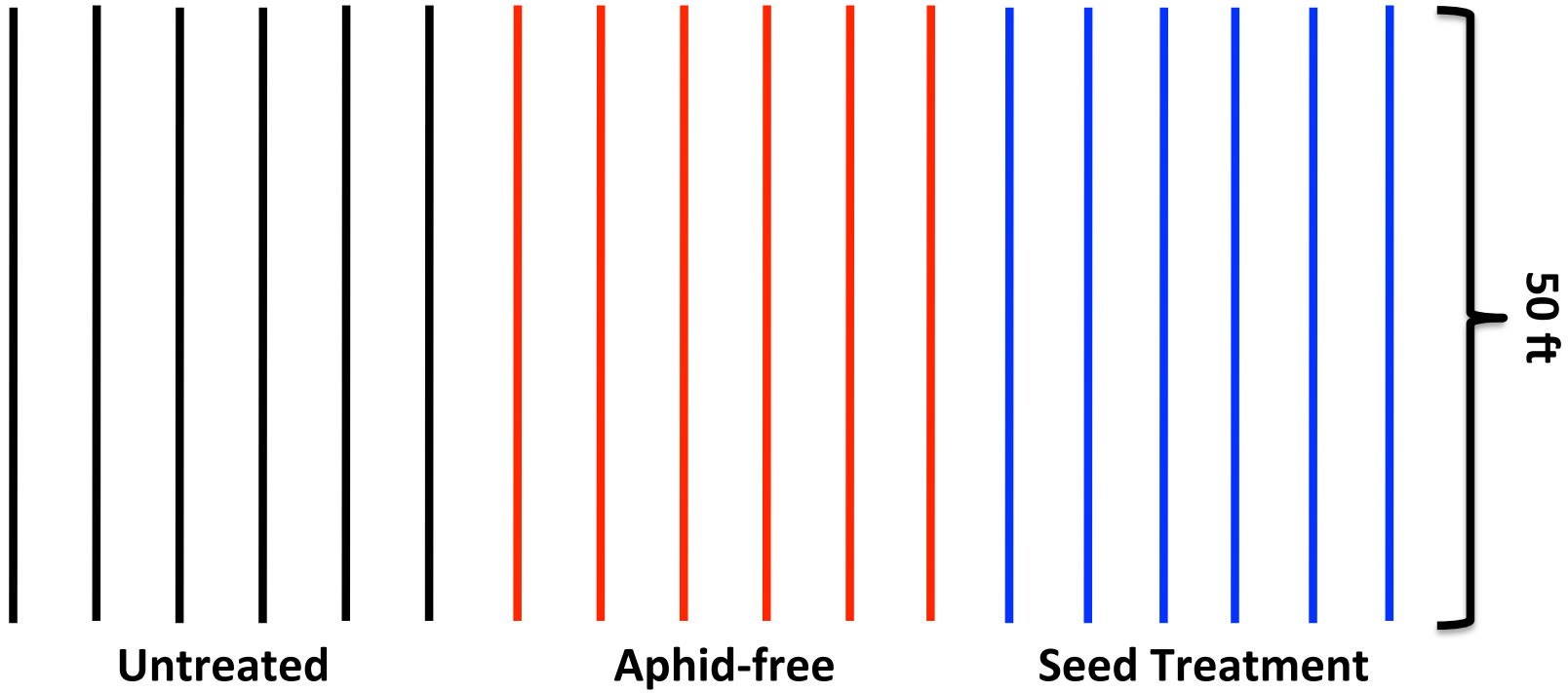
Iowa Study on Seed treatments and Aphid Resistant Soybean

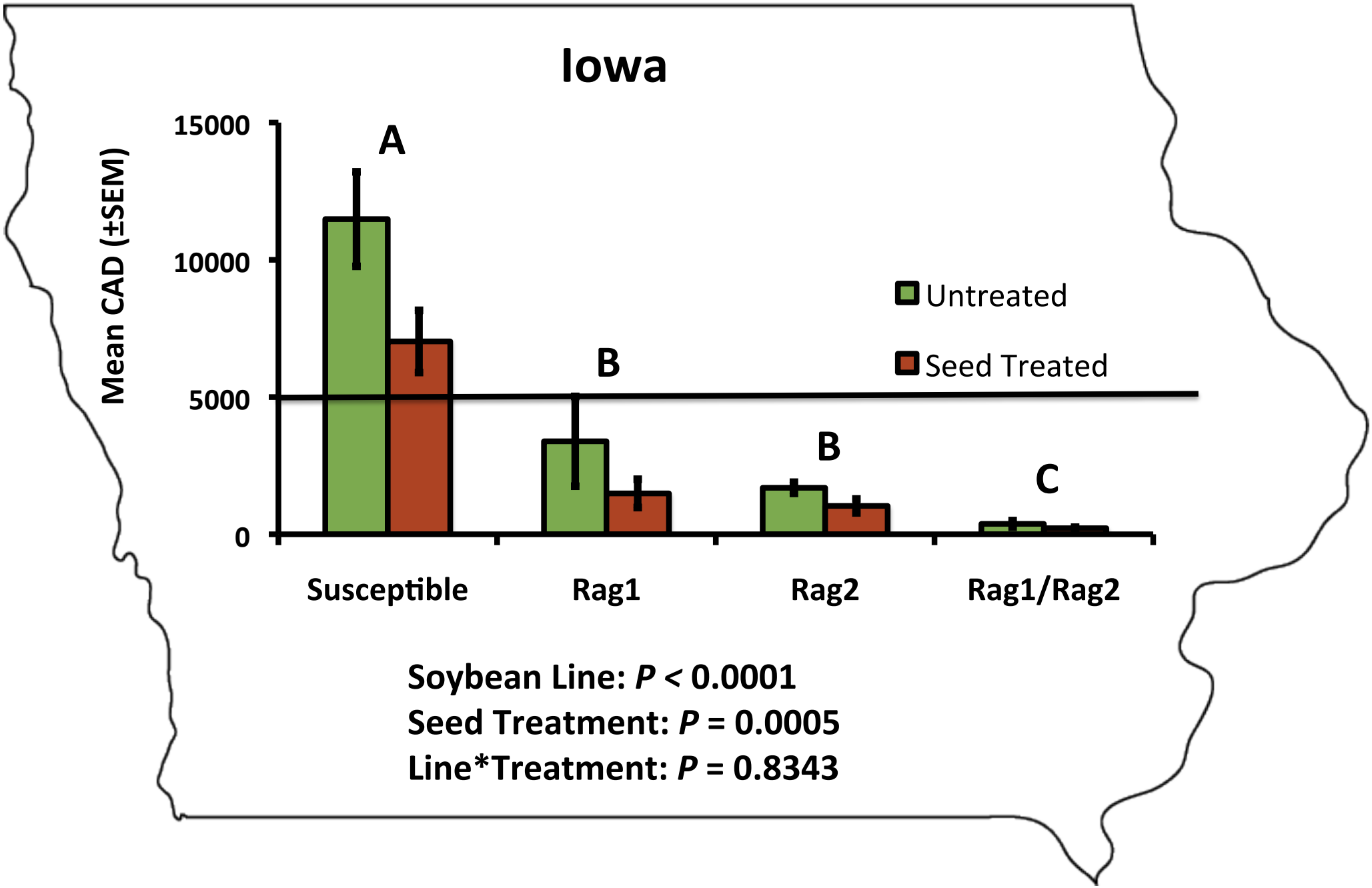


- Question: Do seed treatments provide additional protection to aphid resistant lines?
  - Conducted at the two Iowa study sites
  - Additional split-plot with thiamethoxam treated seed

Experimental Design

- Split-plot design
  - Main plot: genotype- *Rag1, Rag2, Rag1/Rag2,* Susceptible
  - Sub plot: aphid density- Untreated, Aphid-free, Seed treatment




Iowa
Mean CAD (±SEM)
15000
10000
5000
0
A
B
B
C
Untreated
Seed Treated
Susceptible
Rag1
Rag2
Rag1/Rag2
Soybean Line: P < 0.0001
Seed Treatment: P = 0.0005
Line*Treatment: P = 0.8343