



We ran two trials at Maricopa Agricultural Center in 2014. One explored the damage dynamics associated with brown stink bugs, and the other was a chemical efficacy trial. The work was funded by Cotton Incorporated, and much of the work was accomplished with the help of three interns.

Presented in Yuma, AZ, 30 min.; 30 participants



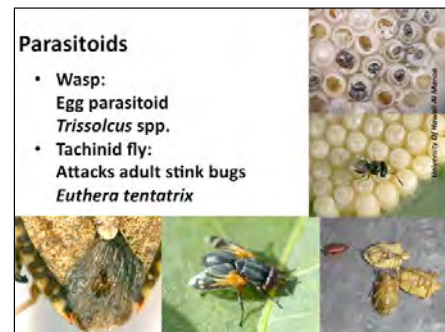
This is THE brown stink bug (BSB), *Euschistus servus*. Some older IPM resources use the name *E. impictiventris*.

The last outbreak in AZ was in 1963. BSB damage was reported in isolated fields in 2011 & 12 and widespread starting in 2013.

BSB lay eggs on the underside of leaves & bracts. Eggs are barrel-shaped and laid in groups. Freshly laid eggs are yellow, changing to a straw color with red spots as they mature. There are 5 nymphal instars; 1st instar nymphs remain near the eggs and disperse after molting. Nymph coloration varies from grey, brown, and green.



Brown stink bugs are seed feeding insects. As nymphs and adults, they use their piercing sucking mouthparts to pierce the boll and feed on the seeds. Their feeding causes warring inside the carpel wall, discoloration of seeds and lint, reduced yield and harvestability, and may cause hard lock, a disease of the boll that reduces the harvestability of a lock or boll. It can also introduce pathogens such as boll rot and *Aspergillus flavus*, which can lead to increased aflatoxin levels. Feeding on young bolls can result in boll shed.



We have collected two species of parasitoids from BSB. The first is a wasp that parasitizes eggs. The other is a fly that lays its eggs on adult BSB. One maggot develops within the stink bug's body, killing the stink bug in the process. The wasp lays eggs in the eggs of the stink bug resulting in the death of that egg. Both species could potentially contribute to biocontrol. The fly parasitoid may impact reproduction, movement, or feeding, but we know that parasitized BSB live for at least a week or two after the fly lays its eggs.

It is likely that generalist predators in our fields feed on at least brown stink bug eggs and young nymphs.



We performed boll cage studies to explore damage dynamics. We wanted to know if susceptibility varies as a boll ages, how long it takes a bug feeding on a boll to cause significant damage, and how bug density impacts damage levels.

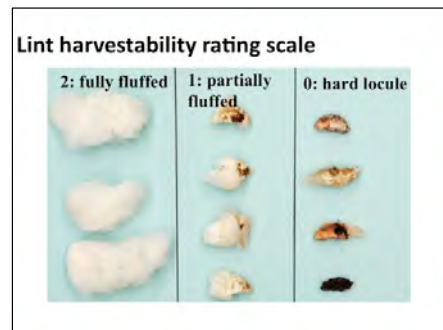
We ran the first experiments in June, and another set with modified age classes and lengths of feeding in August. In the first set of experiments, we opened only green bolls and measured injury. In the August experiments, half the bolls were examined as green bolls and half as open bolls at harvest.



We took any and all measurements we thought would be potentially important to our analysis. We also made observations on which measures will be valuable in field sampling.



In both green and open bolls, we established rating systems to measure damage severity. We invested time in calibrating all team members to rate bolls consistently. Green bolls were rated for carpel wall warting and locule damage. Mature bolls were rated for locule damage and harvestability.



We established another rating scale for dry lint, rating harvestability.



Our interns were invaluable to performing the field work and taking all of the measurements. Their hard work and diligence is greatly appreciated.

What we know now

- External damage is not reliable
- Young bolls more likely to abscise
- Older bolls are less sensitive to damage
- Most bolls sustain injury quickly & early in boll development & the first days of feeding

In all experiments, there was no relationship between external and internal boll damage. Researchers in the southeastern US have established this, and our work confirmed it.

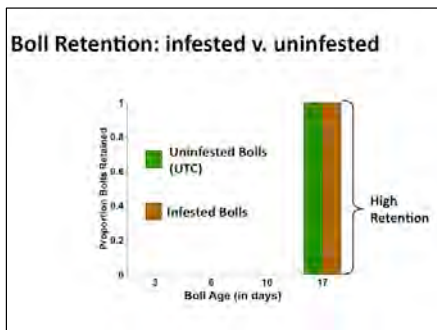
Abscission rates were high in infested, young bolls. As boll age at the time of infestation increases, abscission rates are closer to those of uninfested control bolls.

According to our measurements, older bolls are less susceptible to BSB feeding.

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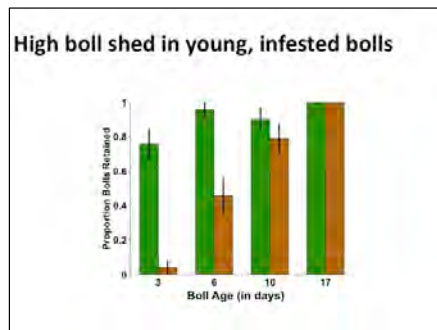
Ellsworth and Brown

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First, one of the most significant observations in our studies is boll retention rates or the impact of stink bug feeding on boll abscission / abortion.

There was high fruit retention in bolls that were initially infested at 17 days of age (brown bar). Retention rates were the same for 17 day old bolls infested (brown bar) and uninfested bolls (green bar).



A very low proportion of 3 day old bolls were retained. As bolls aged at the time of initial infestation, they were less likely to abscise. When infested at 17 days old, bolls were just as likely to be retained as uninfested bolls.

Key Point

An older damaged boll can still contribute some portion of its lint/seed to yield. Very young bolls, however, are extremely susceptible to boll shed due to stink bug feeding. This is a lost site of production, although carbohydrates might be re-allocated to un-damaged bolls partially compensating for this loss. More research will be needed to determine overall impact on a given plants productivity.

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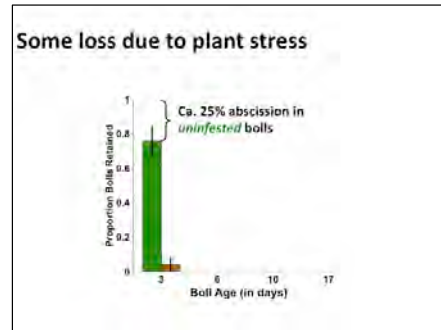
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Abscission & Boll Shed

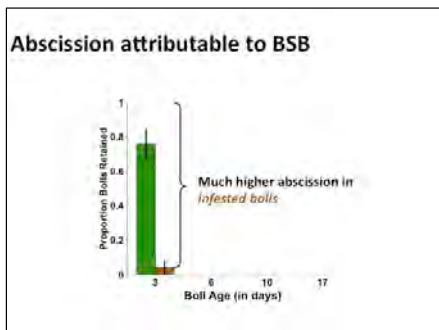
- Bolls shed due to water stress will not show internal injury & usually shed at 1-3 days
- Stink bug related shed will show internal injury & occurs between 1-10 days



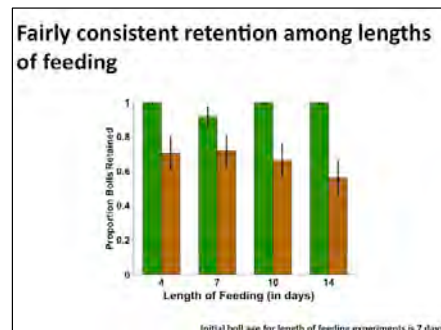
Not all boll shed can be blamed on insects. Heat and water stress can lead to boll shed in young bolls. Shed due to plant stress usually occurs in 1-3 day old bolls. After that, insects are more likely the culprit. If you are noticing boll shed, consider the boll ages and examine shed bolls for internal damage by picking them up and splitting them open to examine evidence of insect feeding.



In 3-day old bolls, there was some abscission that appears to be due to heat stress or other environmental factors. Note that about 25% of this cohort of bolls abscised, even when not exposed to BSB, i.e., the controls. However, less than 10% of the infested bolls were retained.

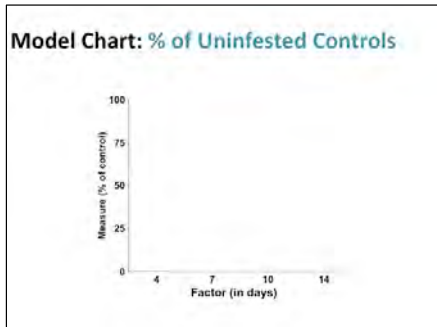


Boll retention was much lower in infested 3-day old bolls than in uninfested bolls, which suggests that BSB was the culprit.

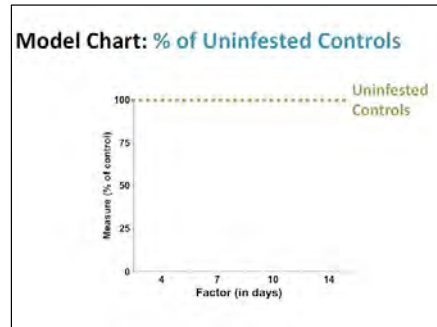


In our length of feeding study, bolls were all 7-days old at the time of initial infestation. The retention of uninfested bolls was very high. Retention was decreased in infested bolls, but is not as low as in the very young, 3-day old bolls in the boll age experiment. There is no difference in retention between infested bolls that were exposed to BSB feeding for 4, 7, 10, or 14 days. I.e., Feeding periods of 4 days or longer resulted in the same level of boll abscission.

This suggests that plant responses that lead to boll abscission are occurring over a fairly short period of time, less than 4 days of feeding.



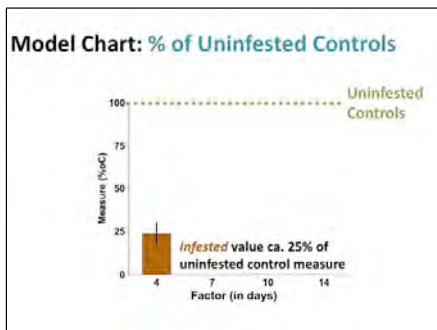
The information here is presented in a way that may be unfamiliar. This is a model chart meant to explain how we are presenting data as percentage of the uninfested controls.



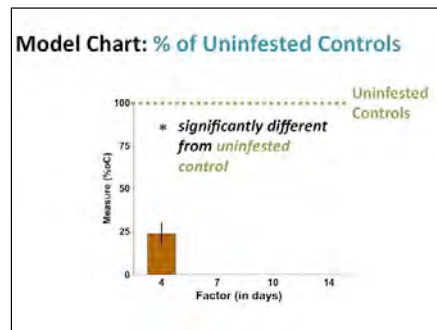
In these charts, the uninfested bolls are set at 100%, because we assume the uninfested bolls are "normal" and undamaged by insects.

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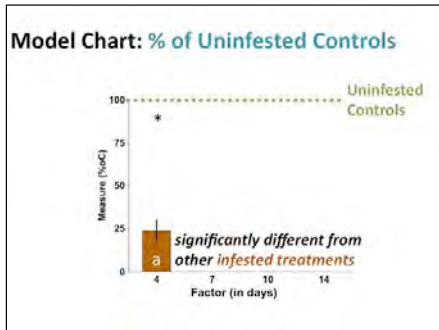
Measurements for infested bolls are then presented as a percent of the uninfested control bolls. For example, the infested bolls weighed 25% of what the uninfested controls weighed. Or, about 75% of the boll's weight was lost due to stink bug feeding.



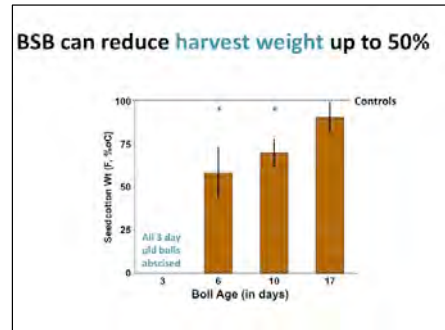
Every measured "difference" may not be an important or statistically significant response. Asterisks on these charts indicate that where there is a significant difference between uninfested controls and infested bolls.

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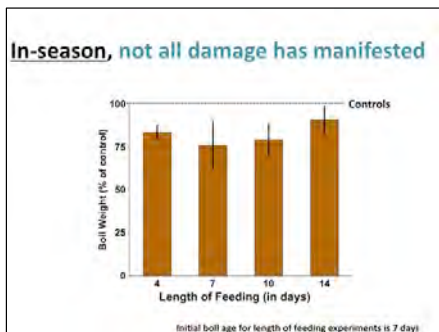


In each study, we examine a range of factors such as boll age at the time of initial infestation or varying lengths of feeding. When comparing among this range of factors, bars not sharing a letter in common (a, b, c) are significantly different from each other.



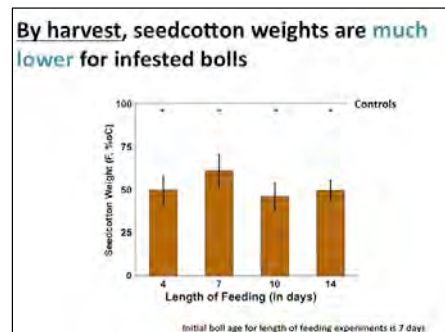
BSB infestation reduced harvest weight by up to 50%. In the boll age experiment, all 3 day old infested bolls abscised. There is significantly more damage on younger bolls (6 & 10 day old bolls). Older 17-day old bolls sustained less damage (locule weight loss) than younger bolls.

Observations of 3 day old boll abscissions and decreased weight at harvest of younger bolls show that stink bugs are more damaging to young bolls, which supports lower thresholds at periods of heavy boll set when the largest number of young bolls are present in the field.

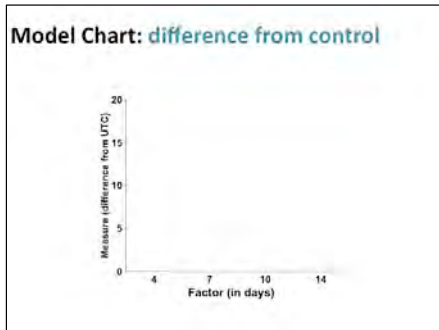


In-season, we took measurements of green bolls. For many measures such as diameter, weight, height, and volume, infested & uninfested green bolls were similarly sized. This, when compared to *harvest weights* of corresponding treatments, indicates that the damage dynamic was incomplete when we collected and measured green bolls.

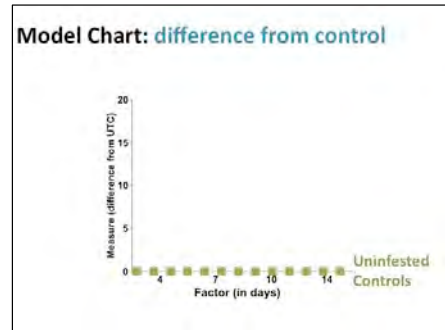
Nevertheless in every case, weights are below those of the controls. If we had more replicates or more sensitive measures, maybe we would have measured statistically significant effects.



At harvest, infested bolls weighed significantly less than uninfested bolls. All lengths of feeding resulted in lowered harvest weights that were statistically similar for this factor.



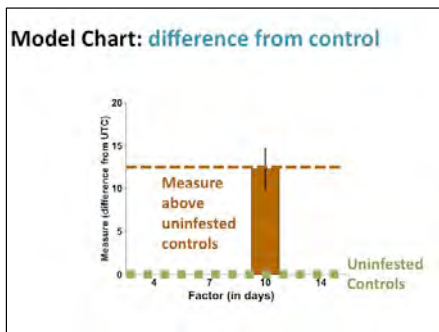
Here is another way to look at differences from the controls but by direct subtraction of the control result from the infested results: Difference from Uninfested Controls (UTC). The next few charts will be presented in this style.



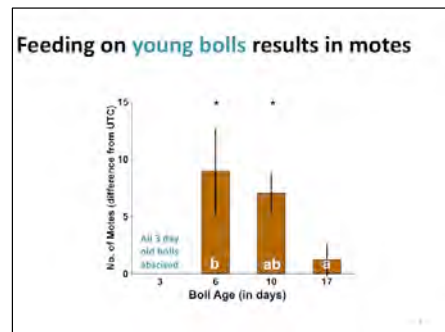
In these charts, the measured levels for the uninfested controls are set to zero.

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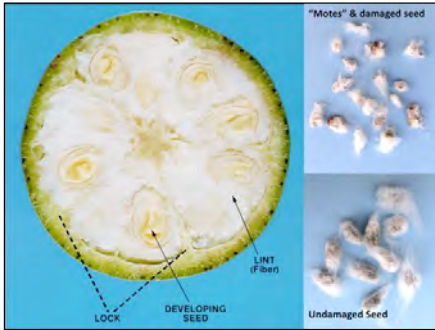
The brown bars show the measure of the infested bolls above the uninfested controls. We have subtracted out the uninfested values.



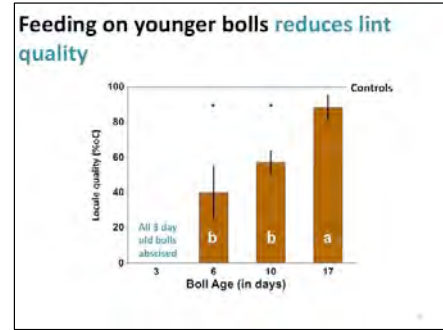
Motes are severely damaged seeds that fail to grow and produce lint. Motes may be caused by incomplete fertilization due to heat stress; unfertilized ovules become motes. Motes can also result from BSB feeding and lead to reduced seed weight and reduced lint production. Feeding on young, undeveloped seeds results in mote formation. Feeding on middle aged, developing seeds will damage seed, reduce or arrest lint production, and may affect future germination. Seeds and lint in older bolls are more developed and less susceptible to stink bug damage.

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Stink bugs use their mouthparts to pierce bolls and feed on the seeds inside. If a seed is very young when attacked, it may die and fail to produce much or any lint. In slightly older bolls, seeds are more well developed and have produced some lint; the yield effects will not be as severe as with young seeds. Stink bug feeding on mature seeds will most likely not affect lint weight, but damaged seeds may have lower lint yields as well as lower germination rates when used as planted seed.



Infestations of younger bolls led to higher damage ratings. Bolls that were 17 days old at infestation are not significantly different from controls.

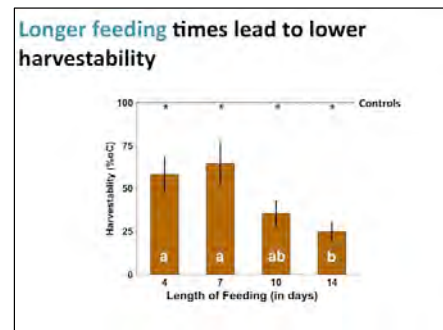
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Bolls that were younger at the time of initial infestation had lower harvestability. Bolls that were closer to maturity at the time of infestation had ratings similar to that of the uninfested controls.

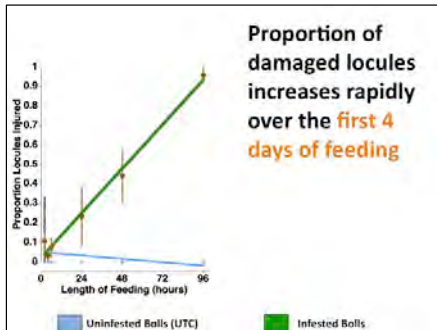
Stink bug feeding can arrest lint development. The damage was more severe in young bolls because lint was still developing from the seeds when the boll was infested. In 6 & 10 day old bolls, lint that was formed prior to infestation was also damaged, and the fiber stopped expanding normally. Stink bug feeding may also introduce fungus and bacteria, resulting in staining, failure to fluff, and hard loc.



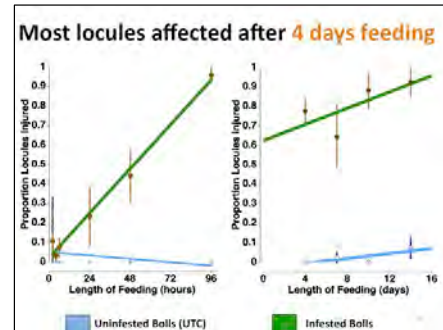
Longer feeding durations led to lower harvestability ratings. It appears that the longer a bug feeds on a boll, the more damage occurs in the boll and fluffiness/harvestability is reduced. Longer feeding times may also allow for more entry sites for fungus and more time for pathogens to grow and progress.

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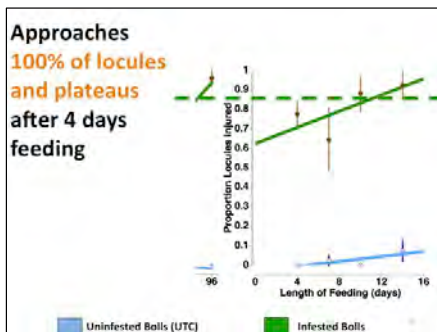
The percentage of damaged locules increases rapidly over the first 4 days of feeding. The proportion of injured locules saturates, approaching 100% over time.



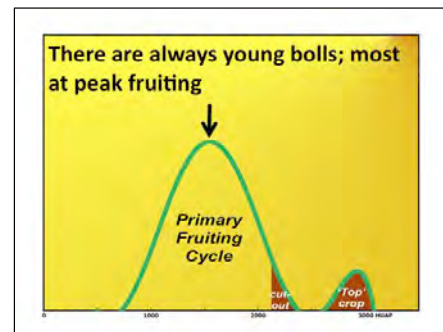
By four days feeding, the majority of locules have been injured by stink bugs as shown by the non-significant trend in the infested balls in the chart on the right. The proportion of injured locules levels off after four days feeding.

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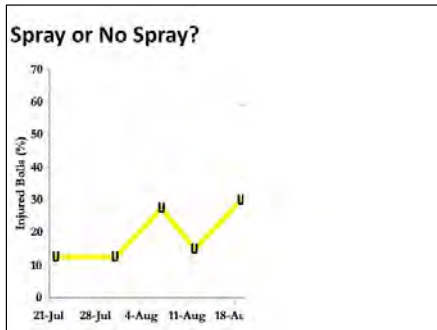
The percentage of damaged locules increased rapidly over the first 4 days of feeding. The proportion of injured locules saturates, approaching 100% over time. So while the proportion of locules injured does not continue to increase, the severity of that damage can still increase.



Our work shows that young bolls are most sensitive to stink bug damage. Protecting young bolls is not the same as protecting the first or early bolls, though this would be a time to make sure that stink bugs or other insects are not contributing to boll shed that might be seen at this time. The largest population of young bolls in need of protection occurs when the crop is at peak flowering. We also found that most damage is sustained in the first few days of feeding. Thus, regular sampling is needed to discover stink bug activity and injury early on in the damage process.

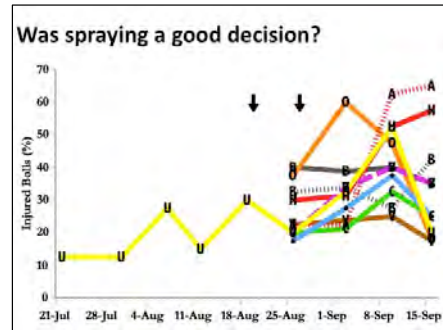
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We also performed chemical efficacy experiments. In the field, we had fairly low stink bug pressure throughout the season. At or near peak bloom, boll damage was at 10%. We chose not to spray because damage levels were low. High fruit retention drove it to cut out prematurely, and it was past peak bloom before 2000 HUAP. We sprayed when 30% of sampled bolls showed injury; by that time, it was headed toward cut out.

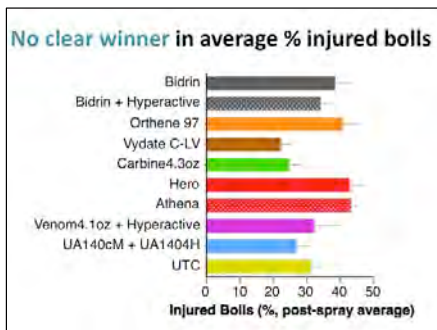
Was our spray effective?



We sprayed twice, a week apart. The only significant difference is in the bolls sampled about 20 days after the second treatment, when the untreated check had some of the lowest levels of injury measured on that date.

The answer is ostensibly "No" it was not a good idea to spray based on these data. These data showed no significant lowering of boll injury among sprayed plots in comparison to untreated plots. In other words, we ostensibly did no better than not spraying at all.

But this is just in boll measurements on each date. Was there any cumulative advantage to spraying?



In looking at seasonal post-spray average boll injury, no chemistry showed clear efficacy in reducing boll injury levels relative to each other or to the untreated check.

This, too, suggests that spraying when we did had no impact on measured damage.

But what about yield?

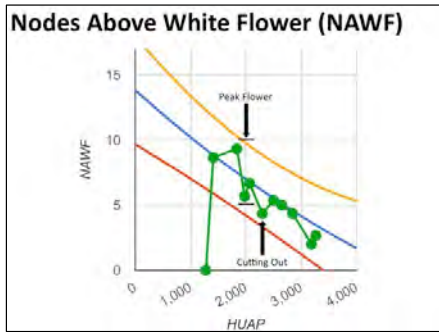
Treatment	Yield (Bales/A)
Bidrin	4.63
Bidrin + Hyperactive	4.86
Orthene 97	4.96
Vydate C-LV	4.75
Carbine 4.3 oz	4.98
Hero	4.50
Athena	4.70
Venom 4.1 oz + Hyperactive	4.75
Experimental	4.75
UTC	4.61

The yields were very high, but not significantly different among sprayed treatments, nor any differences from the unsprayed check.

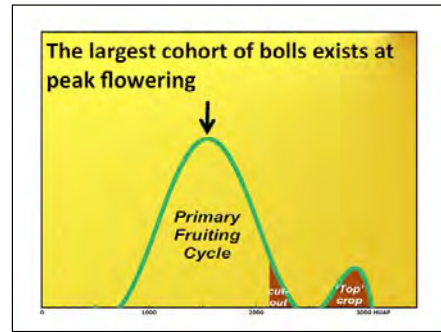
Again, ostensibly, it did not pay to spray when we did. Why?

Perhaps there was an impact on quality and HVI data were collected from these plots and will be analyzed. But assuming there are no differences there, why did we fail to measure any significant differences?

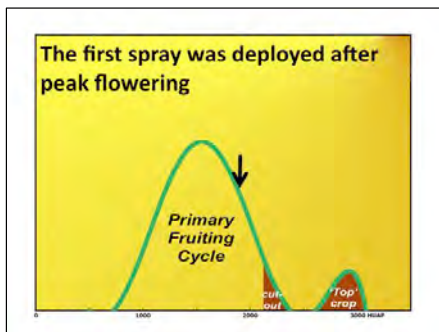
Are any of these compounds capable of killing brown stink bugs?



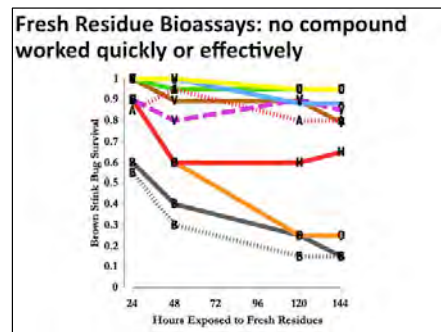
We tracked nodes above white flower (NAWF) in this field. The field hit peak bloom around 2000 HUAP and went rapidly into cut out. As stated in an earlier slide, because young bolls are most sensitive and damage is sustained early in feeding, it is important to protect the largest set of bolls during peak bloom. Our first spray was deployed when the field was driving into cut out. We see from yields and injury levels that our sprays were ineffective.



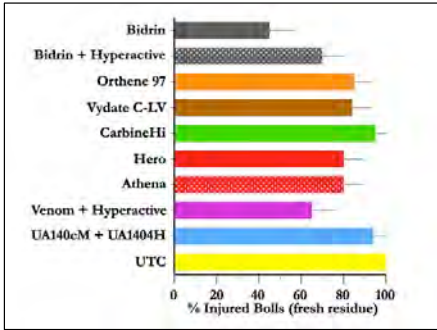
We will never know if spraying this field at peak flowering would have impacted yield or injury. Injury levels were so low at peak flowering that we didn't feel spraying was justified.



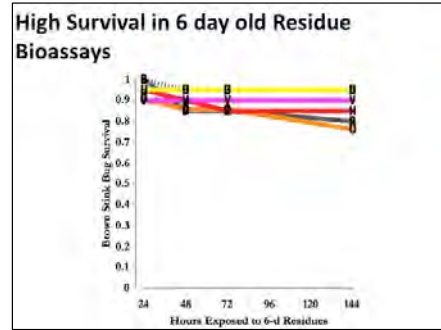
Based on what we know now, we were probably too late in plant development to have had much effect on the largest cohort of bolls, but there were still young, susceptible bolls in the field when we sprayed. 30% may not be a high enough injury level to justify a spray at this particular time. We saw no benefit to spraying at this stage of the fruiting cycle and level of injury. Perhaps there would be more benefit to spraying at another plant stage or injury level, but we cannot know that from these data.



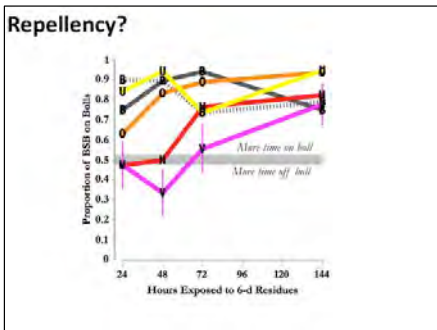
In addition to field sprays, we collected sprayed bolls from the field and caged bugs on them in the lab. The bugs had no food other than the sprayed bolls we provided to them. Mortality was assessed daily. As in the Southeast, the OPs showed the highest efficacy. In the fresh residue bioassays, there was significant mortality in the Bidrin treatments and with Orthene, but it took 5 days to attain about 85% mortality. In the Southeast, they see higher mortality levels much more quickly. They see activity with bifenthrin (a pyrethroid) as well, but here Hero, which is a mixture that contains bifenthrin, only produced 60% mortality, and Athena which also contains bifenthrin did not appear to work at all.



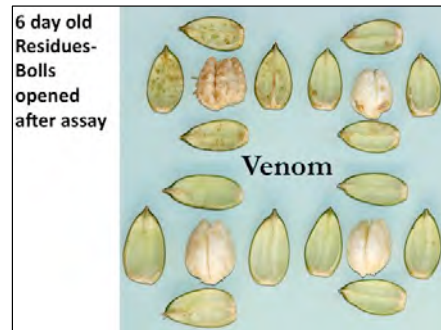
Even Bidrin bolls had more than 40% injured bolls after the bioassay in these confined cages. The bugs had no choice of food, and we found that percent injured bolls is not a very sensitive measure for establishing the severity of damage. We didn't rate locule damage in these bolls, and maybe that would have helped us differentiate between treatments. Percent injury does not give information on the severity of damage. Nonetheless, these results might have suggested that Bidrin, in particular, would have given us a result in the field in either lower boll injury levels or higher yields. Neither occurred. Why?



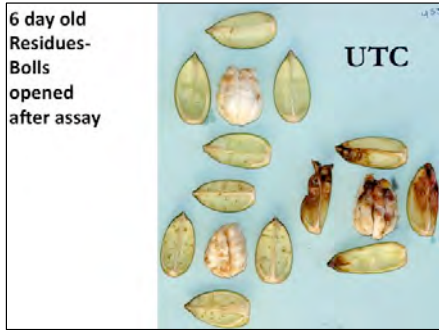
One reason may be the speed of action, which is slow based on the bioassays just shown, and the other reason may be that these compounds are not insecticidal for very long. That fact is supported here. There was no activity in bolls infested 6 days after treatment (6 day residues). I.e., these stink bugs were provided bolls with 6-day old, field-degraded residues on them. Plus, these bolls would have been young, near the top of the plant and largely covered by the enclosing bracts at the time of spraying. Survival was high for all treatments, and none are different. These residues were not insecticidal.



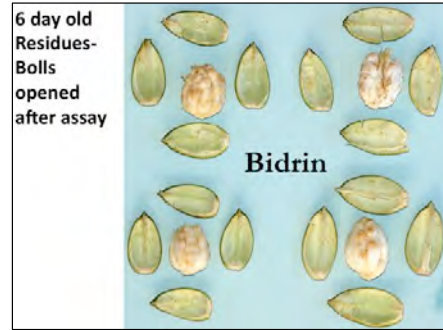
While peering into the cups to check for mortality, we noticed that some bugs seemed to be spending more time on the sides of the cup or on the lid than on the treated boll itself. When we tracked whether the bug was on the boll or not, bugs caged with bolls treated with Venom, and to a lesser extent Hero, initially (for the first 24-48 hrs) spent more time off the boll compared to bugs in other treatments. So despite these residues failing to kill stink bugs, these bugs appeared to be able to still perceive and perhaps avoid the residues on these bolls. Is this one reason why our treatments failed to lower injury rates or increase yields in the field?



Venom-treated bolls visibly showed less damage than the untreated bolls.



Untreated bolls had high damage levels, as expected.



Bidrin bolls showed some damage, but remember that the bugs had no choice of food. However, if mortality had been high and occurred quickly, the bugs may not have been able to feed for very long.



But, as interesting as this potential repellency is, would it be practical in a field setting? The Venom is not actually killing any insects or reducing the population. Where would the bugs go even if they were repelled?

In large structure cotton like we grow in Arizona mid-season, perhaps stink bugs stay below the treated zone for two reasons 1) that's where preferred bolls are developing, and 2) perhaps they are able to perceive and avoid treated residues at the top of the canopy.

Spraying in this trial at the time we started apparently was ineffective, even though most of the preferred bolls were in the upper portions of the canopy.

BSB sampling


- The **ONLY WAY** to accurately survey for BSB is by **popping bolls and examining internal injury.**
- **No AZ thresholds established**

In the Southeast, they recommend sampling 1" bolls. In addition, I suggest monitoring boll shed closely and sampling & opening any shed bolls to investigate natural and insect-related sources of that shed. Keep in mind that these sampling methods and thresholds are for the Southeast and may not apply as well here. We have less risk of boll rot, but aflatoxin may prove problematic.

Considering all experiments

- Must crack bolls!
- Locule ratings are a more sensitive measure
- Young bolls are most susceptible
- Most locules are injured in the first few days of feeding

We have first steps to develop thresholds; would it matter if no effective chemical controls are available?



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We have some understanding now of BSB damage dynamics in cotton. We also have some chemical efficacy data, but none of the chemistry available reduced BSB injury or demonstrated sufficient mortality. We have data now to start developing thresholds, but how valuable are thresholds without effective chemical controls?