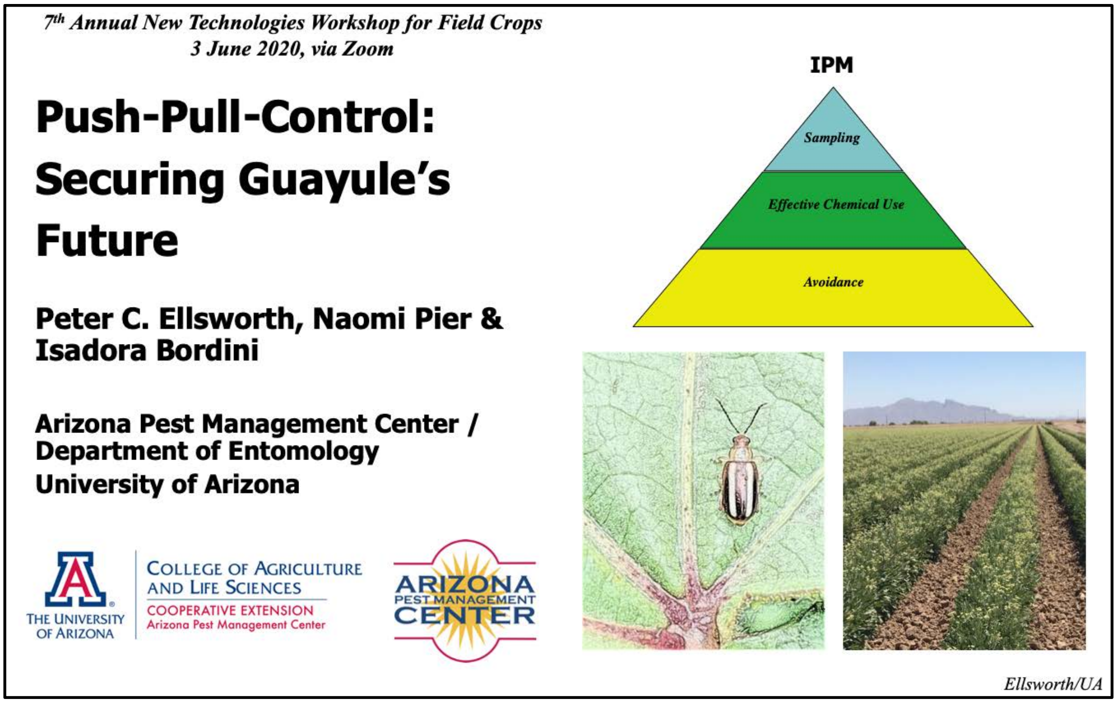


I will speak on this specific topic, but wish to start with some comments about how new crops are developed and protected. And, just what are "new" crops.

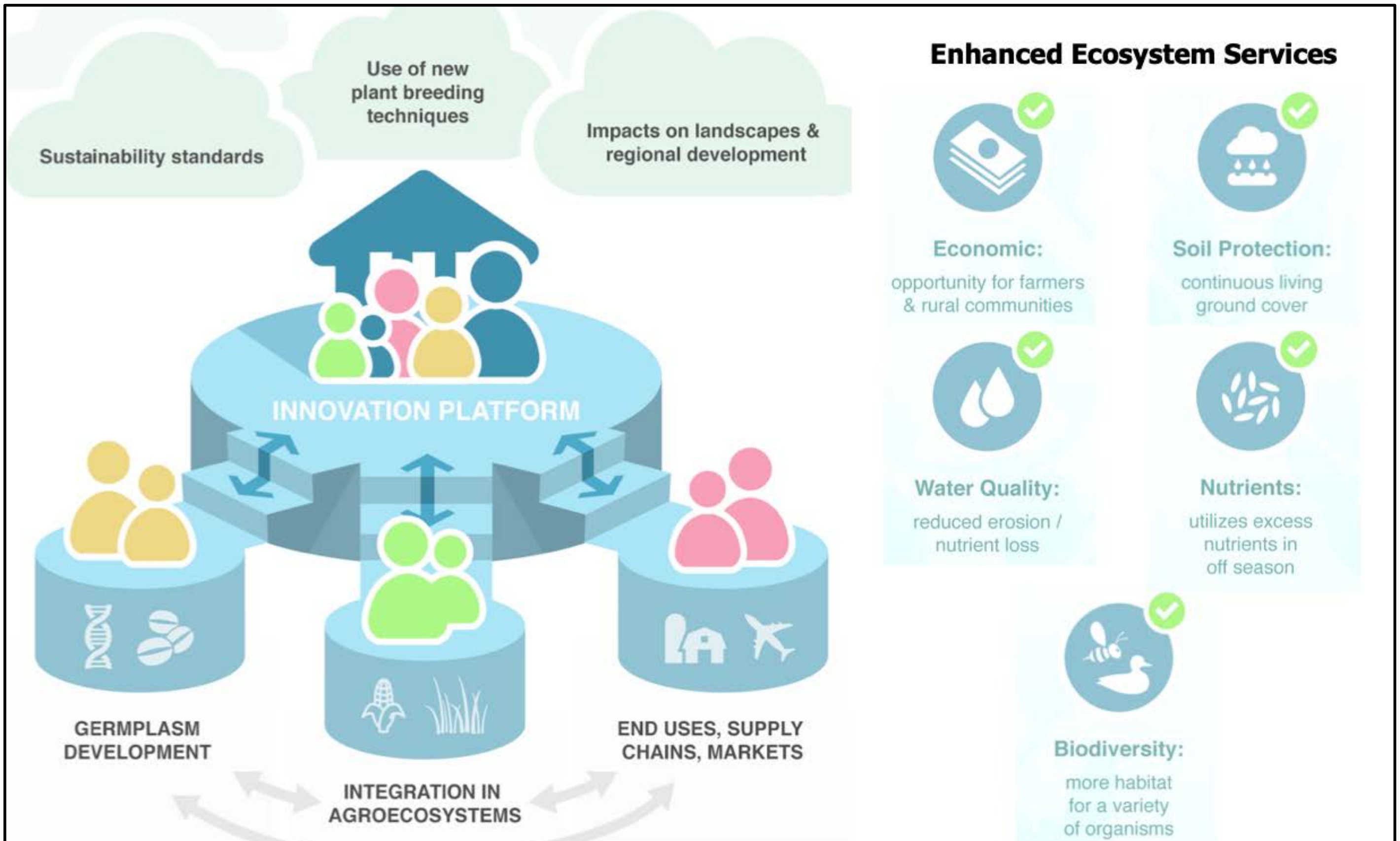
I would also like to acknowledge my co-authors and Assistants in Extension, Naomi Pier and Isadora Bordini, who also moonlight as graduate students.

Virtually presented via Zoom, 20 min.; up to 125 in attendence.

Just what are "new" crops?

I think of them as plants never grown in Arizona before, and/or plants grown in significantly different ways to meet needs of new markets or consumer preferences. My frame of reference is the past 3 decades as I am conducting my 30th field season here in Arizona. We've witnessed a revolutionary change in the food, forage, and fiber produced in Arizona over that time!

Baby carrot, Bagged salad, Baby leaf, Spring mix, Baby spinach, Micro greens, each never produced prior to their production here. Teparies, a traditional or native crop really have taken off in the last 10 years. Garbanzos, industrial hemp, and kale are other recent examples. But there are also the familiar crops grown in Heritage or Heirloom varieties to meet specific market niches, as in wheat. Many of these innovations were grower and/or market driven. What role do academics play?



From Jordan et al. 2015, Elementa

I'm not sure what the average person expects, but there are no centralized or formalized institutions dedicated to the conception and development of new crops. Academics have proposed conceptual structures that include innovation platforms made up of representative expertise, usually from 3 distinct areas: genetics and germplasm development, socio-economic development of end uses, supply chains, and markets, and agro-ecological integration.

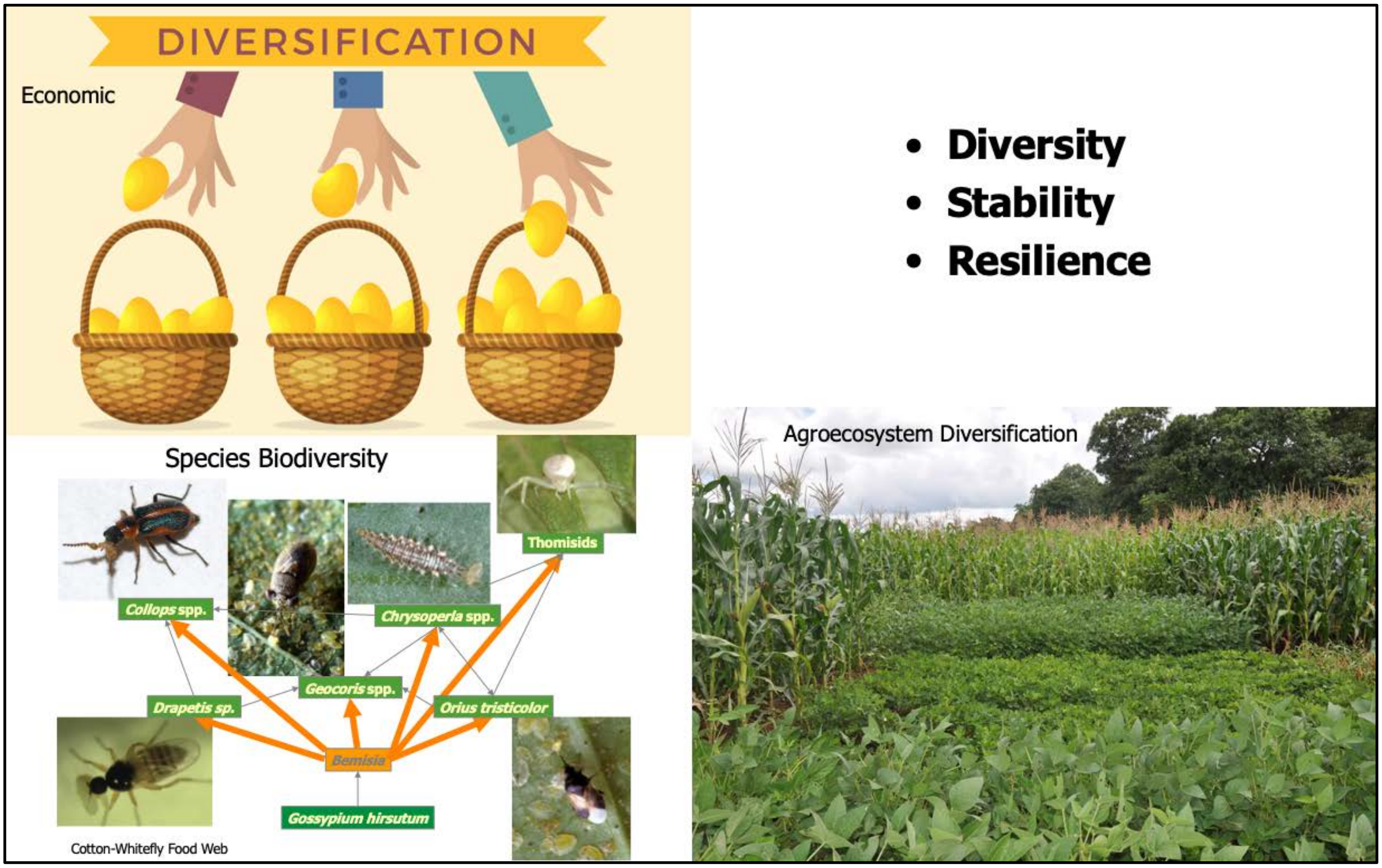
I'm also not sure what the average person thinks when they hear the goal of enhancing "ecosystem services", but it is not all about "trees and bees"! It is about how we generate economic opportunity from the ecosystem while safeguarding soil and water (& air), and enhancing nutrient conversion and biodiversity.

Where does this leave pest control and IPM?

Before I answer that question, let's look at another organizational construct that is similar but is under the category of "sustainable intensification". What is sustainable intensification and why is it more compelling than it's 3-decade old pre-cursor, "low input sustainable agriculture" or LISA. Early in my career, I wondered why sustainable agriculture had to be predicated on "low input". Our growing world needs more food and fiber, not less, and the original concept for sustainability was not about low inputs, so much as input optimization. Today, most support this idea of sustainable intensification, once again depending on genetic, socio-economic, and ecological intensification. Perhaps buried within this last goal, ecological intensification is where IPM happens, making use of precision use of inputs, making maximum use of "natural" capital like biological control, and this key concept of "diversification".

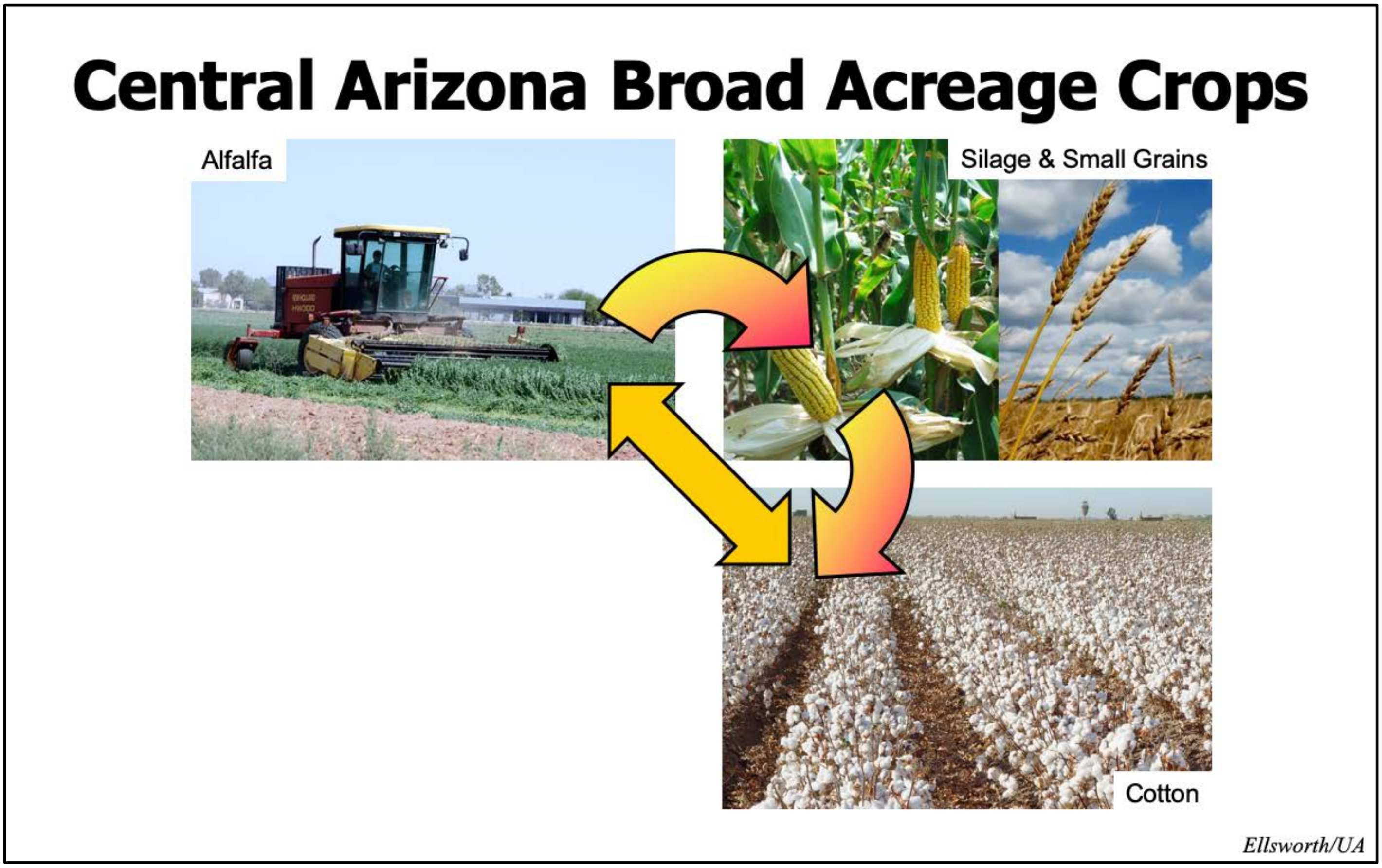
From: https://ag4impact.org/database/

Diversification is a strikingly pervasive concept in our daily lives. How many times have you been told not to place all your eggs in one basket? It turns out that it permeates many of our scientific and social constructs, too. In general, diversity has "existence" value in that we believe it to be beneficial to humankind in some way.



Again, everyone either invests or thinks about investing one day for their future. The first piece of advice from financial advisors is to diversify your risk. Economic diversification is fundamental to risk management. But likewise, agricultural systems are thought of as stronger when diversified in the number and types of crops grown. And even within a crop like cotton, we see large benefits in conserving species biodiversity especially of our generalist predators shown here that assist in whitefly management.

For all, diversity, stability, and resilience are inter-related themes. Thus, diversity plays an important role in our economic, agro-ecological and pest management systems.



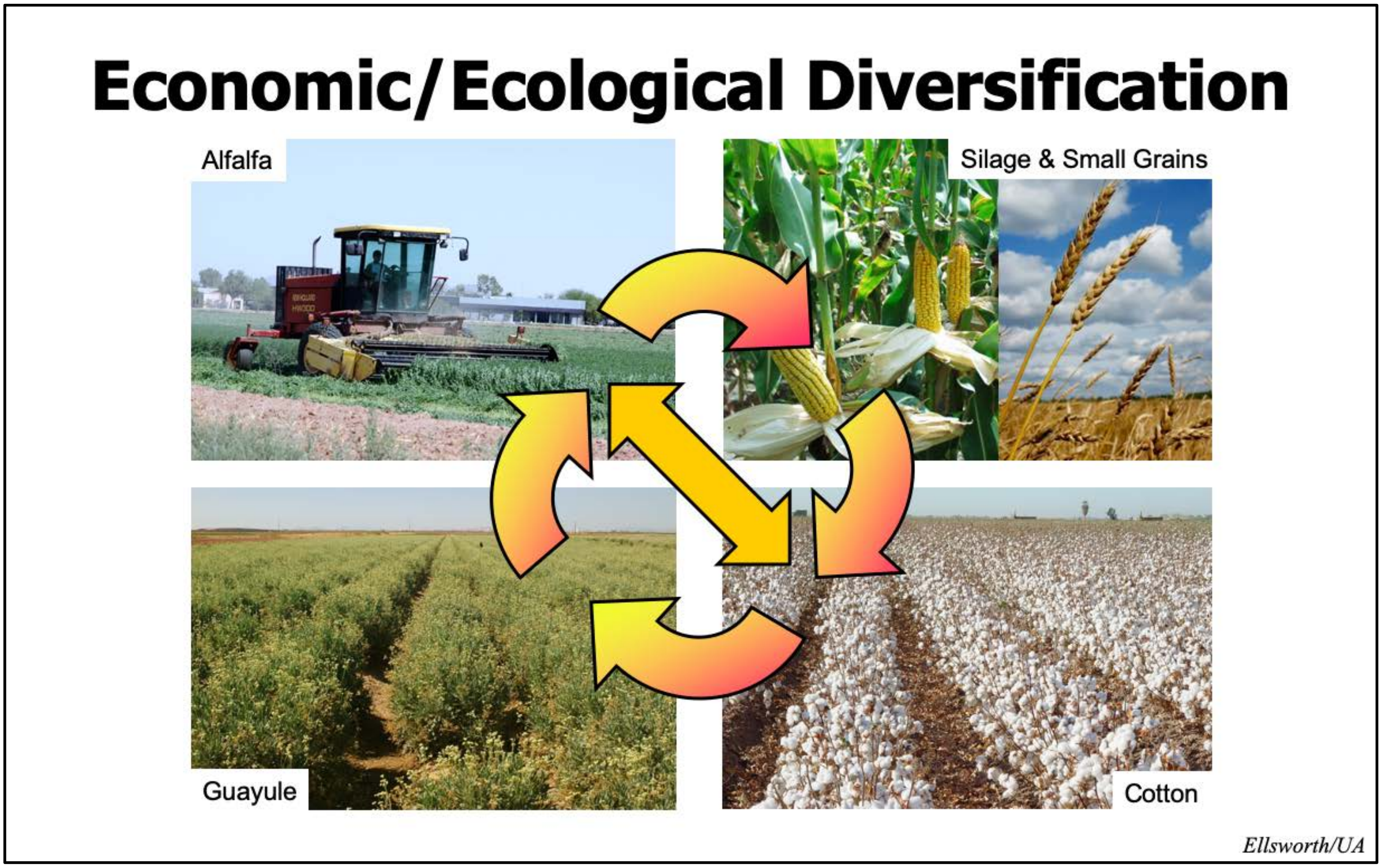
There are many different crops grown in central Arizona, including niche products and other small acreage investments. However, let's consider the cropping diversity of central Arizona for broad acre crops. Most farmers grow a rotation of alfalfa, cotton, and silage and small grains.

What "new" broad-acre crops have been developed for or tried in central Arizona?

In the late 1990s, there was quite a bit of interest in non-dormant alfalfa seed production. Unfortunately, we did not have the pest control tools for this crop or the others like cotton that were impacted by the huge numbers of Lygus bugs produced in seed alfalfa. [Not to mention the challenges of harvesting the crop during the monsoon.]

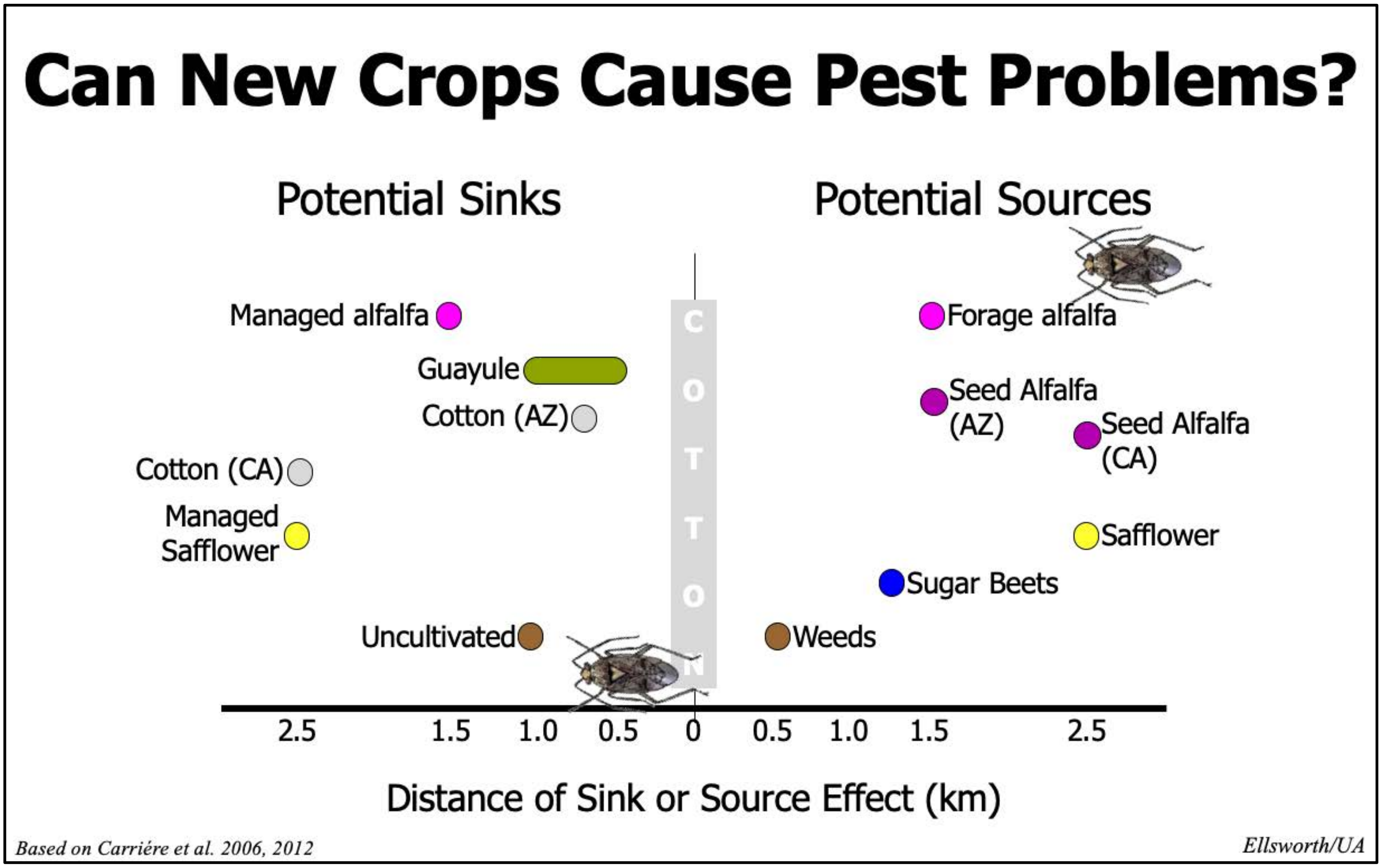
Seed alfalfa was a "grower" experiment. Lesquerella on the other hand was a scientific endeavor. However, her again, pest management challenges were significant, this time in weed control. Today, neither crop is grown.

Can guayule fill this need to diversify our broad acre production system?



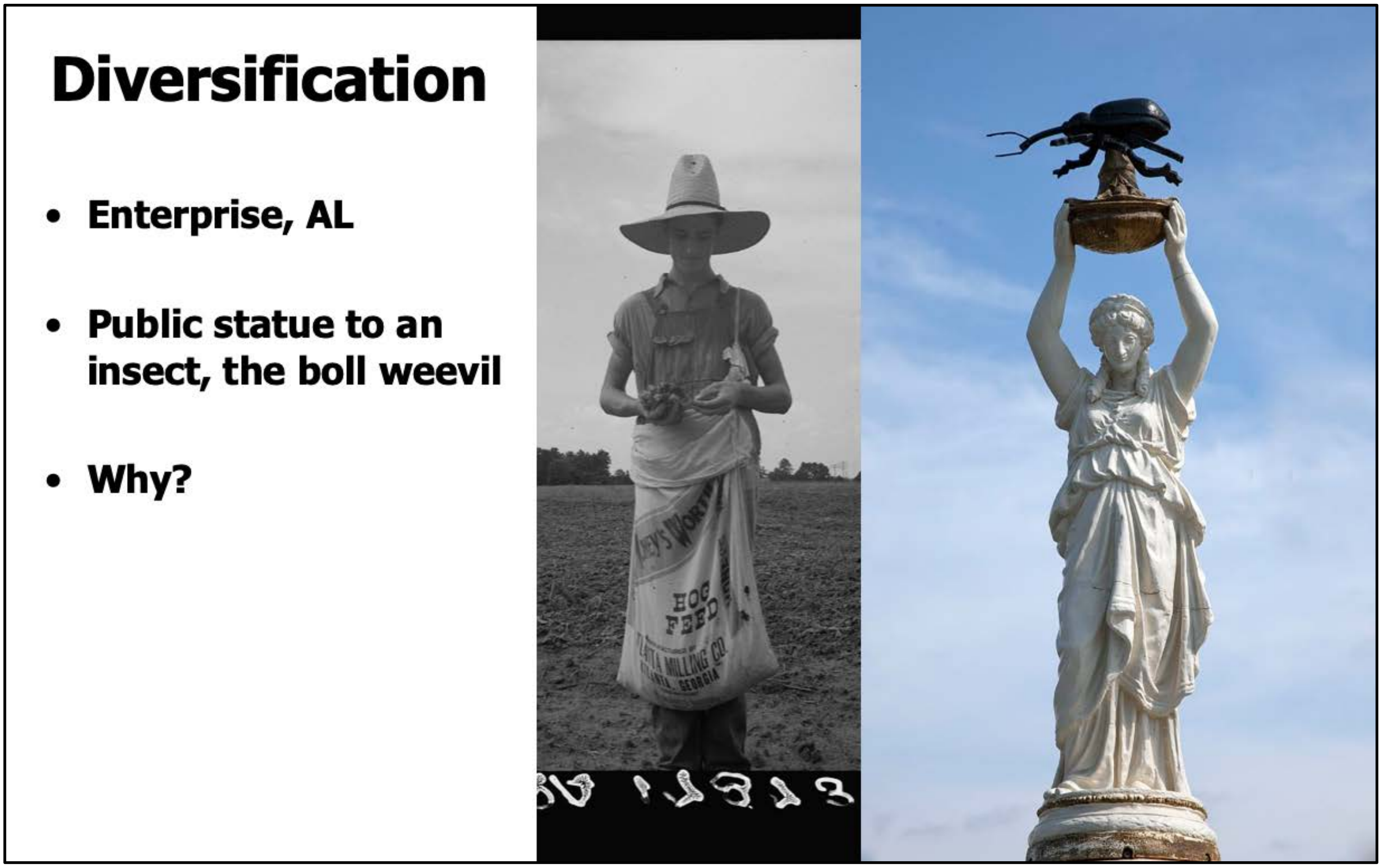
Guayule is summer flowering perennial that is on track for commercialization in large part due to the large industrial interest of Bridgestone, which intends to use the dry rubber in tire production. There are attributes that make this perennial option quite attractive to water-limited central Arizona. Importantly, it is a desert native and can withstand significant periods without irrigation and still remain alive and productive. That sort of flexibility in managing and using water may be key to any new broad-acre crop in this region.

As with alfalfa grown for seed, land-use diversification can lead both to new relationships, some positive (e.g., economic) and some negative (e.g., excess, uncontrolled Lygus in the agro-ecosystem).



It is reasonable to ask, "Can new crops cause pest problems?" We already know that seed alfalfa can in fact exacerbate Lygus problems regionally. It is, in fact, a source for Lygus to other crops. This chart shows the sink-source relationships that we have measured in the West, showing our cotton resource of interest, the one we wish to protect from Lygus, in the center of this chart. A potential source is a crop relationship that shows net increased movement toward or accumulation of Lygus in our subject cotton field. A potential sink is a crop that attracts a net movement or accumulation of Lygus away from our subject cotton field.

Importantly, guayule has served as an important, short-range sink at about 0.5–1km. This means that guayule in that range of cotton can provide a protective benefit. Equally important, guayule appears to be insensitive to Lygus, meaning it doesn't appear to be negatively impacted by Lygus bugs.



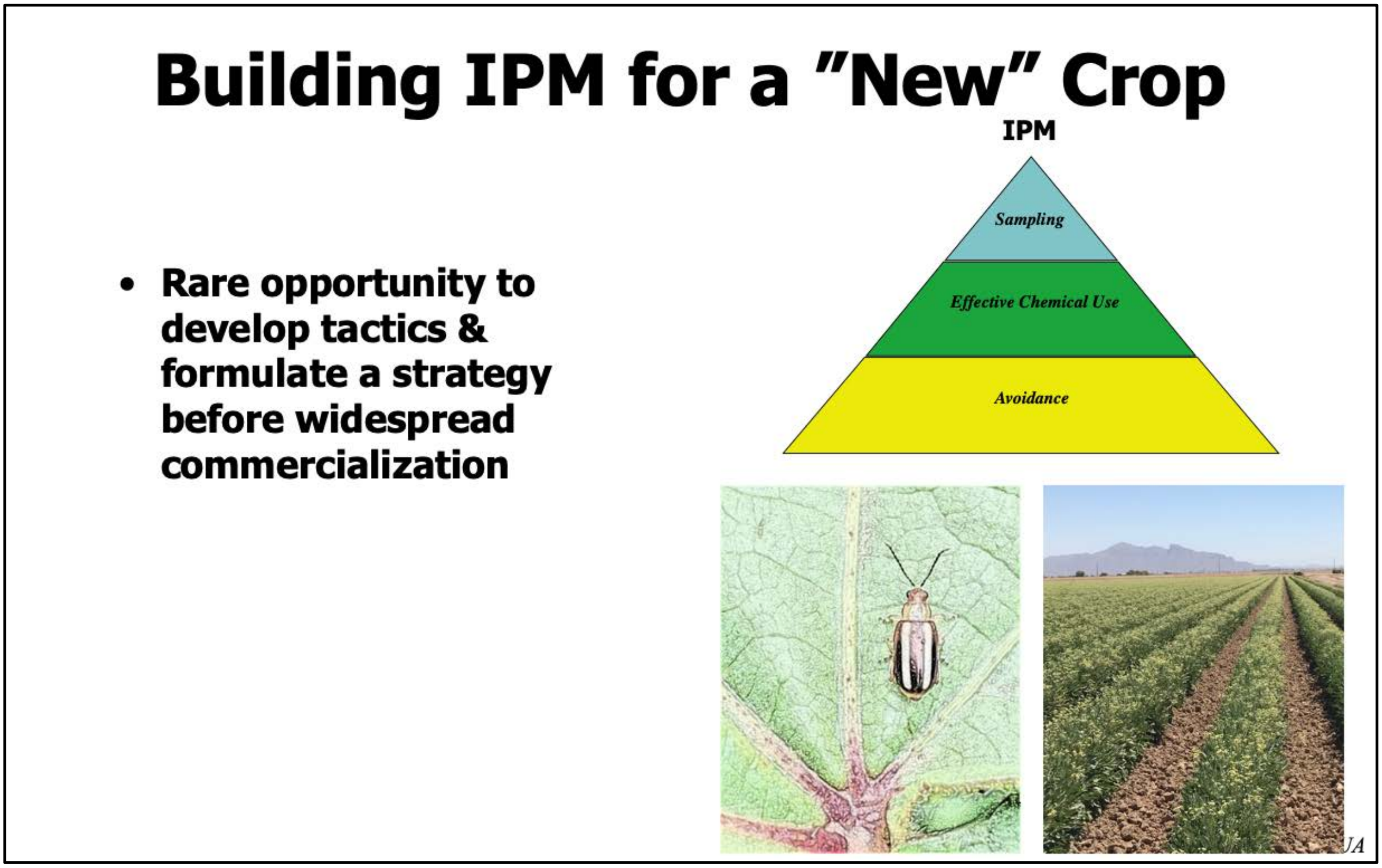
Pictured in the center is a young man in Georgia. What do you think he was doing relative to cotton? As it turns out he was collecting boll weevil infested bolls. Boll weevils ravaged the south. And, in Enterprise, AL, they erected a public statue to the boll weevil, the only statue to an insect in this country. Why do you suppose the citizens of that town supported such a statue?

The answer is “diversification”. Boll weevil forced the region to seek out alternative crops to cotton and greatly diversify their agro-ecological system. And, in the end, that’s what saved the south agro-economically. Thus, the statue.

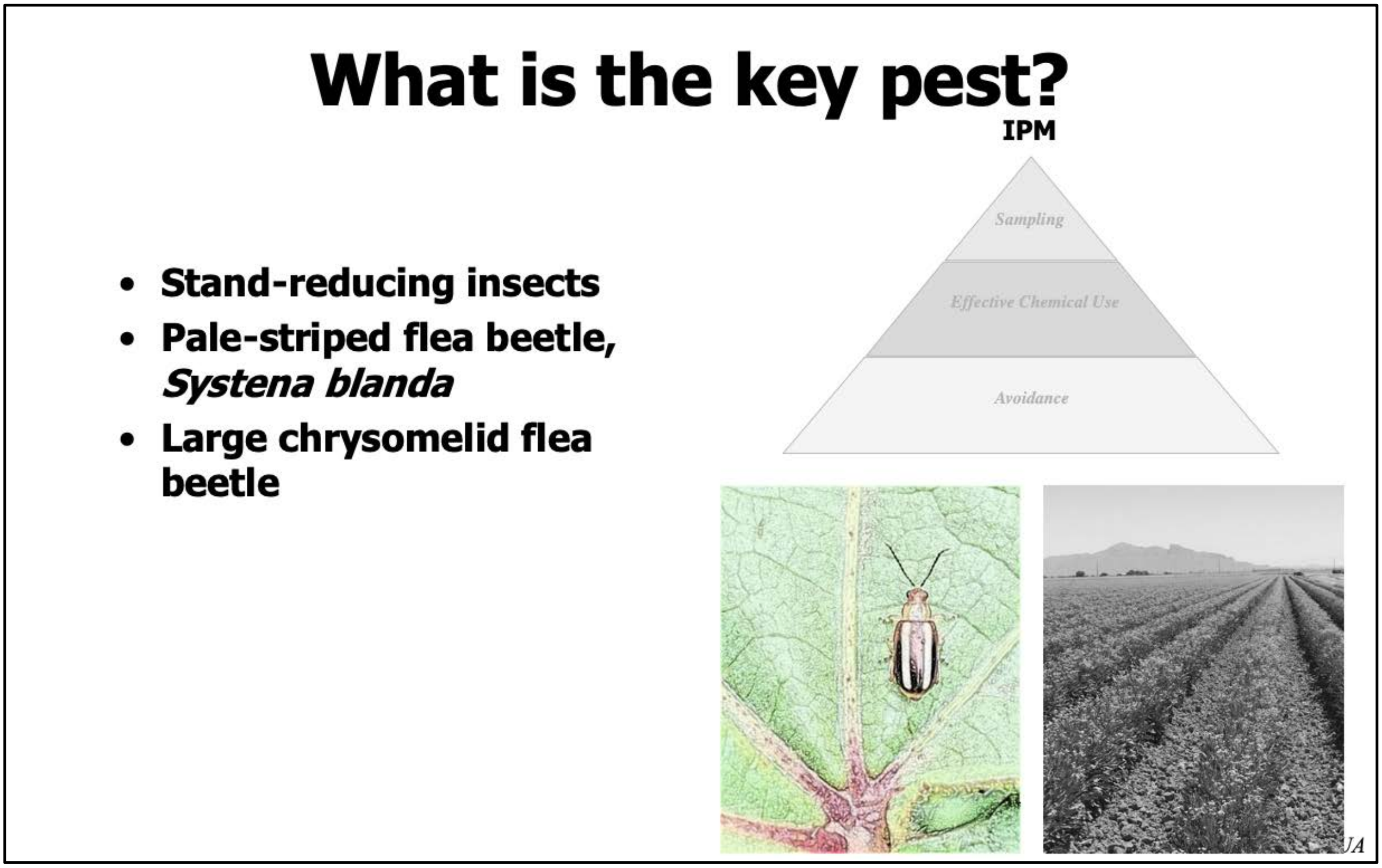
Title: Farm boy with sack full of boll weevils which he has picked off of cotton plants. Macon County, Georgia

Creator(s): Lange, Dorothea, photographer

Date Created/Published: 1937 July.



We are sitting in an interesting point in history with the time and rare opportunity to think about and develop an IPM program for a new crop prior to its broad-scale commercialization. Of course, guayule has been under development in one form or another for more than 100 years, it does appear that that time in history for its commercialization is upon us.



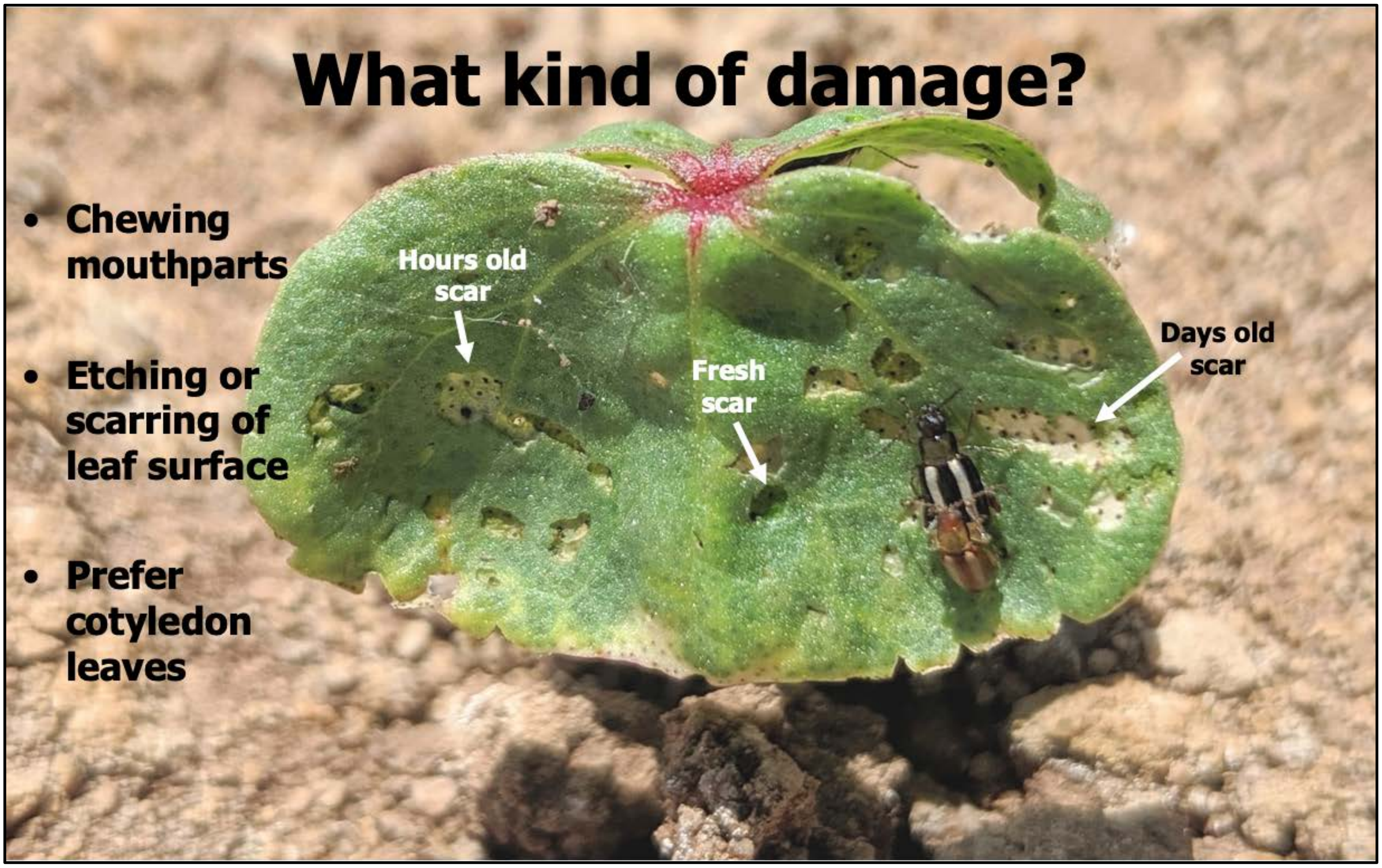
Guayule as a plant is relatively unmolested and unharmed by insects and other arthropods. However, at stand establishment, the very small and vulnerable seedlings are subject to many kinds of stand-reducing insects, chief among them, the pale-striped flea beetle.

What's the threat?

- **Adults invade & feed on newly emerged seedlings**
- **Adults larger than guayule cotyledon leaf**

Ellsworth/UA

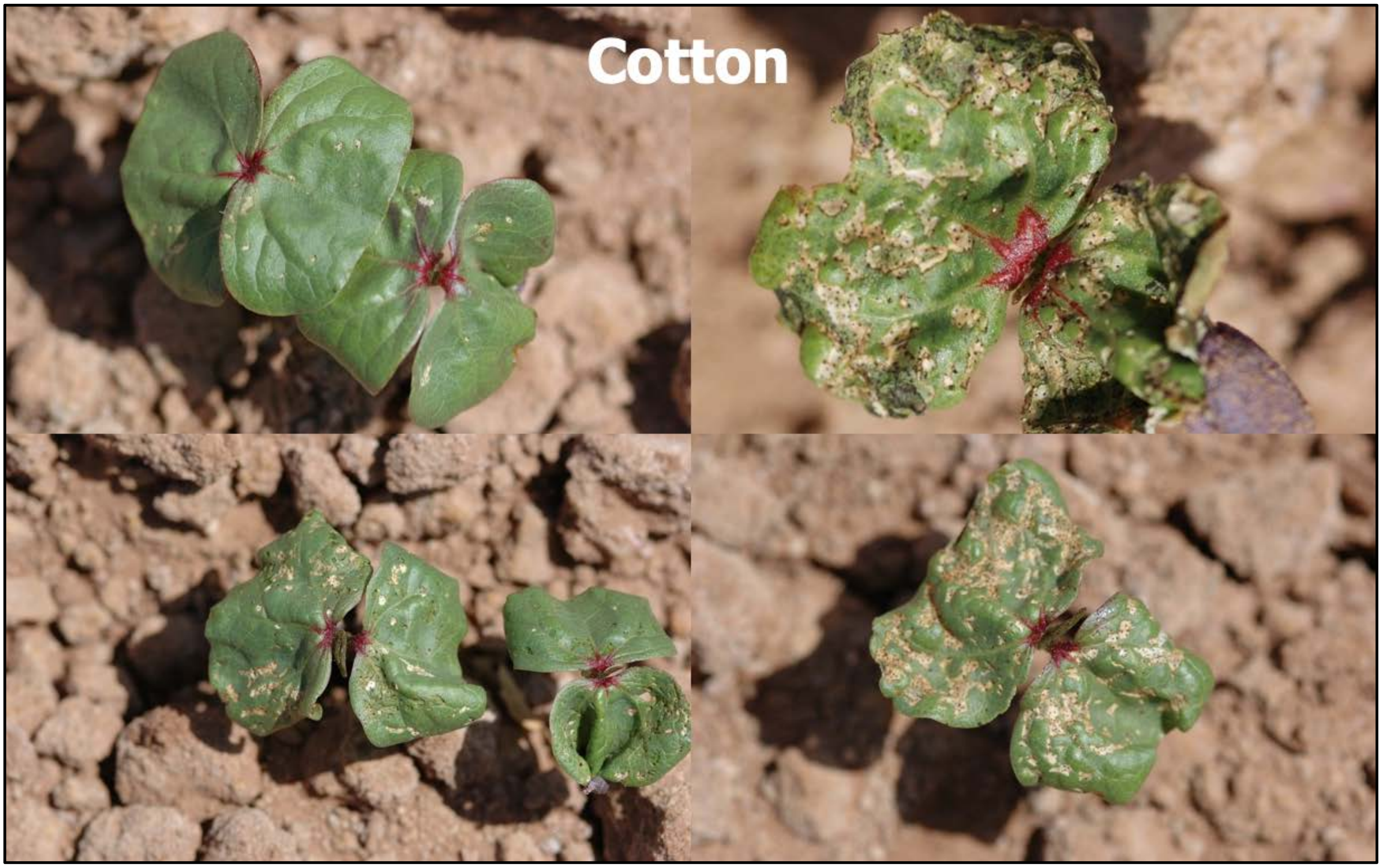
As flea beetles go, this is a large species, and unfortunately they are bigger than one cotyledon leaf of guayule. Loss of stand for a perennial crop has long-lasting consequences for production, directly from the loss of the impacted plant, but also from the large holes in the stand that permit competitive weeds to further erode production.



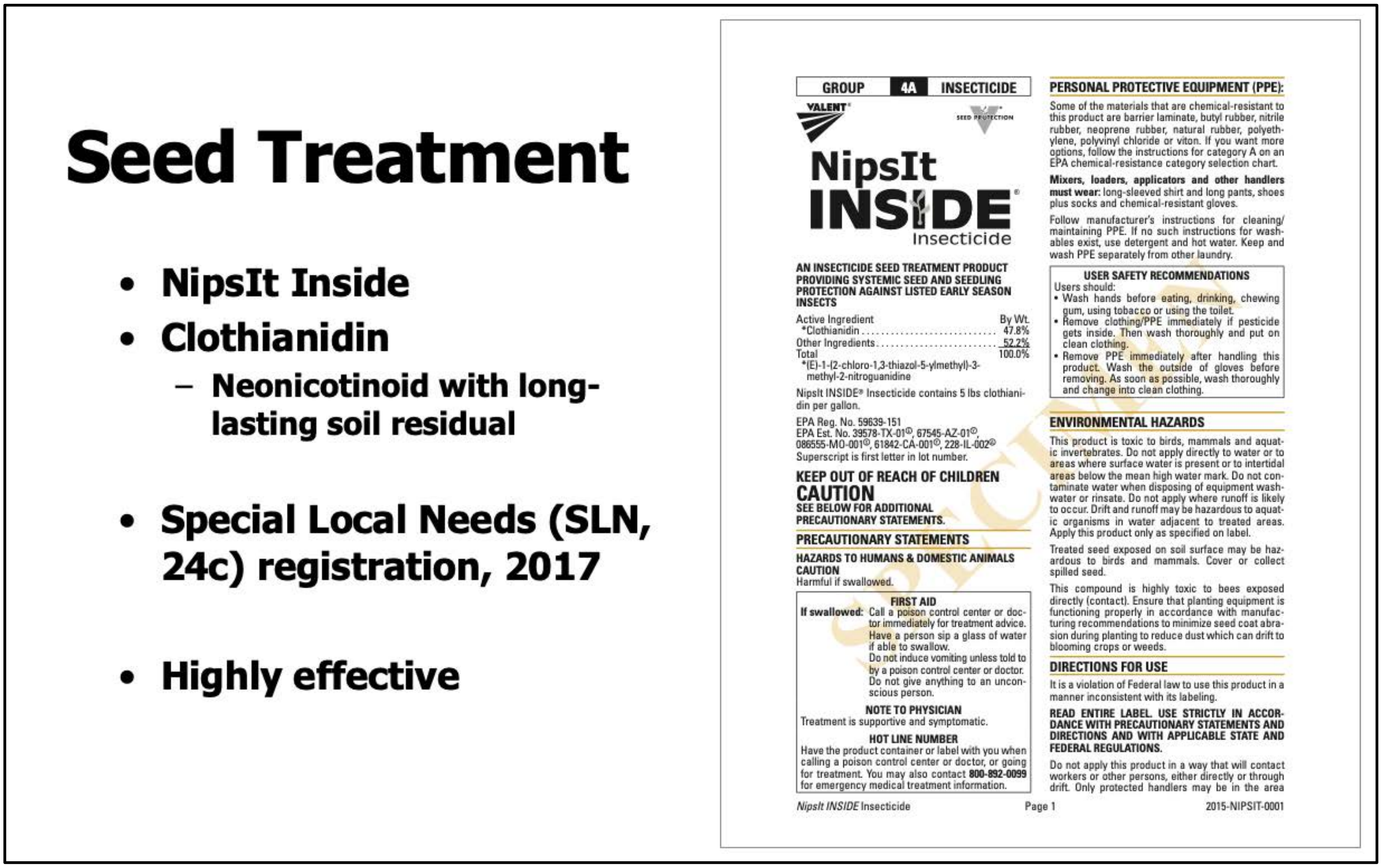
Flea beetles have chewing mouthparts but prefer to etch the surfaces of cotyledons, at least in cotton. Holes are unusual in cotton, and there is a strong preference for cotyledon leaves of all their favorite hosts.

These flea beetles can hide under the cotyledons or in the soil and are easily disturbed, making diagnosis of the damage important. And, knowing how recent the damage is can influence decisions about chemical control, which should only rarely be needed in cotton.

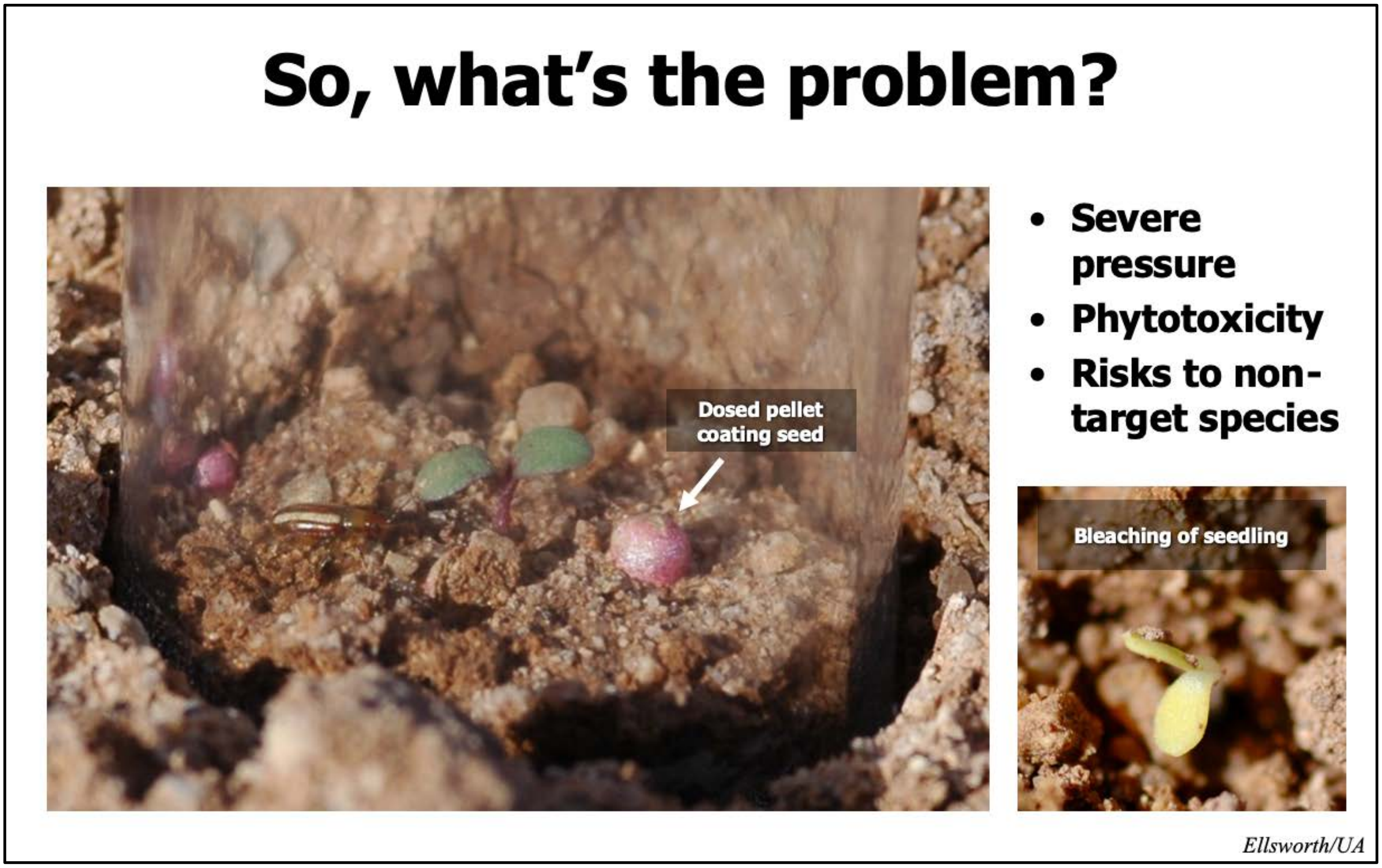
Showing damage in guayule is more problematic, because often times uncontrolled flea beetles completely consume the cotyledon leaves. In this series of photos, all plants could survive the damage shown if it did not advance further.



In cotton, seedling loss is rare when growing conditions are good. Chemical control would be unnecessary for the minor damage as seen on the left. The heavier damage (lower right) is not very pretty, but also not of much consequence if the first true leaf is pushing.



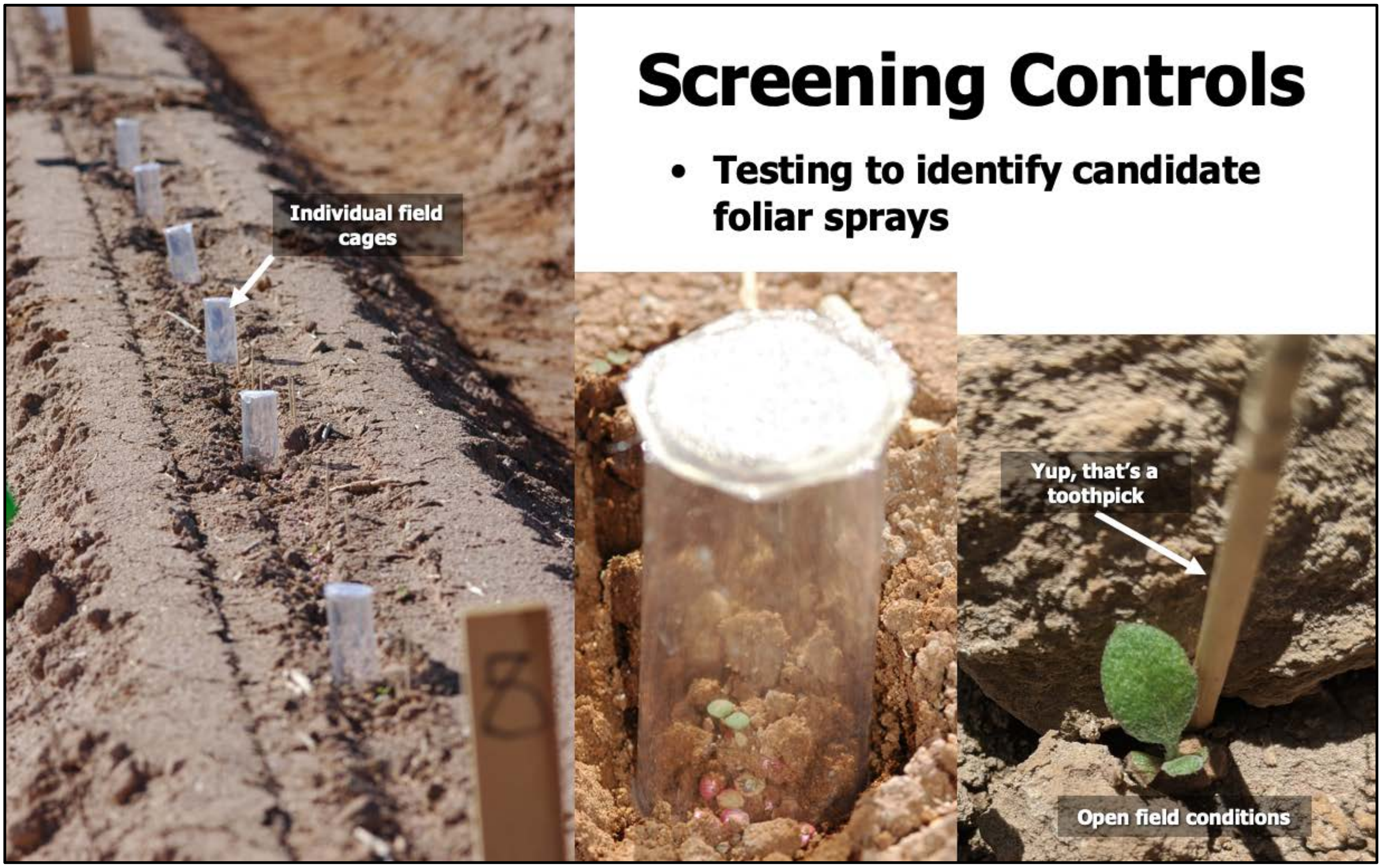
In contrast, under the right conditions, pale-striped flea beetles can wipe out whole fields of newly planted guayule. In 2017, we conducted research and helped to support the SLN registration of NipsIt Inside seed treatment for guayule. It is very effective, and does produce very long soil residuals.



Even with NipsIt Inside, there have been infestations of flea beetles so severe that a foliar spray was also needed. Clothianidin also can cause some phytotoxicity and seed storability issues. And, those long soil residuals can make its use hazardous to non-target organisms including aquatic life and pollinators, as well as many other beneficial insects.

Alternatives are needed.

While this is an exceptional case pictured here, it is rare for guayule to experience much insect damage once it is established and has 3–5 true leaves. That means perhaps no spraying for arthropods after stand establishment for the life of the crop (2–6 years), though more research should be done.



Our research entails many approaches to the assessment of various control tactics including foliar sprays. We don't have time to go into all of these approaches or experiments today, but know that these have all been done under direct seeded, field conditions.

Comprehensive Risk Assessment

- To aquatic life (fish & invertebrates)
- To wildlife (birds & small mammals)
- To pollinators
- To human health (inhalation)
- To key natural enemies
- Highly Hazardous Pesticides

Cotton Insecticide Target Efficacy, Impact on Non-Target Arthropods & Other Pesticide Risks. Insecticides have been screened for efficacy against target pests, *Lygus hesperus*, *Bemisia argentifolii* (MEAM1; silverleaf whitefly, SWF), and *Euschistus servus* (brown stink bug); as well as for their impact on non-target beneficial arthropods including >20 predators common in Arizona cotton. Those insecticides with full selectivity or safety towards these beneficial predators are in green; those that are partially selective or safe are in yellow; broad spectrum insecticides are in red. Some insecticides pose environmental and human health risks that require mitigations such as buffer zones and additional personal protective equipment (PPE). IRAC group numbers to facilitate rotation of chemistry and SWF resistance risks are also shown.

Product Name	Common Name	IRAC No.[1]	Chemical Group	Lygus Bug	Silverleaf Whitefly	Brown Stink Bug	Risk to Aquatic Life	Risk to Wildlife	Risk to Pollinators	Inhalation Risk	SWF, Risk of Resistance
Applaud	buprofezin	16	Chitin inhibitor		**** (N)						under investigation
Beleaf	cyantraniliprole	28	Diamide		****						
Knack / Stone	pyriproxyfen	7C	Juvenoid		**** (E,N)						mild–moderate
Oberon[2]	spiromesifen	23	Lipid synthesis inhibitor		**** (N)						under investigation
Pirifla	pyrifluquinazon	9B	Pyridine azomethine		****						
Sivanto prime	flupyradifurone	4D	Butenolide		****						
Toretto	sulfoxaflor	4C	Sulfoxamine	****	*						
Turbine	flonicamid	29	Feeding inhibitor	****							
Versys	*afidopyropen*	*9D*	*Pyropene*		***						
Actara	thiamethoxam[4]	4A	Neonicotinoid		**		Yes		Yes		
Assail / Rescate[3]	acetamiprid	4A	Neonicotinoid		****		Yes				moderate–severe
Clutch	clothianidin[4]	4A	Neonicotinoid	**	**		Yes		Yes		
Venom	dinotefuran	4A	Neonicotinoid		***		Yes		Yes		
Acefate	acephate	1B	Organophosphate	***		*		Yes	Yes		
Dicrotophos	dicrotophos[5]	1B	Organophosphate	*		*	Yes	Yes	Yes	Yes	
Massada	novaluron	15	Chitin inhibitor	*	*	* (N)	Yes				
Scarlet	novaluron + acetamiprid	15 + 4A	Chitin inhibitor	**	**	* (N)	Yes				
Synergized pyrethroids	various[6]	3A + 1B	Pyrethroid + organophosphate		**		Yes	Yes	Yes		moderate–severe
Vidate	oxamyl[5]	1A	Carbamate	****			Yes	Yes	Yes	Yes	

Background color: Green = Fully selective and safe to beneficials; Yellow = Partially selective or safe to beneficials; Red = broad spectrum, not safe to beneficials; *Italic* = based on preliminary testing. Rev. 10/7/19

Risks as calculated from ipmPRIME (Jepson et al. 2014); 'Yes' indicates moderate to high risk for the given category.

****, Excellent control; ***, Good control; **, Fair control; *, Suppression only; E, N = Efficacy against eggs or nymphs only, respectively.

[1] The Insecticide Resistance Action Committee (IRAC) assigns numbers for each unique mode of action or class of chemistry. Many appear on U.S. insecticide labels and are helpful for resistance management.
[2] At 140–175 g ai / ha only; higher rates are more destructive of natural enemies.
[3] The State of Arizona has approved a Special Local Needs (SLN) increase in acetamiprid use rates by up to +50% against difficult-to-control whiteflies. Impact to beneficials is more severe at these higher rates.
[4] This active ingredient can significantly affect bee populations, other pollinators and birds, can persist for years in soils, and can leach into waterways and groundwater.
[5] This active ingredient is considered highly hazardous by the World Health Organization (WHO Ib), a restricted use pesticide with signal words DANGER and POISON, requiring posting, additional PPE, and closed systems. Avoid if possible.
[6] Beta-cyfluthrin and zeta-cypermethrin are considered highly hazardous by the World Health Organization (WHO Ib), are restricted use pesticides with signal words WARNING, and should be avoided when possible.

Any findings, recommendations, services, or organizations that are mentioned, shown, or indirectly implied in this publication do not imply endorsement by the University of Arizona or USDA.

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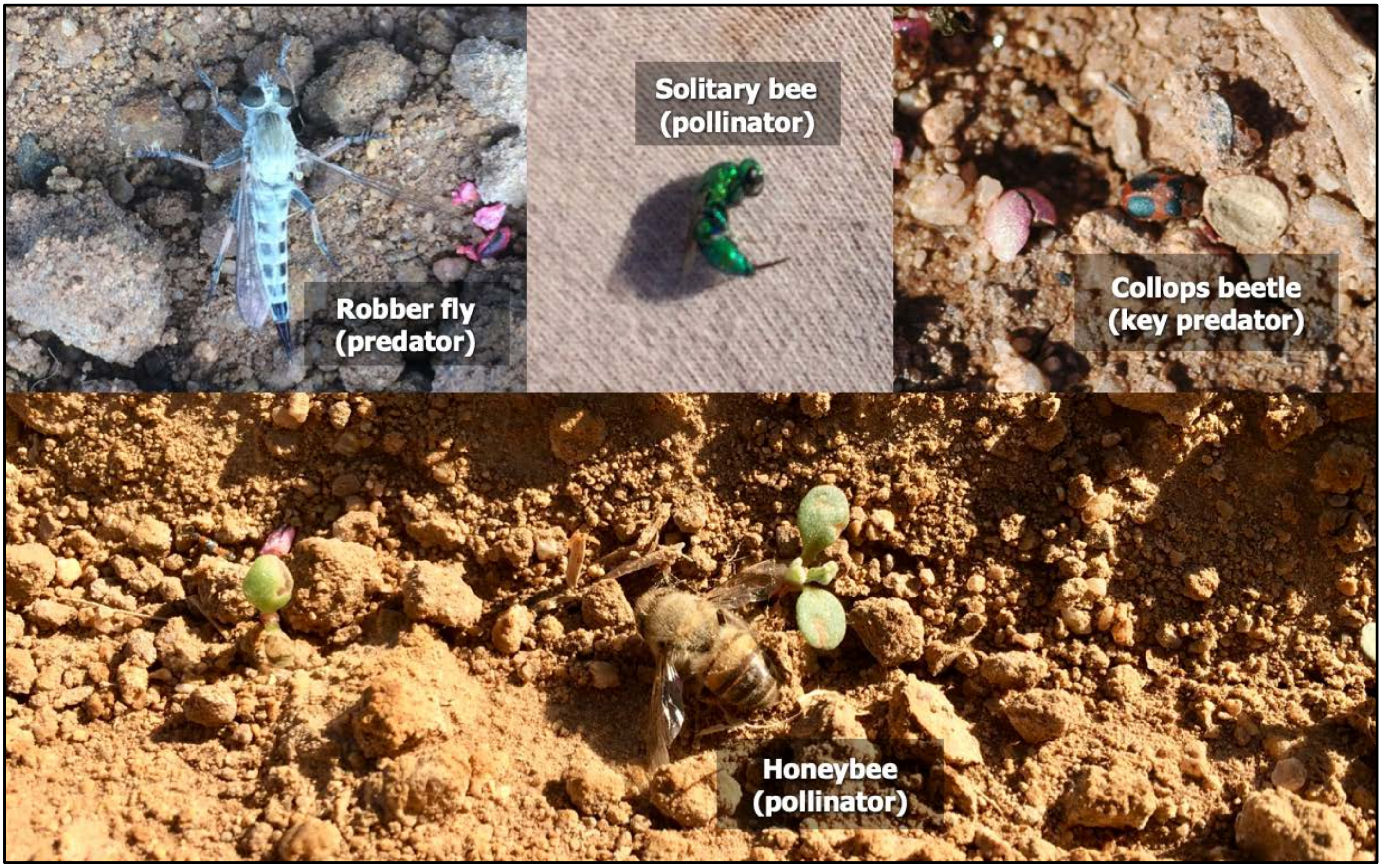
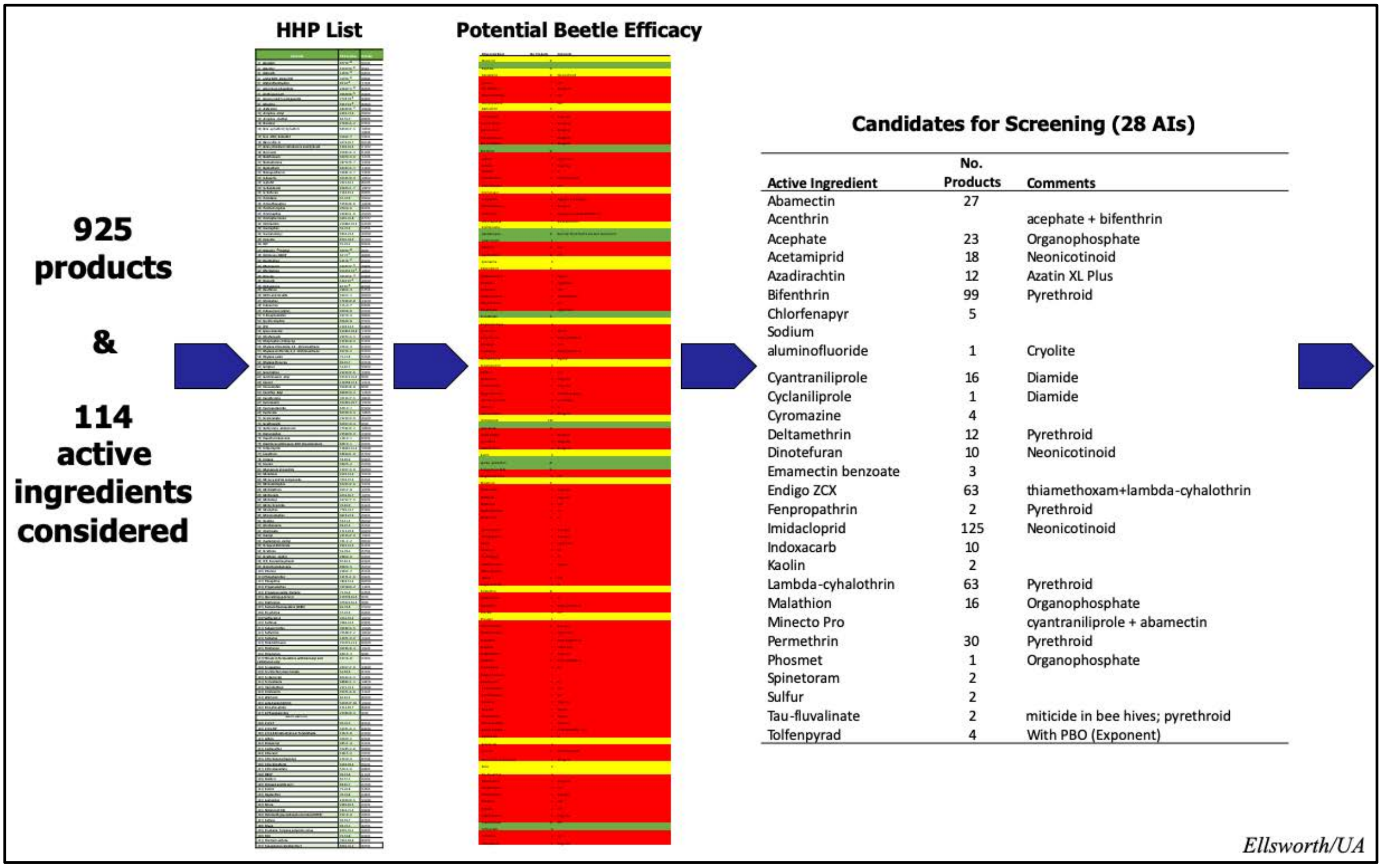
Any foray into locating a new chemical control should start with a comprehensive risk assessment. It makes little sense to screen and discover activity in a molecule that otherwise cannot or will not be registered for that use. Plus, we have the advantage of being more deliberate in our approach, which includes “building natural capital”. That means considering risks to aquatic life, terrestrial wildlife, pollinators, and of course human health.

In our system, it also means understanding risks to the natural enemies that we already depend on in say cotton or alfalfa.

Plus, governments worldwide have agreed, where possible, to reductions and/or phase-outs of any materials considered, by consensus, to be highly hazardous pesticides.



A fall planted crop of guayule is a magnet for all the arthropods that inhabit the central Arizona agro-ecosystem. These are just a few of the observed casualties found while walking a field with guayule emerging from treated seed. These pollinators and predators are important to our system generally, and we should work hard to mitigate these risks.



Active Ingredient	No. Products	Comments
Abamectin	27	
Acenthrin		acephate + bifenthrin
Acephate	23	Organophosphate
Acetamiprid	18	Neonicotinoid
Azadirachtin	12	Azatin XL Plus
Bifenthrin	99	Pyrethroid
Chlorfenapyr	5	
Sodium aluminofluoride	1	Cryolite
Cyantraniliprole	16	Diamide
Cyclaniliprole	1	Diamide
Cyromazine	4	
Deltamethrin	12	Pyrethroid
Dinotefuran	10	Neonicotinoid
Emamectin benzoate	3	
Endigo ZCX	63	thiamethoxam+lambda-cyhalothrin
Fenpropathrin	2	Pyrethroid
Imidacloprid	125	Neonicotinoid
Indoxacarb	10	
Kaolin	2	
Lambda-cyhalothrin	63	Pyrethroid
Malathion	16	Organophosphate
Minecto Pro		cyantraniliprole + abamectin
Permethrin	30	Pyrethroid
Phosmet	1	Organophosphate
Spinetoram	2	
Sulfur	2	
Tau-fluvalinate	2	miticide in bee hives; pyrethroid
Tolfenpyrad	4	With PBO (Exponent)

Our process was to start with nearly 1000 agricultural insecticide products used worldwide, which come from over 100 active ingredients. We looked for any reported "beetle" efficacy and winnowed the list down to 28 candidate active ingredients for testing.

Candidates for Screening (28 AIs)

Active Ingredient	No. Products	Comments
Abamectin	27	
Acenthrin		acephate + bifenthrin
Acephate	23	Organophosphate
Acetamiprid	18	Neonicotinoid
Azadirachtin	12	Azatin XL Plus
Bifenthrin	99	Pyrethroid
Chlorfenapyr	5	
Sodium aluminofluoride	1	Cryolite
Cyantraniliprole	16	Diamide
Cyclaniliprole	1	Diamide
Cyromazine	4	
Deltamethrin	12	Pyrethroid
Dinotefuran	10	Neonicotinoid
Emamectin benzoate	3	
Endigo ZCX	63	thiamethoxam+lambda-cyhalothrin
Fenpropathrin	2	Pyrethroid
Imidacloprid	125	Neonicotinoid
Indoxacarb	10	
Kaolin	2	
Lambda-cyhalothrin	63	Pyrethroid
Malathion	16	Organophosphate
Minecto Pro		cyantraniliprole + abamectin
Permethrin	30	Pyrethroid
Phosmet	1	Organophosphate
Spinetoram	2	
Sulfur	2	
Tau-fluvalinate	2	miticide in bee hives; pyrethroid
Tolfenpyrad	4	With PBO (Exponent)

Results, 4 Promising Leads (more under study)

Active Ingredient	No. Products	Comments
Abamectin	27	
Acenthrin		acephate + bifenthrin
Acephate	23	Organophosphate
Bifenthrin	99	Pyrethroid
Chlorfenapyr	5	
Sodium aluminofluoride	1	Cryolite
Cyantraniliprole	16	Diamide
Dinotefuran	10	Neonicotinoid
Endigo ZCX	63	thiamethoxam+lambda-cyhalothrin
Fenpropathrin	2	Pyrethroid
Indoxacarb	10	
Lambda-cyhalothrin	63	Pyrethroid
Malathion	16	Organophosphate
Minecto Pro		cyantraniliprole + abamectin
Phosmet	1	Organophosphate
Spinetoram	2	
Tolfenpyrad	4	With PBO (Exponent)

Ellsworth/UA

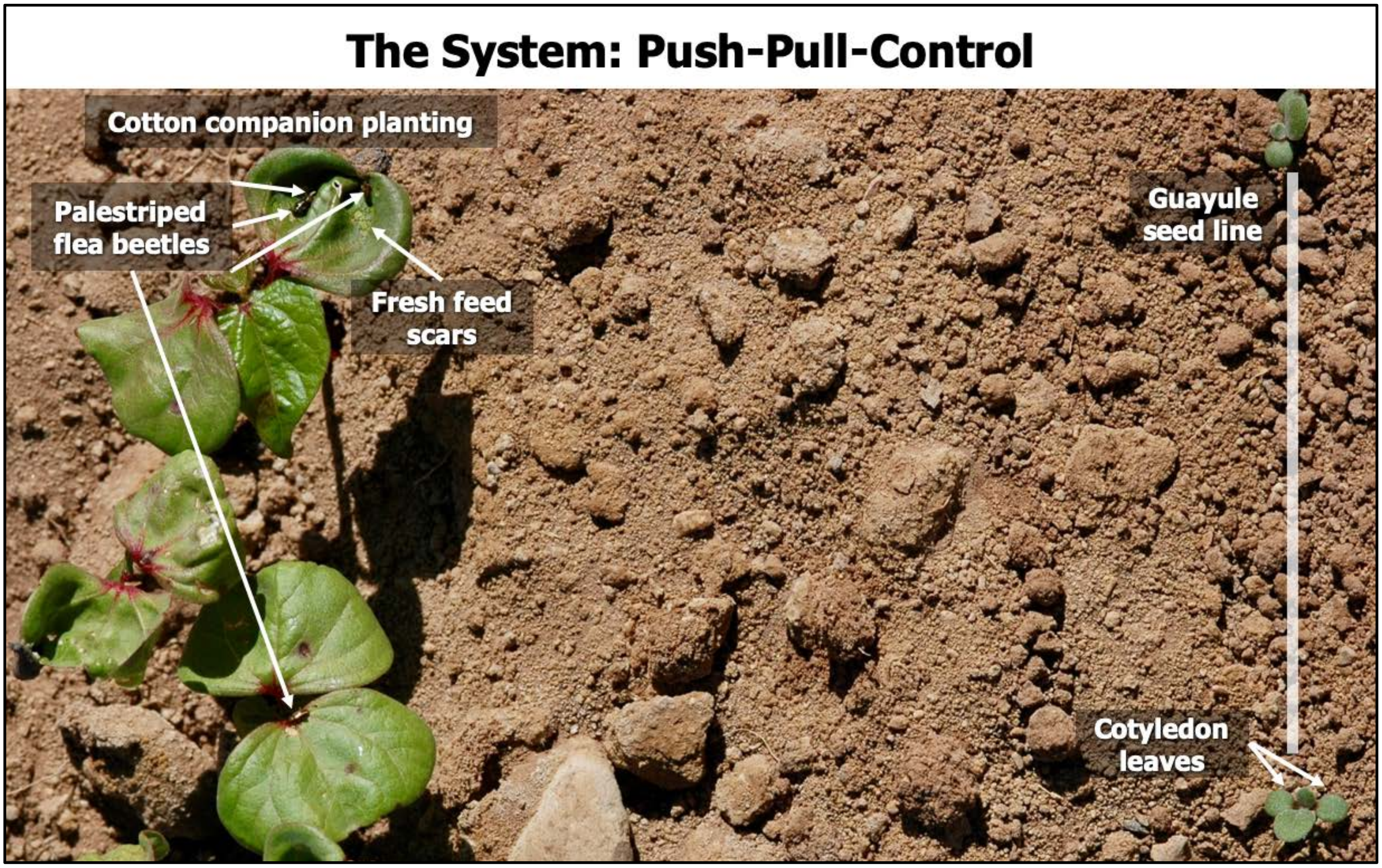
While our screening continues, we have found at least 4 promising leads to further test. They are (alphabetically):

Acephate in a premix with bifenthrin, or Acenthrin,

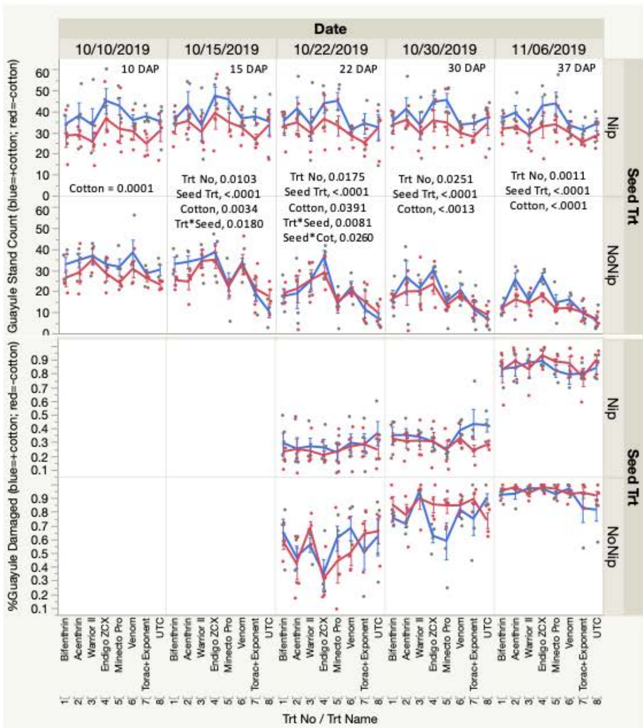
Chlorfenapyr, a compound used only in ornamental systems, or Pylon,

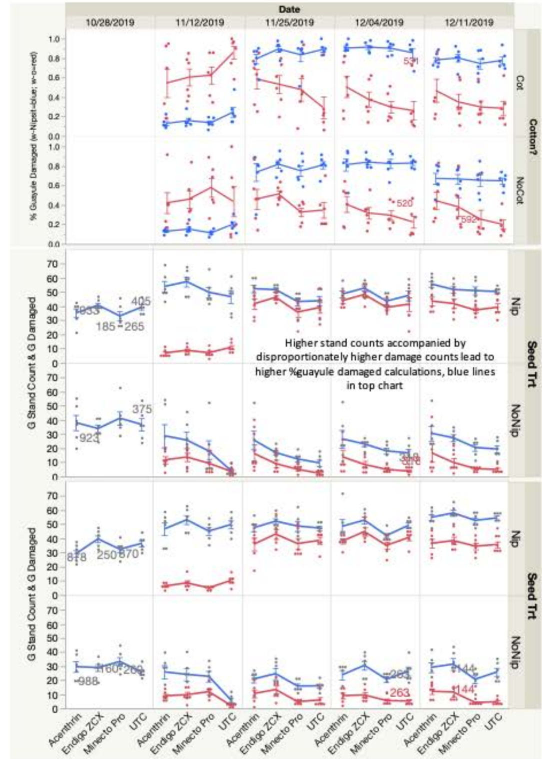
Phosmet, a compound only used in orchard crops, or Imidan, and

Thiamethoxam in a premix with lambda-cyhalothrin, or Endigo ZCX.



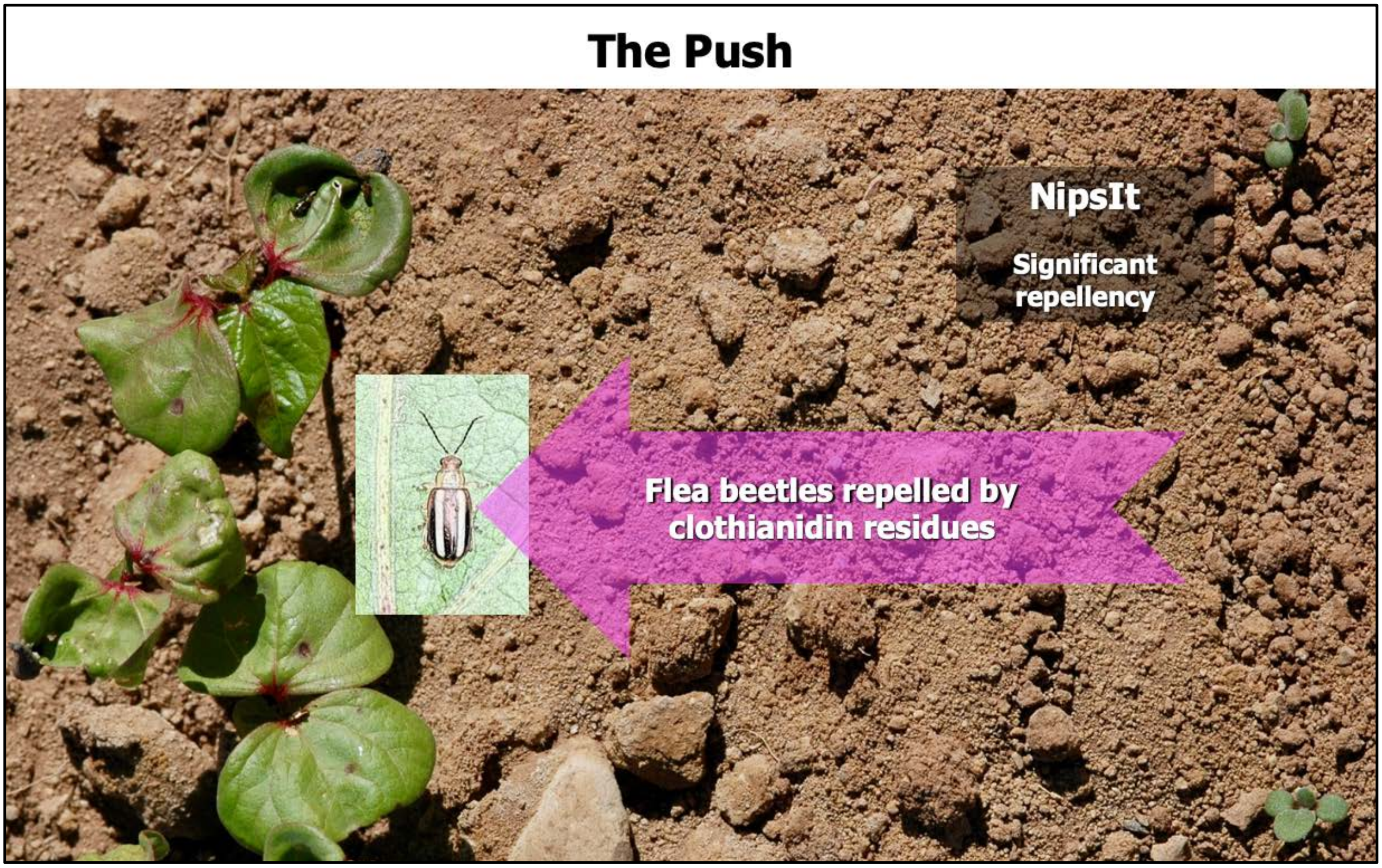
Let's quickly examine the system given in my original title, Push-Pull-Control. In our studies, we have the guayule seed line and the resources we wish to protect, the cotyledon leaves. Adjacent on the same bed, we've played with using cotton as a companion planting.



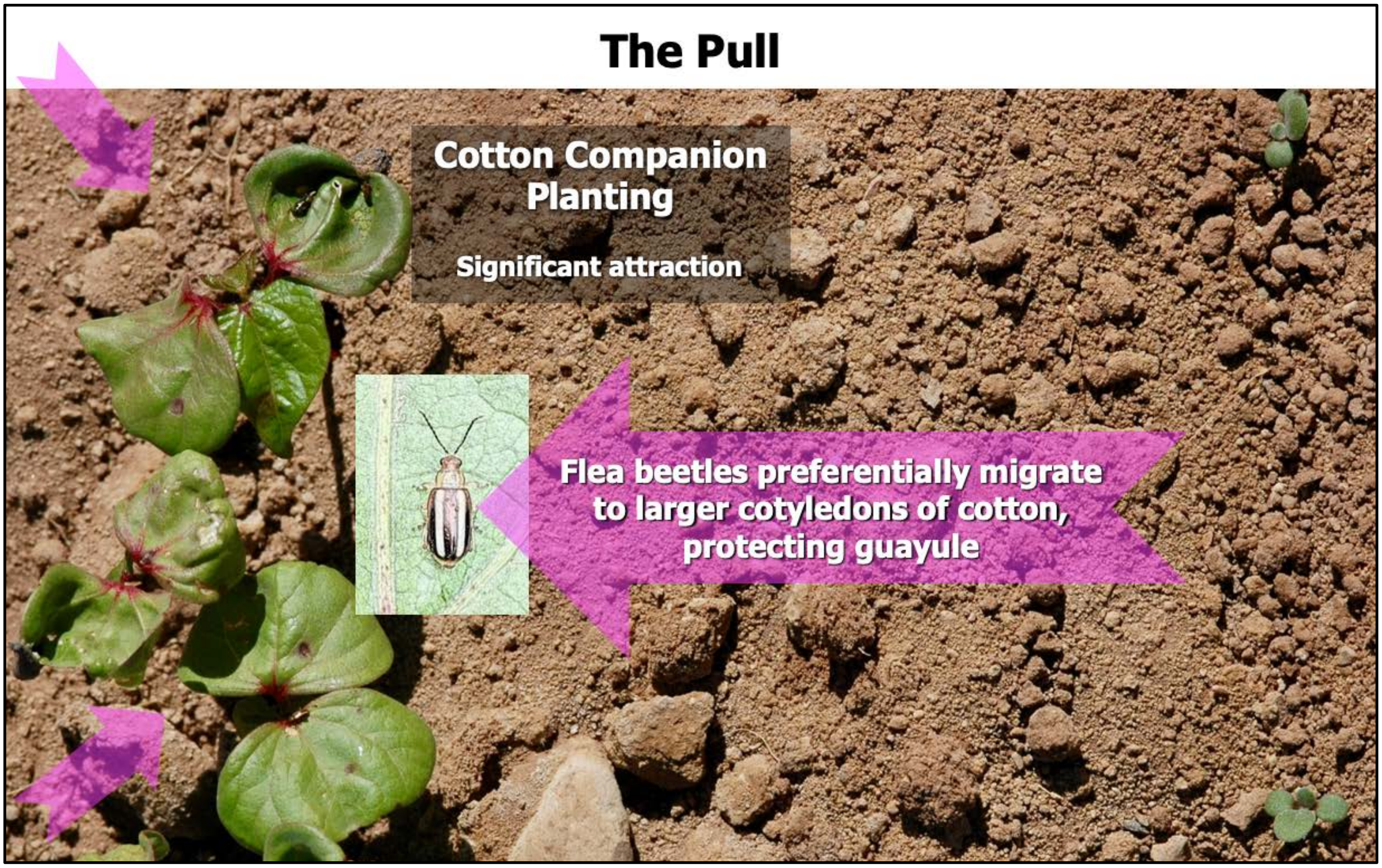


Ellsworth/UA

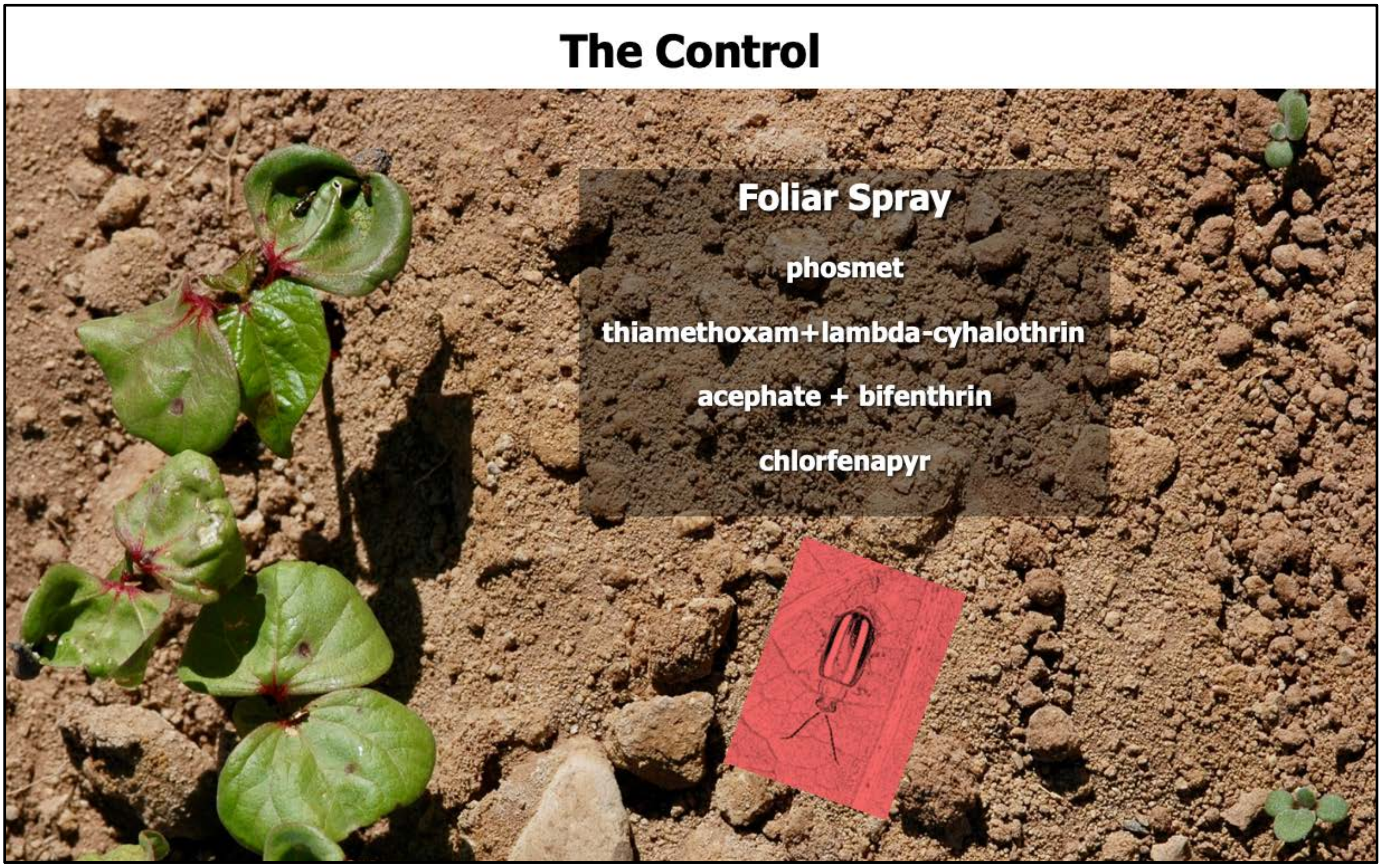
Now for the data! Not really. While we have collected huge amounts of data from a large series of experiments, my goal today is just to expose you to the ideas and concepts we are examining for this new IPM system for a new crop.



First, "The Push". It turns out that while clothianidin is highly toxic to flea beetles, it can also be quite repellent to the beetles. That can present special problems if not considered, for example when there are ample un-dosed weeds nearby. Repelled flea beetles could recover on those weeds and then episodically return to the vulnerable guayule and cause more damage and loss.

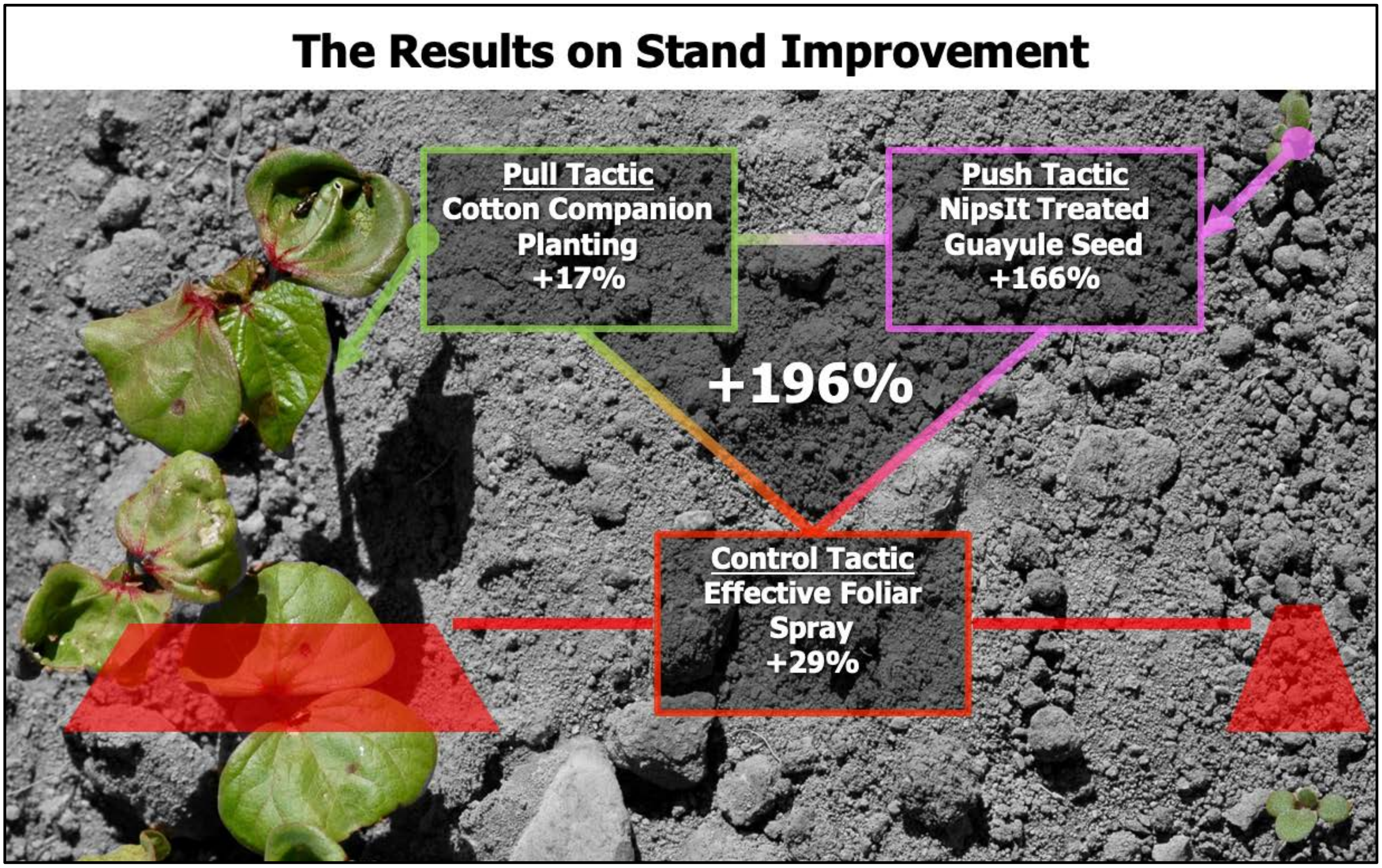


"The Pull" is the companion planting of cotton. Cotton is a relatively large seeded variety and very attractive to flea beetles. The beetles preferentially migrate to the cotton seedlings.



"The Control" is of course the candidate chemistries we have been discussing. Some of these kill outright, but others also have their own repellency attributes.

How do all these parts serve the Push-Pull-Control system? I have only one slide of summary that simplifies what is a complex issue.

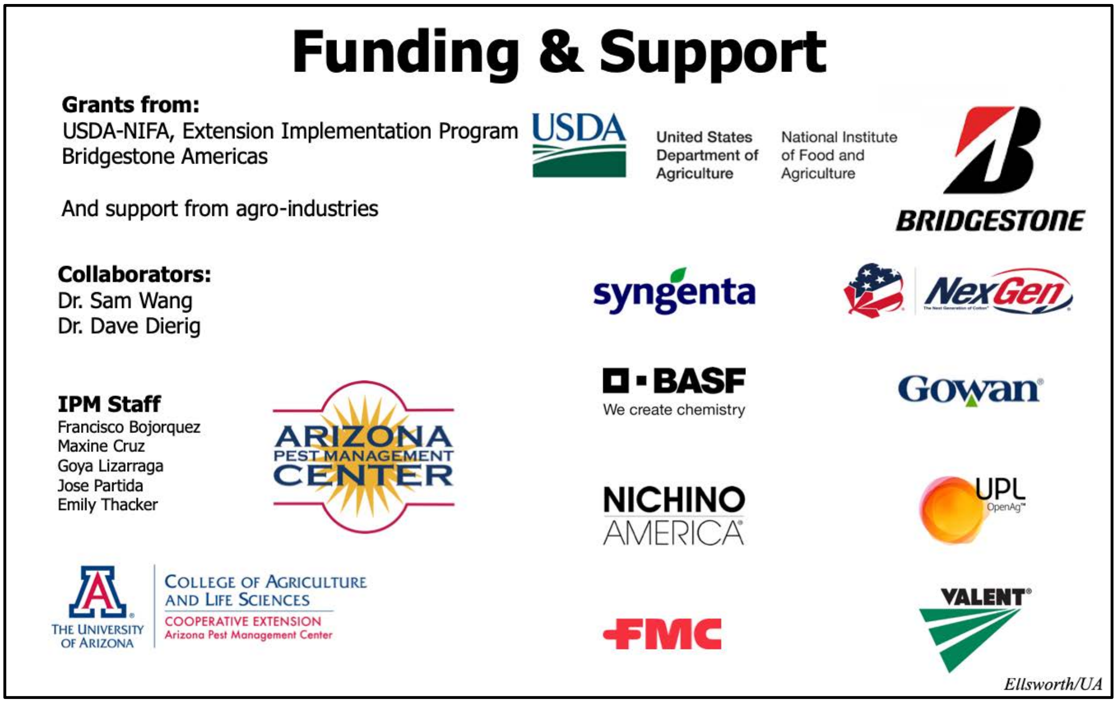


The push tactic (which of course includes the chemical control provided by NipsIt) was responsible for a +166% increase in stand performance. No question about it, NipsIt is very effective.

The pull tactic of cotton averaged +17% increase in stand performance. While relatively modest, the effect was significant and consistent over a variety of trial conditions.

The control tactic provided by the foliar spray provided for +29% increase in stand performance, but was even more critical depending on what other measures were in place. For example, where NipsIt was not in use (untreated guayule seed), Endigo ZCX provided up to +134% increase in stand performance.

Combined, the push-pull-control system enhanced stand performance by +196% or just about tripling guayule stand counts over controls. There is much more work to be done, to be sure, but we hope you enjoyed this early review of our research.



I'd like to close with thanks to the funding organizations and other supporters and collaborators that have been instrumental to our guayule research and Extension programs.

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