

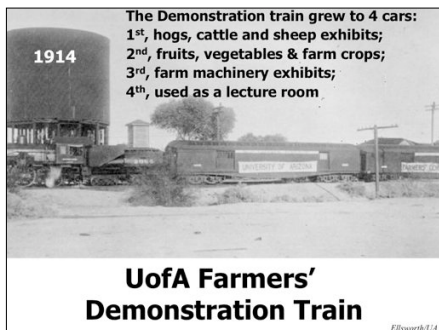
This was a very difficult presentation to prepare for, because the solutions are NOT readily available. This is similar in situation to more than 20 years ago when there was very little known about whitefly management. Bear this in mind when considering the information I have to share with you today.

As a result, I'm going to present more data and more difficult-to-interpret data than I would normally share. But this is because the answers are not self-evident. I have my own interpretations of these data but am open to hear from you about how you view these data or how it is you believe we should contend with BSB in Arizona cotton.

50 minutes; 220 people



It is fitting that I give this presentation on an auspicious day, the actual 100 yr anniversary of the Cooperative Extension system! With our roots firmly planted in agricultural Extension, the University of Arizona has been partnering with your industry for a century now, which got me to thinking more about John Palumbo's presentation yesterday. He reviewed some history and I thought had better do so, too. So I googled "Arizona agriculture 1914" and the very first image to appear was...



...this one, depicting a UofA Farmer's Demonstration Train that ran from Willcox to Yuma making stops along the way to teach growers about advances in agricultural science and technology.

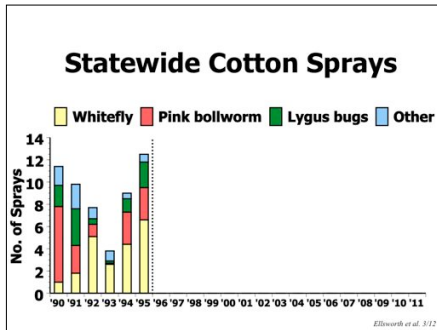
There were 4 cars.

We've come a long way! From railroad cars to this large ballroom of the San Marcos hotel, which by the way was also here in 1914!

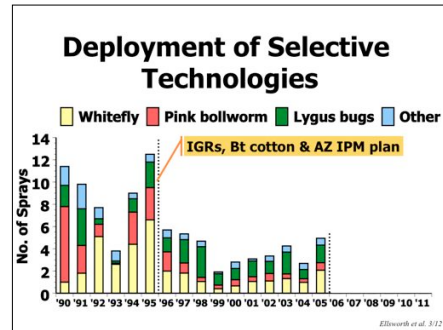
So I wanted to dig a little deeper and it took a great deal of digging by I discovered some extraordinary things!



The man addressing these well-dressed farmers on the demo train is none other than Great Grandpa Giuseppe Palumbo!

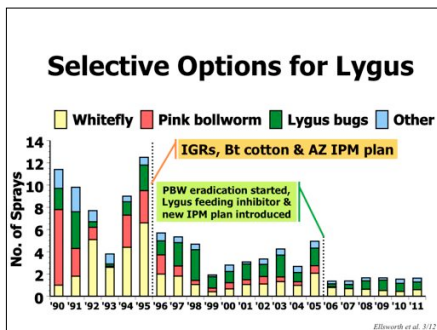


Let's review the history of deployment of selective tactics against key pests in our Arizona system. It is a striking history, where we can see the no. of foliar insecticides used to control each of 3 key pests over time, whitefly, pink bollworm and Lygus bugs.



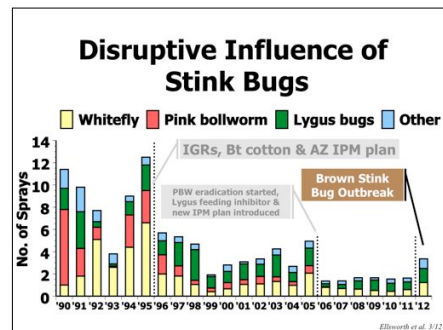
We just spent the better part of two decades purging our system of most of the broad spectrum chemistry we used to depend on routinely. Prior to 1996, growers were spraying on average 8, 10, or 12 times per season. Through development and deployment of selective technologies, first in 1996 with Bt cotton and whitefly IGRs, we saw very dramatic reductions in spray requirements.

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

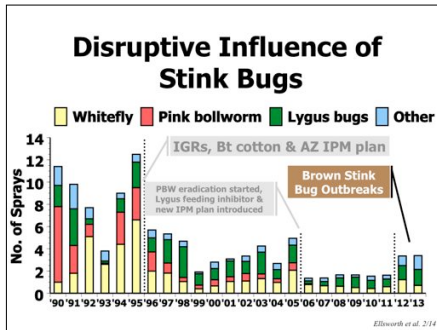


In 2006, we saw deployment of a selective Lygus (a mirid pest) feeding inhibitor [flonicamid (Carbine)], and the cotton industry banded together to develop a major pink bollworm eradication campaign. Under this new IPM plan, growers and pest managers throughout the state saw a continued lowering in the need for foliar insecticides, halving it once again relative to the previous period.

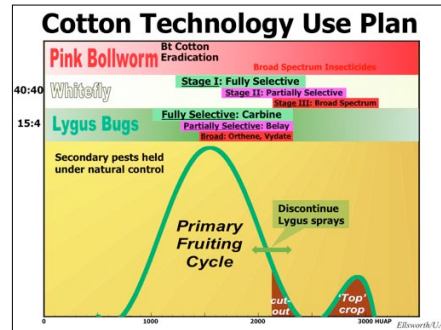
Adapted from Naranjo & Ellsworth 2009, & Ellsworth, unpubl.



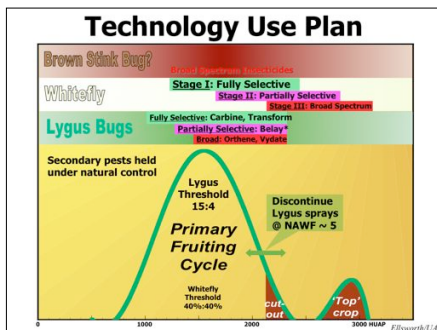
However, in 2012 we witnessed the widespread presence and local outbreaks of the brown stink bug, *Euschistus servus*. The disruptive influence of these stink bugs on our overall insect management plan is apparent. Broad-spectrum insecticides, not used in over a decade, were deployed to control stink bugs, and caused disruptions that led to more frequent and costly investments in whitefly, Lygus, mite and other insect controls. 2012 saw a doubling in the number of sprays required statewide to control all insects and mites. In fact, the blue section of the bar is for "other" insects. This is the highest level for this group since 1993. Prior to 2012, records show that our last outbreak of this particular species was 1963! So there is virtually no prior local expertise on the topic of brown stink bug management.



2013 turned out to be a twin to 2012 in total sprays required to control all arthropod pests. This anomaly has now become a disturbing trend. 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 since the B-biotype first invaded AZ in the early 1990s. Stink bug sprays (0.859) exceeded whitefly sprays statewide (0.712).



In the recent past, our system broke down to 3 key pests and a large array of secondary pests that never became significant, IF disruptions of natural controls did 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 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 had one selective insecticide, flonicamid. Cotton IPM in AZ had become an exceptionally well-developed and selective system where conservation biological control was firmly established as a key element. We also have decision-support information that guides the deployment of these valuable, selective technologies.



However, stink bugs change the picture. If they remain an economic threat to our production, we may see mid- and late-season needs for broad-spectrum chemistry once again. The use of these materials will further destabilize the management system, reducing our ability to hold the other key and secondary pests in check.

2013 turned out to be every bit as challenging, if not more so, than 2012 with respect to brown stink bug management and the consequences of its control on whitefly, Lygus, and mite management.

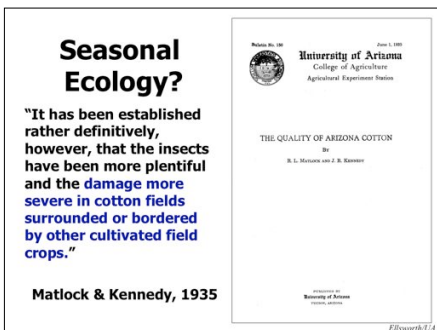
We hope the future is not a repeat of 2012-2013.

### BSB, Significant Challenge

<p><b>Things we don't know</b></p> <ul style="list-style-type: none"> <li>• AZ has no validated threshold                     <ul style="list-style-type: none"> <li>- Is 20% too low?</li> </ul> </li> <li>• Sampling is detecting non-economic injury?</li> <li>• Is aflatoxin incidence related to stink bug activity?</li> <li>• There is no selective chemistry</li> <li>• Seasonal ecology remains uncertain</li> <li>• "The cure may be worse than the disease?"</li> </ul>	<p><b>Things we think we know</b></p> <ul style="list-style-type: none"> <li>• Scouting methods are sound; 1 inch, squeezable bolls</li> <li>• Boll rot is not as large a part of the damage dynamic</li> <li>• BSB can physically damage seed</li> <li>• Direct yield losses appear less than in Georgia</li> <li>• Confirmed efficacy of acephate, Bidrin, or bifenthrin in Georgia</li> </ul>
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BSB is a significant challenge and information can be broadly divided between those things we think we know and those things we definitely don't know. This serves as a summary state of knowledge for BSB management currently in AZ and a summary for this entire presentation. The balance will merely underscore the many uncertain aspects of BSB management.

There are silver-linings, however, in our belief that the damage dynamic may not be as severe as what has been observed back east in GA and the Carolinas.

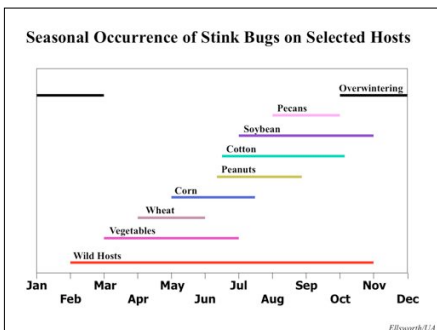


Glancing back at history, we can learn quite quickly that BSB is not a new pest. It is indigenous to AZ and indeed much of the country. Even back through history, scientists thought that BSB damage in cotton was associated with surrounding crops, presumably alfalfa, small grains, and corn.

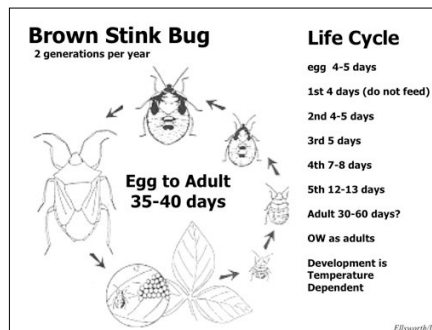


Weeds and wild grasses were also implicated as sources of BSB to cotton.

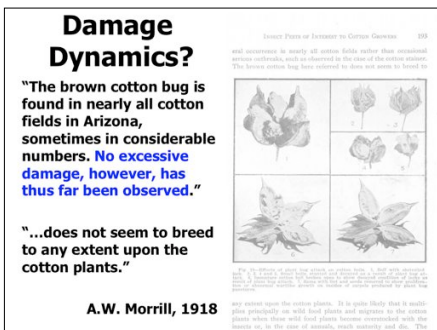
It was also noted that the bugs rarely arrive prior to 1<sup>st</sup> bolls and ostensibly they don't reproduce in this crop.



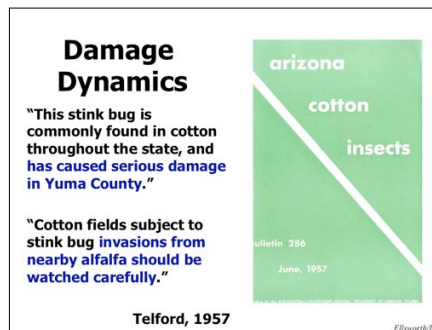
Dr. Phillip Roberts provided this information on the seasonal ecology of stink bugs there. Peanuts are a key summer host, but what makes their system different is the large diversity of hosts that persist throughout the season and the wild hosts that are always available.



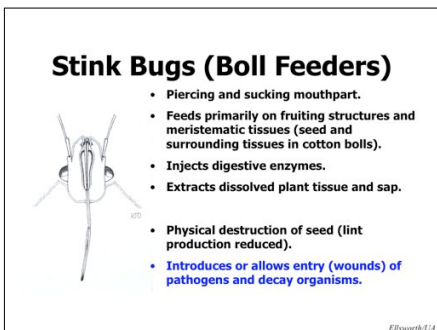
BSB goes through just 2 generations per year back East. The life cycle is typical of any stink bug, going from egg to nymph to adult.



While BSB could be found in all cotton fields 100 years ago, "excessive" damage was not observed. Again, Morrill suggested that breeding does not occur in cotton.



Through the 50's, BSB were cited as being present throughout the state but causing serious damage mainly in Yuma County, which at the time includes present day La Paz County. Perhaps the problems experienced in Parker and Blythe last year reflect these historic distributions. Alfalfa was once again implicated as a source.



Stink bugs are in fact boll feeding or more properly seed feeding insects. Their needle like mouthparts enable a wounding process on the boll that permits entry of pathogens and decay organisms.



Let's be clear. BSB can feed on any size boll. However, detailed research really does support the idea that they damage and prefer "medium" sized bolls that are 1 inch in diameter and are soft or squeezable.



**BSB will not injure pre-bloom cotton**

- No differences between stink bug infested and uninfested plants for:
  - Cotton Seedlings
  - Match-head Squares
  - Pre-Candle Squares

**AZ** • **But, make sure bolls form at bloom!**

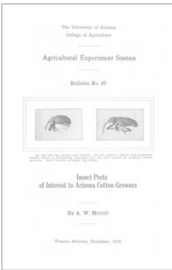
- BSB will feed on & cause to shed 1-7 d old bolls!

**But, if a field is flowering and ostensibly not producing bolls in a timely manner, a scout should check to make sure that BSB are not entering the field and molesting 1-7 day old bolls (under the flower or bloom tag) and causing boll abortion. If a grower is not attentive, this could result in a major delay in boll set and yield loss.**

**Thresholds?**

**"The brown cotton bug is rarely found in sufficient numbers to require treatment except in small areas.... An average of one of these bugs to a plant should be considered as threatening..."**

**A.W. Morrill, 1918**




**Thresholds have been considered even with the earliest infestations of cotton 100 years ago. However, they were rarely considered damaging back then. Even so, a level of one bug per plant was suggested as a treatment threshold. Inspecting an entire plant for the presence of BSB can be very, very time-consuming.**

**Thresholds?**

**"2-4 stink bugs per 100 sweeps"**

**Roney & Wene, 1960**

**Cotton Insect Control**  
In Arizona, 1960



**The last mention of a treatment threshold in AZ cotton was by Roney and Wene in 1960 and they suggested 2-4 bugs per 100 sweeps. However, we know today that sweeps sampling is an extremely and inefficient measure of stink bug activity.**

**External Symptoms of Feeding**

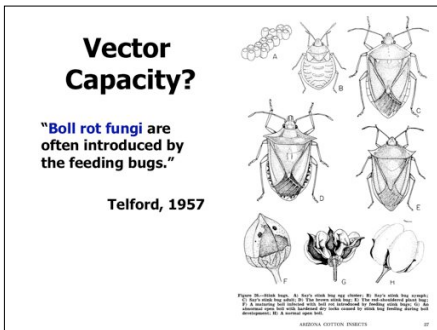
**Not a Reliable Indicator**



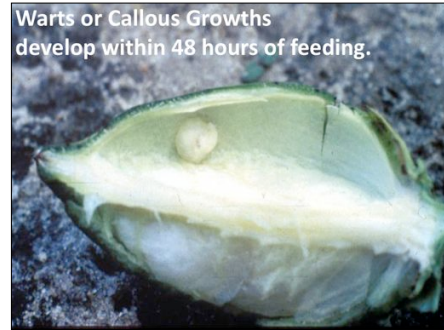
**In fact, even the feeding blemishes on the outside of a 1 inch boll are inadequate for predicting boll damage or tracking stink bug activity. Many studies back East have confirmed this as an unreliable measure of stink bug presence and activity.**



After many decades of cracking bolls for pink bollworm sampling and then seeing this practice disappear altogether, we now have to crack bolls once again to determine internal injury caused by stink bugs. No other measure will track stink bug activity and damage better. Scouts must crack 1 inch soft, squeezable bolls. Symptoms include stained lint or seed and warts.

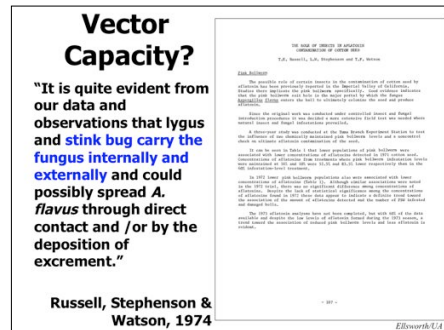


Wounding of the boll permits the entry of boll rot organisms. However, can BSB actually carry these organisms on or in their bodies?



Warts develop quickly, in even less than 48 hrs and is the plant's response to the wound. So technically, just seeing a wart does not mean a stink bug was responsible. Other hemipterans could be involved or even pink bollworm.

However, for stink bug surveys, a scout need only see a wart or a stain to count the boll as "injured". %injured bolls are then used to measure and track stink bug infestations.



In elegant work done in the 1970s, they found that in fact yes stink bugs can carry boll rot organisms both inside their mouthparts and externally.

*Aspergillus flavus* is the causal organism for aflatoxin. Aflatoxin is a hazardous substance in cotton seed and other agricultural commodities. We do not want to be known for producing cotton with high aflatoxin levels.

BSB can transmit *A. flavus* to the boll interior where it can thrive.



This issue of pathogen introduction and associated boll disease and boll rot appears to far more important in the humid Southeast than here in the far West.

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### Bug Injury and Boll Rots

- Severe yield loss occurs when pathogens develop in bolls
- Environmental conditions conducive for boll rots.
- "Clean" bugs vs "Dirty" bugs

There, severe yield loss is associated with the presence of these boll rot organisms.

Dr. Phillip Roberts and I examined commercial and experimental fields where stink bugs had been active all season long. He was struck by how, relatively speaking, light our boll damage was for the level of stink bug activity indicated. We think this is because our arid conditions are not as conducive to the development of the boll rot process.

Thus, the damage dynamic here in AZ may not be nearly as significant as it is in GA.

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### Stink Bug Parasitoids

- Wasps
- Scellionidae
- Flies
- Tachinidae
- Eggs stuck on adults.
  - Reduces longevity and fecundity, slow to kill.

These parasitoids have been found in GA. We have similar ones here including egg parasitoids, where adult female wasps lay eggs into the eggs of stink bugs. There are also parasitoid flies that specialize on stink bugs and lay there eggs on their backs.

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### Stink Bug Predators

- Big-eyed Bugs
- Will feed on eggs and early instars.
- Fire Ants

Generalist predators are active in GA and include one we depend on, Geocoris or big-eyed bugs, and one we don't (fire ants).

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Last year, Lydia took these photos of another tachinid parasitoid that attacks our BSB. Several eggs might be laid on the back of BSB, but only one larva will fully mature and exit the BSB and pupate. The adult have these characteristic picture-window wings with patterns of orange.

### Chemical Control?

- 1918  
Spray weedy hosts with coal oil or burn  
In cotton, **only hand-picking**
- 1935  
Such sucking insects can be controlled on plants only by so-called contact or repellent materials and many of those used effectively have **had to be so strong as to burn the plants**
- 1960  
**30 lbs of dust** (sulfur, benzene hexachloride, DDT) or Dieldrin, Toxaphene in mixtures with DDT & sulfur

*Ellsworth et al*

Chemical control was hardly an option 100 years ago. In fact, a detailed account of what it costs to hand-pick the bugs out of the cotton fields was provided and suggested to be quite economical.

By the 1930's, the materials were so strong that they were phytotoxic and harming the plants directly.

The DDT era brought with it very heavy use of very broad spectrum mixtures.

In all cases, the approaches are very broad spectrum, with an almost scorched earth mentality, in part because that's all that was available and in part because that was what was required to attempt control of BSB.

### Stink Bug Insecticide Selection

Know your Target Species!

	Southern Green Stink Bug	Brown Stink Bug
Pyrethroids	Very Good	Fair (rate response)
OPs (Bifenthrin)	Very Good	Very Good
Pyrethroid+OP	Very Good	Very Good

Consider other pest present and potential for flaring!

Today in GA, they still rely on broad spectrum materials. There, the different species of stink bugs behave differently with respect to chemical control. Pyrethroids are generally thought to be effective against stink bugs, but much less so against BSB. OPs or their mixtures with pyrethroids are routinely called for when BSBs dominate the population of stink bugs.

### BSB Studies (2013)

- Grower unreplicated demonstrations
- Grower replicated experiments
- Small plot replicated studies

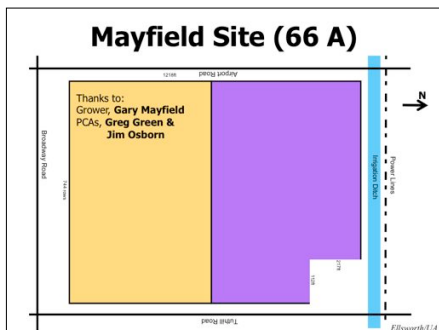
} No UTC

*Ellsworth et al*

The source of our information, beyond the expertise provided from colleagues back East, comes from our examination of BSB management in these 3 venues.

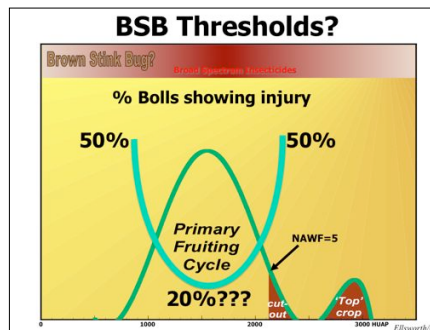
Grower sites are great; this is the real world. But they often suffer from two perspectives: lack of true replication (though we ran an extraordinarily detailed replicated assessment at one site) and the lack of an UTC. We can never be sure of what might have happened or not happened without a proper control.

We also did opportunistic work on the MAC Research Farm, in response to BSB populations there.



When Gary Mayfield and I discussed his field, it was already August and stink bugs were present in the field. The question became, in this situation, did it make economic sense to control for BSB? So we took this field and split it in half, spraying only the right side (purple) for BSBs. Whiteflies were just at threshold, too. So we applied Knack to the left side. These are the real world types of decisions that each grower or PCA has to make routinely but make for interesting "experiments."

Many thanks to the cooperating grower, Gary Mayfield and the two PCAs involved, Greg Green and Jim Osborn. We so appreciate their willingness to collaborate with us with this research.

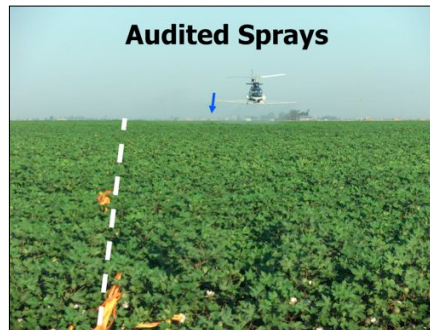


Before we look at the specific data that came from this trial, let's examine BSB thresholds because this is a major question when making decisions about intervening with insecticides.

The primary fruiting cycle & top crop can be represented by this two-humped curve representing flowers per unit area. The dynamic threshold tested extensively in NC, SC & GA is shaped like an inverted 'U' overlaid on the primary fruiting cycle. This suggests that boll injury percentages can be very high at the beginning & end of the fruiting curve, likely as high as 50% without sustaining economic loss. The real question is how low can we go? At peak fruiting, the highest number of bolls susceptible to stink bug feeding are present. The lowest %bolls showing injury value varies by state & region, but because our potential for losses to boll rot are less than the humid SE, we offered a suggestion that 20% might be as low as this should go. There is no specific AZ data on this question yet.



We cut the field in half across rows. Initially Knack on the left side (South) vs. Bidrin + Bifenthrin on the right side (North).



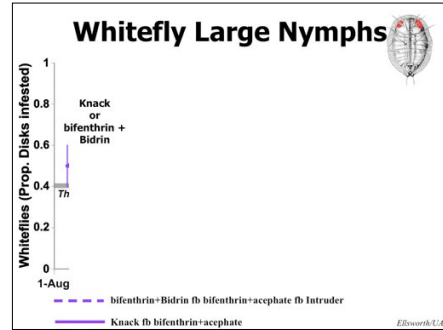
We worked with Tri-Rotor directly and mixed, loaded, and observed the application and its drift directly. This is what is meant by "audited" sprays. We make sure the right insecticides at the right rates and timings are applied to the right places. We are very grateful to those applicators, PCAs, and growers who work with us on these projects.



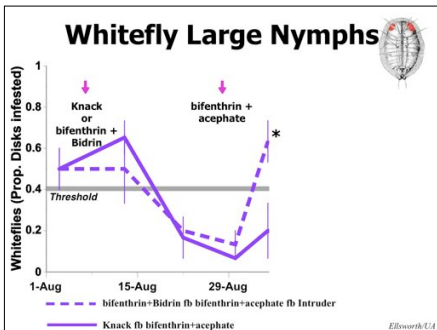
Here is the field after initial defoliation but before it was fully defoliated.

The right side (BSB sprayed side) seems more open. Why? Several things are possible, but the data give us an important clue. Whiteflies and then mites were more abundant on the BSB sprayed side. Defoliation is best done on cotton that is stressed. These pests can contribute to stress as the crop is drying down and enhances defoliation. We hypothesize that the whitefly IGR side was under less plant stress and therefore stayed green longer. But we cannot be certain of these interpretations given the limits of the experimental design.

We hand-harvested along either side of the dotted line all the way across this field so as to sample from agronomically similar areas of the field.



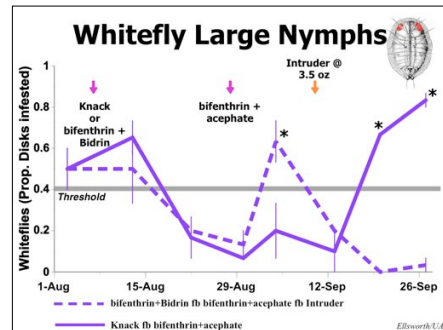
So let's look at the whitefly populations which we know to have been at threshold at the start of our trial. Bifenthrin + Bidrin (dicotophos) is a mixture of a pyrethroid + an organophosphate. As such, we refer to this as a synergized pyrethroid, because these mixtures can overcome resistances in whiteflies to pyrethroids. Thus, both regimes were expected to do something to the whitefly population, albeit one is a broad-spectrum approach and the other a selective approach.



In fact, large nymph populations initially increased where we used Knack and then collapsed as we normally see in this IGR regime. The synergized pyrethroid lowered numbers more directly. The initial results were similar.

The grower then elected to spray the entire field, as will always be his right in studies like this. This does not change our test, because our sides were treated the same way.

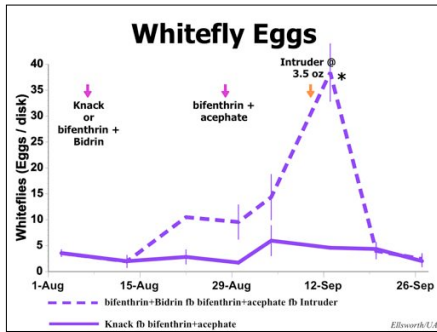
The BSB-sprayed side had whitefly populations that increased quickly at this point in response to the destruction of natural enemies. I.e., they were released from the natural control that was possible and operational on the Knack side.



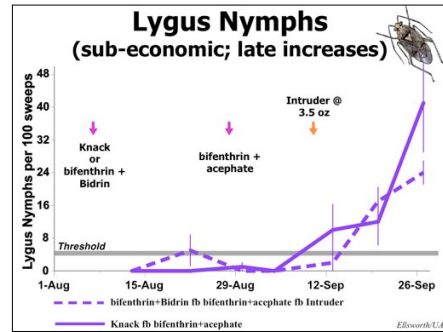
The whiteflies really got out of control thereafter on the BSB-sprayed side. We advised the grower to go with a very high rate of Intruder to overcome this issue, just on that side of the field.

The Intruder (acetamiprid) worked very well.

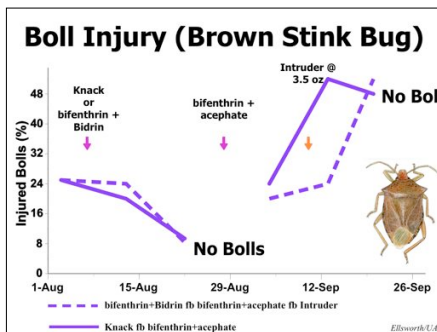
Whiteflies were finally released from the singular spray of Knack 5-6 weeks earlier. However, by this point in time it was very late in the season and defoliations were initiated.



PCAs are not asked to track eggs, but as part of this research we routinely monitor this life stage. These levels in mid-September were very high. Yet, Intruder performed remarkably well returning egg levels to those of the Knack side of the field and doing so quite quickly.



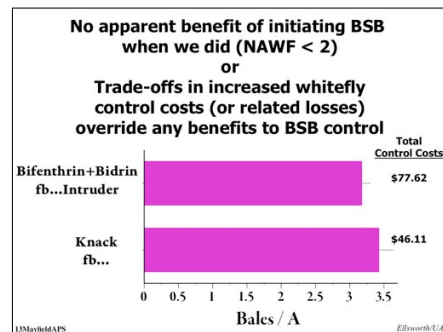
Lygus were sub-economic throughout the season, increasing in numbers only very late in the season.



Here we see that this trial started around 25% injured bolls. Recall that we suggest 20% as the absolutely lowest level to target when in peak fruiting. This was well past peak bloom. Was our threshold too low for this period in crop development?

3 weeks later there weren't even enough bolls to sample, because of complete cutout. The grower grew a large top of 10-12 nodes more of plant.

Boll injury levels are remarkably similar, regardless of whether we were actively spraying them or not. Was there a benefit to going broad spectrum?



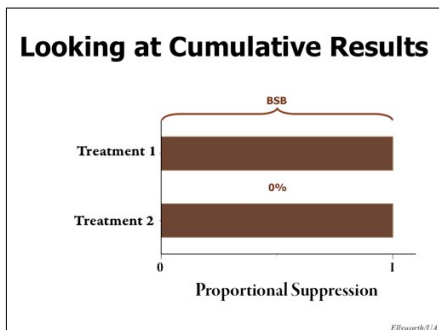
Does this answer the question?

Or, does it result in more questions?

Clearly, the Knack-sprayed side out-yielded, although not significantly, the BSB-sprayed side, and it cost less to do so.

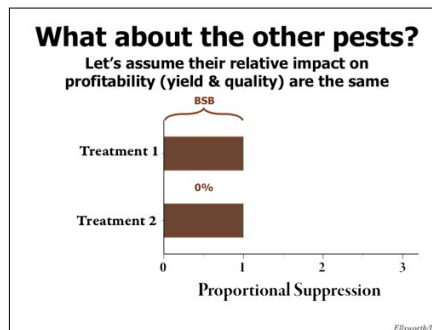
So, either our initiation was too late in crop development or too low in threshold; or, any benefits of controlling BSB were lost to the increased whitefly problems there.

There are other possible explanations, too. We just cannot say for sure why we got these results, because we did not formally replicate, or have a proper control or untreated check.

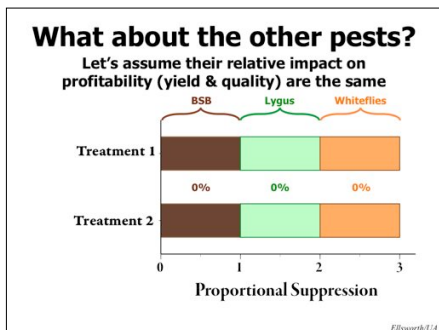


This is a frustrating result, and I wished to somehow develop a framework for showing and understanding the multiple forces (pests) that every grower and PCA contends with simultaneously. So consider this.

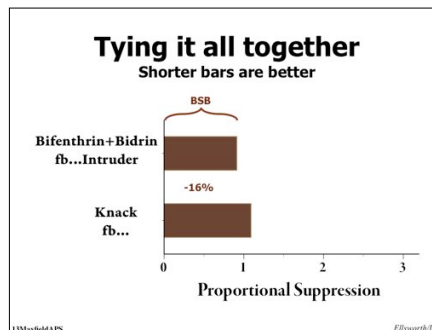
If two different treatment regimes control a target identically, in this case BSB, then they would both exert the same level of proportional suppression, shown here as "1" with 0% difference between the two.



But what if we add a 2<sup>nd</sup> pest to the system? First, we'd have to assume that the pests' relative impact on plant productivity is similar.

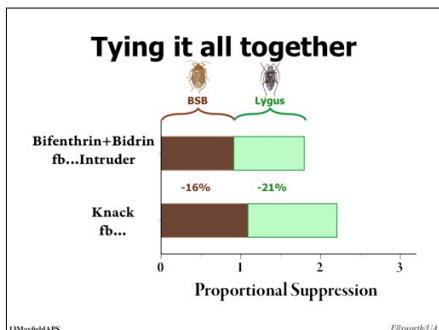


But what if we add a 2<sup>nd</sup> pest to the system? First, we'd have to assume that the pests' relative impact on plant productivity is similar. However, if they were the same or similar, then we could examine their cumulative proportional suppression additively. Here there are no differences between two regimes and 0% difference for each pest.

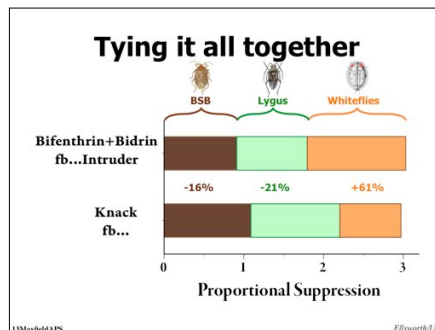


For the Mayfield site, we did actually measure 16% advantage in proportional suppression of boll injury on the BSB-sprayed side. In this rubric, shorter bars are better.





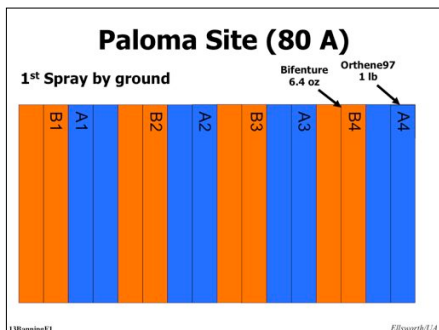
Lygus were also 21% reduced relative to the Knack-sprayed side. However, we need to note that we believe Lygus levels were sub-economic for most if not the entire season.



However, the BSB-sprayed side lost all advantage in proportional suppression when one considers the greatly increased whitefly populations there.

So in looking at things this way, perhaps it is not surprising that we did not measure a yield effect that favored spraying for stink bugs.

This is the conundrum. Controlling stink bugs (to the extent that ostensibly is possible) can result in destruction of key natural enemies that help to keep many other potential pests in check. In this way, these other pests may actually become more damaging, possibly even causing more loss than the original BSB problem.

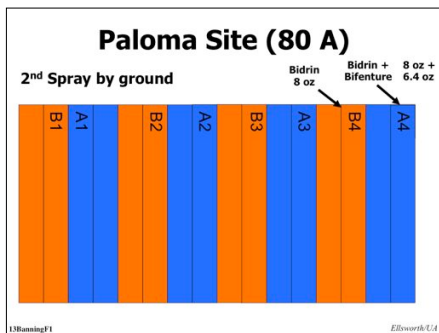


Near Gila Bend, we conducted a trial with a grower and PCA on an 80 A field. The production system was a little unusual in that the grower produces cotton on the flat and irrigates on borders from gated ditches. This conveniently gave us strips (borders) through the field, each about 5 A in size. The grower also had his own spray equipment that we used for the first spray. As with any grower trial, we discussed options and decided to strip the field (as shown in orange and blue) with two contrasted insecticides for stink bug control, bifenthrin (Bifenture) vs. acephate (Orthene97), each at their maximum label rates.

This sort of replication helps us eliminate bias across a field due to various soil or other production related characteristics.

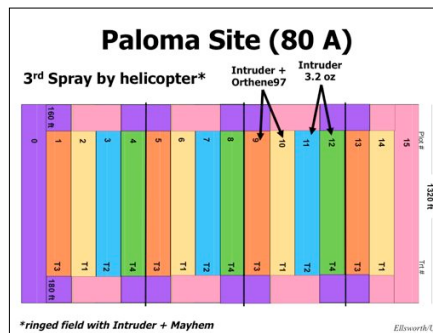


This shows the grower's spray rig putting out the 1st spray. There was nothing fancy or specialized about it. Just a standard ground rig.



As stink bugs persisted, we discussed and decided on a 2<sup>nd</sup> spray. This time Bidrin (at 8 oz/A) was used on both strips but one strip (blue) got the addition of bifenthrin (Bifenture at the full rate, 6.4 oz).

We stayed on pattern, alternating 10 acre "plots".

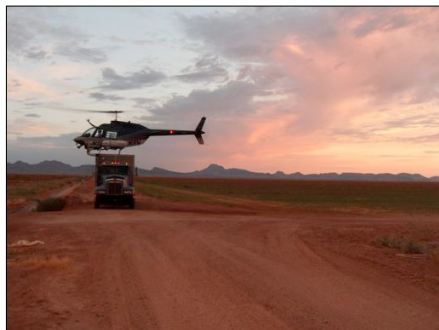


By late in the season, we were concerned about growing whitefly populations, and, we wished to preserve the integrity of the replicated experiment. So we applied acetamiprid (Intruder) at Arizona SLN permitted elevated rates (in this case at 3.2 oz / A). But we also added acephate (Orthene97 at a full 1 lb / A rate) to one set of plots.

This effectively created 4 different regimes. Plus, we sprayed Intruder + Mayhem (novaluron) in a ring around the field creating this mosaic pattern.

This is quite an intricate grower trial. We would not normally expect this in every trial. We really appreciate the cooperation of the grower and PCA here.

By arranging sprays in this way, we get the maximum amount of information from the test.

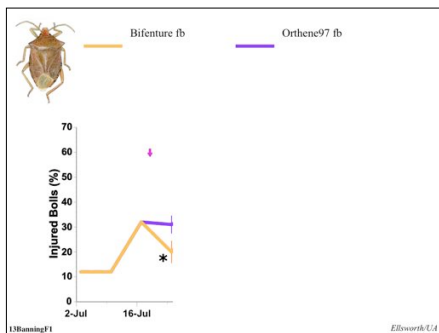


We are especially grateful to Tri-Rotor out of Buckeye who worked directly with us to get the 3<sup>rd</sup> spray out.

Many thanks also to the cooperating grower, Lee Banning, Jr. and the PCAs involved, Doyle Stewart. We so appreciate their willingness to collaborate with us on this research.

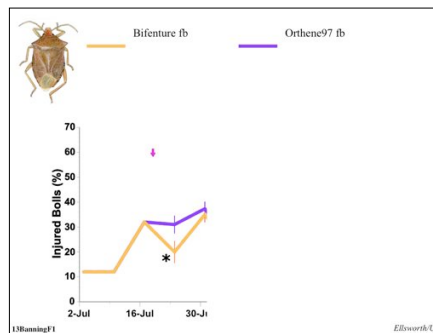


We audited all sprays to make sure they were mixed, loaded and applied properly to the designated strips.

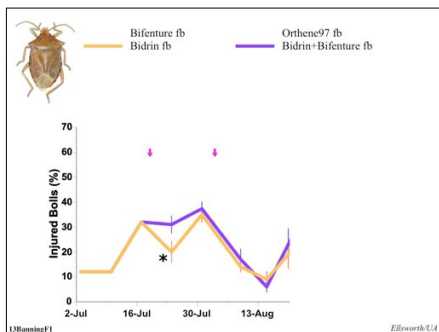


Let's examine the data. Rather than show you the whole trial's data all at once, I will step through date by date so that you can see just what we were seeing and measuring at the time (without the benefit of 20:20 hindsight).

We started at low levels in our boll sample, then climbed to over 30% while we were in peak fruiting. At that time, we discussed with the PCA & grower various options we could contrast — this is an interactive process; we don't simply dictate what should be done. We're trying to learn something together. So we went with Bifenture vs. Orthene. We got a significant lowering with Bifenture. However, one should not conclude that Orthene failed to do anything, because there was no untreated area in this trial to see where these injury lines would have gone without any sprays.



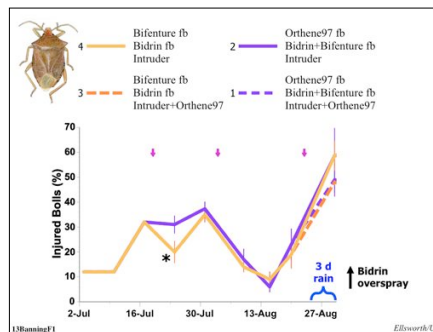
Two weeks later, injury levels increased to their pre-spray levels for both regimes. We were still fruiting well, though now on the downhill side of the fruiting curve. Another set of discussions were had and we decided to contrast two approaches that both contained Bidrin at 8 oz per acre. [Note this is the 1<sup>st</sup> use season for Bidrin in about 30 years in Arizona, but data from GA and elsewhere suggest that this is among the best options for Brown Stink Bug control.]



So we applied Bidrin both with and without the addition of Bifenture. Both regimes came down first to about 16% and then even below 10% two weeks later. We were very happy with this result, though stink bugs were still evident in the field via direct observation. By the 3<sup>rd</sup> week post-spray, fruiting was slowing down considerably but stink bug injured bolls were on the rise again.

At just 20–24% boll injury at this stage of fruiting, we were not overly concerned given the threshold relationship mentioned earlier.

However, whiteflies were becoming more of an issue and our sampling suggested a need to intervene to control these now, rather than waiting, because of the disruptions of natural enemies made with these broad-spectrum stink bug sprays.

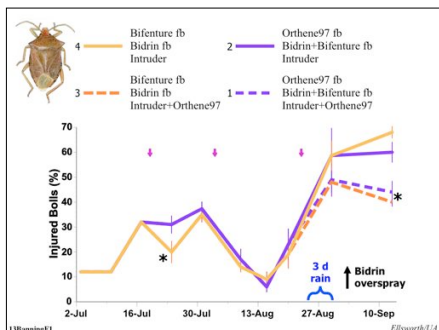


Whitefly adults in particular were a concern. So we did not wish to use the IGRs, Knack or Courier, or the other fully selective option, Oberon. Instead, we elected a high rate of Intruder, newly established last year under a 24c Special Local Needs label that permits a 50% increase in the maximum use rate.

So we applied Intruder at 3.2 oz on everything and added Orthene at 1 lb / A on half the area, spawning another set of regimes to evaluate.

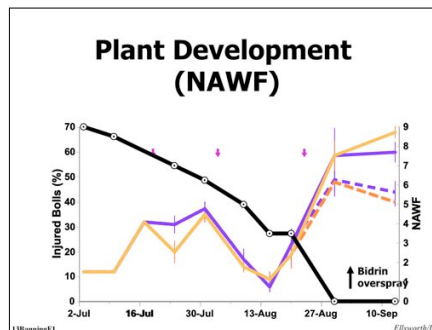
We then hit that rainy period in late August shortly after our spray.

Meanwhile, our stink bug injured boll counts continued to rise & the grower/PCA decided that they did not wish to risk any additional losses and oversprayed the entire trial with Bidrin (8 oz) about 10 days later.

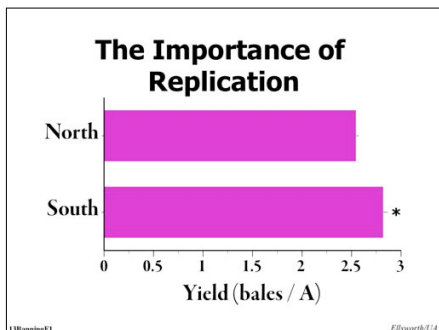


Judge for yourself as to whether the Bidrin spray was needed and/or effective. But since everything was treated the same, the integrity of our 4 spray regimes was still intact. It appears that where we used Orthene previous to the final Bidrin overspray, we got significant reductions in stink bug boll injury, albeit still at high levels around 40%. Where we used just Intruder, the effect was not as apparent.

40–60% of the bolls showing signs of injury by stink bugs may seem like a very high level. But recall the shape of our dynamic threshold, and consider where we were in fruiting.

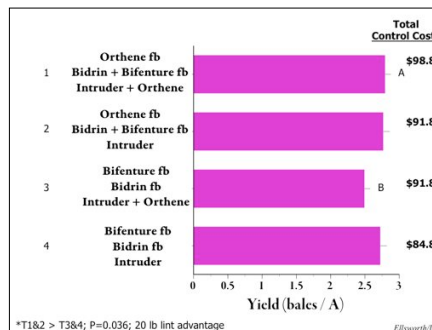


As a PCA or grower, if you measure just one aspect of plant development, this would be the one to measure for insect management, Nodes Above White Flower. NAWF is a reliable metric for tracking the fruiting curve. With it, you can track where you are and when your returns on plant protection inputs might cease to be economical. For instance, our research suggests that Lygus control beyond NAWF=4 is rarely justified economically. In this case, we know that the 'U' shaped dynamic threshold for BSB suggests that high rates of boll injury are tolerable very late in the fruiting curve. When the Bidrin spray was made, NAWF = 0, the plant was completely cut-out and no longer producing new blooms. It is true that there were still some bolls susceptible to injury, but was there enough economic return to justify this spray? We just don't know the answer to this question yet.



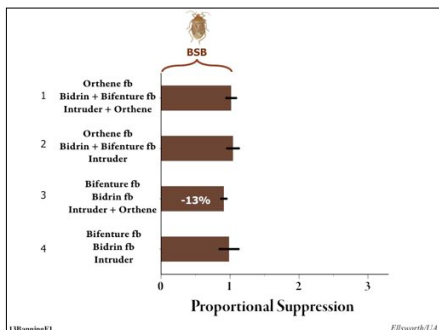
I would like to pause and consider this fact about yields in this grower's field. Had we just chosen one side of the field to compare to the other side, in this case North vs. South, and applied contrasted materials to each, we would have concluded INCORRECTLY that the treatments worked better on the South side. In fact, the North side was just a weaker side of this large field.

This is why replication is so critically important. In this case, we did formally replicate and randomize our treatments. This allows us to account for these spatial biases that occur in nearly every commercial field.



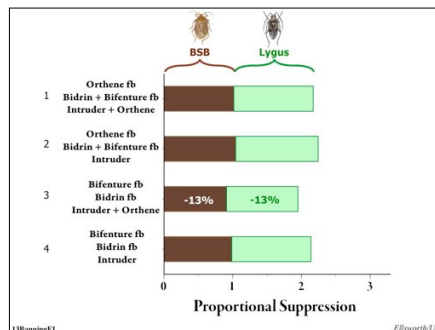
Our machine picked yields did not show large differences. Trt #3 was off a bit, significantly different from Trt #1, though it is not clear why. This difference was mainly due to a large difference in gin turnout for Trt #3, which was much lower than the others. We don't know why this was. Note, our hand-picked yields showed an even larger difference between Trt #3 and the other treatments.

Regardless, these are not large differences in yield, not like when we have outbreak levels of Lygus for example. However, we did use the same range of chemistry in all treatments, and based on this, it looks like where we spent the least amount of money, we maximized our profitability.

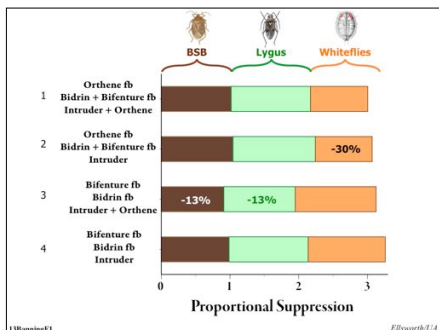


So let's examine this multi-pest rubric for understanding what took place in this field experiment.

Trt #3 actually showed a 13% proportional reduction in BSB injured bolls — recall this was also the lowest yielding treatment!



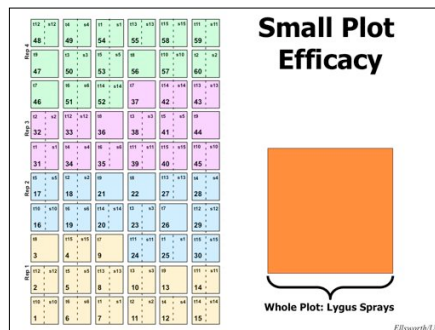
In addition, Lygus were reduced by 13% proportionally for this same treatment.



However, the largest gain in whitefly control was in Trt #2.

The resulting pattern of proportional suppression of the pest complex is quite similar, with Trt #1 having the lowest cumulative levels.

In the end, this trial has not been definitive. It showed some efficacy of bifenthrin (1<sup>st</sup> spray) and some efficacy of acephate (last spray) in controlling BSB. All regimes were disruptive and harmed the natural enemy complex that can help keep whiteflies and other pests in check. Large yield differences were not seen, but similar chemistry was used in all four treatments.

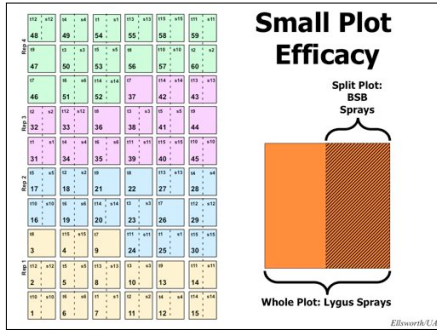


Let's look at a replicated small plot trial on the MAC Research Farm. When this cotton was planted, it was not known that stink bugs were going to be a problem again in 2013. So it was set-up as a Lygus and whitefly trial.

The entire 12-row "whole" plot was sprayed as needed for Lygus control.

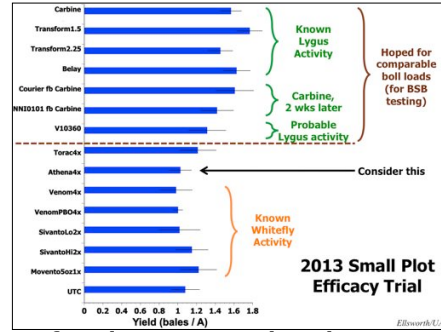
But later, we recognized BSB becoming a problem locally. So without more cotton available to dedicate to an examination of BSB control, we had to adapt this trial.





This meant splitting each plot such that one side also got sprayed for BSB control with another set of chemistry. This is not ideal, and Dr. Phillip Roberts concluded that this sort of arrangement is not optimal when examining BSB control dynamics, in part because BSB adults are quite mobile. It would have been his recommendation to run a separate trial with full-size (12-row) plots dedicated to BSB control.

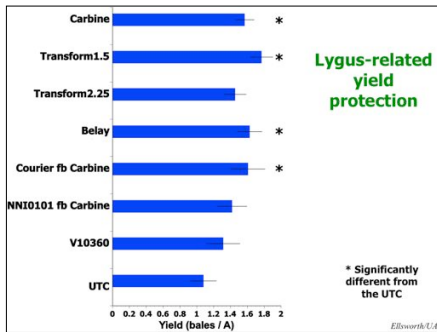
These observations are key to understanding the outcomes we observed.



The array of products we tested can be grouped as noted above: ones with known efficacy against Lygus, those that were eventually protected from Lygus, and those that have no known activity on Lygus (i.e., whitefly materials).

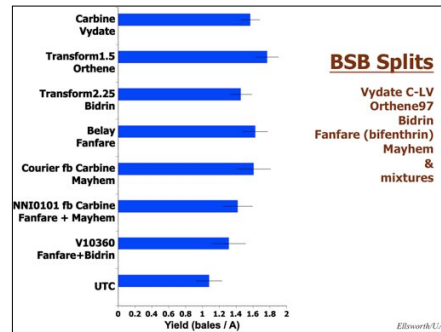
Our goal was to overlay our BSB treatments onto the Lygus protected treatments. Simple reason: You cannot study stink bugs without sufficient boll production, and Lygus can effectively remove squares and prevent boll development.

Our sprays were reactive to the levels of BSB we measured. However, consider the case of Athena, a premix of bifenthrin and abamectin, which was sprayed 4 times, twice before BSB became readily apparent. Surprisingly, there was no apparent yield bump over the other "whitefly" treatments. This calls into question bifenthrin's efficacy under these conditions.



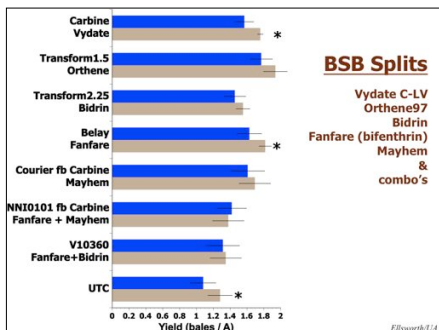
So focusing on the Lygus protected treatments, we can see that in general Carbine, Transform and Belay all increased yields relative to the check (UTC).

This was a very late planted study with very low yield potential. But these increases are significant, as much as about 40% increase over the check.



Now let's examine the splits that were created to accommodate a new set of treatments targeting BSB on just half the plots.

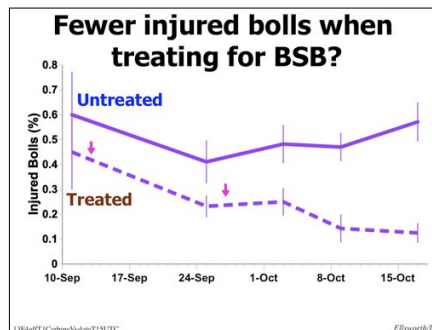
For each bar, there is yield on the base plot (not treated for BSB, Blue bar) followed by a bar indicating the yield on the BSB-sprayed half of the plot (Gray bar).



What we see is a significant increase in yield where Fanfare (bifenthrin) was used and where Vydate C-LV (oxamyl) was used — each BSB split was sprayed twice with this chemistry on top of their base treatments.

One might conclude that these two products and not the others “worked” in controlling BSB. However, there is one problem. The UTC also showed significant increase on the “BSB” side, even though neither side was ever sprayed!

So this calls into question the entire design and any conclusions from it regarding BSB control.



If we plot the “best” BSB treatment, Vydate C-LV over the top of the Carbine base treatment and compare it with the same side in the UTC, we can see that in fact the % of injured bolls was much higher in the UTC than in the Vydate!

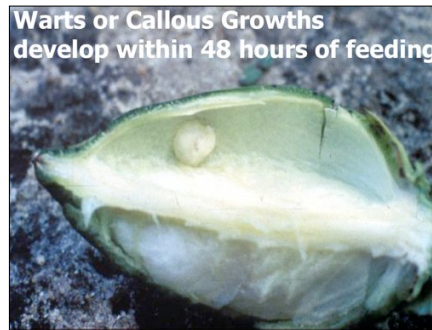
This might suggest that Vydate was an effective product. However, note the difference between these two treatments even before we sprayed Vydate (the first date). This suggests that there is an inherent difference between the UTC and the other plots even before we started spraying for BSB.

What’s going on?



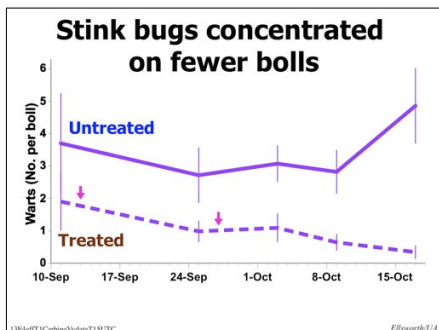
This is my working hypothesis that I will show graphically using a photo from a similar Lygus trial from a few years ago: Carbine on the left showing excellent Lygus control and the UTC showing a much reduced boll load all due to the activities of Lygus knocking squares off the plants.

For the same population of BSB, we would expect lower %boll injury in plots that have lots of bolls, because the stink bugs are distributed among many bolls. Whereas again for the same population of BSB in the UTC, we would expect much higher %boll injury because the stink bugs are concentrated on many fewer bolls.

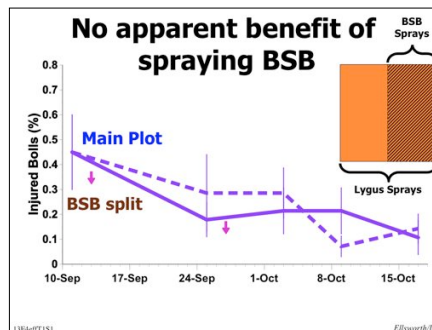


So how else can we examine this problem? One way is to count the number of warts that we saw in this study on a per boll basis. We would assume lots of warts per boll would equate to more stink bugs or at least more stink bug activity.

These warts develop typically in 24 hrs and in response to any boll injury that penetrates the carpel.



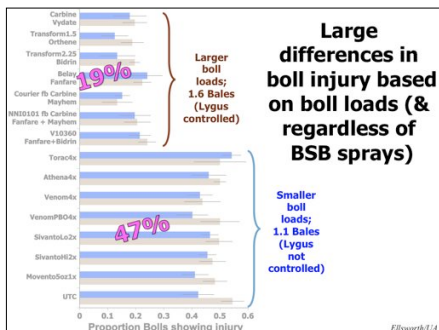
Here we see Vydate compared to the UTC and might again conclude that Vydate lowered wart numbers. However, the levels were already reduced in these plots compared to the UTC before any BSB sprays were made (see first date).



The more appropriate comparison is between the two halves of the Carbine plot, one side with just Carbine (main plot) and the other with Carbine with Vydate over the top (BSB split plot).

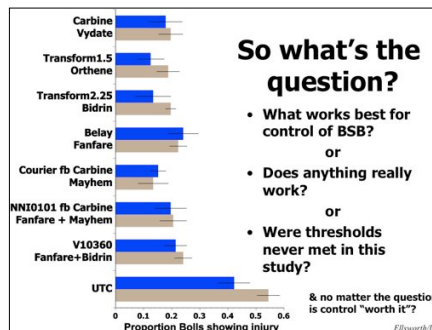
This shows what we suspected. There is no difference in boll injury between the two halves of this plot, despite the two extra sprays of Vydate C-LV.

The patterns are statistically similar, if not identical. I.e., boll injury declined throughout the entire boll sampling period regardless of sprays.

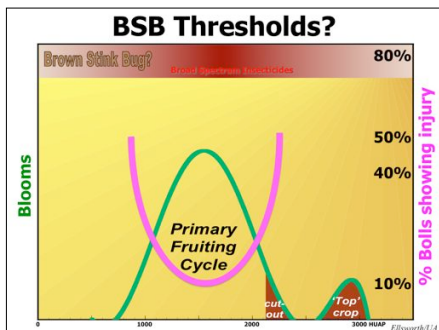


So the issue in this trial seems to be related to the boll loads on the plant and our ability to compare treatments and subplots. Where we had good protection against Lygus, we had lower %boll injury because of the "dilution" effect for BSB, around 19%. Where we had poor boll loads, we had much higher %boll injury because of the concentration of BSB on a fewer bolls, around 47%.

Again, take note of Athena, which is a combo of the max. rate for bifenthrin and abamectin. We failed to enhance yield here at all despite the earlier, presumably preemptive, sprays. This suggests that bifenthrin is not an efficient control chemical for BSB or that none of these products are very efficient at reaching BSB in large structure cotton. I.e., BSB may be avoiding treated residues by staying deep in the canopy. This is just conjecture at this point.

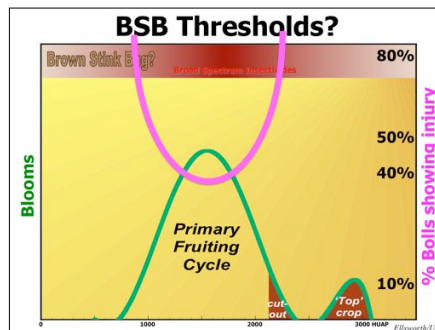


In the end, we have to back-up and re-evaluate what question we are trying to or can answer here. **What works best for control of BSB?** This trial doesn't tell us this definitively. Future work will be designed specifically for BSB evaluation. But our commercial trial does seem to indicate some amount of efficacy of both bifenthrin and acephate, though effects measured were never very large. Bidrin remains GA's favorite. **Does anything really work?** Again, we are trying to kill a large bodied, mobile adult that inhabits the lower portions of a plant. Maybe residues are being avoided. **Were thresholds never met in this study?** This remains an open question, but if they were not then we would not have expected to see differences at harvest. No matter what, we have to consider is the cure worse than the cause? Re-introduction of broad-spectrum chemistry in our system carries with it inherent risks of increased problems with other insect pests.



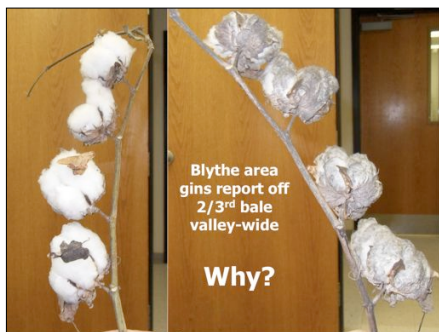
BSB thresholds for Arizona remain an open question. However, this past year's set of experiments and experiences makes me wonder if the lowest thresholds used at peak fruiting should not be raised significantly. This is in part due to the less than definitive or significant findings of our 2013 experiments. But also, it's due to our belief that the damage dynamic as represented by risk of boll rot is much lower here than in GA and the rest of the humid southeast.

At its most extreme, there are pest managers in GA who pull the trigger as early as 10% at peak fruiting. This level is relaxed all the way to 50% at either end of the fruiting curve.



This past year, we suggesting observing a level no lower than 20%. However, given the results so far, I wonder if this cannot be increased significantly without suffering economic loss. I don't know what that level is, but obviously if we were to suggest raising the threshold to 40%, many of the sites we were working in would not have triggered a spray season-long.

Where the true threshold lies is not known. To re-iterate, there is no Arizona validated threshold established for Brown Stink Bug or other stink bugs in cotton. We hope to develop lines of research that will help with this question, but this type of research takes time and resources to complete.




The trade-offs in stink bug control are visibly depicted here. Any branch with 4 bolls on it would make a farmer proud. This field was full of them and was quite obviously a top yielding field, probably well in excess of 4 bales. Yet, on one side of the branch, the bolls were blackened from the sooty mold that grew on the honeydew deposited by whiteflies. These whiteflies were ostensibly overwhelming because all the cotton from boot to collar looked just like this.

In addition, the Blythe, CA, area is reporting yields off by a 2/3 of a bale valley-wide. Why? Was it the early and heavy BSB pressure? Or, was it the fallout that occurred by attempting to aggressively protect the cotton crop, which resulted in resurgent whiteflies? Or was it some combination of both? Was the cure worse than the cause?

### Something Rotten...

Oh, when them cotton bolls get rotten,  
You can't pick very much cotton  
In them old cotton fields back home;

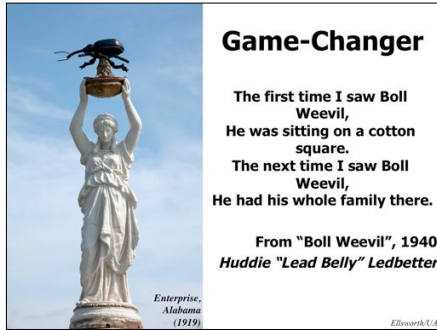


From "Cotton Fields", 1940  
Huddie "Lead Belly" Ledbetter

Edwards/LL

For folk blues fans, you will know and remember Lead Belly Ledbetter. He wrote of the cotton picking experience and boll rot makes its way into one of the more iconic songs of American history, a song that has been covered by the likes of the Beach Boys and Credence Clearwater Revival.

In it he sings of bolls getting rotten. But he wasn't referring to stink bug associated rot.



**He was referring to the boll weevil which effectively wiped out cotton production in places like Enterprise, Alabama, the only place in the world with a statue to an insect pest. Why? Because when the cotton industry collapsed there, it forced the agricultural industry there to diversify, thus enabling a vibrant economy for the decades that followed.**

**Lead Belly wrote about the boll weevil, too. If stink bugs become resident, primary pests of cotton in our system, we could see our pest management system irreparably harmed. This is a significant issue for our growers and the cotton industry, but we hope the impacts will be far less than what was experienced at the turn of the century in the South.**



**We thank the supporters of our research and outreach programs.**