Novel biotic interactions between invasive plants and herbiviores: implications for biological control

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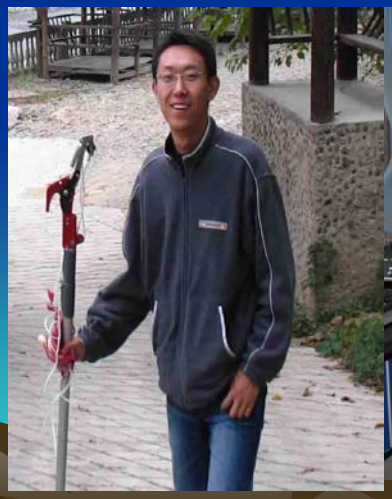


Why low success rate?

- Introduced insects establish populations well, impact is not sufficient
- Need to improve our ability to predict control efficacy prior to release
- Biotic and abiotic factors affecting interactions between invasive plants and herbivores

Biological invasions: novel biotic interaction

- **“Enemy release” hypothesis (Elton 1958, Maron and Vila 2001) :**
  exotic plants escaped suppression from natural enemies in their native range

- **Insect communities:**
  Native range: specialist and generalist herbivores
  Invaded range: only generalist, less or no specialist herbivores

Altered selection in introduced range

- **Evolved increased competitive ability (EICA) hypothesis (Blossey and Nötzold, 1995):** exotic plants to reallocate their resources from defense against natural enemies to growth and reproduction

- **Defense (due to differing insect community)**

  Changes in resistance

  plant trait that reduces the preference or performance of herbivores

  Changes in tolerance

  plant ability to withstand and survive herbivore damage (compensatory re-growth)

Based on EICA

Müller-Schärer *et al*. (TREE, 2004) predicted:

- “plants that have evolved increased vigor in the exotic range will experience a particularly fast population build-up of biological control agents.” due to decreased defense

- the impact of insect agents on plant performance “will depend on the levels of resistance and tolerance evolved during the invasion process in the absence of specialist herbivores.”

Answers to questions

1 why a high abundance of some insect biological control agents has been found on invasive populations relative to their abundance in the native range

2 why these high number of insects failed to control the invader

those theories rarely tested in biocontrol programs.

Case study: Chinese tallow *Triadica sebifera*

Native to China

Invasive in Southern and Southeastern US

Specialists（only in China)

(Environmental Entomology, 2009; Biological Control, in revision)

Generalists（in both China and the US）

Evolution in invasive *Triadica*

- Vigor growth
- High competitive ability
- Increased tolerance to herbivory
- Less resistant

(Siemann and Rogers 2001, 2003a, b, Siemann et al. 2006; Rogers and Siemann 2004, 2005, Zou et al. 2008a, b)

Questions: plant defense to generalist vs. specialists

(1) Do specialists consume and digest more food on invasive populations than on native populations? Do generalists show the opposite pattern? (resistance)

(2) Does the plant show different compensatory response to herbivory by specialists and generalists? (tolerance)

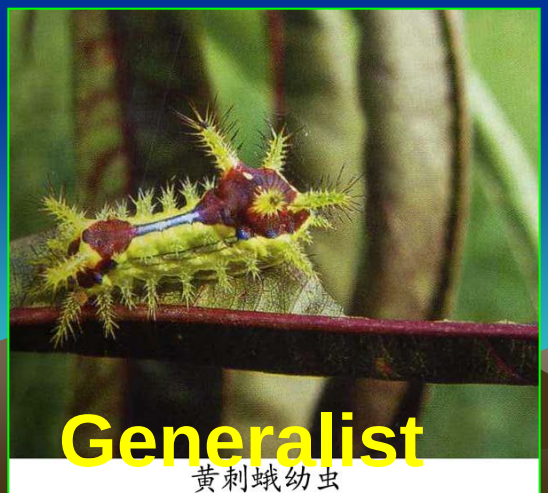
Experimental design

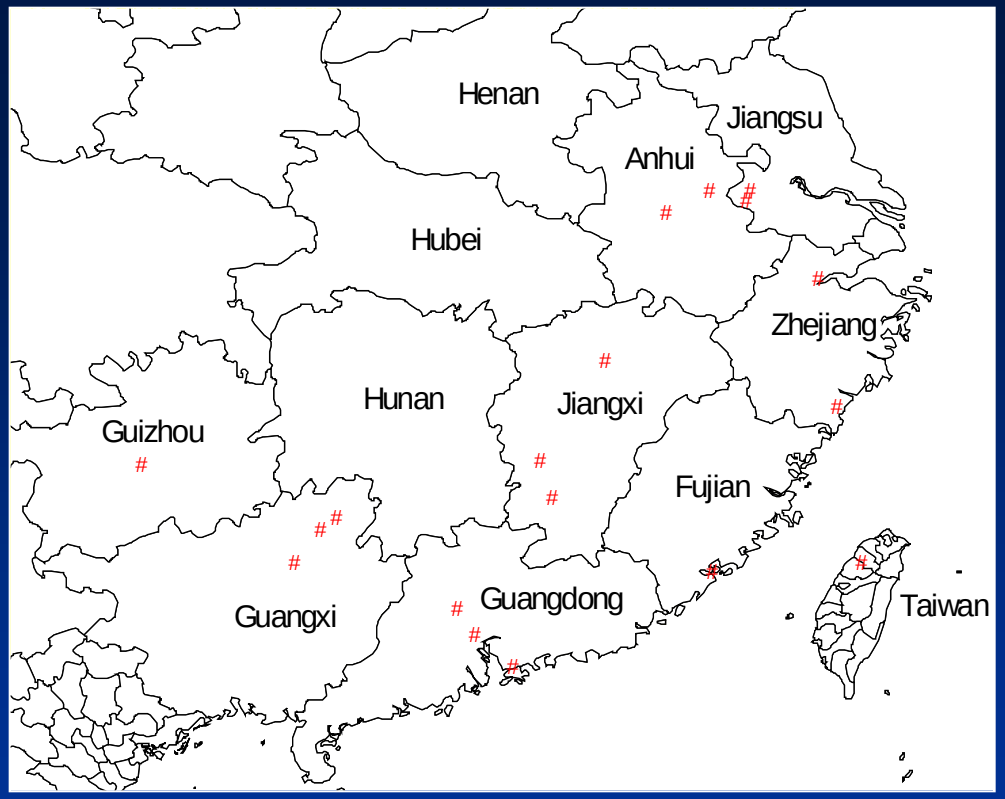
Question 1: Resistance

Lab and field common garden tests: generalist and specialist caterpillar

development of larvae reared on invasive/native plant leaves;

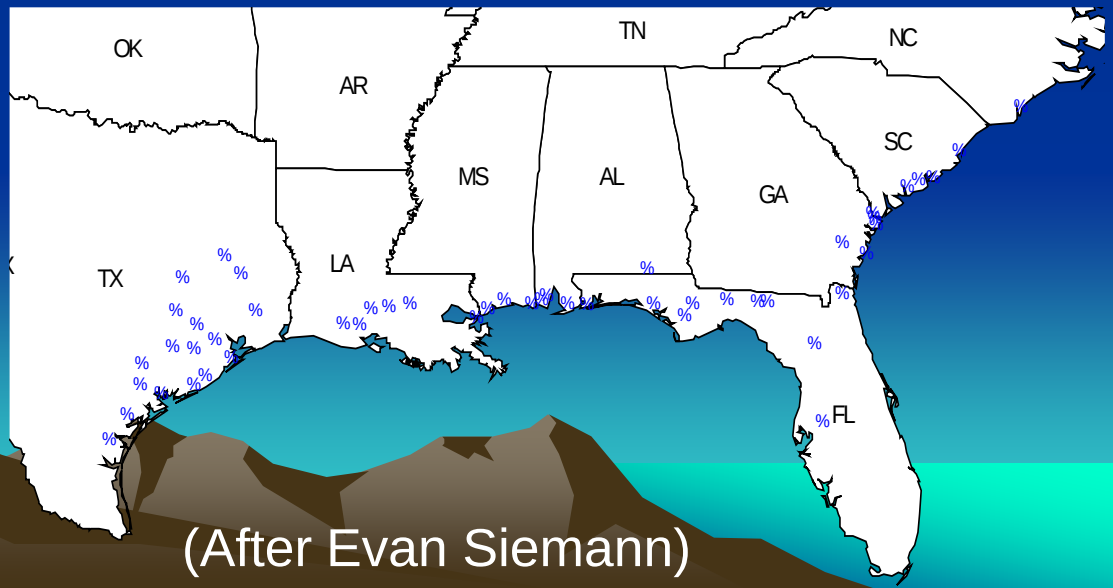
leaf biomass/areas consumed; leaf tannin and other chemicals content





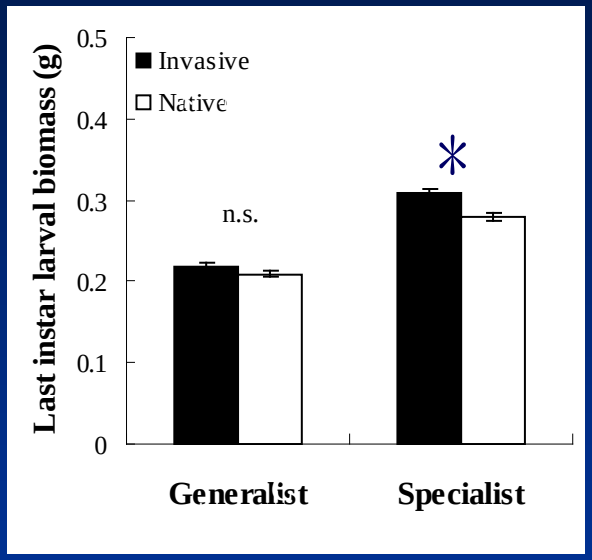
Six populations from China

Six populations from US



(After Evan Siemann)

Results: plant resistance



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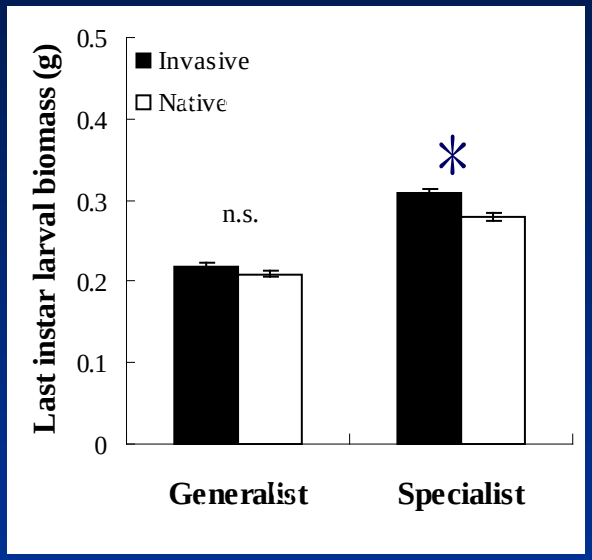

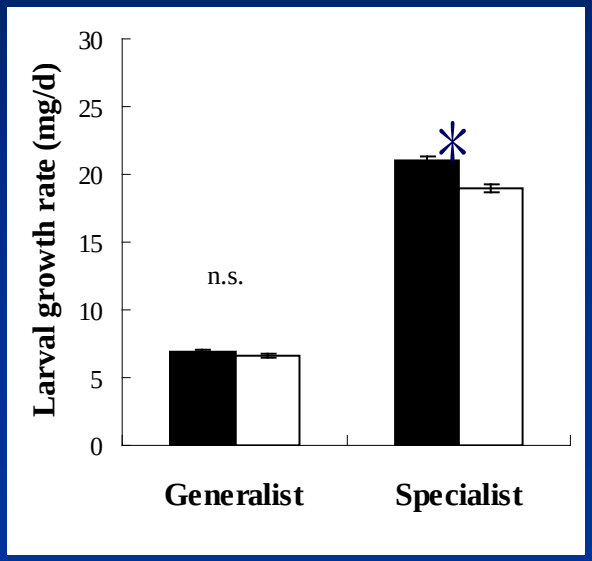

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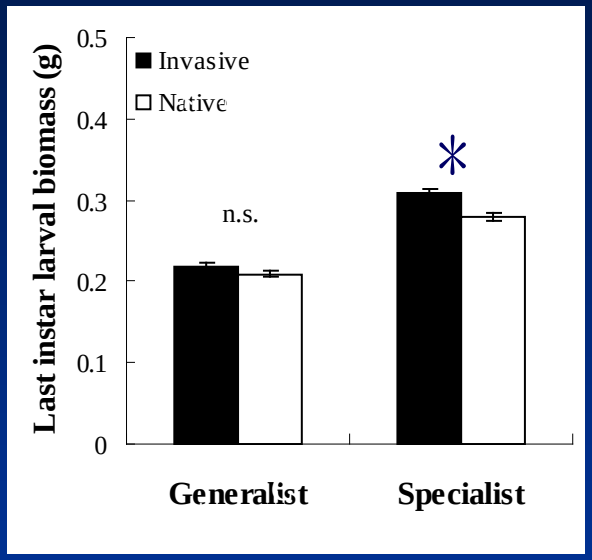

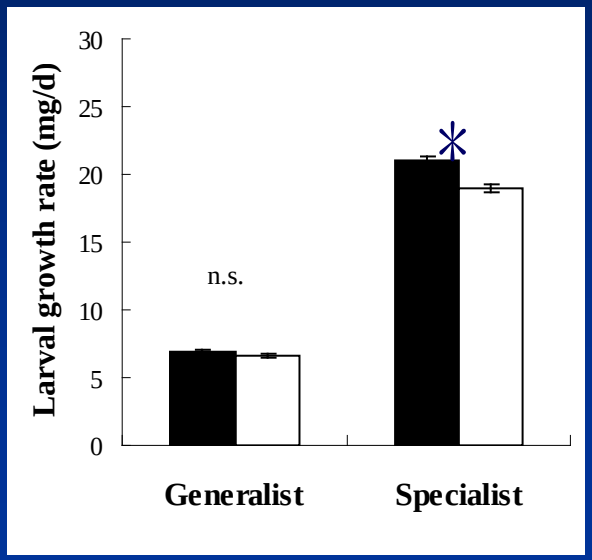

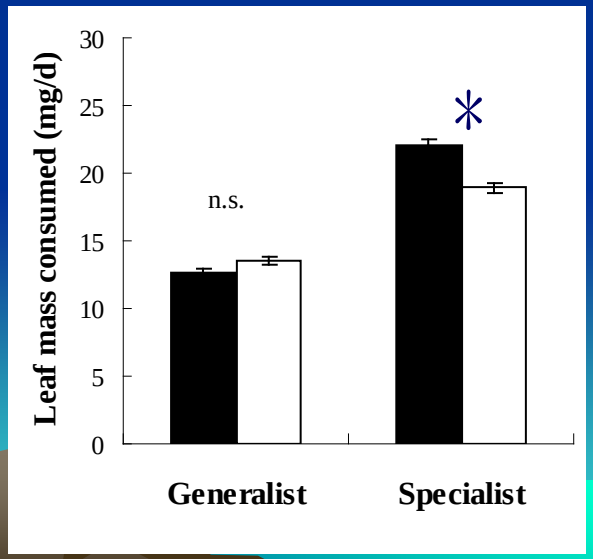

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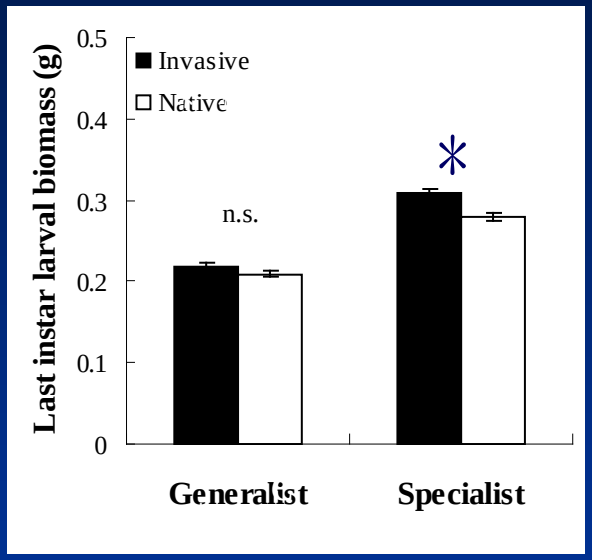
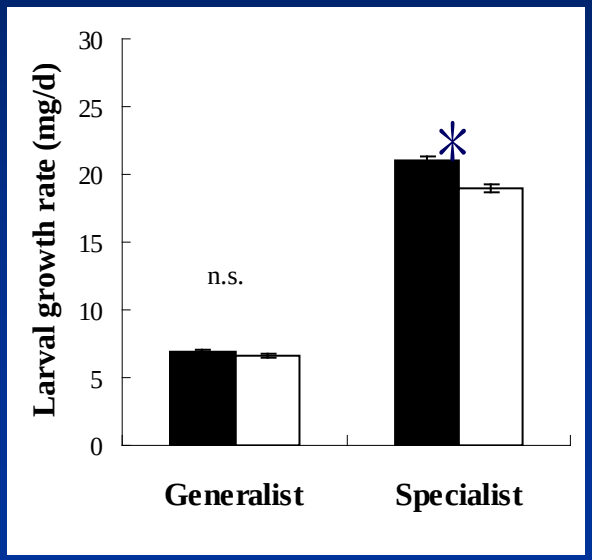
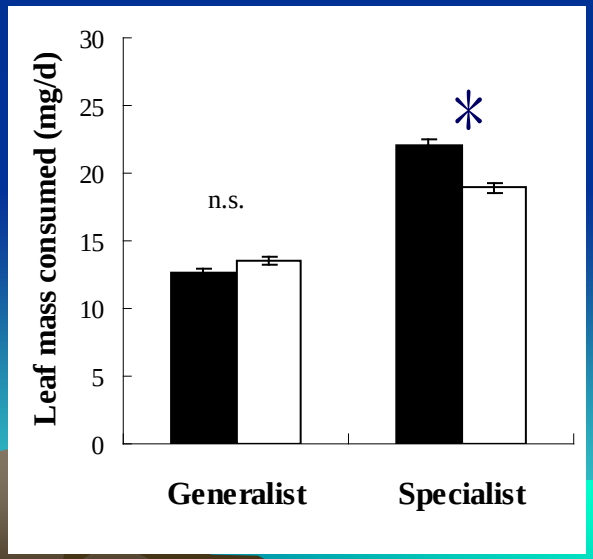


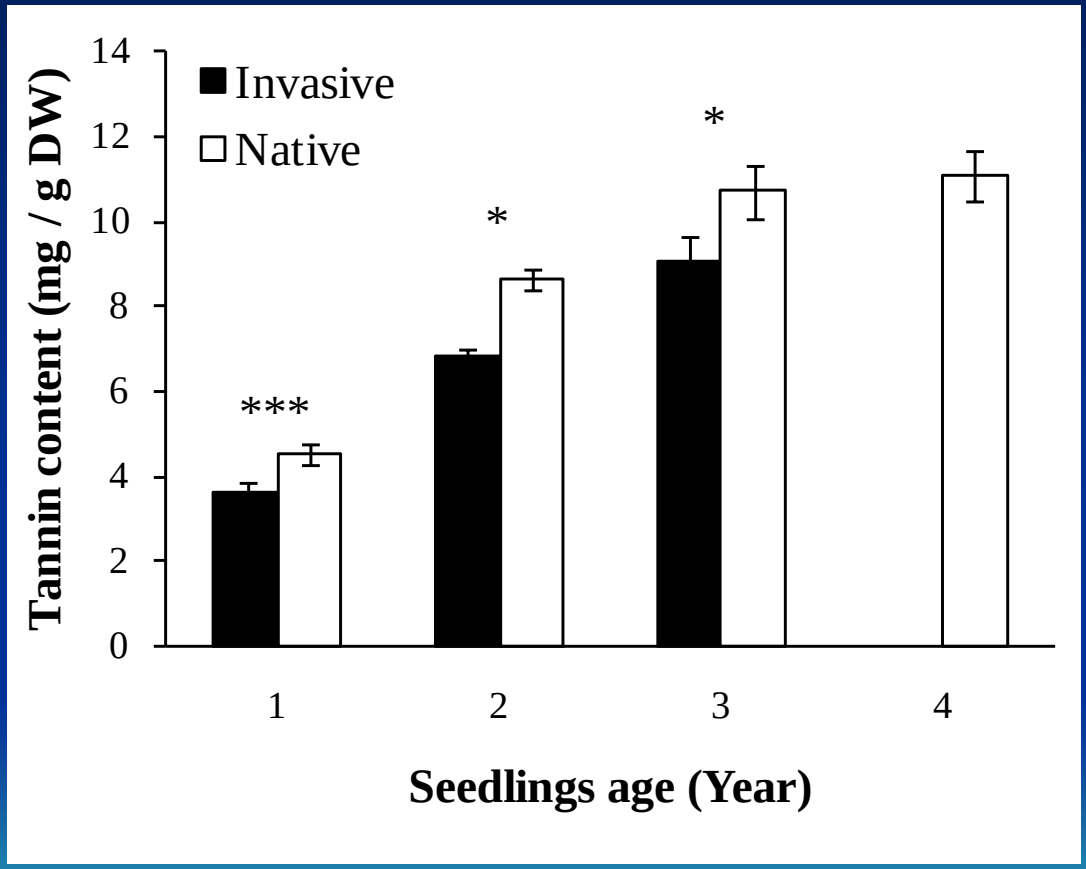




Invasive low resistance to specialist; no difference for generalist

(Journal of Ecology, 2010)

Results: secondary chemistry



High tannin content in invasive populations

(Journal of Ecology, 2010)

Experimental design

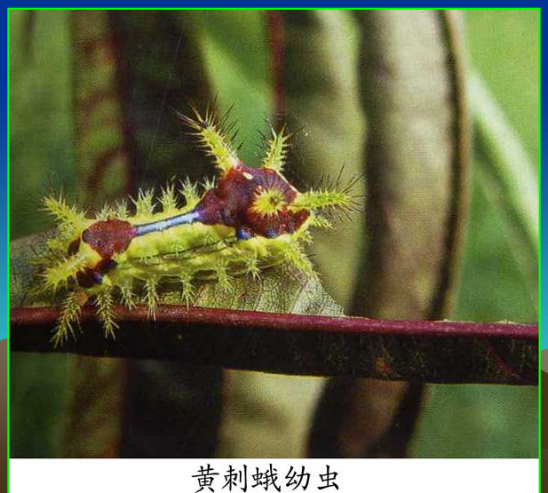
Question 2: Tolerance

Field common garden tests: generalist and specialist caterpillar

place larvae on invasive/native plant seedlings for 10 days;

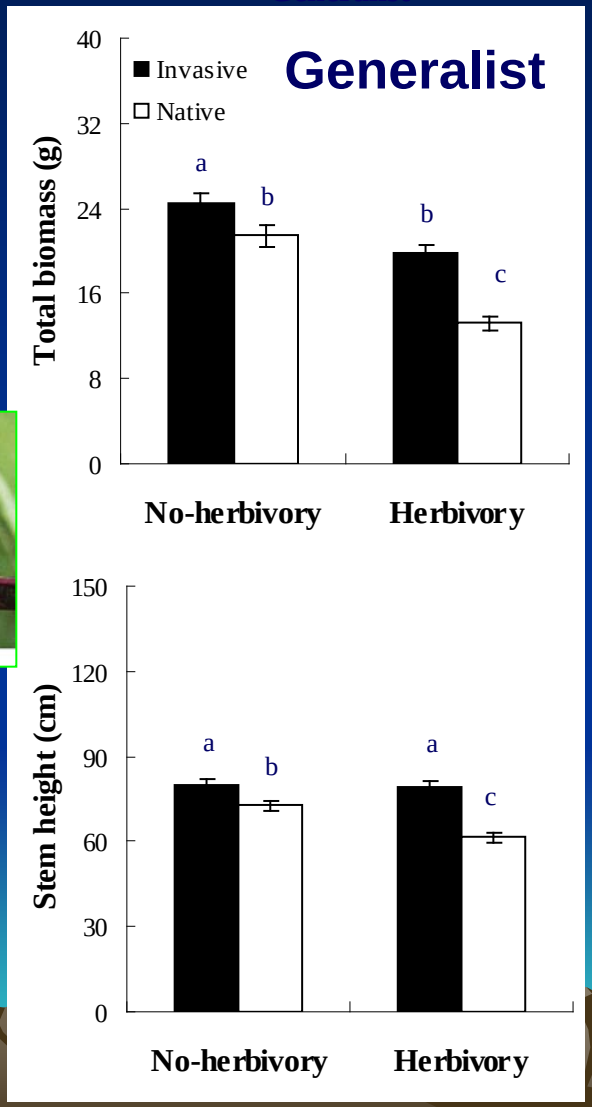
plant re-grow after herbivory for 100 days

plant growth

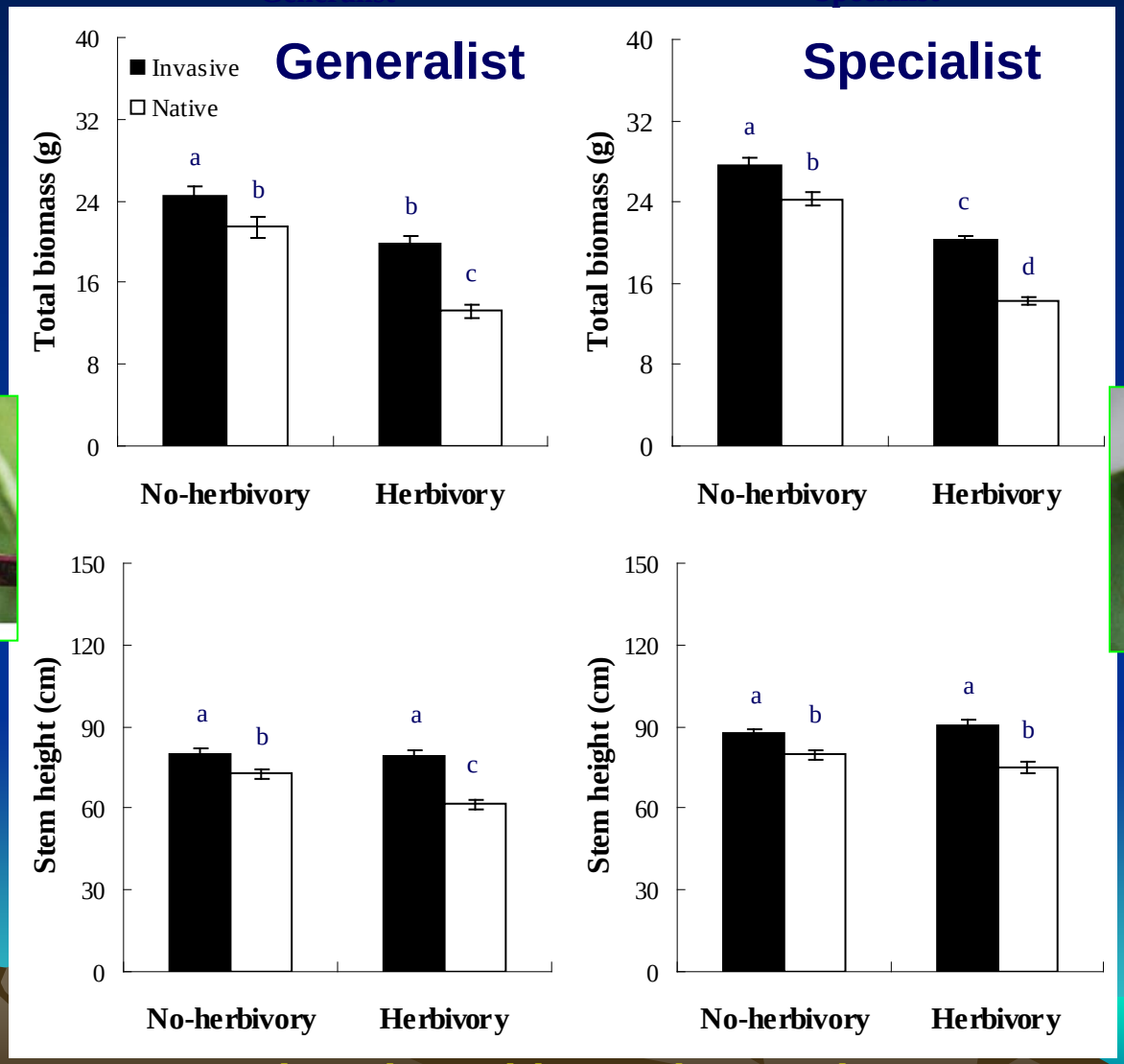


黄刺蛾幼虫

Results: plant tolerance



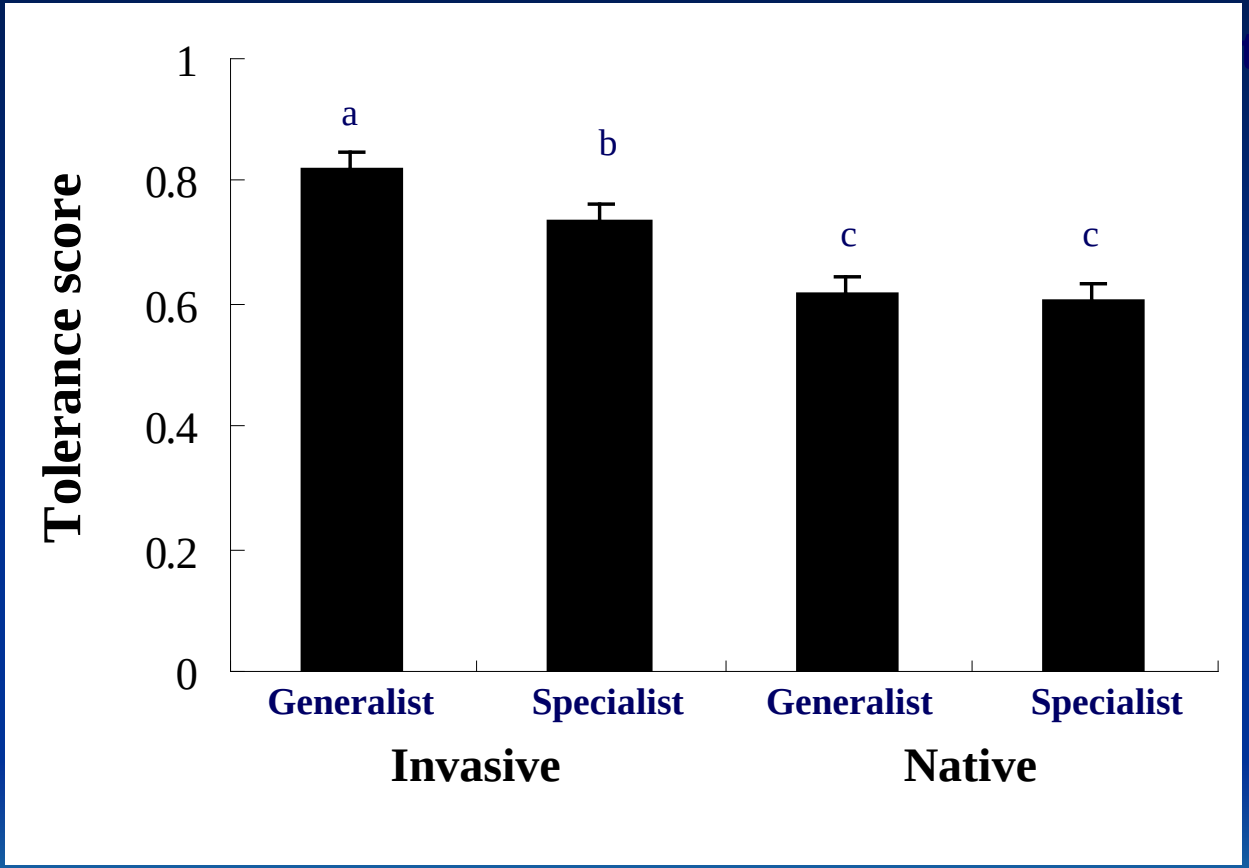
Results: plant tolerance



Invasive plants bigger than natives

(Journal of Ecology, 2010)

Results: plant tolerance



Invasive plants better tolerate herbivory

Tolerance score was calculated as the ratio of fitness (the total biomass) for damaged plants divided by the mean value of undamaged control in the same herbivore treatment in the common garden experiment.

(Journal of Ecology, 2010)

Summary

- Invasive *Triadica* populations had lower resistance and higher tolerance to the specialist caterpillar, compared to native populations.

- With respect to the response to the generalist caterpillar, invasive populations had greater tolerance as was the case for the specialist. No differences in resistance for introduced versus native populations.

- Plants from invasive populations have altered chemistry that has a larger impact on specialist resistance than on generalist resistance.

Questions: biological control of *Triadica*

(3) Will insect population build-up be faster on invasive plant populations than on those from native populations (lower resistance in the introduced range) ?

(4) Under the same herbivore load will invasive populations perform better than native populations (higher tolerance in the introduced range) ?

Leaf-rolling weevil *Heterapoderopsis bicallosicollis*

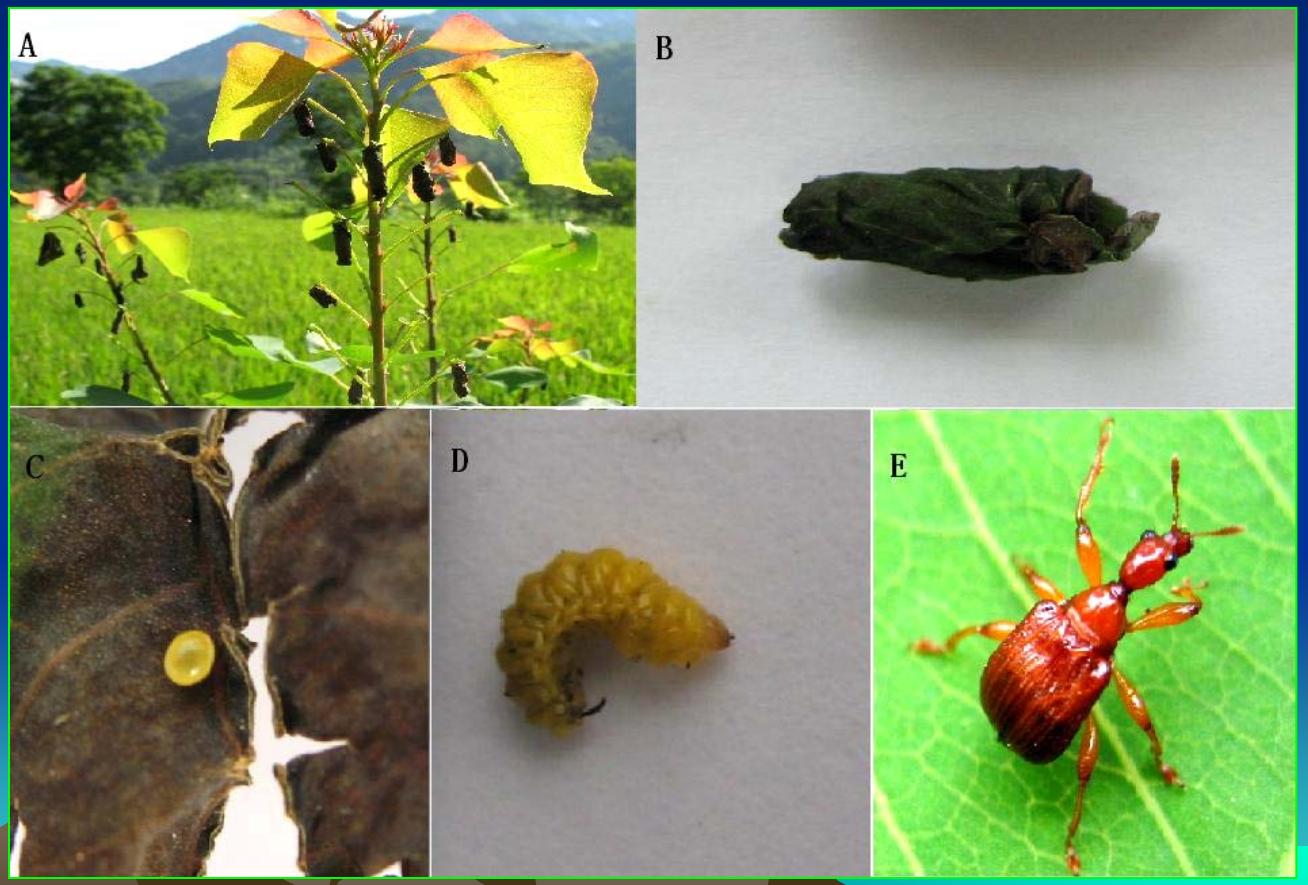
Predict potential biological control impact

Field common garden tests: leaf-rolling weevil

release weevils

(different density)

on caged plants



weevil numbers;

(question 3)

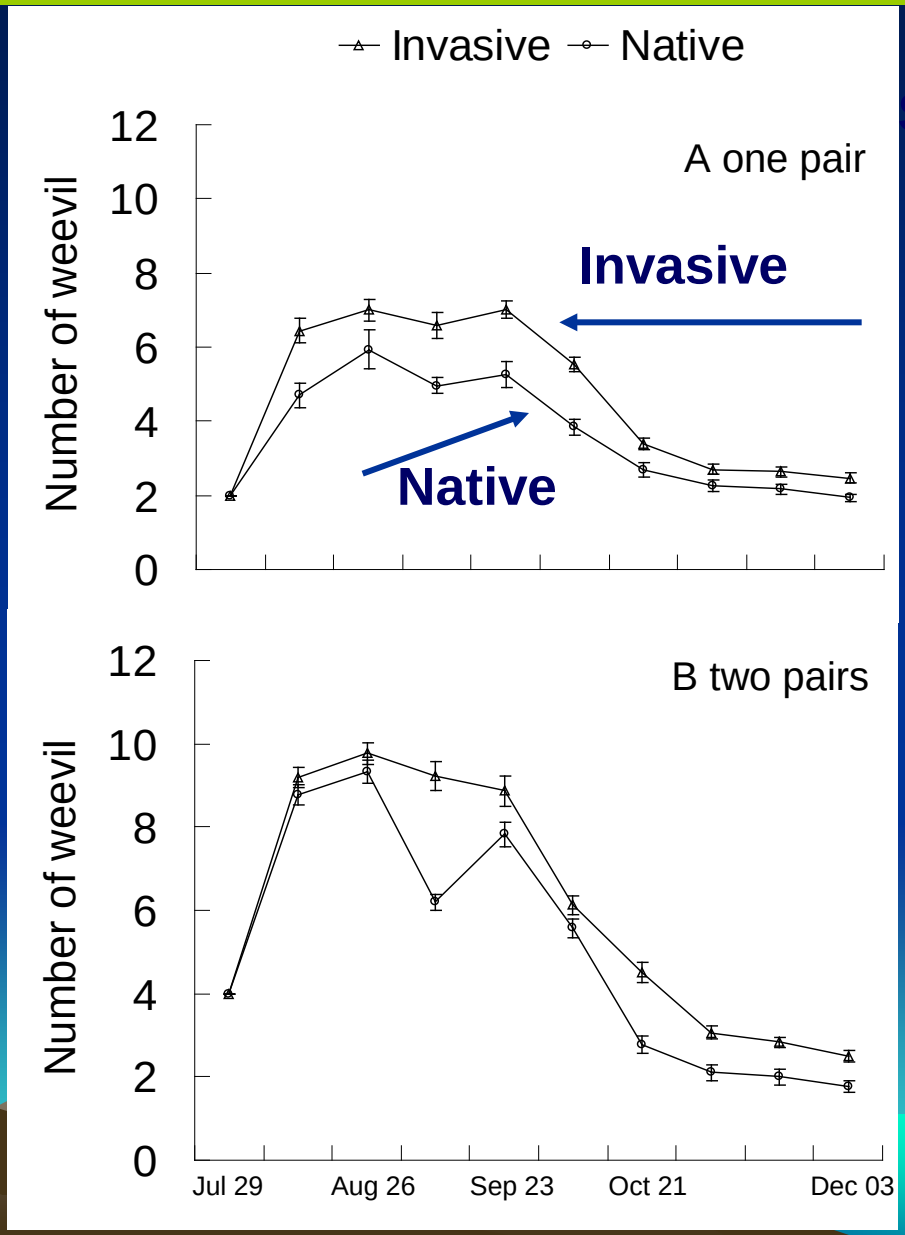
plant growth

(question 4)

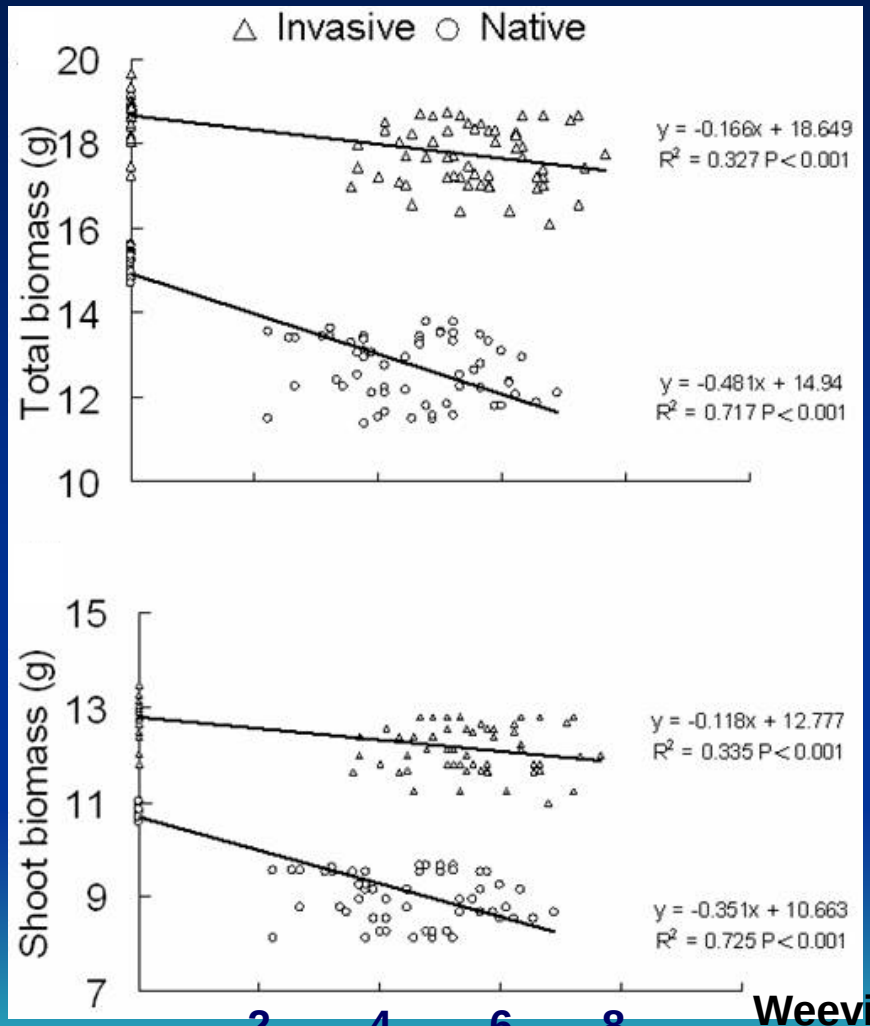
Results: weevil populations

High Insect population on invasive plants than on natives

(Ecological Applications, preprint, 2010)



Results: plant growth



Invasive plants always grow better than natives, regardless of insect number

(Ecological Applications, preprint, 2010)

Caterpillar *Gadirtha inexacta*

potential biological control impact

Field common garden tests:

larval numbers; 0, 4, 8 per seedling

plant fitness

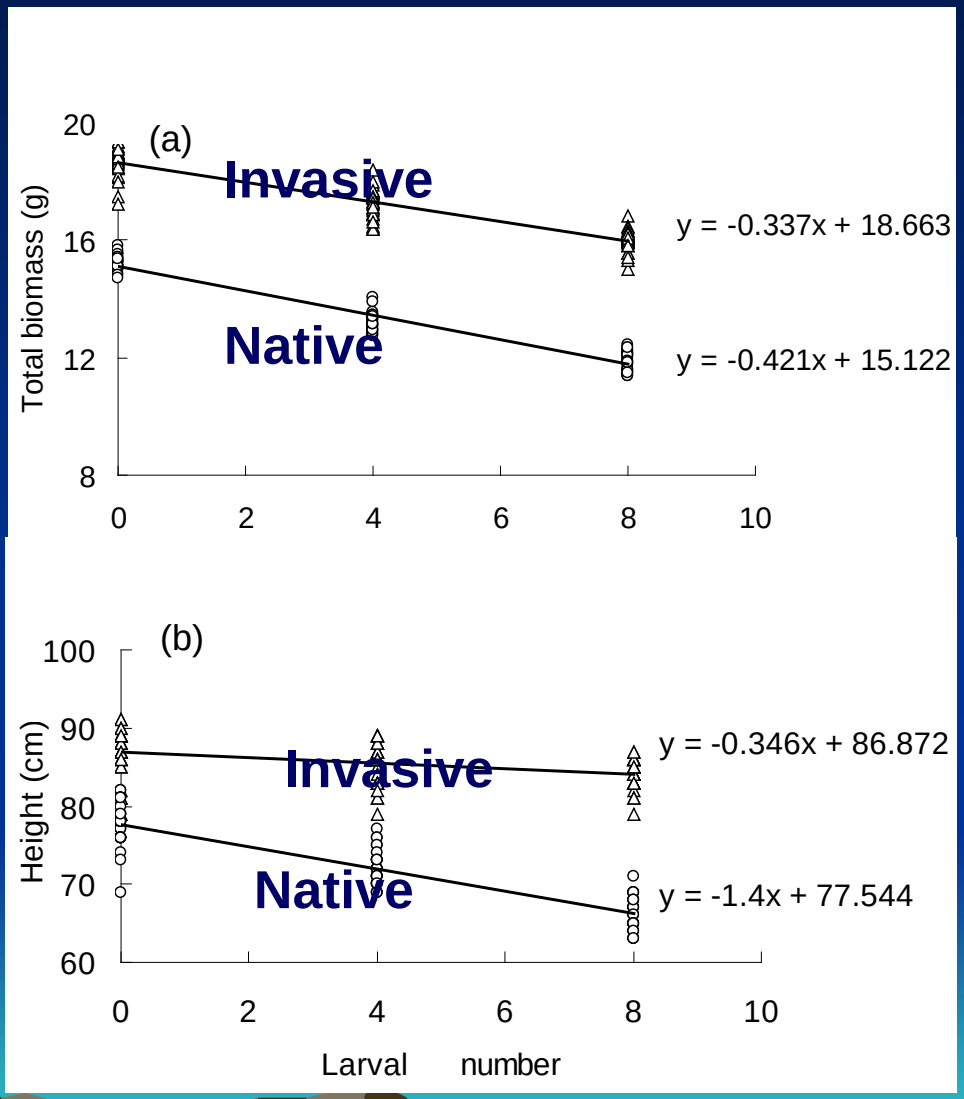
Caterpillar *Gadirtha inexacta*

potential biological control impact

Field common garden tests:

larval numbers; 0, 4, 8 per seedling

plant fitness



(Ecological Applications, preprint, 2010)

Summary

- Weevils (potential biocontrol agent) achieved greater population densities when they fed on invasive trees than on natives, due to lower resistance of the invasive populations.

- Invasive plants had greater herbivore tolerance such that the impact of both potential insect agents (weevil and moth) on plant performance was lower than on native populations (despite higher herbivore loads on those plants).

Discussions: novel interactions

- Differences in selective pressures between ranges have caused dramatic reductions in resistance to specialist herbivores and those changes in plant secondary chemistry likely underlie these differences.

- Increase in tolerance to herbivory appears to (at least partly) reflect an increase in growth rate in the introduced range.

- Greater tolerance to generalist herbivores suggests the possibility of selection for traits that allow plants to tolerate generalist herbivores more than specialist herbivores.

Implications for biological control

- Reduced resistance and increased tolerance to herbivory in introduced populations may

  impede success of biological control, although the insects can reach high density.

- To improve the prediction of insect impact, biological control practitioners should

  include plants from the introduced range in the pre-release evaluation and examine novel interactions of insects and invasive populations.

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