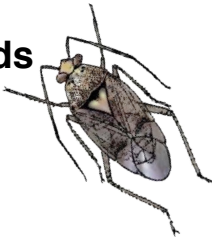




*Beltwide Cotton Conferences
Plant Bug and Stink Bug Management Workshop*

Plant Bug Thresholds in Arizona Cotton

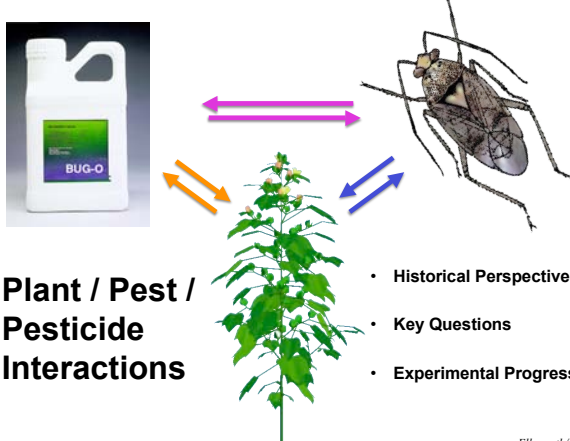
Peter C. Ellsworth
Arizona Pest Management Center /
Department of Entomology
University of Arizona

January 10, 2007 *Ellsworth/UA*

This presentation was invited by organizers of the Plant Bug Management Workshop as part of the Beltwide Cotton Conferences. The subject of this presentation is *Lygus hesperus* thresholds for Arizona cotton.

20 min. / 150



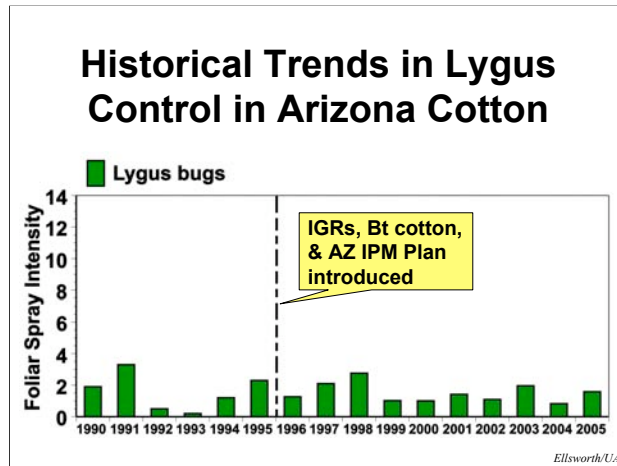
**Plant / Pest /
Pesticide
Interactions**

- Historical Perspective
- Key Questions
- Experimental Progress

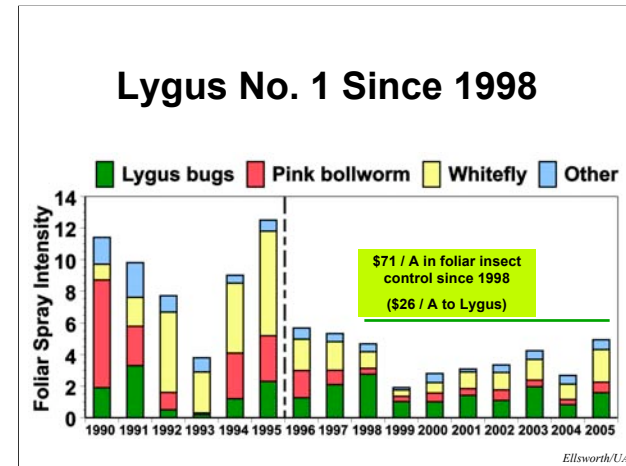
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The development of a threshold for the control of an insect pest is a fundamental aspect to integrated pest management. As straightforward as the practical goal is, however, this development is based on a 3-way interaction among plant - pest and pesticide.

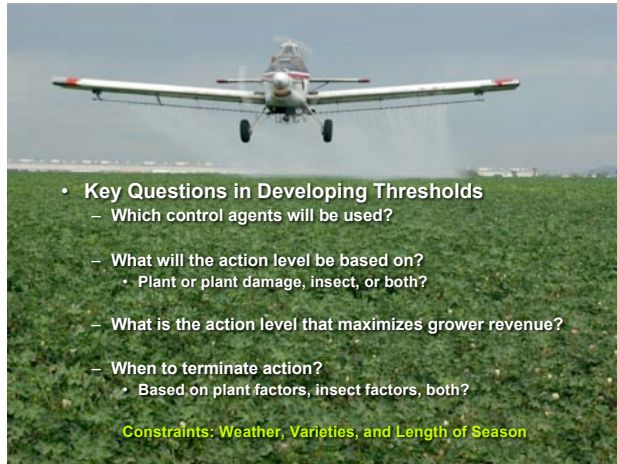
In today's talk I hope to start and end with a bit of a historical perspective, bring out some key questions that need to be asked and answered in the development of a *Lygus* threshold and then review some of the experimental progress we have been making in Arizona over the last 10 years.



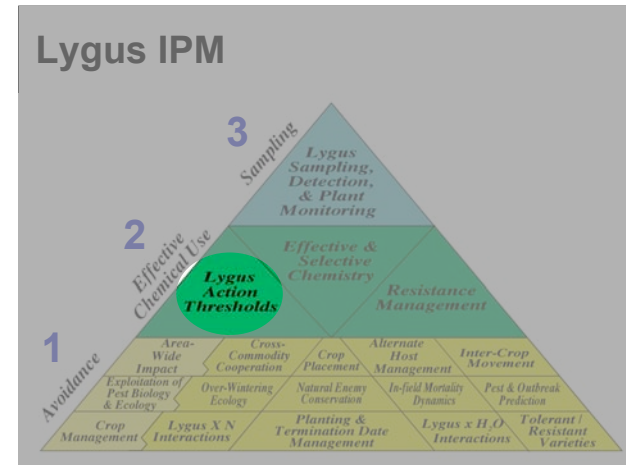
Lygus is not a new pest to Arizona cotton growers. It is one that has been present and at play for a long time. This chart shows the statewide foliar spray intensity for Lygus bugs since 1990. In general, you can see that we have been spraying Lygus ca. 1-3 times per season. This trend appears consistent even after dramatic and major changes to our system. The introduction of Bt cotton and selective whitefly IGRs has not changed the basic need to control Lygus in our system.



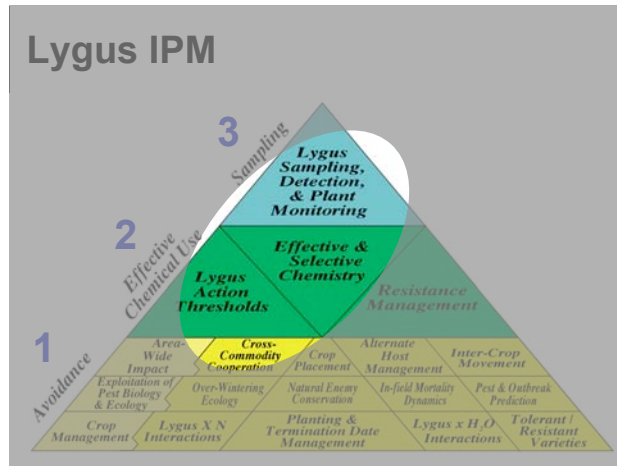
What has changed, however, is the relative status of Lygus, which has been our number one insect pest of cotton since 1998. Lygus has gained in importance simply because it occupies a greater proportion of our spray requirements and budgets. In fact, it is the largest yield threat to AZ cotton.



There are several key questions we must ask and answer if we wish to develop meaningful and practical thresholds for Lygus control...1)... 2)... 3) While we have to build yield relationships to whatever threshold is tested, ultimately, it is necessary to maximize the relationship to grower revenue and not really yield itself, 4)...



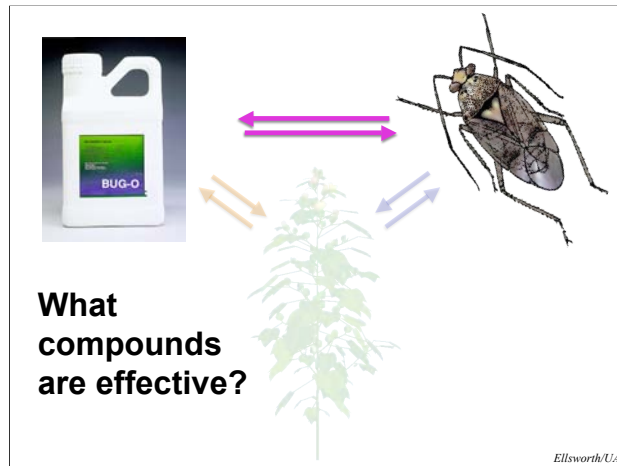
The 3 basic keys to any IPM plan are sampling, effective chemical use, and “avoidance”. And, thresholds are a major building block of any IPM program. However, as revealed in the questions in the previous slide...



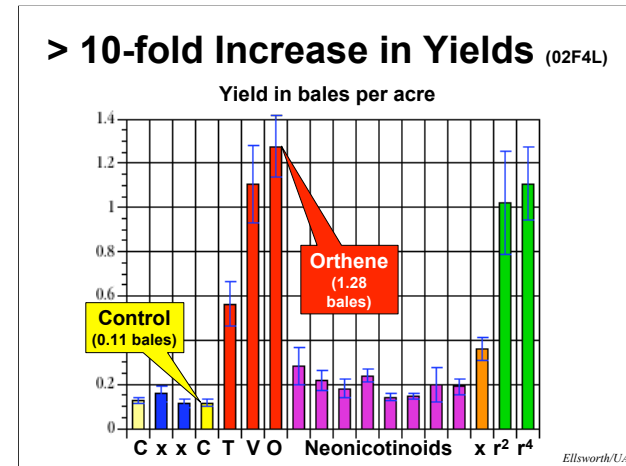
...one can hardly examine Lygus action thresholds without giving due consideration of the chemistry that will be used and the sampling plans that support the system.



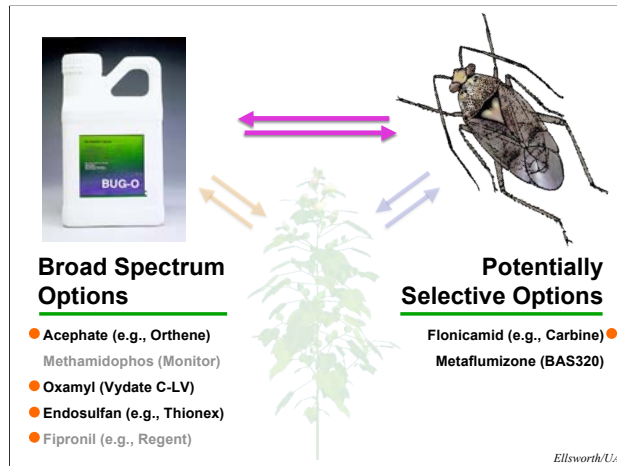
But before I go further, I should point out that major advances in the selective controls of pink bollworm with Bt cotton, and whiteflies with insect growth regulators have enabled our ability to isolate the system on Lygus and develop very specific information. Prior to 1996, it simply was not possible to develop a research plan for development of Lygus action thresholds because of the confounding effects of these other two key pests on our Arizona system. However, now we have essential and nearly complete and selective control of these other two pests.



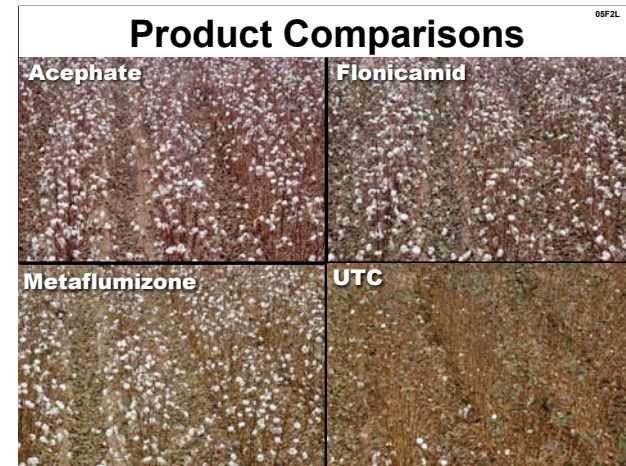
The first question centers around what compounds are effective against the target pest, in this case Lygus. Without a clear understanding of the control system, it is not possible to develop a threshold for the triggering of remedial action.



I will not review the more than 10-yr's worth of efficacy information that we have developed in Arizona. But I do want to let you know that all these evaluations have been done under extreme Lygus pressure where once again we have isolated the impacts on yield to this pest through the use of Bt cotton and selective controls of other insects. In this case, you can see a 10-fold increase in yield where plants were adequately protected against Lygus damage. It is not at all unusual for us to see 3, 4, or 5-fold differences in our efficacy evaluations of this pest.

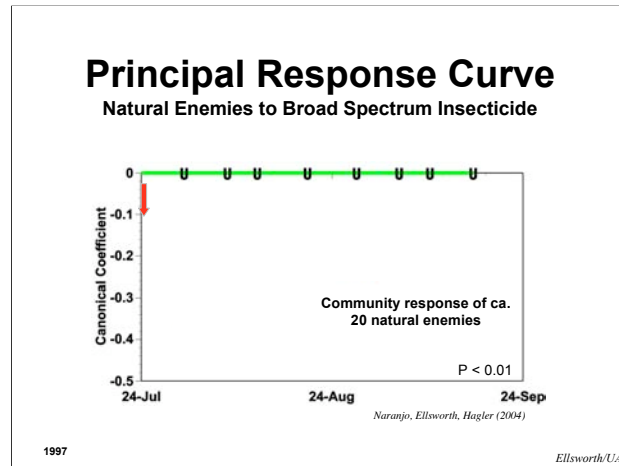


For many years now, we have depended on a set of broad spectrum options. That is, compounds that are effective but are rather broad spectrum in their impact on the arthropods present in the system. These include acephate, methamidophos (which sees little use today), oxamyl, endosulfan, and fipronil or Regent, which does not have a U.S. registration in cotton but is a standard for mirid control in Australia and in Mexico. More recently, we have had exciting new advances with potentially selective options: flonicamid was recently registered as Carbine and is very effective against Lygus, and metaflumizone is on track for registration very soon. These two compounds bring us new chemistry that might in fact be more selective than our traditional, broad spectrum options.

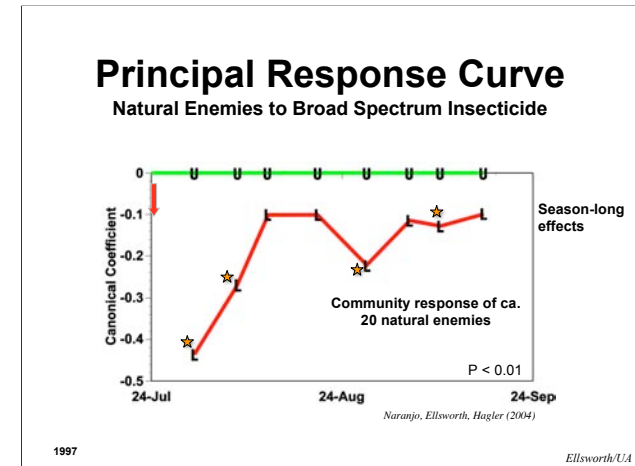


05F2L-T18 Carbine WG (2.8 oz) in NE, Orthene (1.0 lb ai/A) in NW, 320WVI (0.25 lbs ai/A) in SW, UTC in SE; 5-fold yield increase over the Untreated Check.

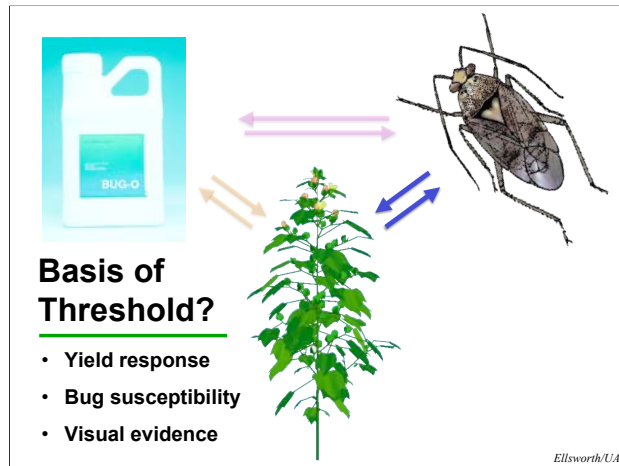
While flonicamid and metaflumizone have performed admirably against Lygus and helped to preserve the yield component in dramatic fashion, a major potential attribute of their use in our system will be to drive more and more to a selective system that helps preserve our natural enemy complex...



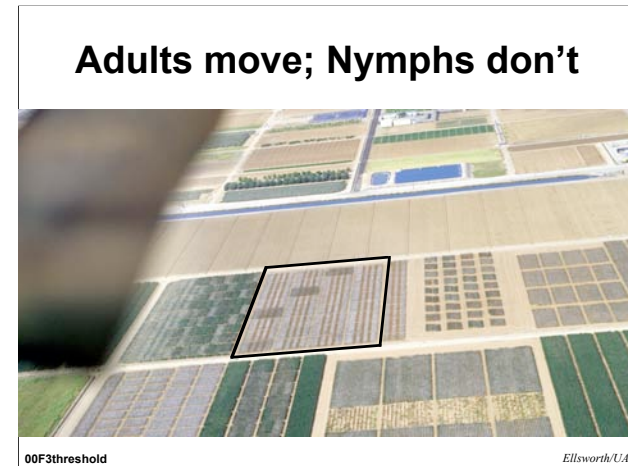
As an example, I would like to briefly explain a multivariate analytic approach that is represented graphically in Principal Response Curves. In this example we can see the green 'U' line representing the UTC as a baseline from which we compare other treatments. In this analysis, we examine the response of an entire community of natural enemies, here about 20 species. 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 I did several years ago with Steve Naranjo and James Hagler...



...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.



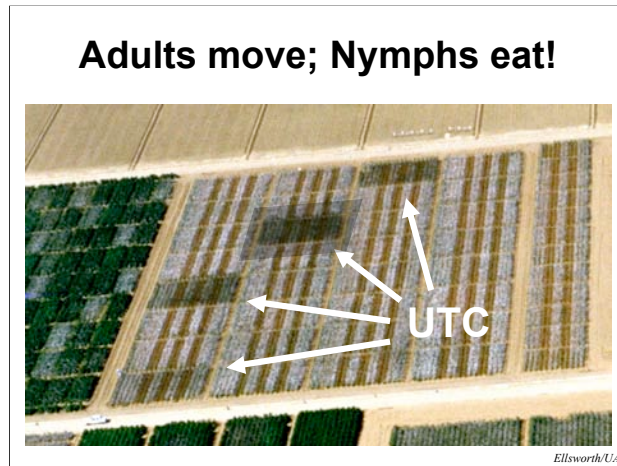
The next question we need to ask is what will be the basis of our threshold? For our Arizona cotton system, we have evidence from efficacy and other studies of yield response and bug susceptibility by life stage; however, our visual evidence provides the most compelling case for the choices we have made in our threshold system...



First, we all know that only adults have wings and therefore only they can move any significant distances. In fact it is unlikely that nymphs move across or down rows very much.

This is an aerial photograph of my 2000 Threshold study. In the outlined area you can see several borders of cotton each with 3 harvested strips taken from them. However, in addition to the 3 dark stripes down each border, we can also see some darker areas of growth.

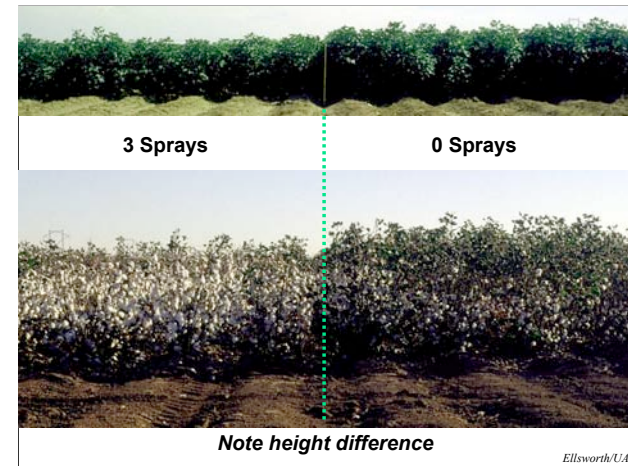
This is photographic evidence that adults are not major damagers of cotton. If they were...



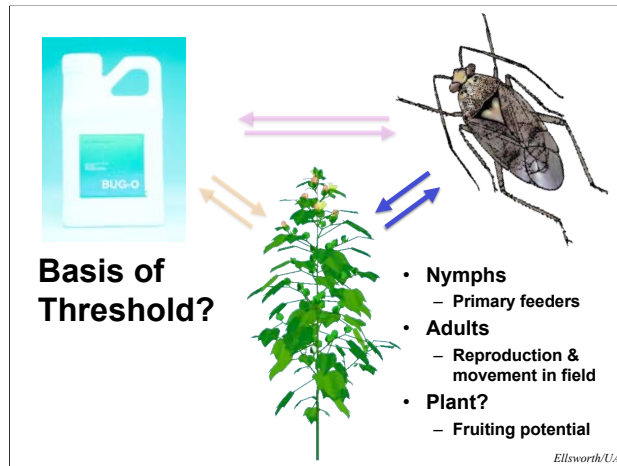
We would expect a halo of damage (as drawn in on plot in center) to develop around these UTC plots due to the frequent movements of *Lygus* adults from those plots. However, the demarcation between unprotected v. adjacent protected areas is distinct. This indicates damage by a plant-bound life form, nymphs. *Lygus* were well-managed in all areas around these untreated plots. Yet, no pattern of damage occurs around these UTC plots.

Indeed, adults do move and probably do eat as well, but comparatively they are in this world to move and reproduce, whereas nymphs have one objective in life, to eat and grow.

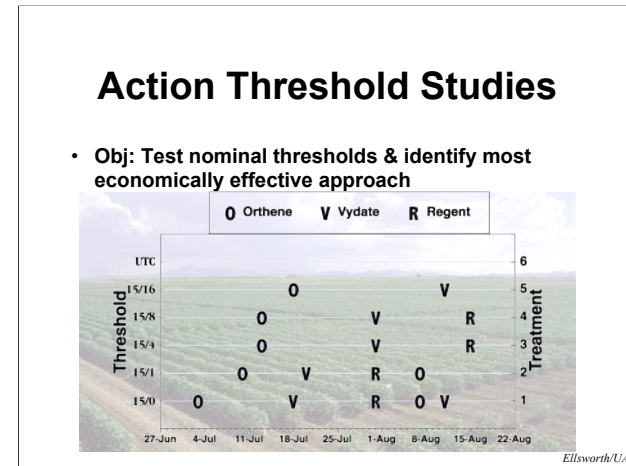
So nymphs have become the basis for development of our threshold system.



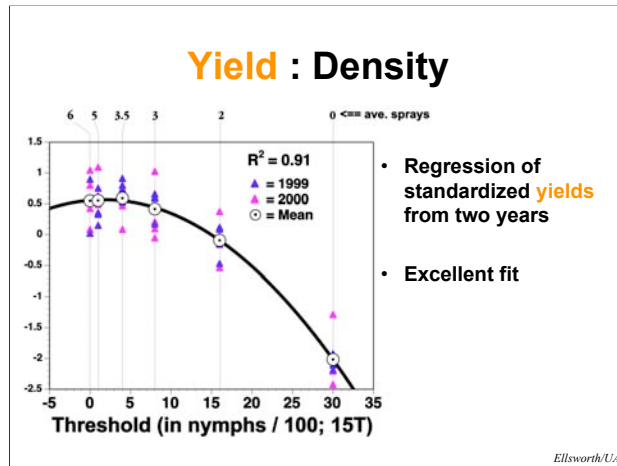
As further evidence, these effects occur over the shortest spatial scale. That is in adjacent rows, shown here in a commercial trial where cotton was sprayed 3 times on the left for *Lygus* and not at all on the right. The height and eventual yield differences we see are as a result of *Lygus* feeding and damage, as these plots were planted to Bt cotton and all other pests were selectively controlled.



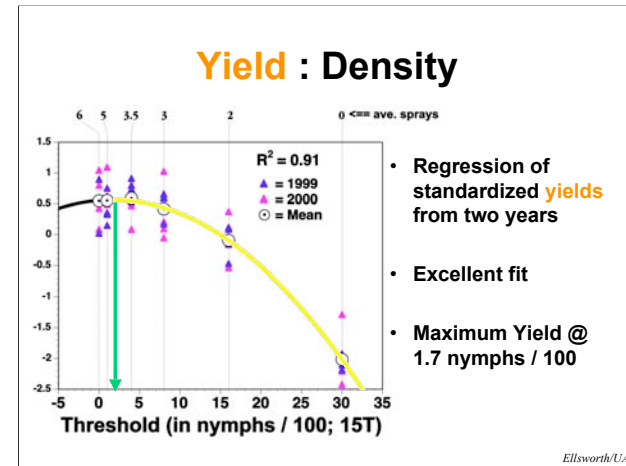
So in our system, the basis of our threshold is nymphs as the primary feeders in the system; however, adults are also considered and are of course key to the reproduction and movement in the system. What we have not done as yet is incorporate any plant-based factors such as fruiting potential.



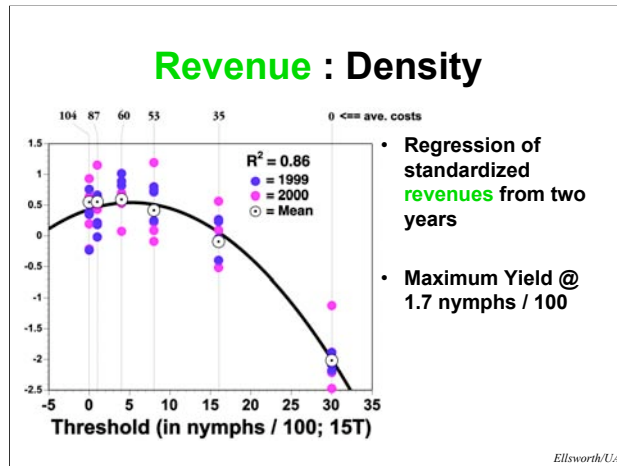
In some range-finding experiments in 1997, we found that 15 total lygus per 100 sweeps was associated with our yield protection. So starting in 1999, we initiated trials where we tested nominal thresholds that had as a criterion that there be at least 15 total lygus per 100 sweeps with varying numbers of nymphs contained within these samples. Specifically, we looked at 15 total Lygus with 0 nymphs, 1 nymph, 4 nymphs, 8 nymphs, and the nonsensical 16 nymphs per 100 sweeps. We then triggered applications of Lygus-effective insecticides in a set rotation of chemistry.



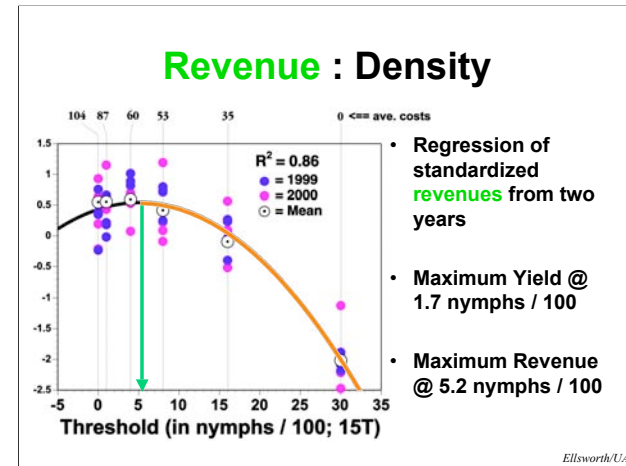
After two years of study, we conducted regressions of standardized yields using a 2nd degree fitted polynomial (quadratic). The fit was excellent...



From this relationship, we can examine the point of maximum yield, which occurred at 15 total Lygus with ca. 1.7 nymphs per 100 sweeps. Of course, yield is only partly the answer,...



To understand the point of diminishing return, we developed this regression that shows the relationship between standardized revenues and our tested thresholds.



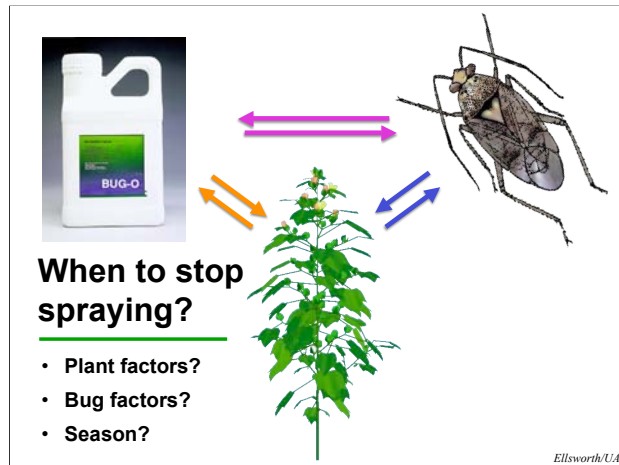
Following this curve to its maximum, we see that more money is made when a threshold of 15 total Lygus with 5.2 nymphs per 100 sweeps is observed. Furthermore, this basic relationship held up under a huge variety of cotton economic conditions (\$0.20-1.20 / lb). So these studies have given rise to our current recommendation which is intentionally set to be somewhat conservative to guard against excessive yield loss...



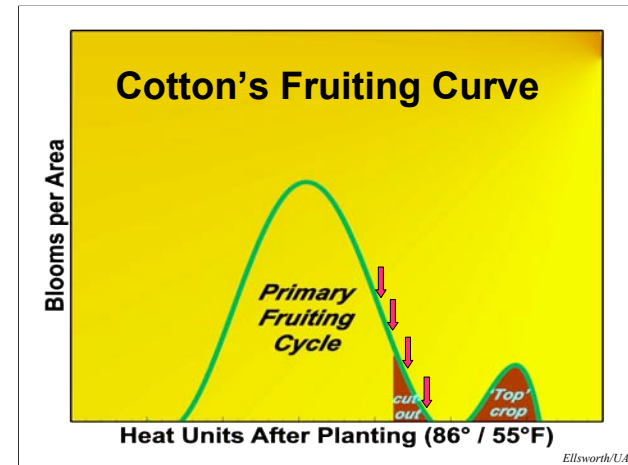
This so-called '15:4' threshold represents 15 total Lygus per 100 sweeps with at least 4 nymphs per 100 sweeps. I should add here that a sweep-net is a standard method used by our consulting community in Arizona. It is widely used and we don't have limitations of early morning dews that cause the sweep bag to get too wet to efficiently sample.



Note that the 15 in the 15:4 represents the total count of Lygus (and not just the adults), and that both components must be satisfied in order to properly interpret the threshold. That is, there must be at least 15 total Lygus, but also, there must be at least 4 nymphs per 100 sweeps. When these conditions are met, a grower is advised to spray; short of this, he/she should continue to wait and monitor the situation. Even at 15:4, I advise growers to consider the abundance of natural enemies, other pests, and fruiting potentials. These factors could serve to further delay or hasten an application. I do work with some growers that are very comfortable with 15:8 and routinely average over 3-3.5 bales / A on their acreage.



Threshold work is not done, however. Once a threshold is established, at a minimum, one has to consider under what conditions should spraying be stopped. Decision-making could potentially be based on plant factors, bug factors, or elements related to length of season remaining (environment x variety).

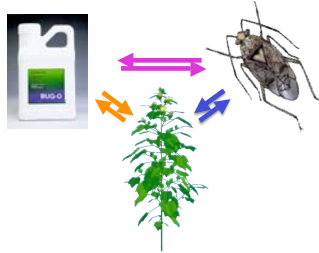


This is a graphical depiction of Cotton's Fruiting Curve expressed as blooms per unit area over time (HUs). In AZ cotton, we do have the capacity in some varieties to grow a second or true top crop after crop cut-out. Some growers manage irrigations to mature out the primary fruiting cycle only, while others elect to continue irrigations to mature out the top crop.

So experimentally, we set-out to examine 4 different Lygus chemical control termination timings centered around initiation of cut-out, where cut-out is defined as $NAWF \leq 5$.

Lygus Termination Studies

- Obj: Identify best timing (of 4 tested) for discontinuing Lygus chemical controls
- Compare 12 different production scenarios (3 x 2 x 2)
 - Variety (S, M, L)
 - Planting (Opt., Late)
 - Irrigation termination (Opt., Late)



Ellsworth/UA

However, given this 3-way interaction, it seemed important to consider different production scenarios that influenced season length and fruiting potential. So we looked at 12 production scenarios in a factorial arrangement of varieties (short-, medium-, or long-season), planting dates (optimum or "early", and late), and irrigation termination (optimum or "early", and late).

This was an ambitious plan and results in some extensive data that I wish to share with you. Mind you, my goal will not be to examine each point today, but to look at broader trends. So don't panic when the screen fills with data.

Timing Late Season Controls

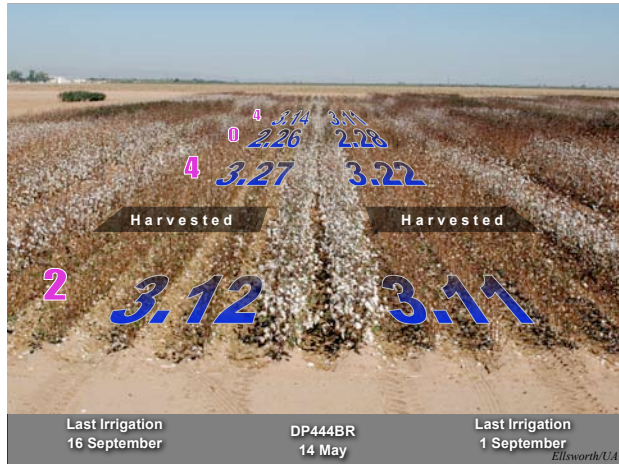
(when should you stop spraying?)

Lygus Termination (LT)	Spray Dates				
	5-Aug	16-Aug 2 wk < c.o.	23-Aug 1 wk < c.o.	6-Sep 1 wk > c.o.	20-Sep 3 wk > c.o.
LT4	•	•	•	•	•
LT3	•	•	•	•	
LT2	•	•	•		
LT1	•	•			

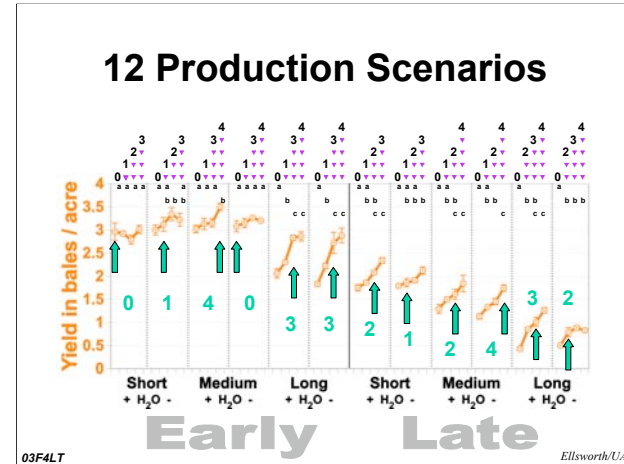
c.o. = cut-out or nodes above white flower = 5

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In a range-finding experiment that we conducted in 2002, we looked at 4 chemical termination timings that resulted in a varying number of sprays as shown here, 2–5 sprays. After this initial pilot test, we settled on 3 timings to test and included an UTC for comparative purposes.

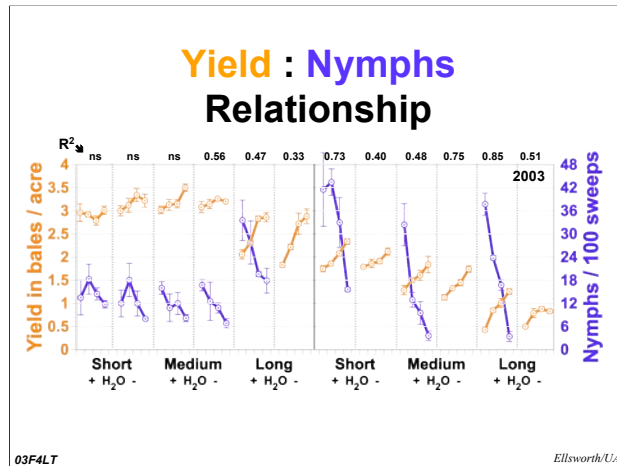


And before I share the data with you, I'd like to show you how these production scenarios were implemented in the field. In this case (2005), we are looking at a 12-row whole plot of a short-season variety, DP444B/R, that was planted late (14 May). This shot is after our machine harvest of the two subplots. So 4 of 6 rows were harvested out in each case where irrigations were stopped earlier (on the right) or later (on the left). The numbers you see represent the total number of Lygus sprays made to these plots. Yields were good in the 2-spray plots, not statistically better in the 4-spray plots, and off 1 whole bale in the UTC. You can even see the darkened area where the UTC was much more rank than the surrounding cotton. Note, too, that this short-season variety did not respond to the added water.

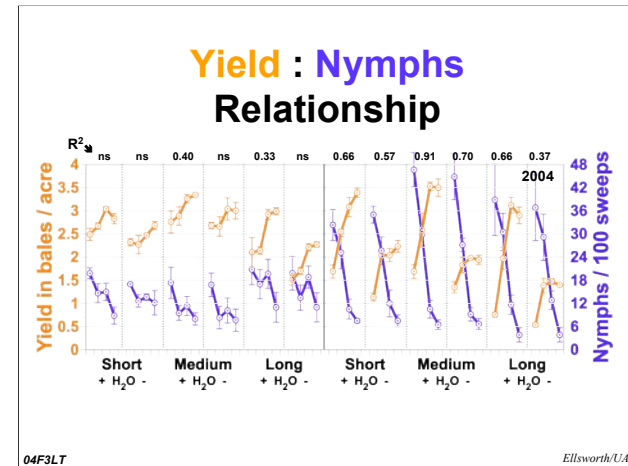


So let's look at the yield data (in bales / A) for these 12 production scenarios, early planted for the 6 cells on the left and late planted for the six on the right. Yields are plotted for each lygus termination timing and the number of sprays are shown above; for the two irrigation termination timings, either with more water (on left) or less water (on right) sides of each cell.

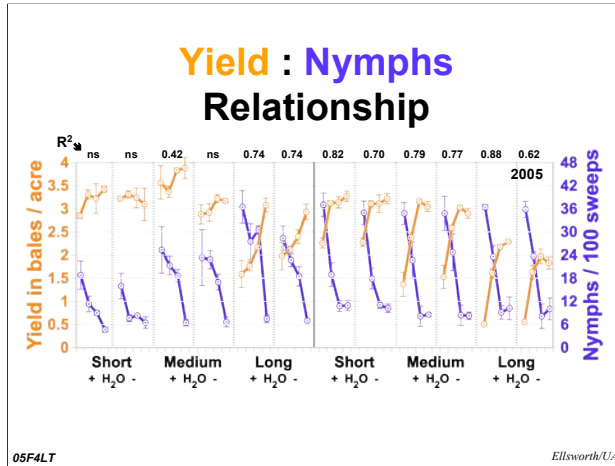
As we reveal each cell, you can see how yield potential was consistently greater as we adopted a more normal planting date and as we moved to more determinant varieties. The green arrows and numbers indicate the statistical break-off points where additional sprays failed to return significantly more yield.



Make note here that where yields are highest among the production scenarios, that's where revenue is the highest. Later on, I will show you relative, marginal revenues, that focus on incremental improvements over the poorest outcome for each variety x irrigation scenario. But before we do, let's look at the relationship between nymphs per 100 sweeps (blues on right scale) and yield (bales/A on left scale, orange). There appears to be a very good correspondence between the two measures with yields going up as nymphs go down. In fact, the R² for the simple linear regressions are quite good in most cases and highly significant. This is the 2003 data.

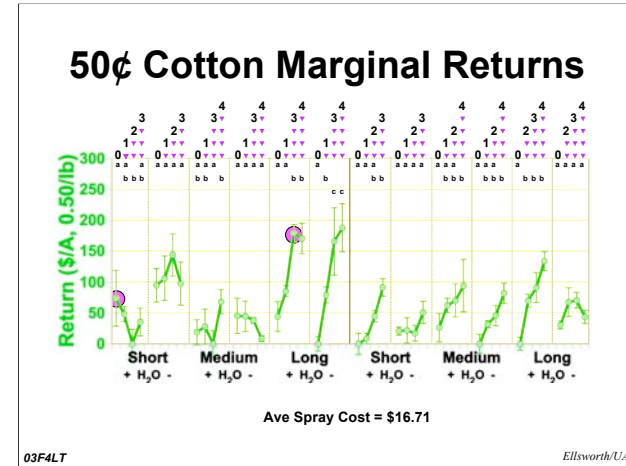


A different year (2004) with some different yield outcomes — in this case, the late planted varieties responded much more to the added irrigations than in 2003. However, the overall relationships between nymphs and yields is once again very impressive for very simple linear regressions. Note, too, that nymphs were usually the best predictor of yield, though occasionally the regressions were improved somewhat when adults were added in as well. Adults by themselves were very poor predictors of yield.



In 2005, we hit yields as high as 4 bales and as low as 0.5 bales. And the yield : nymph relationships held up with very high degrees of fit.

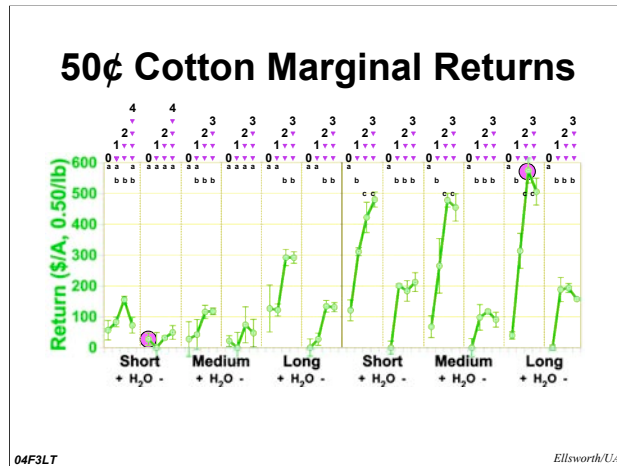
Of course, as stated before, yields are only part of the answer. We need to look at revenues as well. The data I am about to show is still being analyzed.



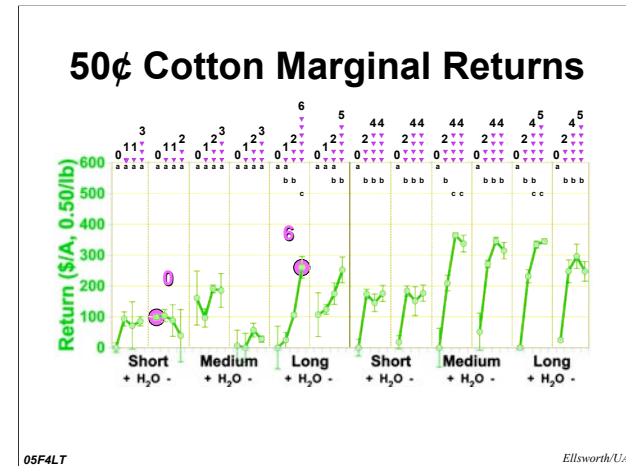
Looking at 50¢ cotton, and comparing each pair of cells (variety x planting), we get this relationship. My goal was to look at what happens after a grower plants. This fixes his variety and his planting date. His decisions after this relate to when to terminate irrigations and when to terminate Lygus controls. So each pair of cells shows the amount of revenue above the minimum baseline for each pair of cells.

Clearly, sometimes no action is the best, most profitable course (late irrigated, short-season cotton planted early); other times, more aggressive action is called for as in the late irrigated, long-season early planted scenario.

Lygus spray costs were held to \$16.71 per spray (5-yr ave.; and includes application costs). One extra water was priced at \$12, but this varies widely across the state.



Again in 2004, the additional irrigations in the late planted scenarios really paid off and especially so, if protection against Lygus was also extended. However, the short season system (early planted and early terminated) failed to benefit by any additional Lygus control.

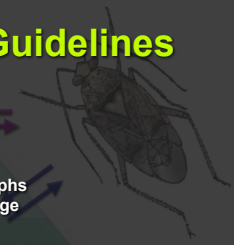


In 2005, we got our greatest contrast where as few as 0 sprays were indicated and as many as 6 sprays were warranted depending on the production scenario.

As I said, we are not done analyzing this data as yet. But what is clear is that this 4-way interaction (planting date, termination date, variety, and Lygus control termination) late in the season is dynamic and complex. Yet there are huge pay-outs possible if the "right" decisions are made.

Arizona Lygus Guidelines

- Before 1997
 - Ca. 15–20 Lygus / 100 sweeps
- 1998
 - 15–20 total Lygus / 100 with nymphs present and/or 25% square damage
- 1999
 - 15–20 total Lygus / 100 with ca. 1/3 of total being nymphs
- After 2000
 - '15:4' or 15 total Lygus with at least 4 nymphs per 100 sweeps
 - Consider natural enemies, fruit retention and damage levels
- Termination rules?



Ellsworth, U.A.

To summarize a decade's worth of threshold research with this insect, let me review our cotton guidelines. Prior to 1997, we adopted a long-standing recommendation to spray when there were 15-20 Lygus / 100 sweeps. In 1998 this was altered to include mention of nymphs and the possibility of using a plant-based measurement system (25% internally damaged squares). By 1999, the nymph fraction was suggested to be 1/3 of the total count. After 2000, we have been teaching the '15:4' threshold and further suggested that other factors be considered.

As to termination rules, these have turned out to be less uniform than what would have been convenient and more sophisticated modeling and/or statistical / economic approaches will be applied to these data in the future.



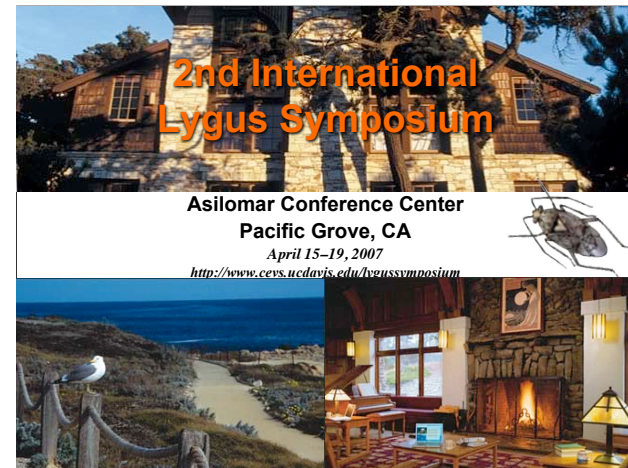
Many, many people contribute to and support our research and extension efforts. I wish to thank them all and especially to those that shouldered the biggest burden of doing the thousands of sweeps necessary to collect the samples for these studies and to Virginia Barkley who manages our crews and laboratory each year.



Thanks, too, to Cotton Incorporated and especially to Dr. Pat O’Leary who supported much of this work as has the two grower organizations in our state, State Support Committee of the Arizona Cotton Growers Association, and the Arizona Cotton Research and Protection Council.

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, including a PDF version of this presentation for those interested in reviewing its content (<http://cals.arizona.edu/crops>).

Photo credit: J. Silvertooth



One final note of advertisement! For those scientists, interested growers and consultants, I’d like to invite you to attend the 2nd International Lygus Symposium in beautiful Pacific Grove, CA, hosted at the wonderful Asilomar Conference Center. The location is spectacular on the Monterey coast, and the scientific exchange that takes place with participants from around the world should prove very beneficial to anyone wishing to learn more about Lygus and their management in an array of cropping systems. Please join us 15–19 April 2007.