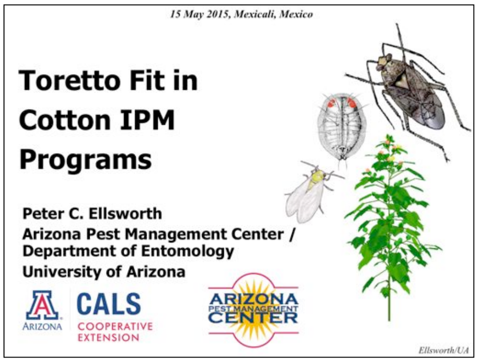
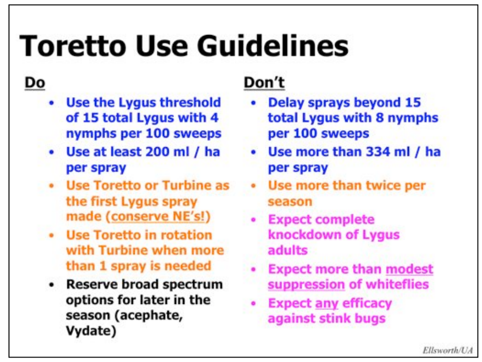


Invited presentation, Mexicali, Mexico; Dow Agrosciences, Toretto meeting, 64 people (growers & consultants), 1.5 hrs



Follow these guidelines for Toretto use. Do the things on the left and Don't do the things on the right.

So what happened here? Inappropriate selection and use of a broad-spectrum Lygus insecticide (acephate, Orthene) destroyed the NE complex. Only this time, whiteflies did not resurge nearly as much as did two-spotted spider mites. The resulting stress on the plants defoliated the entire plot right down to the row. In contrast 3 sprays of any of the other products including Toretto at 223 ml / ha (or no sprays at all, UTC) resulted in conserved NEs that were critical in maintaining natural control of spider mites.

These sorts of results on a large plot basis give us the confidence to categorize products as to selectivity in our system.

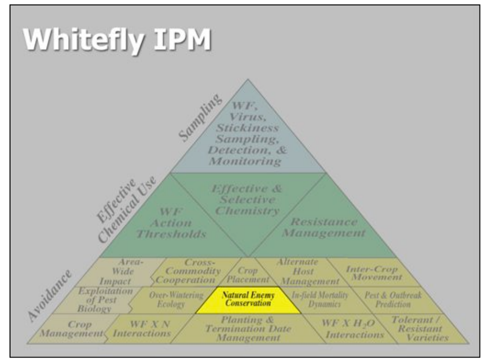
11F32NTO, 2011 large plot study, 3 sprays at roughly 2 week intervals; effects visible prior to 3rd spray.

This is a non-target study.

My graduate student, Tim Vandervoet, conducted workshops with me in 2014 here in Mexicali, and he described how we are now using beneficial insect counts along with our whitefly thresholds to make better decisions on when and if we need to spray for whiteflies. This is how important beneficials / natural enemies are in our system.

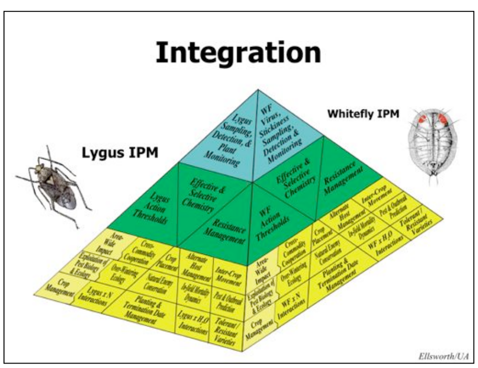
What is this insect?

Collops beetle, one of the key natural enemies in our system.



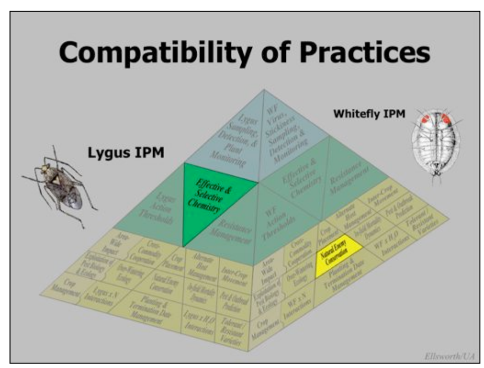
So we are talking about Lygus management. What does this have to do with whiteflies?

Whitefly management is paramount in our system. Natural enemy conservation is central to our whitefly management system…



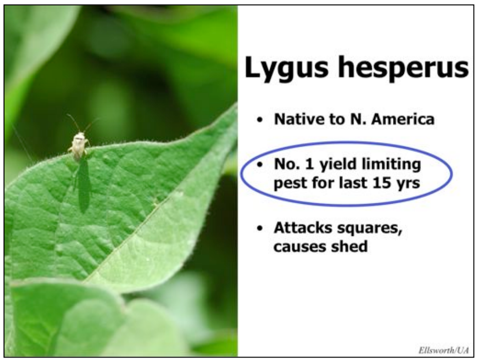
For IPM to work, our management practices (tactics) for one pest must be fully integrated and compatible with the practices for the other key pests.

We are never just considering the activities and tactics for control of just 1 pest.

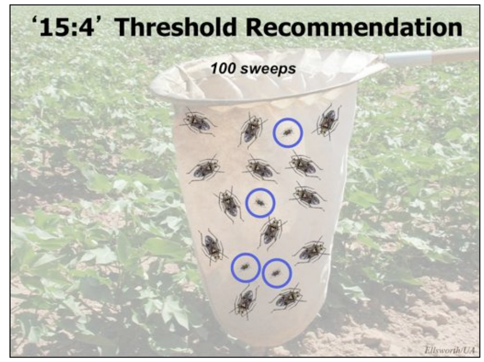


In managing any other arthropod pest, in this example Lygus, that means paying attention to the chemistry used to control Lygus such that NEs are conserved for whitefly (and secondary) pest control.

We are fortunate to have access to two fully selective options for Lygus control in Arizona cotton. These products can be used without risk to the natural enemies we depend on in whitefly and other pest management.

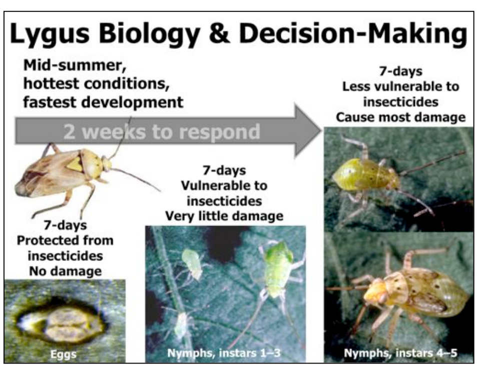


Lygus bugs have become our number one pest since about 1997, ever since more selective components of our system became available, specifically Bt cotton for PBW control and the IGRs for whitefly control. This mirid attacks squares and causes them to shed. Compatibility and integration of controls with this pest are very important.



This so-called '15:4' threshold represents 15 total Lygus per 100 sweeps with at least 4 nymphs per 100 sweeps. I should add here that a 15 inch sweep-net is a standard method used by our consulting community in Arizona.

This is a conservative threshold and under most normal conditions, there should be little reason to advance a spray sooner than these levels.



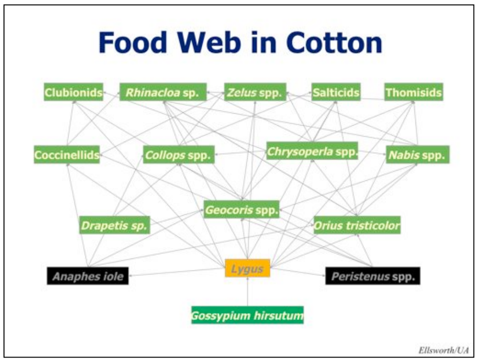
These biological facts are important to understanding the value in close monitoring and how much time a grower has to respond to Lygus infestations.

Bear in mind that the response time one has to react is entirely based on how well a pest manager scouts a field and detects the activities first of adults arriving (and staying) in a field and then later in detecting the hatching of 1st instars.

We have a large complement of potential generalist predators. Just a few pictured here.

We also have 2 parasitoids; however, Anaphes, an egg parasitoid, will not readily colonize cotton; and I've seen Peristenus (nymphal parasitoid) just once in 20 years.

These predators play a role in primary pest control (whiteflies and Lygus), while suppressing/controlling all secondary pests (mites, leps, etc.).



The food web in cotton is complex and dynamic. How one determines which species are driving the system has historically been a difficult problem to deal with. Experimentally, people have tried caged systems that exclude all predators or confine one or a few species with fixed numbers of prey, and even then usually only the target pest as the prey item. These are highly artificial conditions. Survey work has sometimes focused on one or a few species and failed to identify consistent patterns and relationships. These problems faced us as well; however, we applied some multivariate approaches to our data, which help us understand the complex dynamics that are operational.

A key point is that these predators feed on pests as well as each other at any given point in the season.

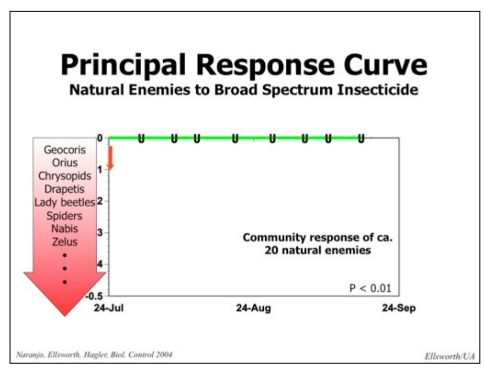
What is this insect?

Big-eyed bug or Geocoris. There are two different species that are common in this part of the world, both are workhorses in the control of many different types of pests.

The balance of my talk will cover product efficacy & selectivity, starting with the last first, because of the paramount importance of pest resurgence in our system.

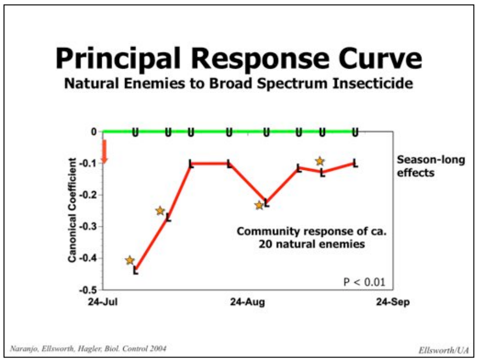
How do you determine product selectivity or safety to beneficials?

You could do evaluations in the lab; you would have to take a guess at which species were important and spray them in isolation. But that's not how it works in the real world. So what follows will be direct assessments in the field system where these beneficials make a living every day. And, we'll examine all species simultaneously. This requires some specific math and statistics that thankfully we can depict fairly easily & graphically through Principal Response Curves.



We used a multivariate, time-dependent, analytic approach that is represented graphically in Principal Response Curves. In this example we can see the green 'U' line representing the UTC as a baseline from which we compare other treatments. Departures from the baseline may be interpreted as density changes in this natural enemy community. In our case, we track densities on ca. 20 different species or species groups. The small red arrow indicates the timing of a single, very broad spectrum insecticide sprayed to control Lygus in a study that we did several years ago…

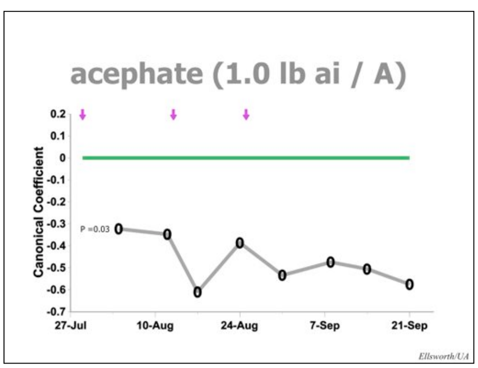
U = UTC = Untreated check



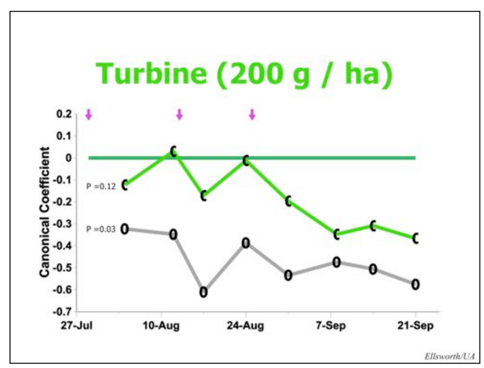
…What we see is a dramatic and immediate lowering of the density of these natural enemies in comparison to the UTC. What is more sobering is the duration and significance of this effect, all the way out to 7 weeks post-treatment. These season-long effects have grave consequences in the control of many other primary and secondary pests. Each PRC is accompanied by a table of species weights for each species represented (not shown). We have shown in past analyses that both buprofezin and pyriproxyfen (whitefly IGRs) are fully selective in our cotton system. We have extended this approach to examine candidate, novel compounds so that we can properly advise growers on how to exploit selectivity and biological controls.

What is this insect?

Orius or Minute Pirate bugs. Note the bright orange nymph shown and adults with the black and white “X” like pattern on their back. There are at least 2 species common in our area. These are small but very effective predators, especially on eggs.



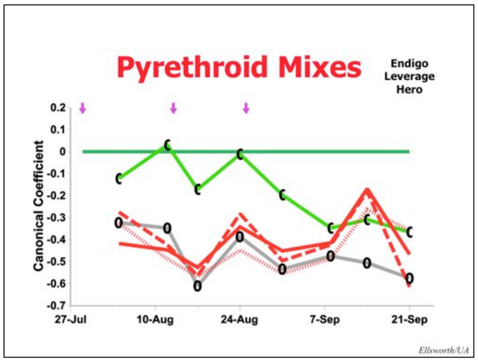
In a smaller plot (not optimal) 2009 study, we once again examined NE community responses to insecticides. Orthene sprayed 3 times; NE community severely impacted.



Turbine at the maximum labeled rate turned up not significantly different from the UTC, i.e., fully selective.

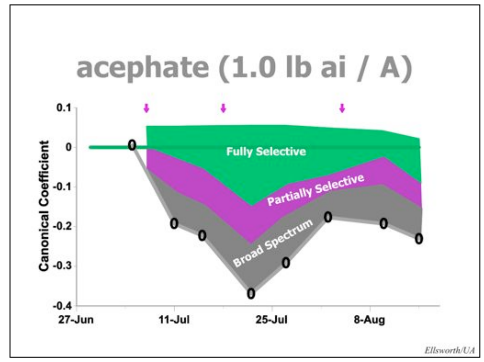
The late season decline in numbers could reflect the declining amount of prey items, in this case Lygus, for predators to feed on in the Turbine plots. In other words, Turbine has effectively controlled lygus there.

09F3L 2.8 oz of Carbine



If there is any doubt, pyrethroid mixtures are very potent and damaging to NE populations, just as damaging as Orthene.

09F3L Hero, Endigo, Leverage360Hi



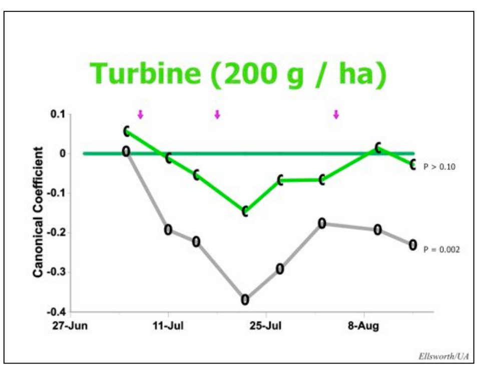
We ran a large plot study in 2011 where we once again examined NE community responses to insecticides. Orthene (& candidate chemistry) was sprayed 3 times; NE community severely impacted.

Responses at or near the response of Orthene would signal a compound with broad spectrum impacts on this NE community (ca. 20 species).

Responses at or near the y=0 or untreated check line would signal a compound with great safety for the NE community, which we term fully selective.

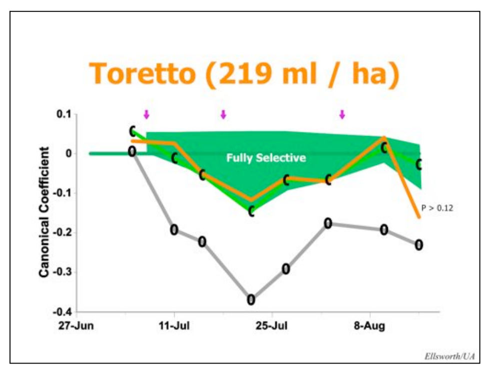
Responses falling between these two zones would be classified as "partially selective".

11F32NTO



Turbine at the maximum labeled rate was once again not significantly different from the UTC, i.e., fully selective.

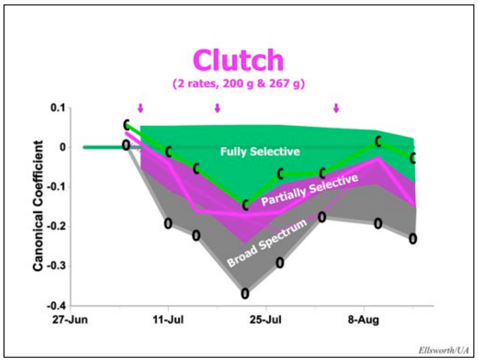
11F32NTO 2.8 oz of Carbine sprayed 3 times



Toretto (219 ml) at the Lygus rate (~Transform at 1.5 oz/A) was not significantly different from the UTC and fell at or above the Turbine line in most cases, i.e., fully selective.

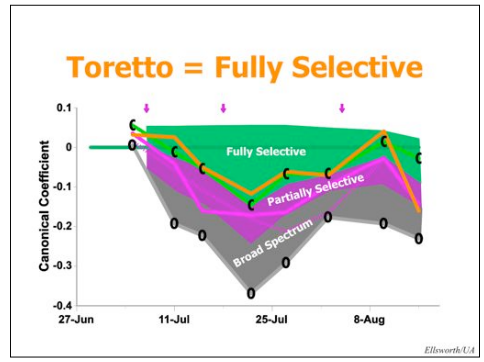
oz/A	lbs ai/A	g ai/ha	Toretto g
0.7	0.022	25	104
1.4	0.044	50	208
1.5	0.0469	52.7	219
2.051	0.064	72	300
2.1	0.066	75	312

11F32NTO 1.5 oz of Transform sprayed 3 times



Clutch/Belay was tested at two rates, 4.5 and 6 oz / A (solid & dashed line, respectively). In general, the response falls between the broad spectrum and fully selective zones; i.e., partially selective, regardless of rate used.

11F32NTO 4.5 & 6 oz rates of Belay, each sprayed 3 times

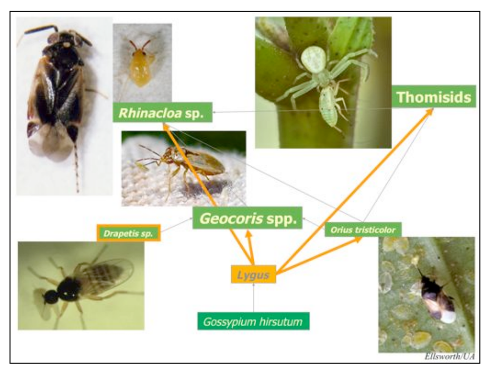


To summarize, Toretto now tested in both small plot and large plot platforms tested out in our cotton system as fully selective.

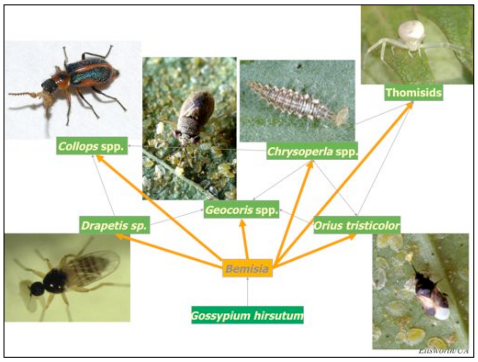
11F32NTO 1.5 oz of Transform sprayed 3 times

What is this insect?

Crab spider or Misumenops celer, another excellent generalist predator and good bio-indicator of the health of the system.



Here are photos of those same species that turned up as most important in the 2009 analyses.



Over many years of intensive field study, Naranjo and I have found that most often one or more of these six predators dominated the relationship between whiteflies and their predation. So many of the species found to be influential when Lygus insecticides were used are in fact important to whitefly management.

Drapetis, A small empidid fly that feeds on whitefly adults (not eggs or nymphs).

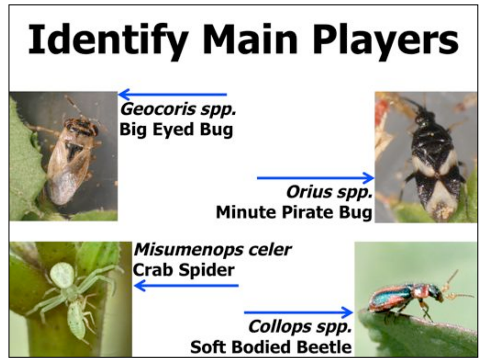
Collops beetle.

Big-eyed bugs.

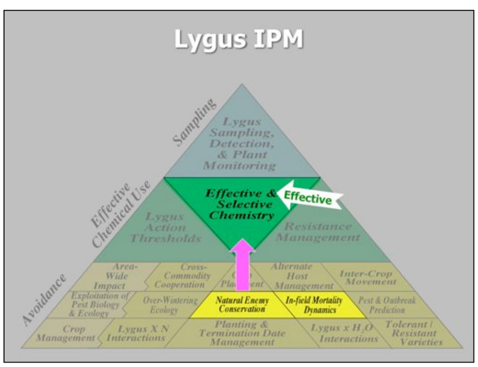
Lacewings.

Crab and other spiders.

Minute Pirate bugs.



In Tim's research, we have found that these 4 species of predators represent the most stable estimate of the biocontrol potential for a field, specifically when evaluating potential for whitefly control. He has been evaluating the levels of these predators in commercial fields and we hope to report the results of that work soon.

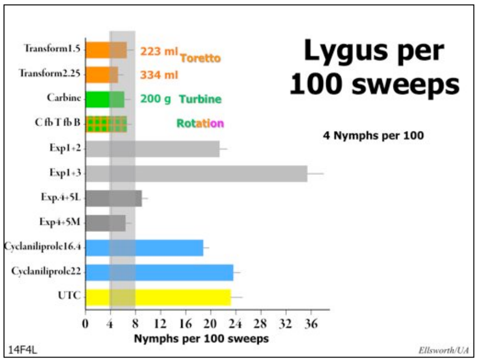


So NE conservation becomes an important objective of our overall management program including Lygus. But in the end, NEs alone are often not sufficient to control economic levels of Lygus (or whiteflies) and effective and selective chemistry is still needed.

No matter how selective a chemistry is, efficacy against the target pest is still very important.

In order to develop lygus management systems, you need Lygus! And, we typically have pretty severe pressure at my trial sites in Maricopa, AZ, perfect for doing product efficacy comparisons.

Here's a shot of one border in my 2009 trial. Pretty easy to pick out the untreated check where Lygus bugs reduced yields over 5-fold. And right next to the foreground plot where we used three products in rotation, Carbine (feeding inhibitor) followed by Vydate followed by Orthene.

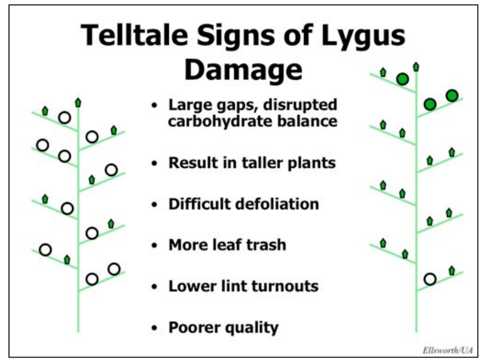


Here we have Lygus NYMPHS per 100 sweeps from a seasonal mean of 5 weeks during the primary fruiting curve in 2014.

In my experience, the 4 nymphs per 100 is a good, but conservative threshold. If after spraying, under this kind of pressure, a product manages to hold nymph levels below 8 nymphs per 100 (gray bar), it is performing maximally.

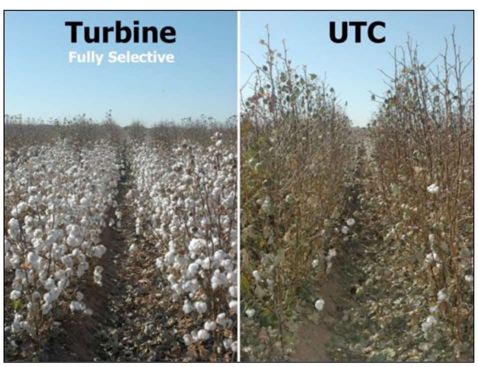
You can see that some products managed this level of control; some did not.

You can see that we had sustained pressure in excess of 20 nymphs / 100 sweeps. Our threshold is 15 total Lygus with just 4 nymphs per 100 sweeps (line shown). We were at 5-fold that level over a sustained period!



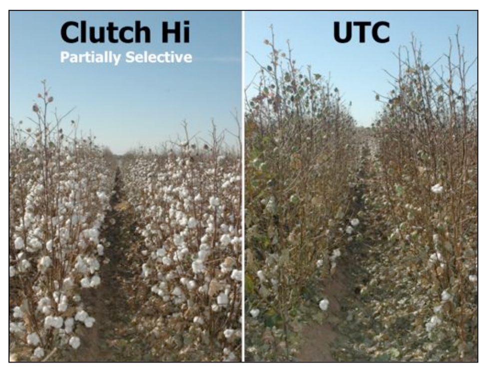
Lygus damage also affects the pattern of fruiting to such extent that large gaps can sometimes be created. These gaps represent disruptions to the allocation of carbohydrates. Where normally, carbohydrates are shunted to the boll sinks, now they are redirected to the growing tip of the plant, making for a taller plant, one that is more difficult to defoliate (also because of disrupted / excess N-balance). This leads to more leaf trash in the harvest, which in turn, lowers lint turnouts and produces lint of poorer quality.

Each of these effects has been measured in our studies and represents some of the hidden costs of Lygus damage. Yield impacts can be great, but we should not forget these other losses as well.



Turbine/Carbine has continued to perform outstanding in control of Lygus and protection of yield. Note the height differences.

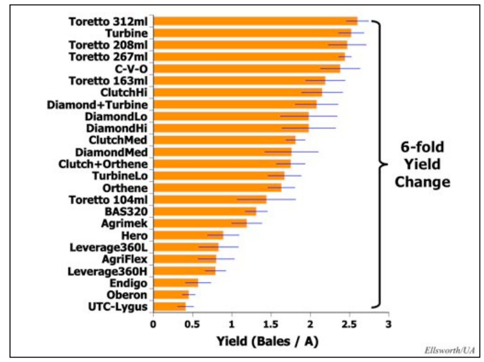
It is our Lygus control standard and was adopted in over 80% of all Lygus applications made in Arizona cotton and in over 90% of the first applications made for Lygus (2006-2012).



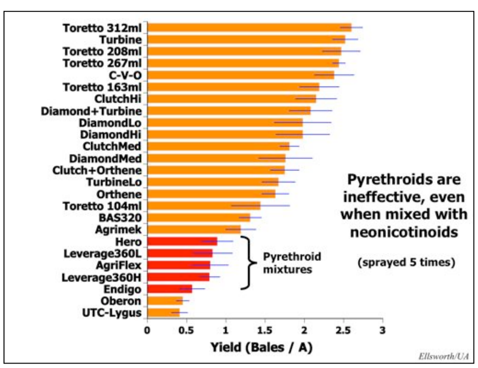
Belay (Clutch) was registered in 2010. Control was very good though somewhat less than Carbine. This seems to be an enduring trend. Turbine / Carbine is generally more effective than Belay. While it remains an option, few growers use this product today in cotton.

Here is sulfoxaflor (Toretto/Transform) used at a very high rate and showing very good Lygus control. Note the huge difference in plant heights. When Lygus are not controlled, fruiting positions (and fruit) are lost. Then all the energy the plant produces goes into unproductive vertical growth. Tall cotton is a telltale sign of Lygus injury many times.

Transform (=Toretto) was registered for use in Arizona for the first time in 2013 (2014 in CA). Since then, almost all Lygus applications are either with Transform or Carbine, or a rotation of these two effective and selective products.



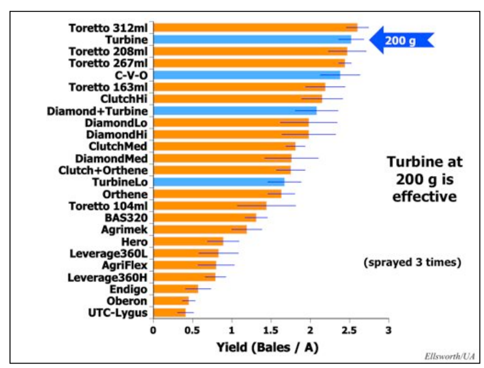
Many products were tested here. Lygus pressure was very extreme. There is a 6-fold increase in yield when this cotton was protected from damaging Lygus populations in this trial.



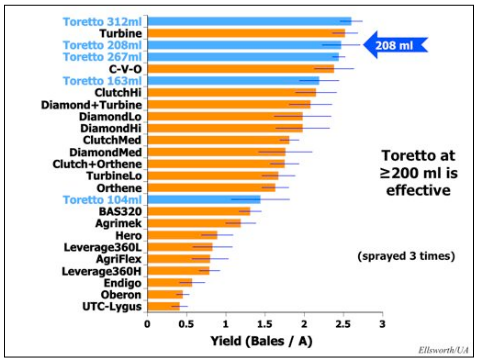
It is just as important to demonstrate to farmers which products do not perform well. Here we show yield from the lowest UTC at less than 0.5 bales/A to our best products at ca. 2.5 bales/A.

The red bars show all the pyrethroid containing treatments. None performed well, despite being sprayed 5 times (2 more than any other material).

Note, too, that Orthene is off 1 bale. This is not due to poor Lygus control; Lygus control was good. This is due to the defoliation that occurred due to mites which broke out after destroying their natural enemies (most likely Western Flower Thrips, an important mite predator in our system).

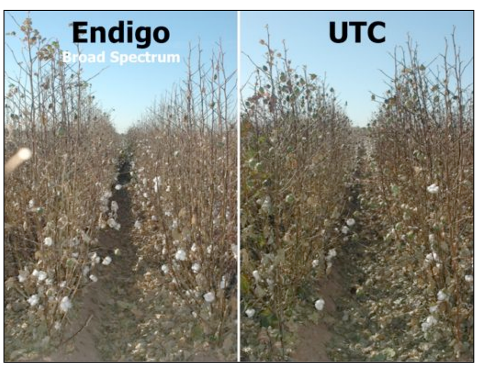


These are the flonicamid containing treatments.

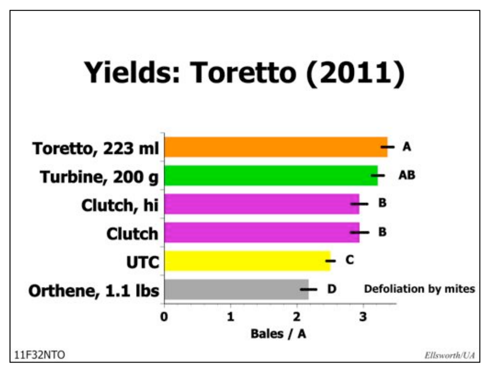


The 1.4 oz rate(209 ml) seems to perform as well as even higher rates but much better than lower rates. Control of Lygus and yields were excellent with Transform/Toretto. The lower rates were less reliable. [2009 study].

Pyrethroids still don't work in our system against Lygus in cotton. Every so often, people argue this point with me. So periodically, we re-examine this in trials. This time we chose to use Hero, a new very active mixture of two pyrethroids (bifenthrin + cypermethrin). As you can see there was no significant control of Lygus. Note the height of the crop. (Sprayed 5 times instead of just 3 of the standard).



Addition of neonicotinoids to these pyrethroids does nothing to enhance control.

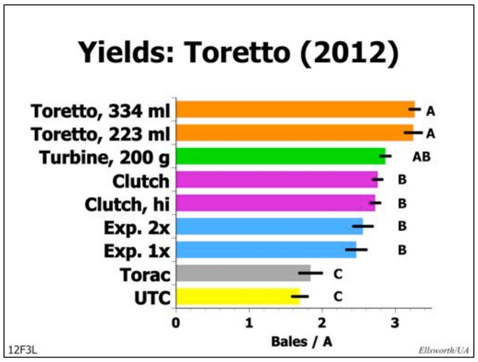


11F32NTO, final lint yield, 480 lb bales.

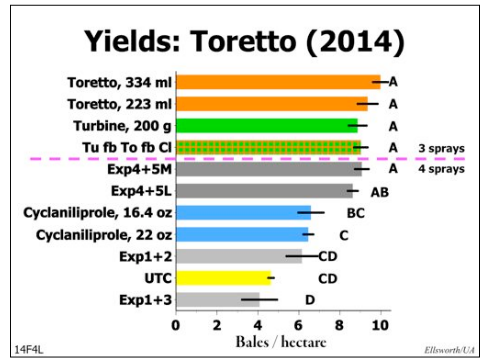
3 sprays of each, 1st prior to threshold.

Clutch is not as effective as Turbine or Toretto.

Again, Orthene is effective against Lygus but also very destructive to natural enemies and in this case mites resurged and defoliated the cotton there.

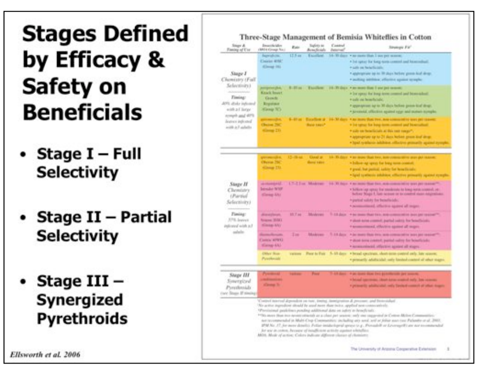


Another small plot trial where Toretto performed very well, though there was no added benefit from the highest rate over the 223 ml rate.



In 2014 small plot tests, we compared experimental chemistry sprayed 4 times against our standards, Toretto or Turbine sprayed just 3 times. Growing conditions and yields were outstanding.

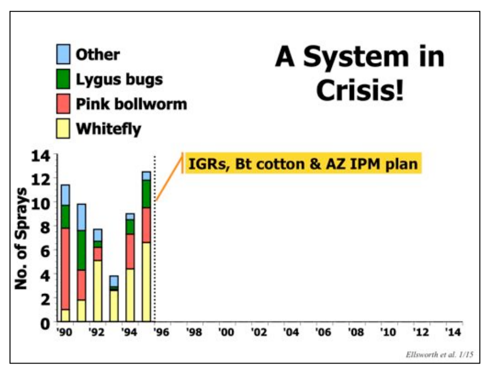
Tu fb To fb Cl = Turbine followed by Toretto followed by Clutch.



In our system, resistance management cannot be addressed without considering the actual efficacy of the products involved; and efficacy in our system cannot be completely considered without looking at selectivity once again. It's circular, but it all comes back to selectivity of the approach.

As part of our IPM program, a 3-stage chemical use plan for whitefly control identifies chemistry based on efficacy and selectivity attributes, with the ultimate goal of exploiting selectivity as much as is possible. It does not mandate a sequence but teaches growers that more selective approaches will create more effective ecosystem services that provide regulation of all pest species.

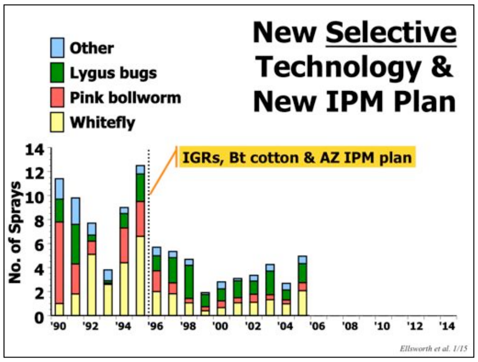
Not surprisingly, we construct parallel recommendations for Lygus.



Let's review the history of deployment of selective tactics against key pests in our Arizona system using data we generate as part of the Cotton Pest Losses and Impact Assessment Program. It is a striking history, where we can see the number of foliar insecticides used to control each of 3 key pests over time, whitefly, pink bollworm and Lygus bugs.

Cotton was a system in crisis in the early 1990's.

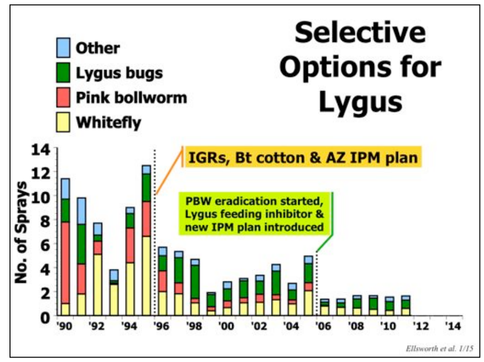
The 1992 and 1995 whitefly outbreaks resulted in excess sugars on our cotton fiber that reached the marketplace and caused severe market penalties to this region of production. These penalties lasted at least 5 years from the initial problems in 1992, and they were indiscriminately applied to all cotton purchased from AZ. So this is a large potential problem that can ruin an industry.



Prior to 1996, growers were spraying on average 8, 10, or 12 times per season, most of this being driven by whiteflies. A watershed of change occurred in 1996 with the introduction of very safe and selective Insect Growth Regulators (IGRs) for whitefly control, and transgenic Bt cotton, along with an IPM plan especially for whitefly & pink bollworm management and comprehensive outreach campaign that consisted of extensive grower and pest manager education.

Because these were new technologies that worked in very different ways than the approaches they replaced, a large educational campaign was mounted with the industry to teach the new IPM plan.

This intentional move to selective technologies by our industry has fostered one of the most dramatic and long-lasting recoveries of a pest management system worldwide.

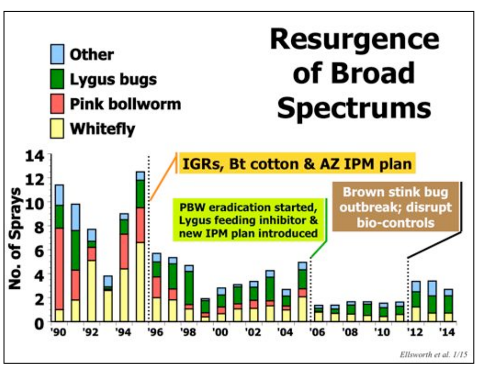


Progress did not stop there. In 2006, we saw deployment of a selective Lygus (a mirid pest) feeding inhibitor [flonicamid (Carbine/Turbine)], and the cotton industry banded together to develop a major pink bollworm eradication campaign.

Under this new IPM plan, growers and pest managers throughout the state saw a continued lowering in the need for foliar insecticides for all insect pests, halving it once again relative to the previous period.

These advances in "selective" technologies and approaches to insect pest management were based on our need to better manage and conserve the natural controls in our system, such as predators of whiteflies.

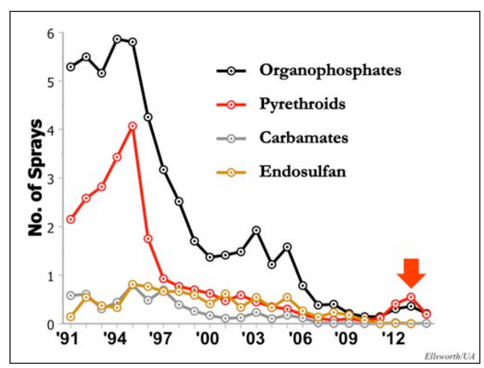
Adapted from Naranjo & Ellsworth 2009, & Ellsworth, unpubl.



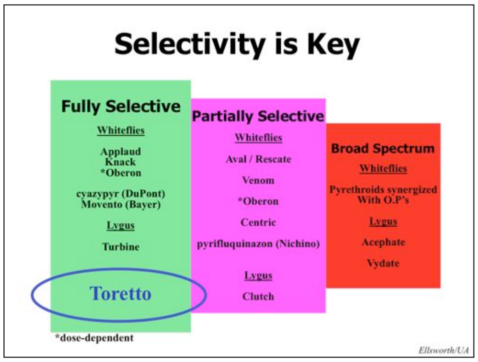
However, starting in 2012 we saw the increase in importance of the Brown Stink Bug as a cotton pest, a pest for which we have no selective chemical control options. The blue "other" category is dominated by sprays against Brown Stink Bug and is the highest this category has been since 1991! It's also the first time the "other" category has exceeded the whitefly sprays (yellow bars) since the B-biotype first invaded AZ in the early 1990s.

BSB had not broken out in AZ cotton since 1963.

Much new research is now being done to understand the economic status of the Brown Stink Bug in the cotton system. The broad-spectrum insecticides used in attempts to "control" BSB are highly disruptive to the programs of natural enemy conservation on which we have come to depend for whitefly & other pest control.

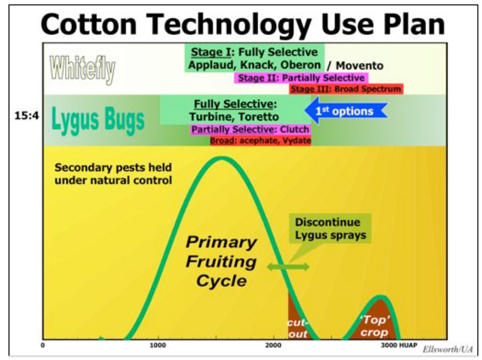


Stink bug outbreaks in 2012–2014 have contributed to an increase in pyrethroid use in cotton. For the first time in history, pyrethroid usage (in no. of sprays / A) exceeds the usage of organophosphates.



So we teach growers not only the efficacy of key insecticides but their selectivity in our system. We place all chemistry into one of three boxes and encourage growers to use fully or partially selective insecticides, if needed and whenever possible.

The key message here is that the important attribute of Toretto is <u>not</u> that it kills the target pest effectively, it is that it does so selectively by <u>not</u> killing the natural enemies critical to our system of conservation. Once this fact is realized, it becomes clear why using Toretto as "just another control agent" or mixing it with broad-spectrum Lygus or whitefly insecticides is a foolhardy approach that denies the central value of this product.



Our system breaks down to 3 key pests and a large array of secondary pests that never become significant, IF disruptions of natural controls do not occur. For PBW, Bt cotton is the ultimate biorational, and now with eradication, broad spectrum insecticides for its control have faded completely from our system. For whitefly, we have organized our insecticides into 3-stages based on selectivity, deferring all broad-spectrum inputs until the end of the season, if needed at all. For Lygus, we have two selective insecticides, Turbine (2006) & Toretto (2013), and perhaps one partially selective compound, Clutch (2010). Cotton IPM in AZ has become an exceptionally well-developed and selective system where conservation biological control is firmly established as a key element. We hope to add new insecticides and new classes of chemistry to our management system, and Toretto has proven to be critically important.

Thank you to the supporters of my cotton IPM research and outreach program.

The Arizona Pest Management Center (APMC) as part of its function maintains a website, the Arizona Crop Information Site (ACIS), which houses all crop production and protection information for our low desert crops, *(http://cals.arizona.edu/crops),* including a copy of this presentation.

Photo credit: J. Silvertooth