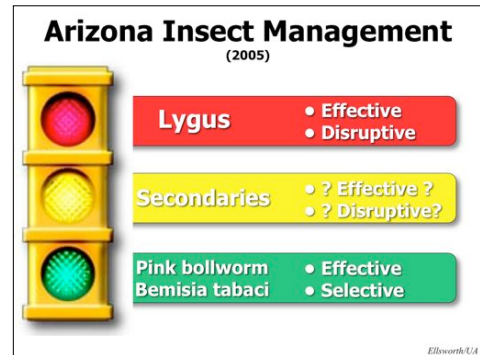




While there are many important considerations when trying to manage Lygus populations in cotton, I will focus my comments today on chemical control of this key pest of Arizona cotton. These suggestions are specific to the Arizona cotton system, but might be useful in similar low-desert conditions.

For this presentation I will be discussing Carbine usage in Arizona cotton. Carbine's active ingredient is flonicamid, a novel feeding inhibitor, and is equivalent to the Mexican product, Turbine, both by FMC.

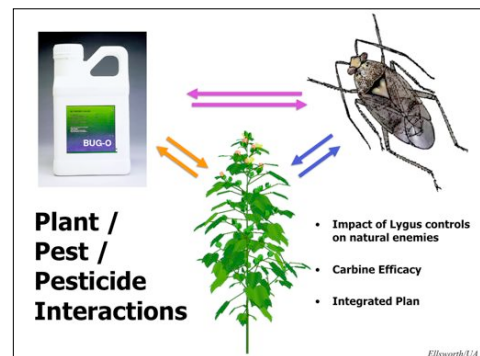


Our system breaks down to 3 key pests and a set of secondaries. For PBW and whiteflies we have very effective and selective technologies. At the other end of the spectrum, we did have effective technologies for Lygus (in 2005), but they were also quite disruptive and often implicated in secondary pest outbreaks and resurgences.

The use of these technologies may or may not be "effective" or selective on secondary pests.

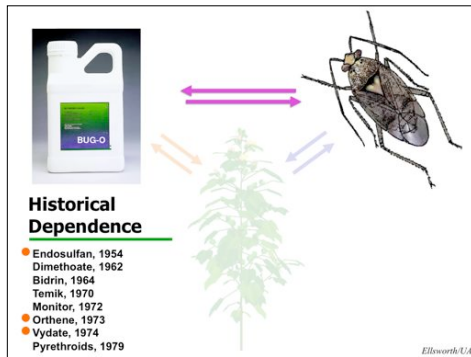


But today (2011), we have Lygus chemical controls that are either effective against Lygus but safe on beneficials (Carbine = Turbine = flonicamid) or effective against Lygus but very broad spectrum or non-selective, i.e., potentially very disruptive controls that are not safe on beneficials.



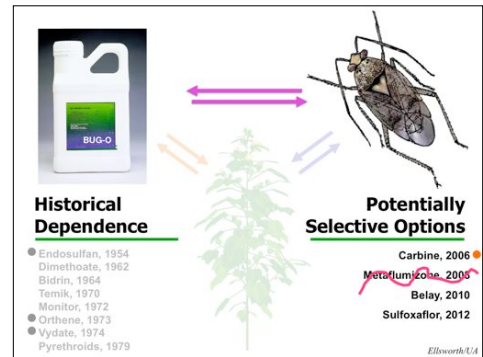
The development of a threshold for the control of an insect pest is a fundamental aspect to integrated pest management. As straightforward as the practical goal is, however, this development is based on a 3-way interaction among plant - pest and pesticide.

In today's talk will start by discussing the impact of Lygus chemical controls on the natural enemy community. Then I will discuss Carbine efficacy on Lygus and touch on the integrated plan that has helped Arizona cotton realize huge economic savings and helped reduced risks to the environment.



For many years now, we have depended on a set of broad spectrum options. That is, compounds that are effective but are rather broad spectrum in their impact on the arthropods present in the system. These include acephate, methamidophos (which sees little use today), oxamyl, endosulfan (which is currently in phase-out), all in AZ, but also dimethoate, Temik (aldicarb), and Bidrin (dicrotophos), throughout the South, and pyrethroids in other parts of the West. Until only very recently — nearly 30 years! — there have been no new chemistries developed with consistent control of the Lygus bug complex.

Note: Fipronil has been used for Mirid control in



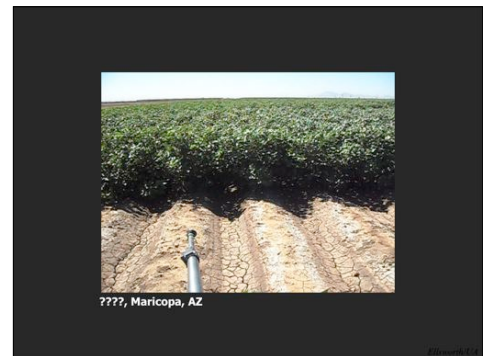
More recently, we have had exciting new advances with potentially selective options: flonicamid was registered as Carbine and is very effective against Lygus, and metaflumizone was on track for being quite selective, too. But alas, development of this product has ceased for the U.S. and we may never enjoy its benefits. However, Belay (~Clutch, clothianidin) has been recently registered and may provide some selectivity benefits to us. A more exciting prospect is sulfoxaflor which we hope to see commercialized in 2012. These compounds bring us new chemistry that may in fact be more selective than our traditional, broad spectrum options.

This not only gives us new “effective” options, but

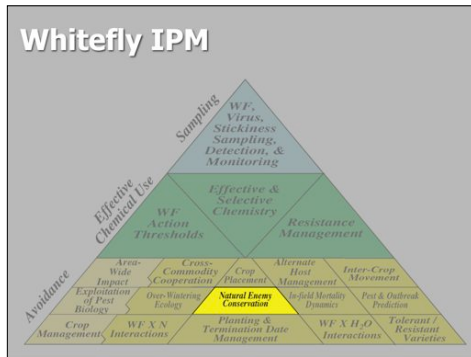


This was the scene we were facing when the invasive B-biotype came to Arizona. The numerical pressure was overwhelming and impacting not only agricultural areas, but also Arizona’s largest city, Phoenix, as seen here on the campus of a local college.

This is a tangible example of how local dynamics ultimately feed into areawide problems.

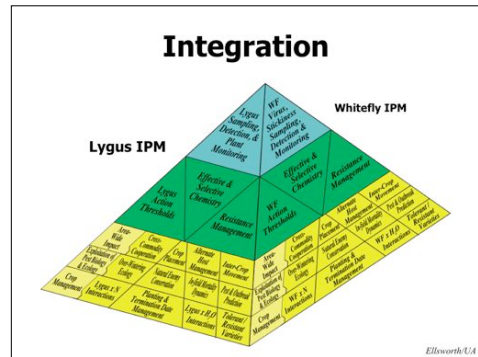


But when was this video shot? (Answer: September, 2010 in experimental manipulated plots, a set of bad decisions!!) This tells us that the same factors that were operational in the early ‘90’s could still be operational today, if not for the superior practices that were in place on a field-to-field basis and creating areawide benefits for all (I.e., lower pressure).

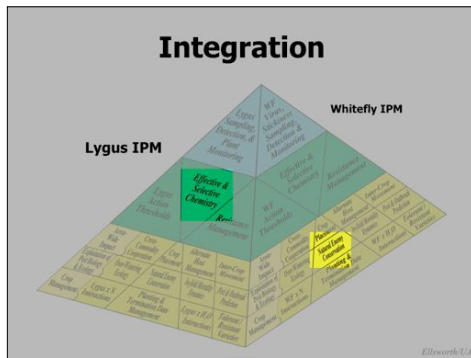


Based in over a decade of research that Steve Naranjo and I have conducted in the AZ cotton system, we can show that NE conservation is central and key to enabling a more sustainable IPM plan for whiteflies.

NE = Natural Enemies (i.e., beneficial arthropods).



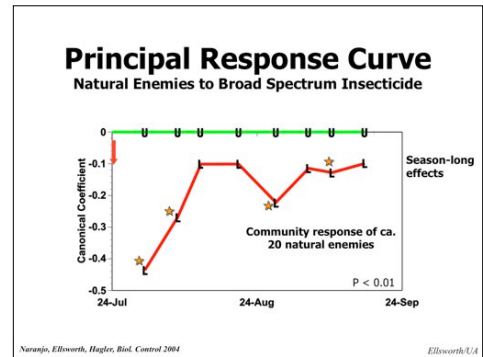
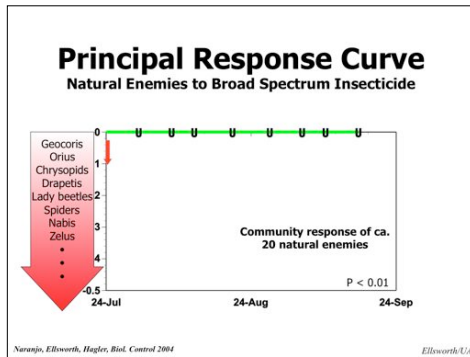
However, IPM is never singularly practiced on only 1 pest. We have to consider interactions with control measures and management approaches for other pests, in this case Lygus.



And, we have demonstrated as recently as that 2010 video that the chemical control decisions made for Lygus can have drastic impacts on the NE fauna that we depend on for whitefly suppression.



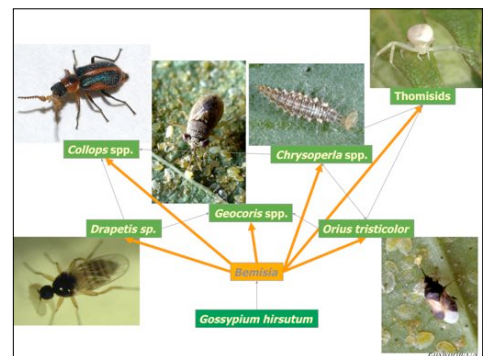
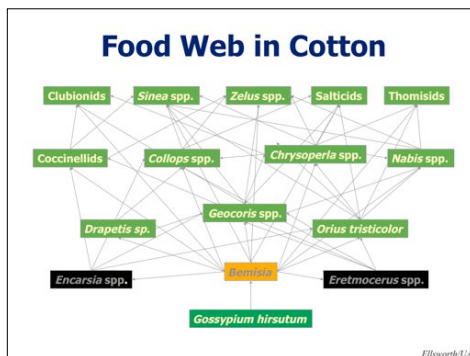
In 2005 here, we saw scenes like this from the Yaqui Valley of Sonora, Mexico. This was the appearance of 7-leaf cotton in some areas, completely encrusted in whitefly nymphs. The growers invited me there again this past April over concerns that they not repeat the episodes of 2005. In 2005, fields like this had already been sprayed 4 times with methamidophos, endosulfan, and dimethoate for thrips and aphids. To recover from the induced whitefly problem, this grower had to apply acetamiprid (Rescate = Intruder) multiple times. The overall approach was very costly.



One way to validate a selective approach is to measure and analyze whole community responses. 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. The 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...

...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, as well as Lygus. So having potentially selective options to reduce the risks of natural enemy destruction is quite important to us. And, the decision to use a broad spectrum insecticide in cotton any time during the season, let alone as an early season spray, should be taken very seriously with these consequences well in mind.

U = UTC = Untreated check (testigo sin tratar)



Different species dominate the relationships measured in different years or locations in AZ cotton and is a remarkable testament to the complexity of the food web. Certain conditions may favor certain pathways in certain years and other pathways in other years. Yet the same, generally, level of natural mortality in whiteflies is expressed if the system is not disrupted with broad spectrum insecticides.

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.

Note these are mostly generalist predators who spend time feeding on each other as well as on pest insects.

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

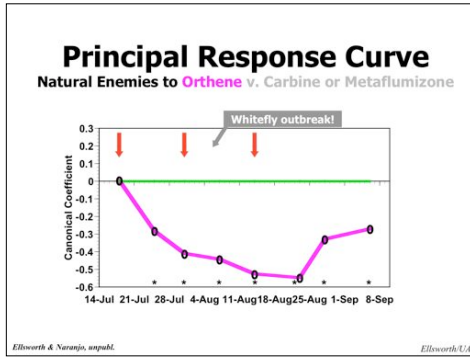
Collops beetle.

Big-eyed bugs.

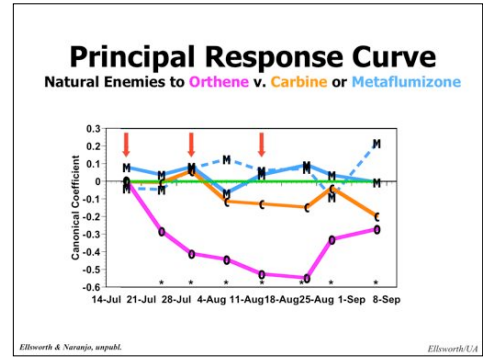
Lacewings.

Crab and other spiders.

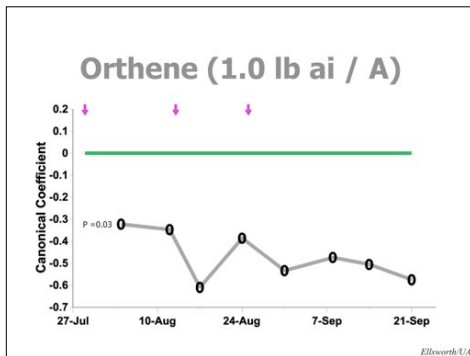
Minute Pirate bugs.



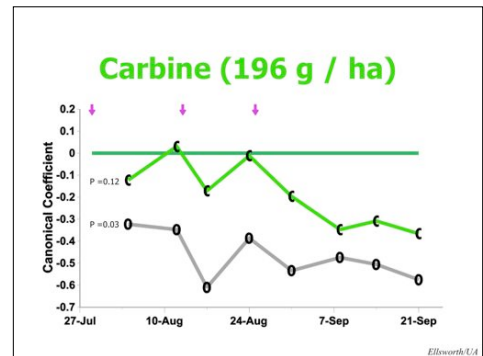
To understand the role that NE's play in our system, we test candidate compounds and compare whole communities of NEs there and in untreated areas. In our 2006 study, we did repeated (every other week) sprays (for a total of 3) of Lygus control chemicals. First, we can see that Orthene (acephate) predictably lowers the densities of the natural enemy community very significantly and for the duration of the season. Interestingly, 2006 was a historic low in whitefly pressure. Yet, shortly after the 2nd spray, we noted a severe and uncontrollable whitefly outbreak in these large plots (1/3 A) of Orthene. Effectively, we had damaged the natural enemy community that otherwise maintains whiteflies at very low densities.



Carbine or flonicamid (orange line) showed no significant declines in the NE community. Metaflumizone at its maximum rate and for two different formulations (blue lines) also had no impact on the NE community. And neither compound suffered from whitefly resurgence. So we were on our way to development of the last biorational or selective building block of our cotton IPM system. Carbine has been registered in AZ since 2006.

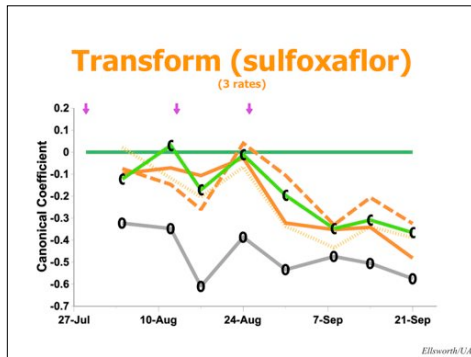


In more recent studies (2009), we again compare Orthene to the UTC.



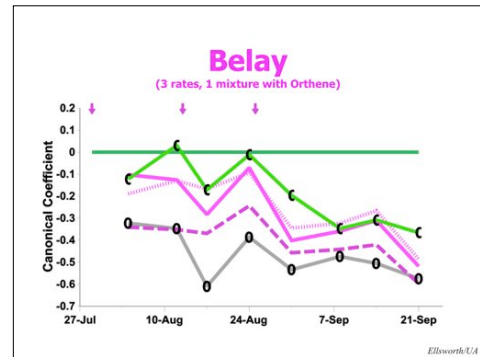
Carbine performs as expected, with no significant differences in the NE community compared to the UTC. It is "fully selective" and safe for beneficials in our system.

09F3L 2.8 oz (= 196 g / ha) of Carbine (maximum U.S. rate for Carbine).



Transform, a new insecticide under development by Dow AgroSciences and with activity discovered in our screening program against Lygus, was tested at multiple rates. Despite a 3-fold difference in rates from low to high, Transform appears to be relatively harmless to beneficials in our system. We are conducting large scale tests to confirm this result this year (2011) with hopes to have this product registered for use in 2012.

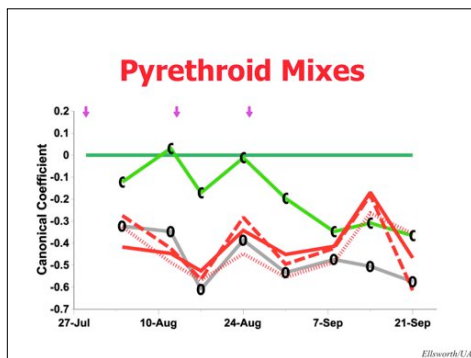
09F3L Sulfoxaflor R1, R3, R5 0.7oz, 1.4 and 2.1 oz (in that order on last date).



Belay, a neonicotinoid with Lygus activity registered in 2010, was tested at 3 rates, the lowest mixed with Orthene. Can you tell which one is mixed with the disruptive Orthene?

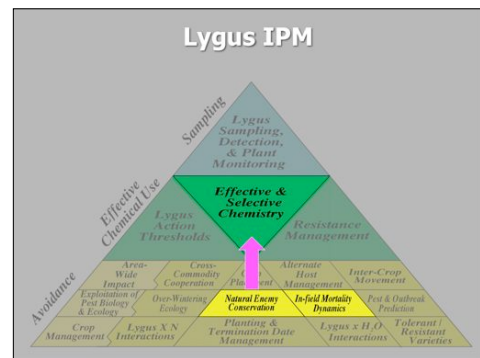
While less harmful to NE's than Orthene, Belay is significantly different from the UTC at the higher rate. Thus, we view this compound as "partially selective", though large scale tests will be conducted in 2011.

09F3L Belay 4.5 oz and 6 oz (darker purple), and 3 oz + 0.5 lb Orthene (dashed line)



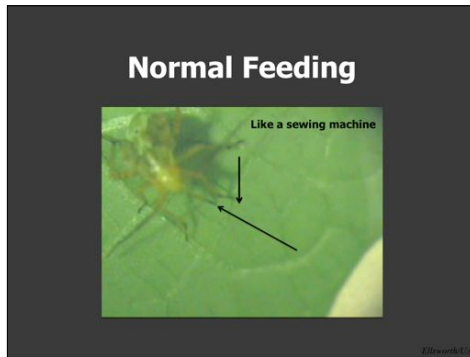
Pyrethroid mixtures are very damaging to the NE fauna as show for these 3 products, two of which are mixed with neonicotinoids.

09F3L Hero, Endigo, Leverage360Hi



Central to remedial tactics is an effective chemical arsenal. In AZ, we have shown in whitefly management that when selective options are available and effective, huge gains in both target and collateral control can be achieved due to much better natural enemy conservation.

Our RAMP (a large USDA grant) team has worked to expand "reduced-risk" technologies for Lygus control in an array of crops. Our goal has been to replace or minimize the impact of the broadly toxic insecticides and achieve better compatibility with natural enemy conservation. My focus has been on the cotton system.



The following video depicts the normal feeding behavior of a Lygus nymph on a leaf. Their needle-like piercing/sucking mouthparts are normally rigid and operate much like a sewing machine, probing in and out searching for a suitable feeding site.



In contrast, this video shows a Carbine-treated adult attempting to orient and feed on a leaf. Notice that the mouthparts are no longer rigid and that the adult is unable to penetrate the leaf surface. This unique feeding inhibition works very quickly and eliminates any damage by Lygus. In time, these individuals either starve or desiccate under field conditions.



Typically our small plots are 12 rows by about 35 or 40 ft. Even so, evidence of down to the inch control is quite pronounced as we look down a series of borders at various treatments. The darker areas represent plots where ineffective controls were applied and cotton yield was lost.

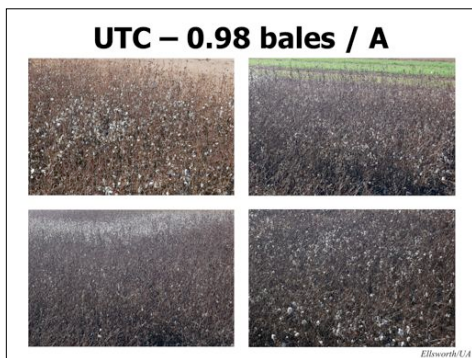
In this border, Carbine at 2.8 oz and 2 oz look very good, but then there is a plot (a band) of poor control with an experimental product, followed again by a plot of very good control by Vydato C-LV, max. rate, one of our standards of the time.

2004, Border 93

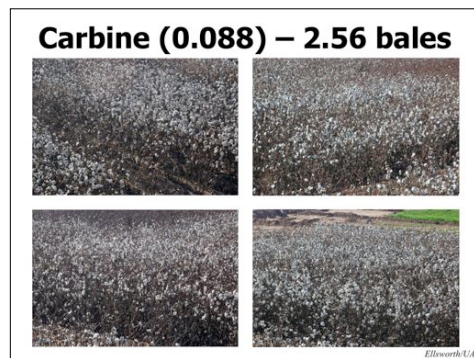


Poor control with an experimental up front, followed by fair, but only partial control, with a high rate of Diamond (novaluron).

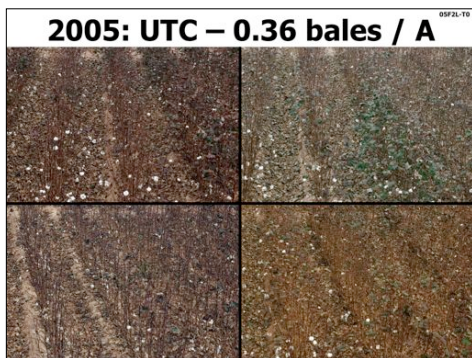
2004, Border 91



From our 2004 small plot trial, we can view each of the four reps for the Untreated Check (UTC), where yields were severely affected by Lygus. [Bt cotton was used and whiteflies were selectively controlled with IGRs; no other yield limiting insects were present.] All the damage (yield loss) shown here was due to Lygus.



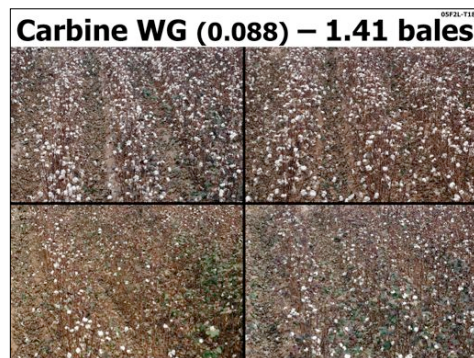
Flonicamid (Carbine) at 2.8 oz, max. U.S. rate, was the yield leader.



05F2L-T0

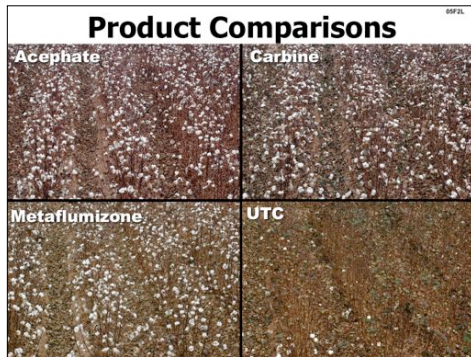
The following series of photos are from the 2005 Lygus efficacy trial in Maricopa, AZ. Each shows all four replicate plots, which were late planted to a Bt variety where other insects (whiteflies) were controlled selectively with IGRs as needed.

The UTC was severely affected by Lygus in this trial yielding just 1/3 of a bale / A.



05F2L-T18 Carbine WG

Carbine performed very well once again given these extreme conditions of very late planted cotton and extremely high Lygus populations in the area. [The highest yielding plots were from the Carbine treatment, but there were some other replicates where defoliation was not as complete and may have artificially lowered some plot yields; see lower left replicate and incomplete chemical defoliation.]



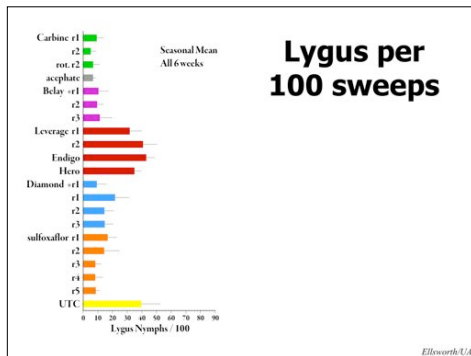
05F2L-T18 Carbine WG (2.8 oz) in NE, Orthene (1.0 lb ai/A) in NW, 320WVI (0.25 lbs ai/A) in SW, UTC in SE; 5-fold yield increase over the Untreated Check.

While flonicamid and metaflumizone have performed admirably against Lygus and helped to preserve the yield component in dramatic fashion, a major potential attribute of their use in our system will be to drive more and more to a selective system that helps preserve our natural enemy complex.

The way we know this is from trials we routinely perform for independent product testing. This was from 2005, before flonicamid registration. We told growers at the time this would be an important technology, a Lygus feeding inhibitor, in the future,

Here's a shot of one border in this 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.

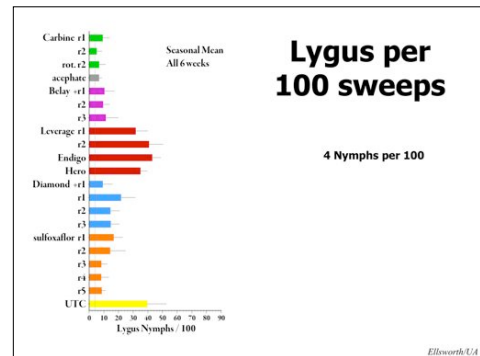
2009



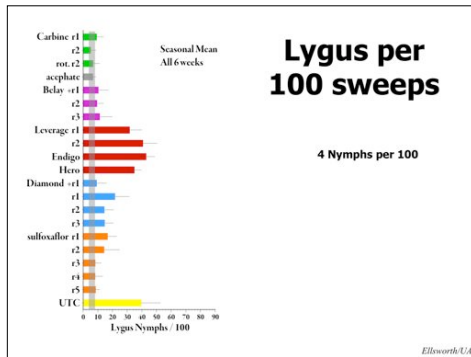
It is a challenge to show you all the data at once. But once I orient you to the overall data, we will examine it one section at a time.

Here we have Lygus NYMPHS per 100 sweeps from a seasonal mean of 6 weeks during the primary fruiting curve.

Different chemistries are color-coded.

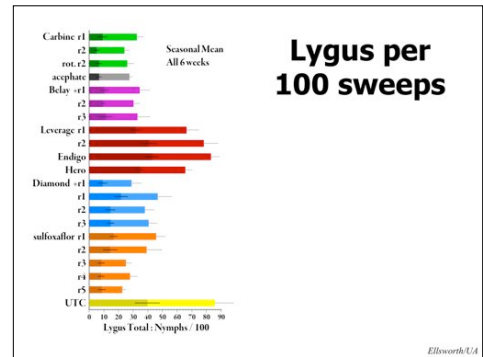


You can see that we had sustained pressure in excess of 40 nymphs / 100 sweeps. Our threshold is 15 total Lygus with just 4 nymphs per 100 sweeps (line shown). We were at 10-fold that level over a sustained period (see yellow UTC bar)!

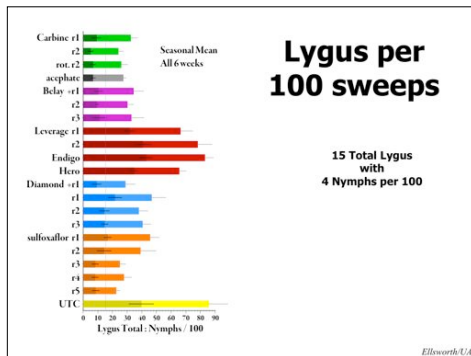


In my experience, the 4 nymphs per 100 is a good, but conservative threshold. If after spraying, under this kind of pressure, a product manages to hold nymph levels below 8 nymphs per 100 (gray bar), it is performing maximally.

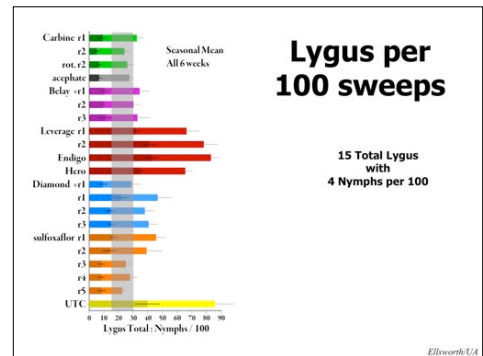
You can see that some products managed this level of control; some didn't.



Now I am overlaying the remaining Lygus numbers to give a total count (total Lygus / 100) with nymphs shaded.



The threshold is 15 total Lygus per 100 sweeps (line shown). We sustained 5-6 times this level for 6 weeks.

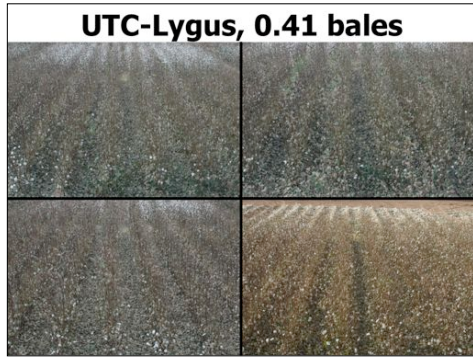


Again, operationally, if a product held levels below 30 per 100 sweeps (gray band), it was performing very, very well.

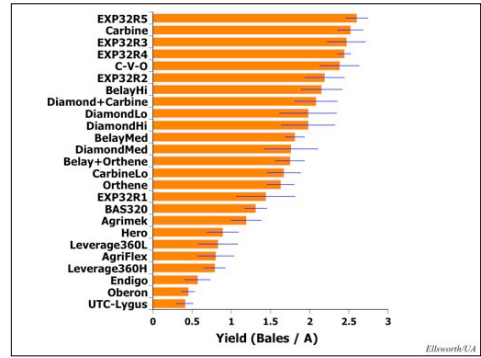
By all criteria, Carbine performed great as usual. Orthene also did well. Of the new compounds, Belay was right there and sulfoxaflor (examined at 5 rates) did very well from rate 3 and up.

Pyrethroids (red bars) and neonicotinoids (except for Belay in purple bars) performed poorly.

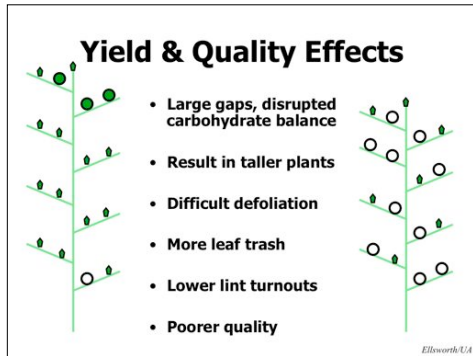
Diamond (blue bars) performed only when mixed with a low rate of Carbine.



Here are the 4 replicate plots for the untreated check (UTC). Only 0.41 bales to the acre, not much cotton.



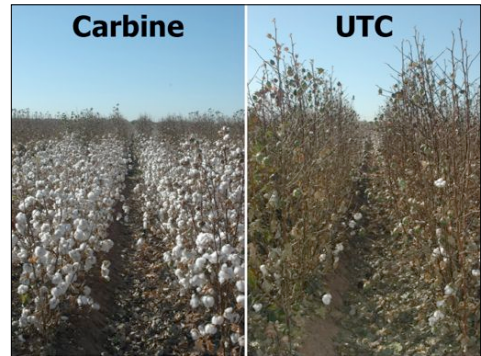
Here are the yield data, showing UTC at the bottom.



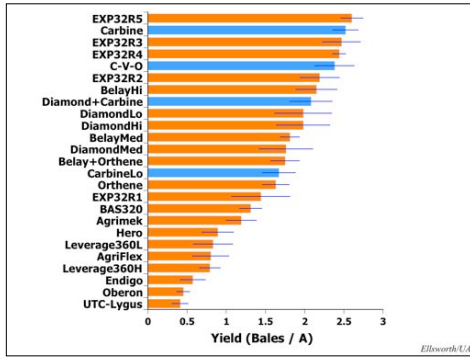
While yield is the main impact of uncontrolled lygus damage, quality, too, is impacted.

Lygus damage 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.

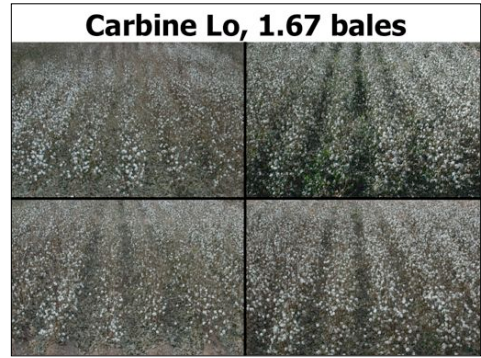
Each of these effects has been measured in our studies and represents some of the hidden costs of Lygus



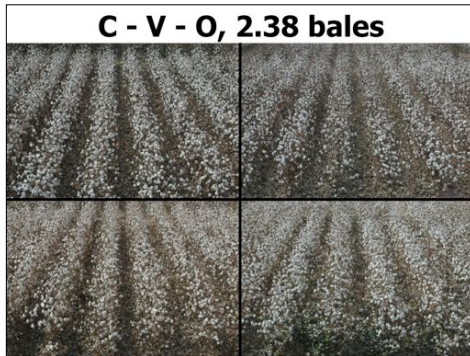
Carbine has continued to perform outstanding in control of Lygus and protection of yield. Note the height differences between the two plots and the large gaps in fruiting in the UTC.



Here are the Carbine containing treatments. Note the very low rate (1.7 oz) of Carbine is too low for this kind of pressure, which was extreme in this year.



This is a very low rate of Carbine and I would not recommend this practice in the face of the Lygus numbers we were seeing. This was done for comparative purposes only.

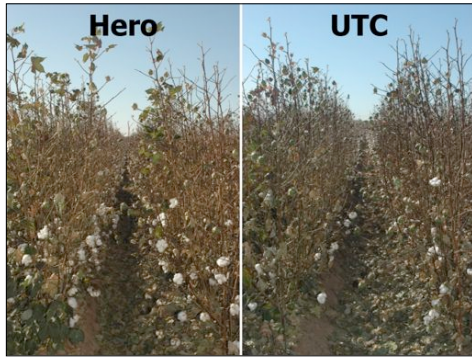


The rotation performed well, though mites resurged a bit in the end of the season.

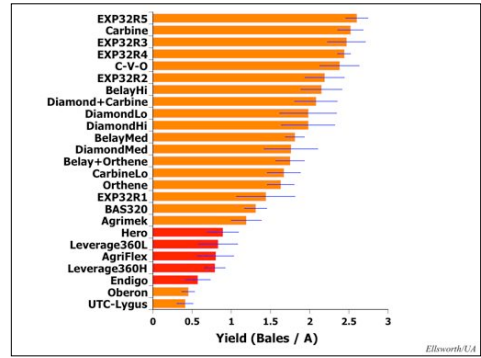
C-V-O = 1 spray of Carbine, followed by 1 sprays of Vydate, followed by Orthene.



Carbine alone at the highest labeled rate really did well, leading the trial.



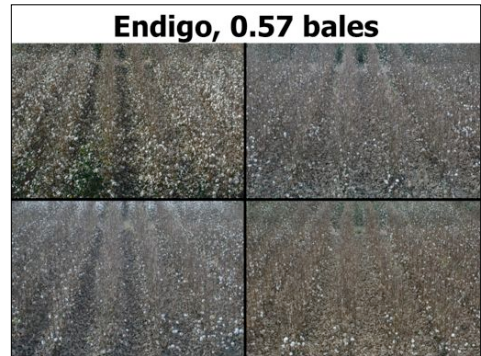
Pyrethroids still don't work in our system against Lygus in cotton. Every so often, people argue this point with me. So periodically, we re-examine this in trials. This time we chose to use Hero, a new very active mixture of two pyrethroids (you can think of it as Capture mixed with Mustang). As you can see there was no significant control of Lygus. Note the height of the crop.



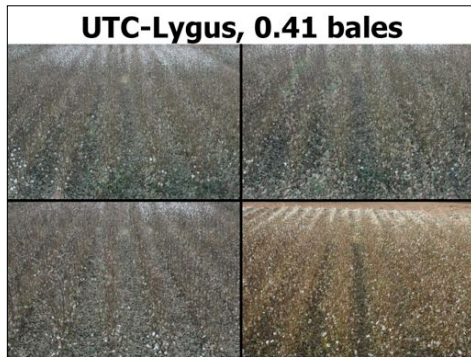
These are all pyrethroid containing treatments. None performed well.



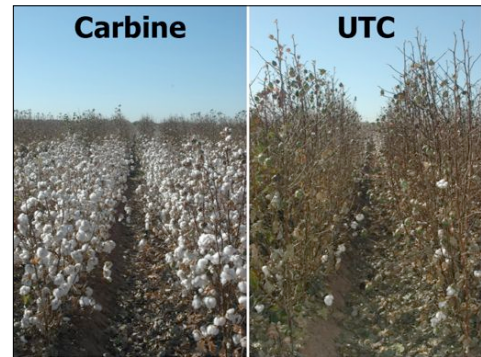
Hero.



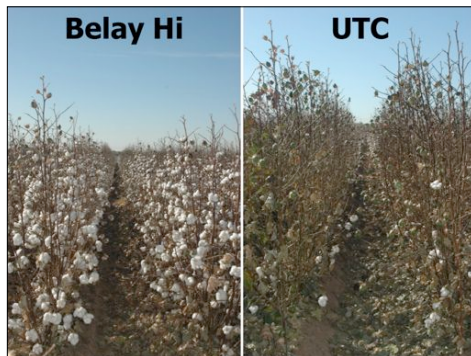
A premix of thiamethoxam and lambda cyhalothrin.



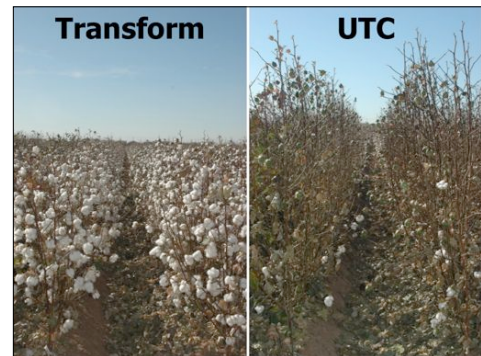
The UTC.



So today, we have core recommendations for Lygus chemical control. They include a suggestion that Carbine be used and used as the first Lygus chemical control, if needed.

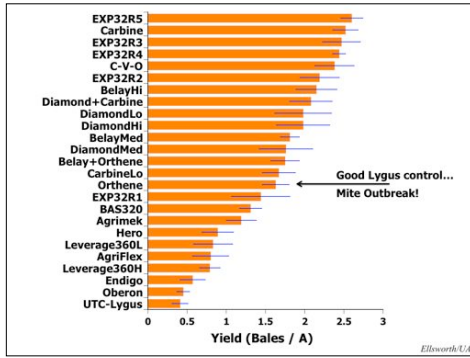


Belay (6 oz) was registered in 2010. Control was very good though somewhat less than Carbine. We suggest it as a partially selective rotational partner to Carbine, especially if a grower expects a need for more than one or two Lygus sprays in a season.

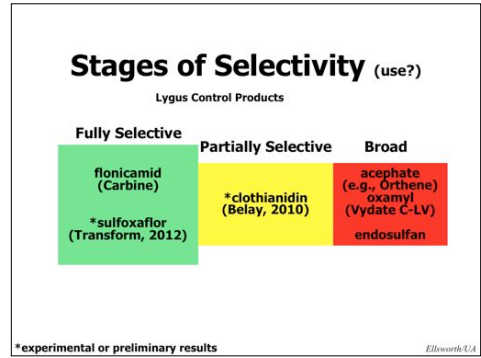


Here is Transform (sulfoxaflor) used at a very high rate and showing very good Lygus control. Note the huge difference in plant heights. When Lygus are not controlled, fruiting positions (and fruit) are lost. Then all the energy the plant produces goes into unproductive vertical growth. Tall cotton is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

We are still testing the selectivity of this compound, but are hopeful that it will prove to be both effective on Lygus and selective on beneficials, and available for commercial use in cotton in the U.S. in 2012.

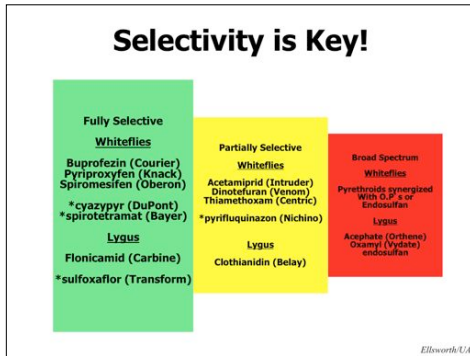


Returning to the yield data, note that Orthene, which is a very effective Lygus chemical control, is off the yield-leaders by about 1 bale / A. This illustrates the added risk of using a broad spectrum material to control our cotton pests. Even if effective, they place the system at risk for secondary pest outbreaks, as in this case with mites that defoliated the plots prematurely and caused this 1 bale loss.

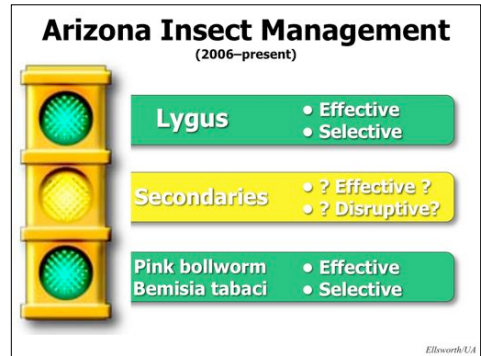


So we have options today that we did not have just a few years ago, fully selective ones, partially selective ones, and broad spectrum standbys that are also effective and provide value to us especially late season.

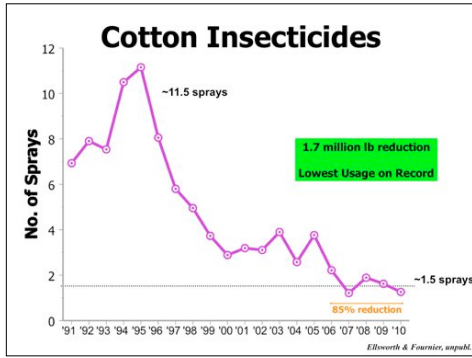
Our guidelines to do not require a specific pattern of use; however, we do suggest using fully selective materials first, partially selective materials as rotational options, and broad spectrum materials only at the very end of the season if needed at all.



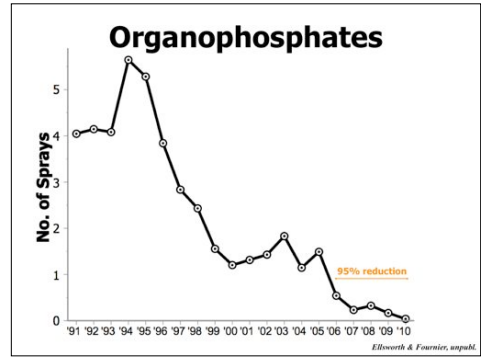
Consider that back in 1992, all we had for whitefly and Lygus control was in the red box, the non-selective or broad-spectrum box. Today we have options for fully or partially selective control of whiteflies and lygus.



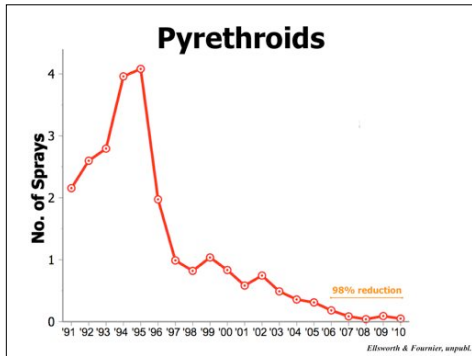
Today, with the addition of a strategic, selective feeding inhibitor for Lygus in Carbine, we now have effective and selective options for our 3 key pests. Secondary pests can still derail our goals in keeping our system safe for beneficials. So controls against these pests must still be cautiously approached.



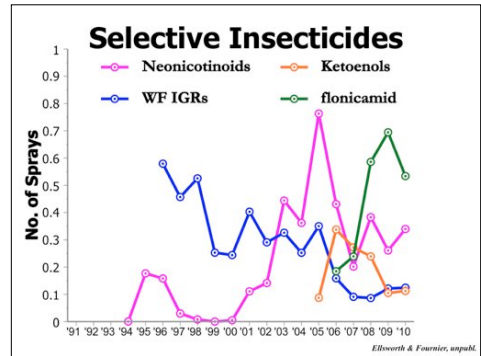
Striking trends in insecticide use are the result. From a 30-yr high in 1995 of over 11 sprays used on average statewide for arthropod control to just 1.5 sprays in recent years. And virtually all pyrethroids, most organophosphates, all carbamates, and nearly all endosulfan uses have been eliminated in cotton in favor of reduced risk chemistries, mainly neonicotinoids, flonicamid (feeding inhibitor), ketoenols (lipid inhibitors, i.e., spiromesifen or Oberon), and IGRs, all of course, used over the top of Bt cottons.



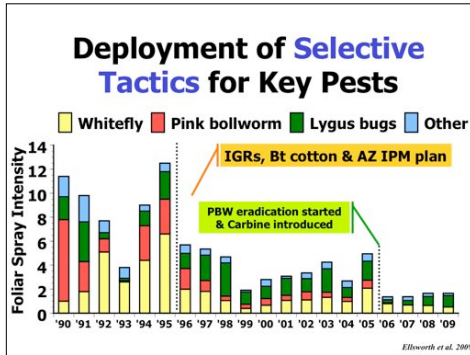
Organophosphates are another important group of insecticides used to control PBW, whiteflies and Lygus, especially chlorpyrifos, methyl-parathion, and acephate. This group has also declined to almost nothing. Carbine introduction has been very important to this continued trend in recent years as a selective Lygus feeding inhibitor (since 2006).



Pyrethroids, too, were used and became very important in whitefly control in the early – mid 1990s; however, their usage has declined almost to zero in cotton here.

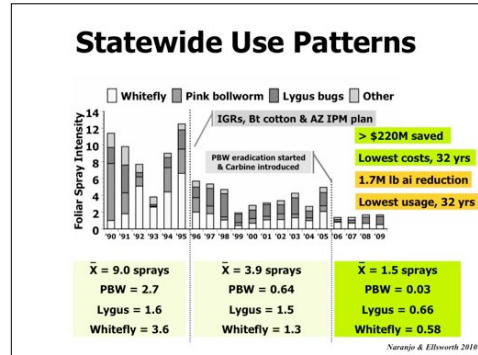


Selective or partially selective options have displaced those broad-spectrum insecticides, and at a much lower rate (less than 1 spray per year on average). The major neonicotinoid has been Intruder (acetamiprid = Rescate) for whitefly control and major ketoenol has been Oberon (spiromesifen) for whitefly/mite control. Flonicamid = Carbine; WF IGRs are Knack (pyriproxyfen) and Courier (buprofezin).



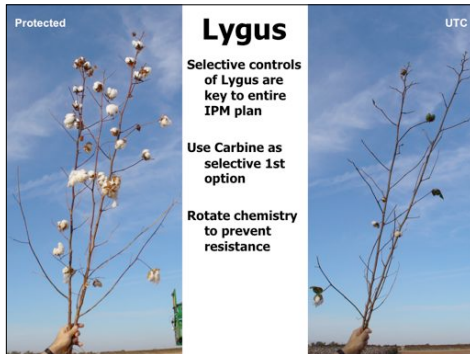
Each time we have deployed a major selective tactic for one or more of our key pests, the shift in insecticide use (downward) has been substantial. Starting in 2006, growers in collaboration with state agencies began PBW eradication. At the same time, we introduced flonicamid (Carbine) in 2006 as our first fully selective control agent, a feeding inhibitor, for Lygus.

Adapted from Naranjo & Ellsworth 2009.



If we draw out information from these critical periods, we can see rather dramatic declines in overall insecticide use, as well as huge declines in PBW sprays made by growers. Bt cotton adoption rose to 94% over this last period, and even higher over the last 2 years shown, ca. 98.25%.

We now average just 0.66 sprays against Lygus and 0.58 sprays against whiteflies. This means that growers are spraying fields once or twice or not at all for each of these targets. In 2010, 29% of Arizona's cotton acreage was not sprayed at all for any arthropod pest.



Summarizing our chemical control guidelines for Lygus, we suggest using selective controls wherever possible as a means of preventing problems with whiteflies or in secondary pest outbreaks. By responding 1st with Carbine as the first selective option for control of Lygus, this extends the period over which beneficials can contribute to overall pest management.

At the same time, we have to be aware of the potential for resistance in this pest and consider sensible rotations with other Lygus control chemistries if more than one or two sprays are needed to control Lygus.

Representative plants (2) from the Carbine (2.8 oz) plot on the left v.



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 are fading 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 one selective insecticide, flonicamid, and perhaps one partially selective compound, Belay, that was registered in 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.



Thank you for your attention.

Thanks, too, to the many growers, pest control advisors and others who have already collaborated with us and allowed us into their fields and provided pesticide records for this project.

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