Classical Stink Bug Biocontrol: What Does Success Look Like?

Elizabeth H. Beers, WSU

Paul Abram, Ag Canada Agassiz

Nick Mills, UC Berkeley

StopBMSB.org

Funding

USDA United States Department of Agriculture National Institute of Food and Agriculture

Specialty Crop Research Initiative

Collaborating Institutions

ars
NC STATE UNIVERSITY
PennState
OSU Oregon State
UNIVERSITY OF MARYLAND
UNIVERSITY OF GEORGIA
WASHINGTON STATE UNIVERSITY
Northeastern IPM Center
Cornell University
UtahStateUniversity
RUTGERS UNIVERSITY
THE OHIO STATE UNIVERSITY
University of Kentucky
UCDAVIS
UNIVERSITY OF MINNESOTA
VirginiaTech
Berkeley
MICHIGAN STATE UNIVERSITY
UCRIVERSIDE

This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, Specialty Crop Research Initiative under award number 2016-51181-25409.

Coming Soon….

https://onlinelibrary.wiley.com/doi/abs/10.1002/ps.5813

Pest Management Science SCI

Review: Classical biological control of invasive stink bugs with egg parasitoids – what does success look like?

Journal:	*Pest Management Science*
Manuscript ID	PM-19-1141.R1
Wiley - Manuscript type:	Review
Date Submitted by the Author:	n/a
Complete List of Authors:	Abram, Paul ; Agriculture and Agri-Food Canada, Agassiz Research and Development Centre Mills, Nicholas; University of California Berkeley, Department of Environmental Science, Policy & Management Beers, Elizabeth; Washington State University, Department of Entomology
Key Words:	egg parasitoids, matrix models, Halyomorpha halys, Nezara viridula, Murgantia histrionica, Bagrada hilaris, Pentatomidae, Scelionidae, enemy release

SCHOLARONE™
Manuscripts

Classical (importation) Biocontrol Enemy Release Hypothesis (ERH)

- BMSB, an introduced pest, progressed to outbreak status in US [1]
- Broad evidence that native NEs had low impact [2]
- Asian parasitoids better adapted/more effective [3, 4, 5]
- *Ergo*: Enemy Release [6]

1 Leskey et al. 2012
2 Abram et al 2017
3-5 Zhang et al 2017, Hedstrom et al 2017, Botch & Delfosse 2018, Hoelmer et al unpublished
6 Ogburn et al 2016

Why do we think CBC is the ultimate answer?

they are not easily observed and recorded; thus they tend to be overlooked.

A principal phase of applied biological control is the importation and establishment of natural enemies of pests that accidentally gain entry into new geographical regions. These new pests frequently escape the natural enemies that help to regulate their densities in the areas to which they are indigenous (Elton, 1958). Under satisfactory conditions in the new environment, the pest may flourish and reach damaging abundance. As a counter measure, the natural enemies are obtained from the native home of the pest and transplanted into the new environment to increase the biotic resistance of the environment to the pest.

Biological control is thus utilized to permanently increase environmental resistance to an introduced pest. The hope is that the introduced enemies will lower the general equilibrium position of the pest sufficiently to maintain it permanently below the economic threshold. Most often the introduction of a biotic agent is not so spectacular, and it is an exception when the general equilibrium position of the introduced pest is lowered sufficiently to prevent its occasionally or even commonly reaching economic abundance

Stern, V. M., R. F. Smith, R. van den Bosch, and K. S. Hagen. 1959. The integrated control concept. Hilgardia 29: 81-101.

LANDMARK EXAMPLES IN CLASSICAL BIOLOGICAL CONTROL

◆6207

L. E. Caltagirone

Division of Biological Control, Department of Entomological Sciences, University of California, Albany, California 94706

INTRODUCTION

Classical biological control, as it is commonly understood, is the regulation of a pest population (insect, mite, mammal, weed, pathogen) by exotic natural enemies (parasites, predators, pathogens) that are imported for this purpose. Usually, the target species (pest) is an exotic that has reached higher population density in the new environment because of more favorable conditions than in its area of indigeneity. The favorable conditions may include the lack of natural enemies capable of regulating the pest population to lower levels. In these cases, the establishment of natural enemies from the native environment may result in the reduction of the target species population to non-pest levels. I believe that the label "classical," when referring to the type of biological control just described, has been adopted because the spectacular early successes in pest control, by using natural enemies, involved the importation of exotics, e.g. control of the cottony cushion scale, *Icerya purchasi*, in California with the predatory coccinellid *Rodolia cardinalis* imported from Australia in 1888; control of prickly pear, *Opuntia* spp., in Australia with the pyralid *Cactoblastis cactorum* imported

Egg parasitism is an important population regulation mechanism of stink bugs that does not appear to be effectively operating against *H. halys* outside of its native range in Asia. In the pest's introduced ranges, the absence of highly effective *H. halys* egg parasitoids that occur in China and Japan (Arakawa et al., 2004; Arakawa and Namura, 2002; Yang et al., 2009) is consistent with the natural enemy release hypothesis (Keane and Crawley, 2002) and has likely contributed to the high population densities of this insect in the US. *Trissolcus japonicus* (Ashmead), an Asian parasitoid

of *H. halys* studied in US quarantine facilities since 2007 as a candidate for classical biological control, was recently detected in the field in Maryland (Talamas et al., 2015) and Washington state (Milnes and Beers, 2016). As *Trissolcus basalis* classical biological control programs demonstrate, release of the laboratory strain could increase the probability of establishment and success of this biocontrol agent, as introduction of multiple parasitoid strains increases the chance of establishment of an optimal a strain, best adapted to the new environment and most effective at control (Caltagirone, 1981). There likely have been several accidental introductions of *T. japonicus* in the US and natural spread of the parasitoid along with the potential for releases of the laboratory strain offer promise of more effective parasitism of *H. halys*.

Ogburn, E. C., R. Bessin, C. Dieckhoff, R. Dobson, M. Grieshop, K. A. Hoelmer, C. R. Mathews, J. Moore, A. L. Nielsen, K. Poley, J. M. Pote, M. Rogers, C. Welty, and J. F. Walgenbach. 2016. Natural enemy impact on the invasive brown marmorated stink bug, *Halyomorpha halys (Stål) (Hemiptera: Pentatomidae), in organic agroecosystems: a regional assessment. Biol. Control 101: 39-51.*

Literature Amplification?

4.6.4 Biological Control

In the invaded ranges of the United States and Europe, populations of *H. halys* are thought to have been able to establish and increase, in some cases, to outbreak levels due in part to the enemy release hypothesis (i.e., *H. halys* individuals escaping natural enemies from their native range). However, biological control is likely considered to be the long-term solution for this bug; the impact of predators, pathogens, and parasites is self-sustaining and can occur at landscape levels (Leskey et al. 2012a) where it is likely to be the only management option available for stink bug populations. Indeed, a number of natural enemies present within the invaded areas have been documented in different habitats and crops.

Chewing and sucking predators reported to feed on the eggs, nymphs, and adults of *H. halys* in the United States include (but are not limited to) members of the Anthocoridae, Asilidae, Cantharidae,

Hamilton, G. C., J. J. Ahn, W. Bu, T. C. Leskey, A. L. Nielsen, Y.-L. Park, W. Rabitsch, and K. Hoelmer. 2018. *Halyomorpha halys (Stål), pp. 243-292. In J. E. McPherson (ed.), Invasive stink bugs and related species (Pentatomoidea). CRC Press, Boca Raton, FL.*

coupled with the poor performance of indigenous natural enemies (Haye et al. 2015, Herlihy et al. 2016, Ogburn et al. 2016, Abram et al. 2017, Dieckhoff et al. 2017), is consistent with the 'enemy release hypothesis' (Ogburn et al. 2016, Heimpel and Mills 2017, Hamilton et al. 2018). Fundamentally, classical biological control seeks to reverse the effects of this phenomenon by restoring the biotic pressure absent in the pest's invaded range (Hoddle 2004).

Trissolcus japonicus (Ashmead), a scelionid egg parasitoid of *H. halys*, is considered an important natural enemy in the latter's native range (Yang et al. 2009, Zhang et al. 2017). When its potential as a biological control agent was recognized, *T. japonicus* was

Milnes, J. M., and E. H. Beers. 2019. *Trissolcus japonicus (Hymenoptera: Scelionidae) causes low levels of parasitism in three North American pentatomids under field conditions. J. Insect Sci. 19: 15.*

The CBC Success Continuum

Complete Success!

Complete Failure!

BMSB becomes a non-pest

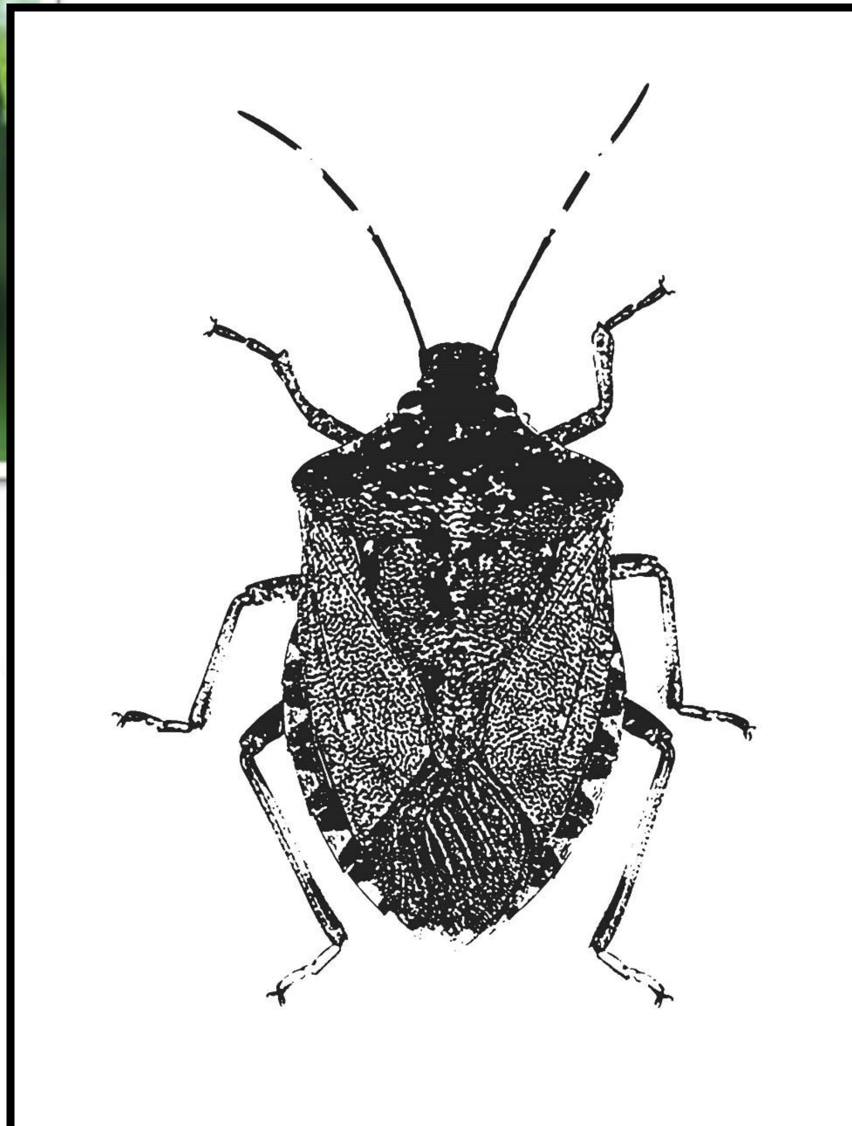
T. japonicus fails to establish

Abram et al. 2020: Key Messages

- ERH is theoretical basis of CBC
- Core assumptions need to be critically examined:
  - Enemy release has contributed to invasiveness of pentatomids in NA
  - CBC with egg parasitoids will reduce populations below the EIL

Model Parameters: 3 invasive stink bugs

Nezara viridula
(Photo L. Ingram/Bugwood.org)



alyomorpha halys
Photo E. Beers/WSU)

Matrix Models

- ✓ Stage structured
- ✓ Duration
- ✓ Mortality
- ✓ Fecundity
- ✓ Sex Ratio

What it is NOT:

Age structured
Multi-generational
Density dependence
No EIL considerations

Generic stink bug 2

Control

Stage	Duration	Survivorship	Fecundity	% female
	fixed	variable	variable	fixed
Egg	5.2	84.07	200	50
Nymph	32.1	65.3		
Pre-reproductive adult	15.4	78.58365313		
Reproductive adult	49	46.44790557		
Gen time (calculated)	101.7			

Stage	γ	σ	G	P	F
Egg	0.1923	0.9672	0.1860	0.78118	
Nymph	0.0312	0.9868	0.0307	0.95607	
Pre-reproductive adult	0.0649	0.9845	0.0639	0.92055	
Reproductive adult	0.0204	0.9845	0.0201	0.98447	2.040816

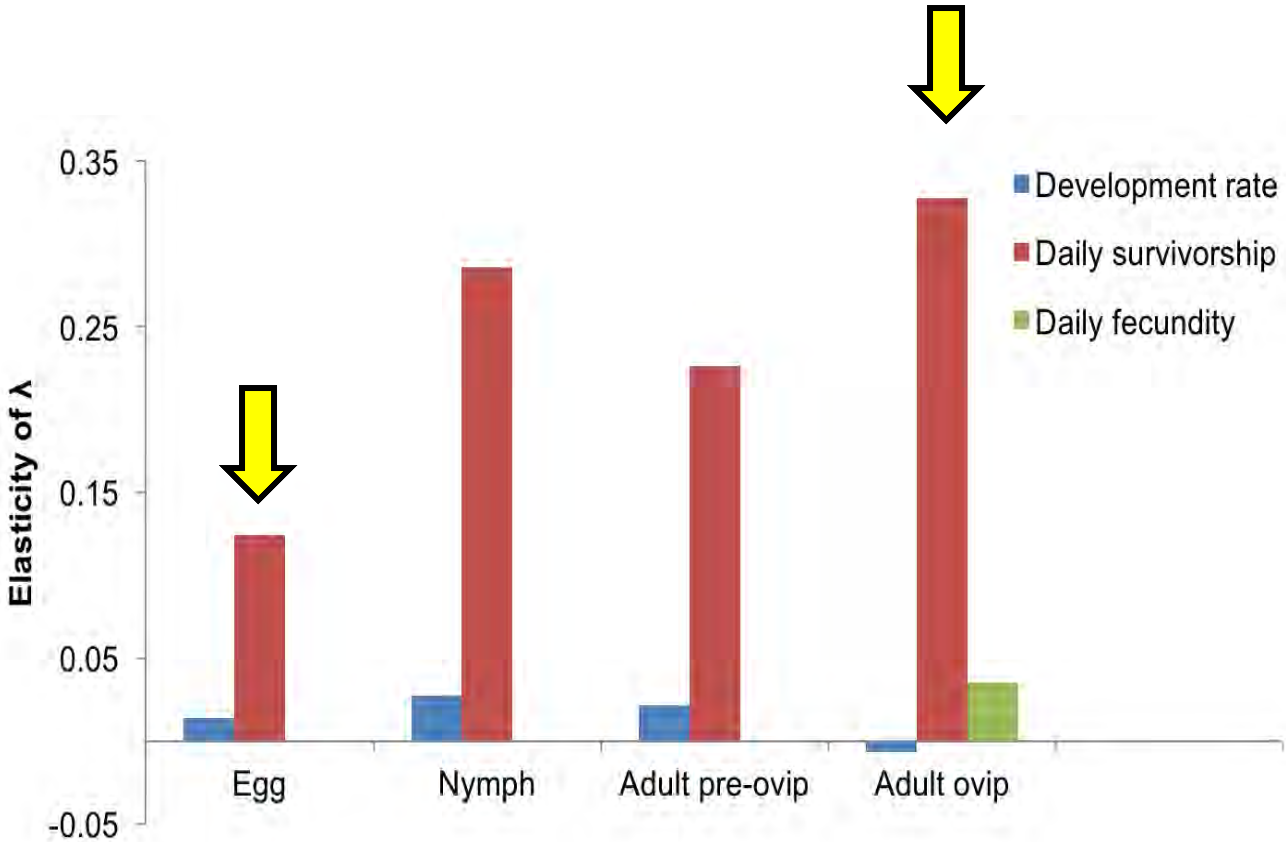
Projection matrix

	Egg	Immature	Adult pre-ovip	Adult repro
Egg	0.781184901	0	0	2.04081633
Nymph	0.185996405	0.956069386	0	0
Pre-reproductive adult	0	0.030741781	0.92054529	0
Reproductive adult	0	0	0.06392676	0.98447205

<u>Outputs:</u>

R – rate of increase
R_0 expected number of replacements
T – generation time
Stable age distribution

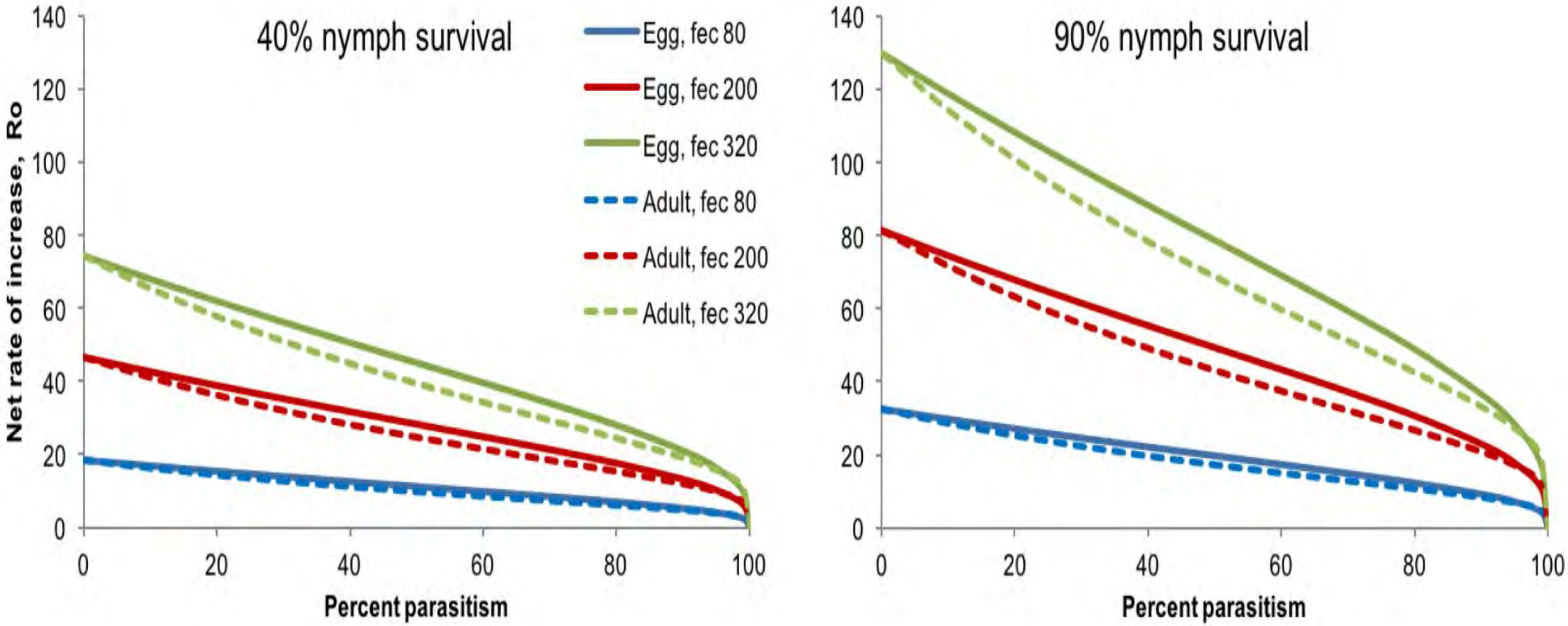
Fig. 1: Elasticity Analysis



Proportion response of the finite rate of increase lambda (λ) to proportion change in vital rates

The greater the elasticity, the greater the proportional contribution of a vital rate to population growth

Fig. 2: How does parasitism influence R_0?



Higher fecundity = higher R0
Higher nymph survival = higher R0
Adult parasitism similar to egg parasitism

Egg Parasitism Underperforms

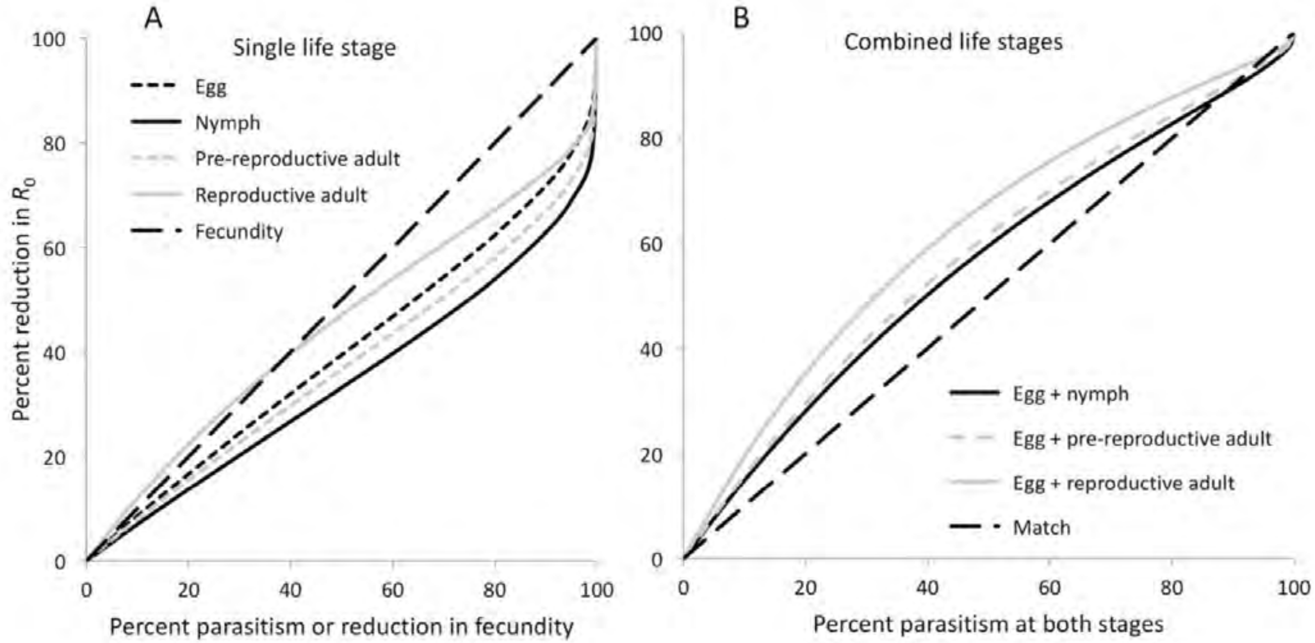


Figure 3. The relationship between percent reduction in net reproductive rate (R_0)and either percent parasitism or percent reduction in lifetime fecundity for a generic stage-structured stink bug model in which parasitism can cause mortality at (A) any individual life stage or (B) the egg stage combined with any other life stage (in this case the diagonal dotted grey line represents a matching response).

50-80% egg parasitism = 40-62% reduction in population growth

A Model is a Model is a Model…

NOT a phenology model (reasonable predictor of real life stage events)

Exploration of how parameters interact

Examine questions on when best to inflict mortality (biocontrol, other)

Conclusions

- ✓ERH may create unrealistic expectations of BC
- ✓Complete control (non-pest status) is rare
- ✓Success of BC likely to be variable over space and time
- ✓Impact of BC will vary with type of crop damage, crop value, EIL
- ✓Egg parasitism is ‘ideal’ for IPM – if the pest is monophagous (but, immigrants?)
- ✓IPM bar is lower than CBC: all help appreciated! (success = fewer inputs)
- ✓BC is one of the tools in the toolbox (we will likely need several…)