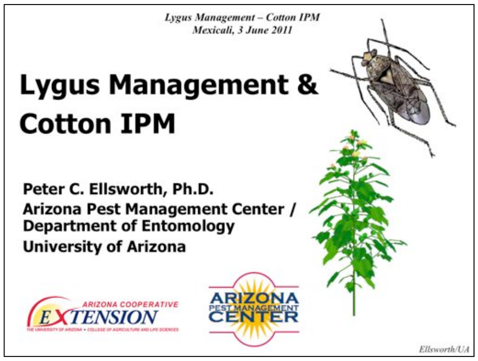
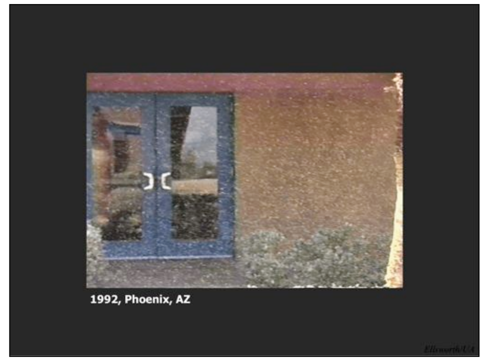


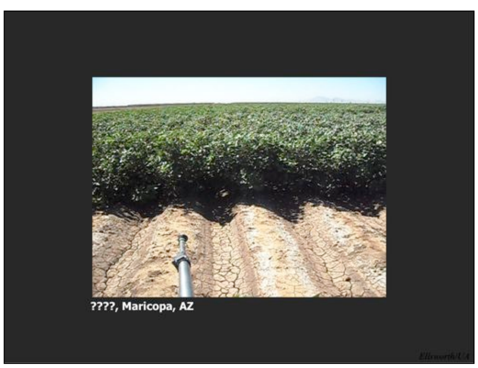
Yesterday, my comments focused on chemical control of this key pest of Arizona cotton. Earlier this morning we reviewed scouting measures for Lygus and whitefly in the field with a subset of you. Today, I will recap some of yesterday's comments for the benefit of the new people in the audience and then concentrate on the other important elements of a Cotton IPM program with emphasis on Lygus management.

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

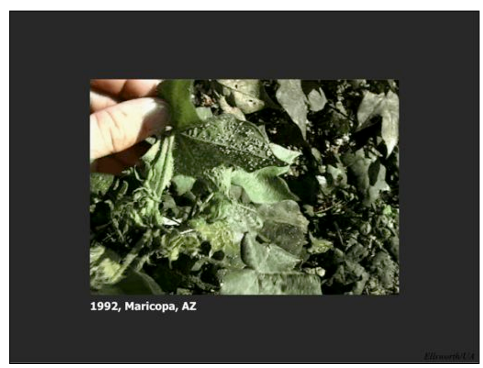


This was the scene we were facing when the invasive B-biotype came to Arizona. The numerical pressure was overwhelming and impacting not only agricultural areas, but also Arizona's largest city, Phoenix, as seen here on the campus of a local college.

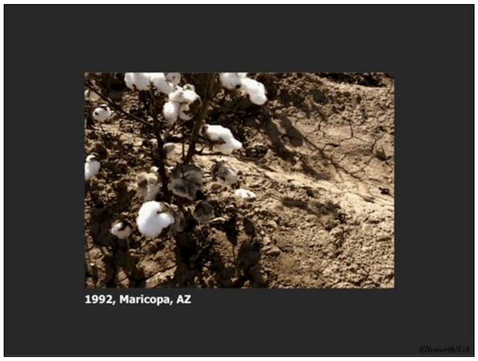
This is a tangible example of how local dynamics ultimately feed into areawide problems.



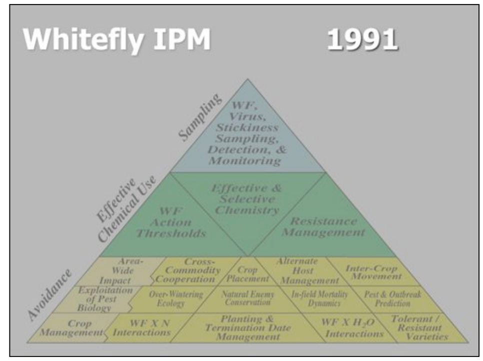
But when was this video shot? (Answer: September, 2010 in experimental manipulated plots, a set of bad decisions!!) This tells us that the same factors that were operational in the early 1990's could still be operational today, if not for the superior practices that were in place on a field-to-field basis and creating areawide benefits for all (I.e., lower pressure).



This "new" pest attacked many different crops. Here, adults cover the surface of a cotton leaf, and the immobile immatures (eggs and nymphs) encrust the leaf underside. When this first happens in a region and is unfamiliar to growers, what do you do?!



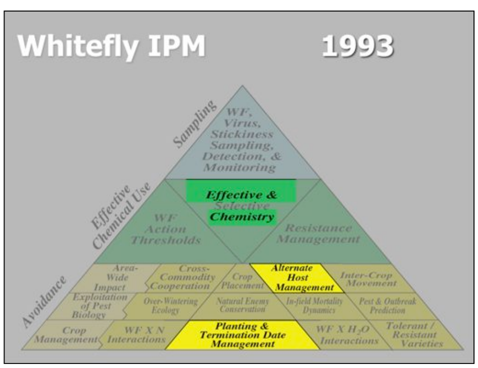
Our largest challenge was to protect the major summer crop, cotton, from unacceptable losses of quality due to honeydew and sooty mold contamination. Without doing so, the entire AZ cotton industry would develop a hard-to-shake reputation for producing contaminated or "sticky" cotton. So this really is an industry-wide challenge. Individual practices are important, but are not enough to protect any area from suffering significantly lower prices in the cotton marketplace if only a few people fail in their whitefly management program.



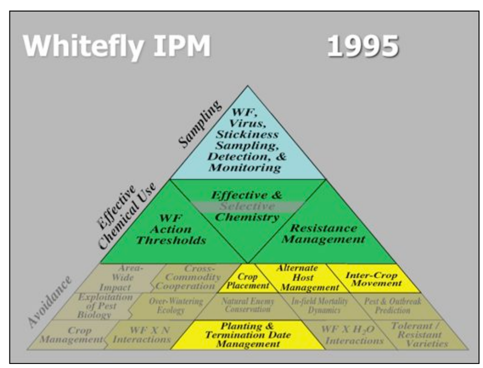
We were starting from nothing in 1991.

The form that our IPM plan takes today was not even conceivable with the severe pressures we were facing and the vast gaps in our knowledge base that were present at the time.

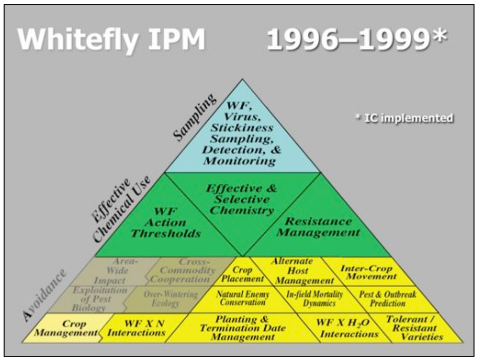
An entire scientific industry mobilized to address the problem, and Dr. Steve Naranjo and I began our collaboration with each other as well as with many other academic and industry stakeholders.



By 1993, we at least had identified some commercial chemistries that could be used to combat this problem. We had some idea of the alternate host interactions that were present in our desert agro-ecoystem and were faced with telling growers to shorten their season at all costs to avoid major damage from whiteflies.

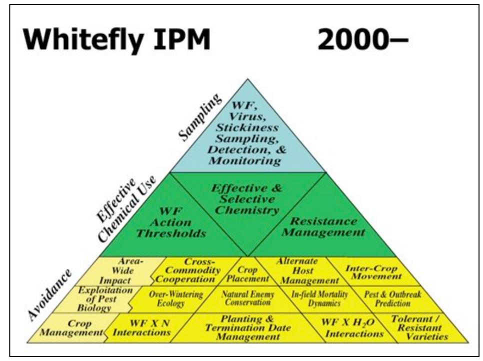


By 1995, we had major progress in the upper layers of the IPM pyramid, in sampling and chemical use. We were also gaining more insight into the areawide impact of whitefly movement and crop placement.

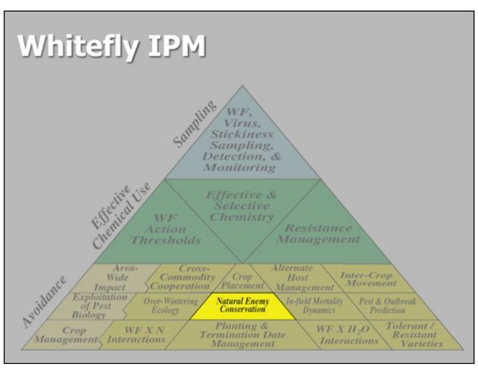


In 1996, we introduced some key selective chemistry that changed everything for us. It enabled a broader base of avoidance tactics, and we were well on our way to stabilizing a previously and seriously destabilized system.

This was the beginning of functional Integrated Control in the Arizona cotton-whitefly system.

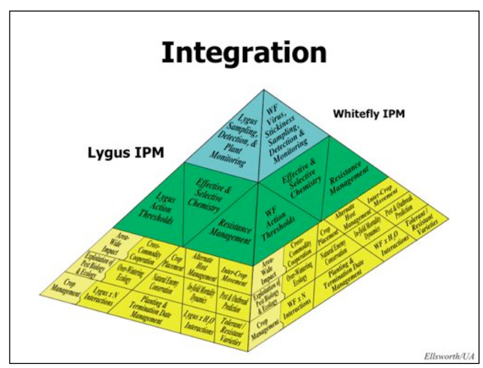


By 2000, we had installed some critical cross-commodity agreements among cotton, vegetable and melon producers and our IPM plan came into full focus. This pyramid metaphor serves as our heuristic representation of whitefly IPM in Arizona cotton. This continues to be our operational IPM plan. At its simplest, it is just 3 keys to management, Sampling, Effective Chemical Use, and Avoidance. One can break this down further and examine each building block of the pyramid and see an intricate set of interrelated tactics and other advances that have helped to stabilize our management system.

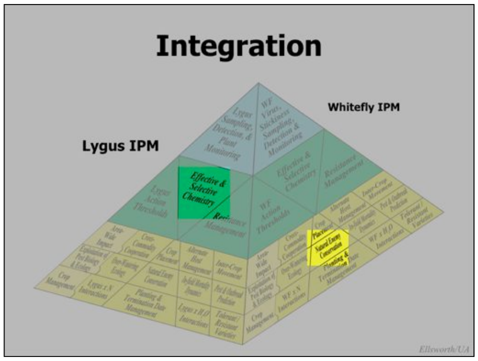


Based in over a decade of research that Steve Naranjo and I have conducted in the AZ cotton system, we can show that NE conservation is central and key to enabling a more sustainable IPM plan for whiteflies.

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

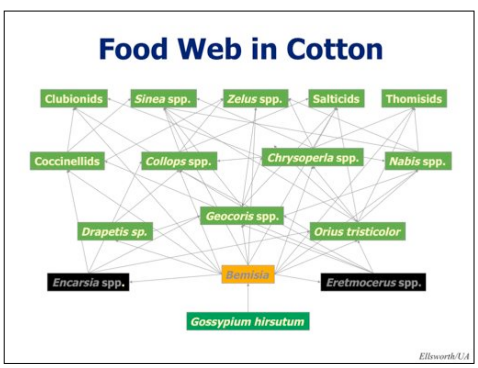


However, IPM is never singularly practiced on only 1 pest. We have to consider interactions with control measures and management approaches for other pests, in this case Lygus.



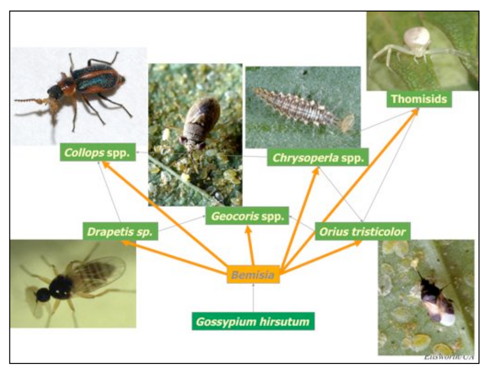
And, we have demonstrated as recently as that 2010 video that the control decisions made for Lygus can have drastic impacts on the NE fauna that we depend on for whitefly suppression.

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



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

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



Over many years of intensive field study, Naranjo and I have found that most often one or more of these six predators dominated the relationship between whiteflies and their predation.

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

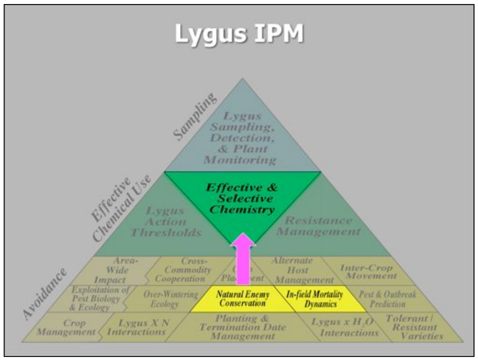
Collops beetle.

Big-eyed bugs.

Lacewings.

Crab and other spiders.

Minute Pirate bugs.



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

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

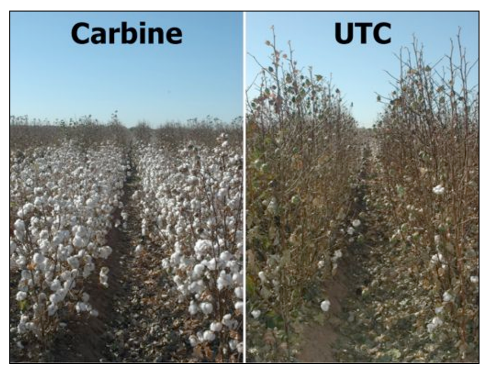
Typically our small plots are 12 rows by about 35 or 40 ft. Even so, evidence of down to the inch control is quite pronounced as we look down a series of borders at various treatments.

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

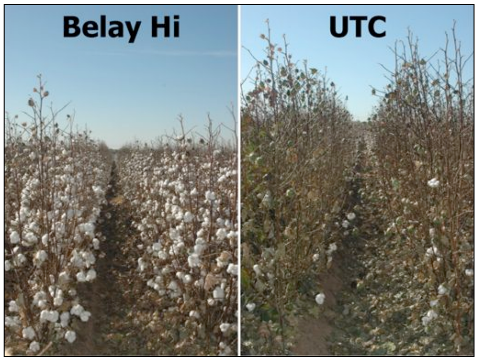
2004, Border 93

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

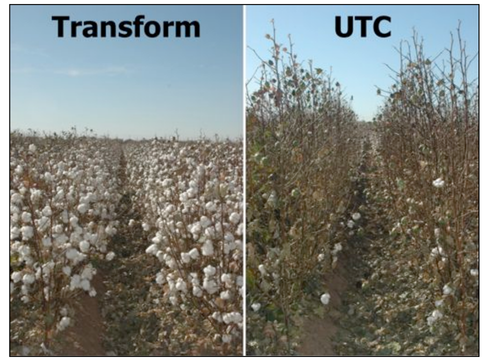
2009



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

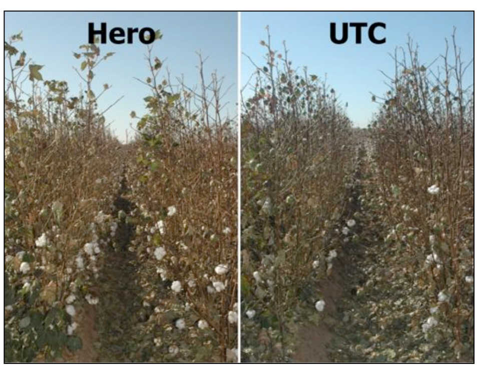


Belay (6 oz) was registered in 2010. Control was very good though somewhat less than Carbine. We suggest it as a partially selective rotational partner to Carbine, especially if a grower expects a need for more than one or two Lygus sprays in a season.

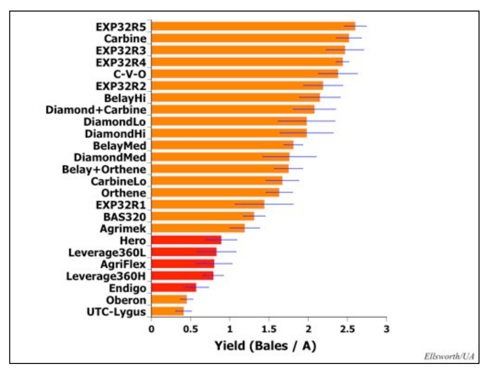


Here is Transform (sulfoxaflor) used at a very high rate and showing very good Lygus control. Note the huge difference in plant heights. When Lygus are not controlled, fruiting positions (and fruit) are lost. Then all the energy the plant produces goes into unproductive vertical growth. Tall cotton is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

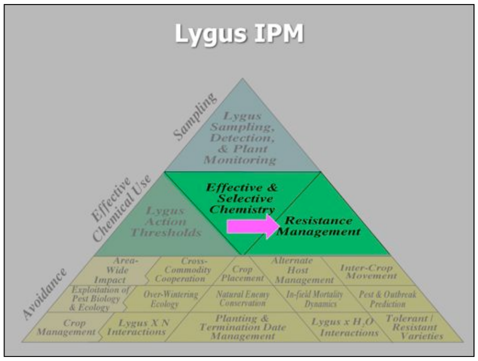
We are still testing the selectivity of this compound, but are hopeful that it will prove to be both effective on Lygus and selective on beneficials, and available for commercial use in cotton in the U.S. in 2012.



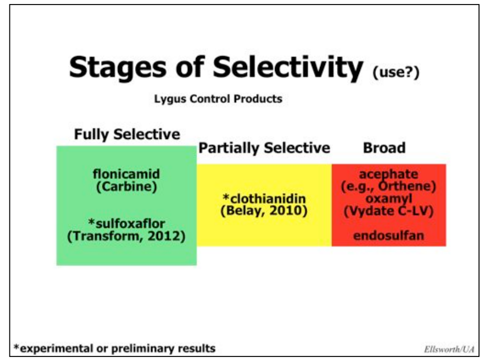
Pyrethroids still don't work in our system against Lygus in cotton. Every so often, people argue this point with me. So periodically, we re-examine this in trials. This time we chose to use Hero, a new very active mixture of two pyrethroids (you can think of it as Capture mixed with Mustang). As you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



These are all pyrethroid containing treatments. None performed well.

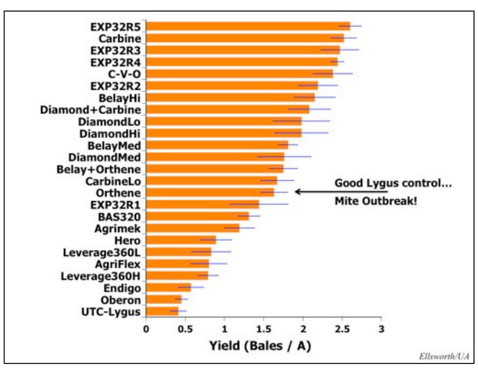


Stewardship of effective and especially selective chemistry demands a program of resistance management that will help us preserve the usage of all chemistry for generations to come.

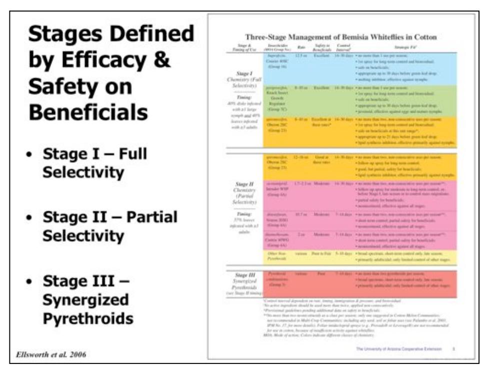


So we have options today that we did not have just a few years ago, fully selective ones, partially selective ones, and broad spectrum standbys that are also effective and provide value to us especially late season.

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



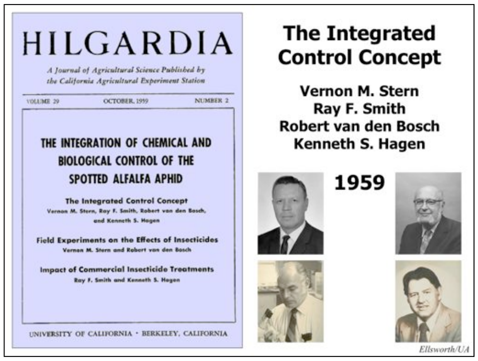
Returning to the yield data, note that Orthene, which is a very effective Lygus chemical control, is off the yield-leaders by about 1 bale / A. This illustrates the added risk of using a broad spectrum material to control our cotton pests. Even if effective, they place the system at risk for secondary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



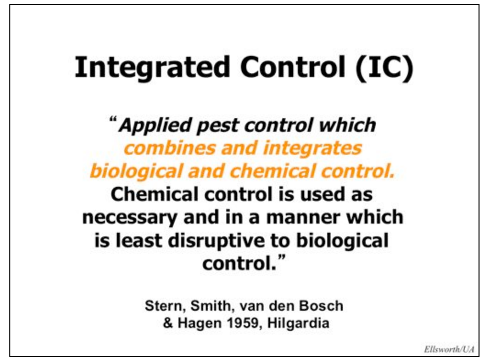
This sort of organization is familiar to our growers who have consulted our whitefly guidelines, because they reflect efficacy against the target (whiteflies) and safety on beneficials, too.

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

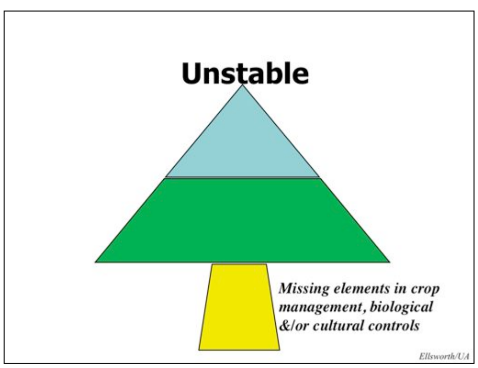
Not surprisingly, we wish to construct parallel recommendations for Lygus as soon as testing is



The Integrated Control Concept was published by Stern and his Californian colleagues in Hilgardia some 50 years ago. Their experiences were in field crops in California including alfalfa, cotton and safflower. The insights provided in this paper form the conceptual basis for IPM today. The pest that drove them to the brink was Spotted Alfalfa Aphid in alfalfa. They used parathion and malathion to control it, but Stern noted this practice as terribly damaging to the NEs present in the system. Then, Systox became available, an OP with some rate-sensitive selectivity and this formed the basis of Stern's new management system where chemical controls were effective but also selective.

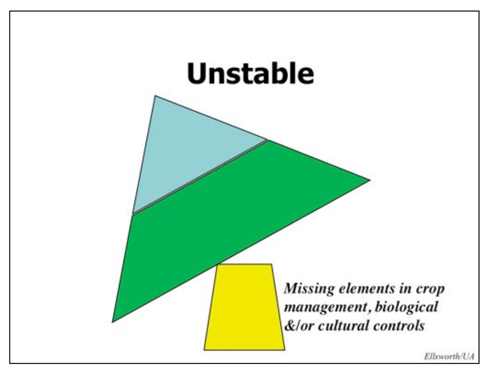


They called it Integrated Control back then. We have further evolved the concept to Integrated Pest Management. But this is how Stern described IC more than 50 years ago.



We should also acknowledge the structure of this management system. It is based in crop management, biological and cultural control as well as other prevention practices.

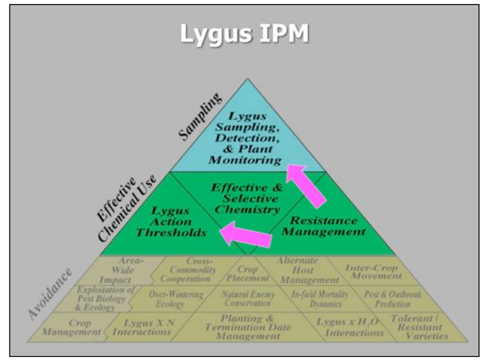
As such, if we are missing key elements in crop management, biological and/or cultural control, the system is inherently unstable and unsustainable.



The steps for realizing the Integrated Control Concept were very clearly laid out by Stern and colleagues in 1959:

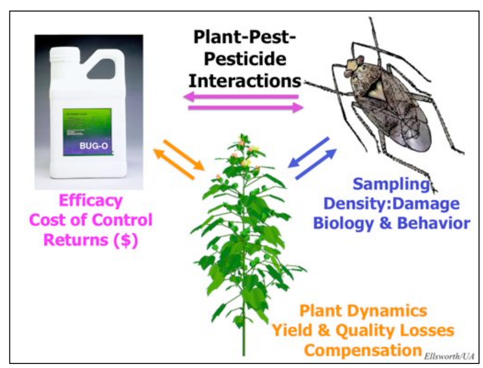
You need economic thresholds, rapid sampling methods, and selective insecticides.

Initially, we had none of these things in place for whitefly management. But even for Lygus, a long-time indigenous pest, we needed to develop this key information. Our challenge was to envision a new system and develop the scientific and practical assets necessary to overcome this problem.

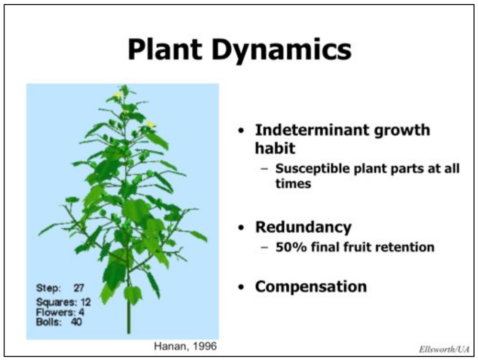


Proper guidance for use of these chemical tools requires efficient sampling plans and economically relevant action thresholds.

By using Bt cotton to control pink bollworm selectively (and having no effect on Lygus) and by using whitefly selective IGRs, we were able to isolate the control system just to the pest of interest, Lygus. Historically, it is rare to be able to isolate on one pest's action in a field situation. Consider that 40 years ago in AZ and in CA, growers, ag-chem suppliers and academic scientists vociferously debated whether Lygus was a pest or not! But also consider, there were many pests at that time that required sprays including boll weevil, pink bollworm, bollworm/budworm, even cotton leafperforator. As a result, it was very difficult to parse out the impacts of each in the system. Not so here, where we have had

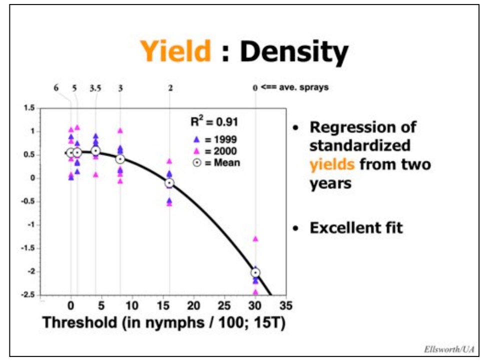


This topic is influenced by a 3-way interaction of plant, pest, and pesticide. By the time a solution is formulated, a grower and PCA will need to consider the plant's development, potential for yield loss and compensation; the number of Lygus present, the damage they cause, and the timing of their entry and eventual exit from the cotton field, which occurs naturally each year as adults retreat and stop reproducing for a time; as well, the efficacy and costs of various controls and what potential returns on control investment are possible.

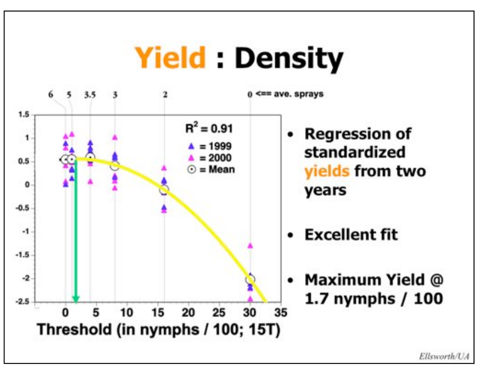


Cotton is an incredibly dynamic plant. It is essentially a perennial grown as an annual. As such, it has an indeterminant growth habit. This means that there are plant parts susceptible to Lygus and other insects at all times. We also know that there is much redundancy in the plant machinery and a great capacity for compensation even under shorter seasons.

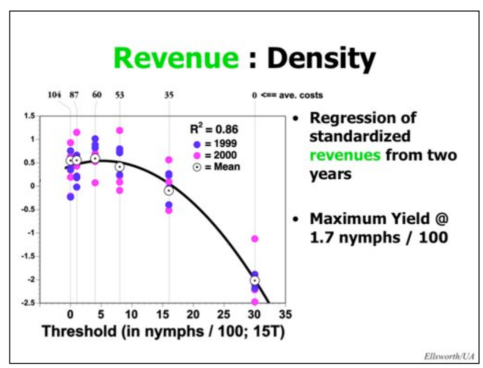
Well-fruited, maximally yielding plants will often only express final fruit retentions of 45-55%. This tells us that physiologically, Lygus present or not, a plant will naturally shed about half of the fruiting positions on the plant.



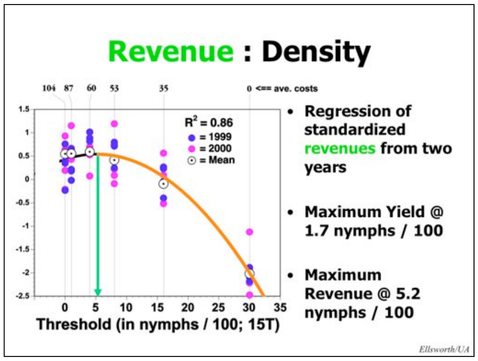
After two years of study, we conducted regressions of standardized yields using a 2nd degree fitted polynomial (quadratic). The fit was excellent…



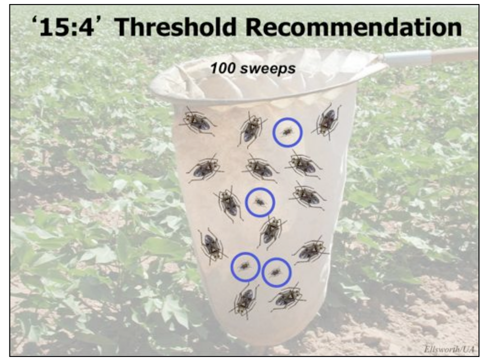
From this relationship, we can examine the point of maximum yield, which occurred at 15 total Lygus with ca. 1.7 nymphs per 100 sweeps. Of course, yield is only partly the answer,…



To understand the point of diminishing return, we developed this regression that shows the relationship between standardized revenues and our tested thresholds. This incorporates the important element of costs for control.



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 and to accommodate the normal time-lag between sampling, decision-making, and implementation of the action (spraying)…



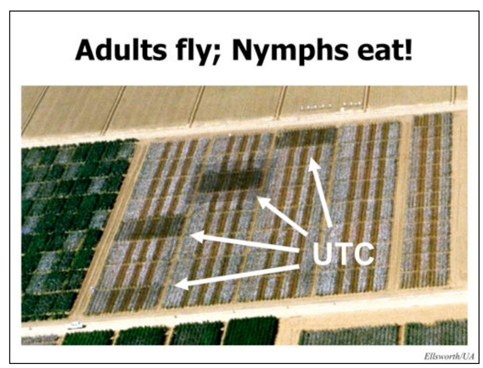
This so-called '15:4' threshold represents 15 total Lygus per 100 sweeps with at least 4 nymphs per 100 sweeps. I should add here that a 15 inch sweep-net is a standard method used by our consulting community in Arizona.

So why the emphasis on nymphs?

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. They are plant-bound.

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.

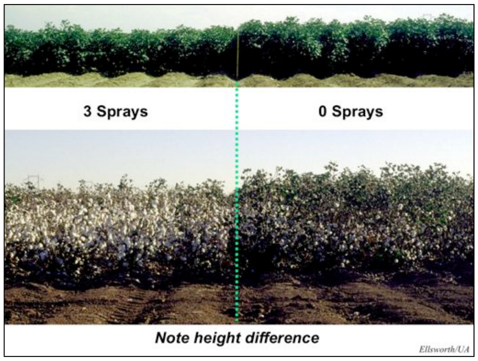
This is photographic evidence that adults are not



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

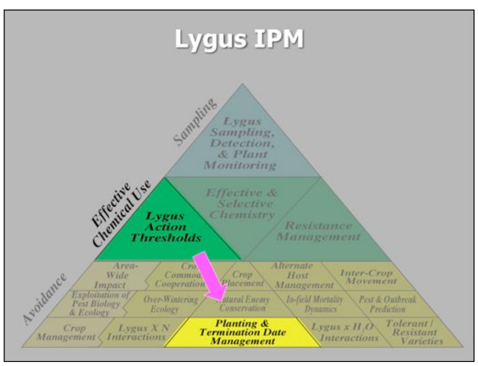
So nymphs have become an important basis for



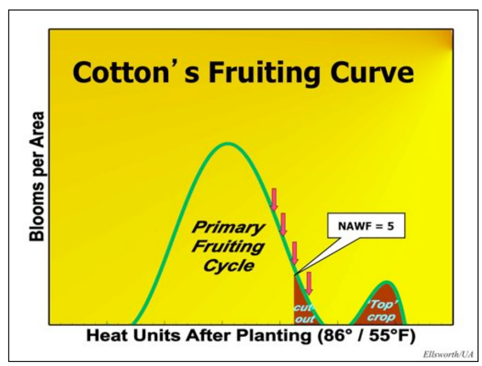
As further evidence, these effects occur over the shortest spatial scale. That is in adjacent rows, shown here in a commercial trial where cotton was sprayed 3 times on the left for Lygus and not at all on the right. The height and eventual yield differences we see are as a result of Lygus feeding and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

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 (an environment by variety interaction).

In fact, information in all 3 areas are needed to make the best decisions.



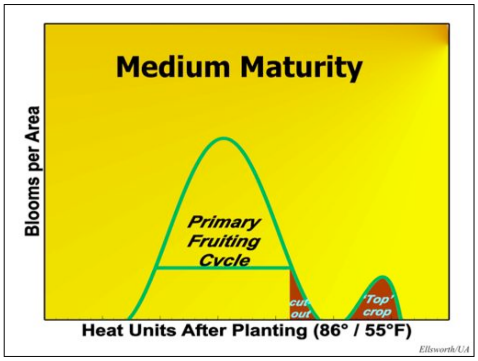
So here, too, there are interactions among IPM tactics whereby planting and termination dates interact directly with Lygus chemical control decisions.



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.

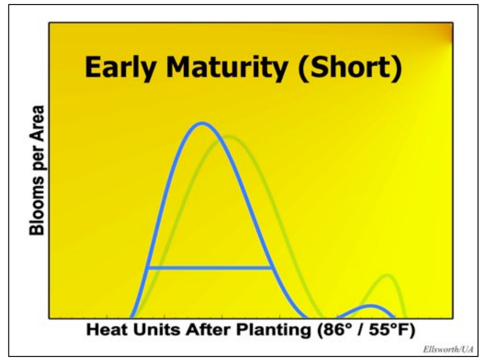
So experimentally, we set-out to examine 4 different Lygus chemical control termination timings centered around initiation of cut-out, where cut-out is defined as NAWF ≤ 5. (NAWF = Nodes above upper-most, first-position white flower, a standard measure of cotton phenology).

As a shorthand to NAWF = 5, we referred to this

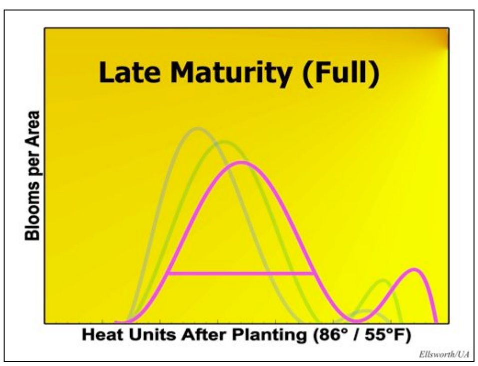


We must consider the plant damage dynamics:

For a "medium" maturity variety, the fruiting curve looks like this. We can take a width of the base of that curve aligned with the timing of initiation of cut-out as a measure of risk or period of vulnerability to Lygus damage.

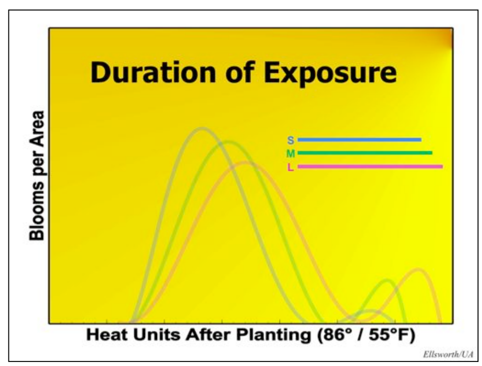


An early maturity variety, fruits more quickly and more compactly, with little to no capacity to "come back" and produce a true top crop. Note the width of the curve.

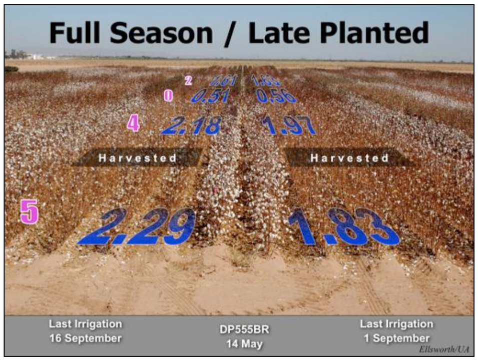


Full season varieties have the greatest potential for a top crop but fruit somewhat later and longer than the other types.

In general, full-season varieties, which grow over a longer period, have the highest yield potential (assuming no losses to pests) and early maturing or short-season varieties have the lowest yield potential (but also the shortest period of vulnerability).

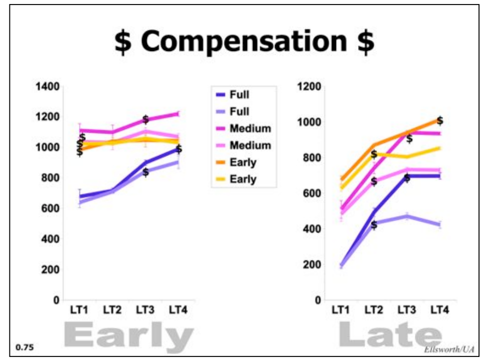


So just the choice of variety impacts the relative duration when flowering plants are present and vulnerable to Lygus attack.



Just to give a sense of how the experimental field work was done, this is how the trial looked in the field for one variety and one planting date.

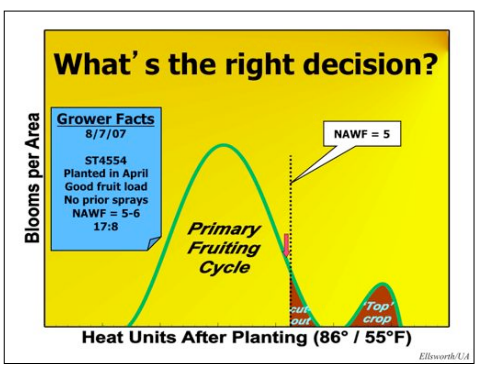
Average yields (bales / A) for DP555BR planted late (14 May 2005) and irrigated late (left, 16 September) or optimally (right, 1 September) showing 1 replicate where Lygus were sprayed 5, 4, 0, or 2 times (front to back). Each subplot is 6-rows wide with the 4 center rows already harvested; compare middle two rows.



Lygus control termination guidelines are presented here as a family of curves for one cotton price (75¢). We also assumed ca. 17$/lygus application and 12$ / late season irrigation — the absolute returns are affected by these latter two variables, but the decisions within a line do not change as a result.

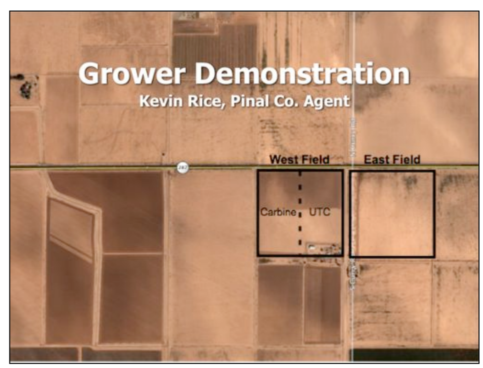
For these parameters, the ultimate best pay-off point varies by planting date, variety and irrigation termination timing. Early season varieties planted early saw no economic benefit of controlling Lygus. However, planted late and irrigated late (darker shades), the early season variety should be sprayed until LT4 (= ca. one week after initiation of cut-out).

The decisions are in fact very dynamic!

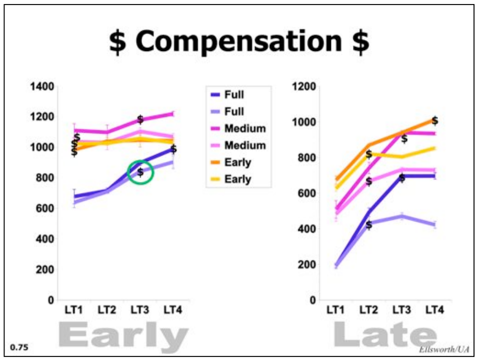


So what happens in the real world? Here are a set of grower facts. What would you do? Spray or not?

[Think of ST4554 as a medium to full season maturity variety; and April as a timely, early planting].

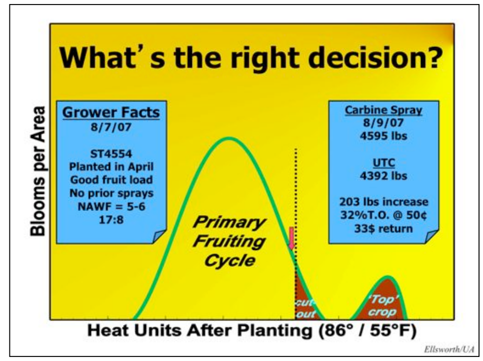


Let's find out what should have happened by splitting the field in half and treating one side and leaving the other alone.



This variety is a bit between medium and full season. As a full season variety (blue lines) not carried late with extra irrigation(s) (light blue line), the proper termination timing would be LT3 (green circle) or when the crop is at NAWF ~ 5.

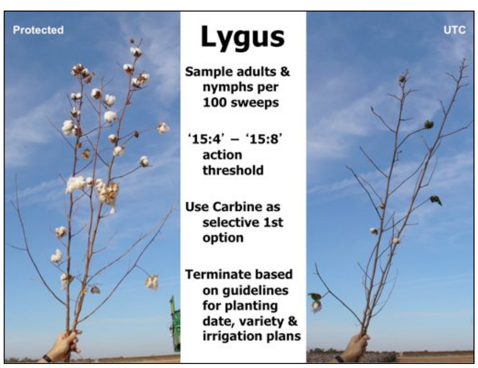
[As a medium maturity variety (purple line), irrigations terminated normally (lighter shade), cotton should not benefit by these late Lygus sprays. However, as cotton prices go up 85–90¢ or higher, as they are today, the decision to terminate sprays advances to LT3).



The spray returned over 200 lbs of seedcotton. At 32% turnout to lint, that is about 65 lbs of lint. Even at 50 cents / lb, the grower made about 33$ more where he sprayed. What did the spray cost? In this case, probably about $17.

Was the spray a good choice? An investment of $17 that returns almost double that is in fact an excellent investment. But in the world of Lygus, that is only a small savings as compared to a miss-timed mid-season spray when even larger potentials for loss exist. This decision was truly on the edge of profitability, but clearly it was a better decision to spray.

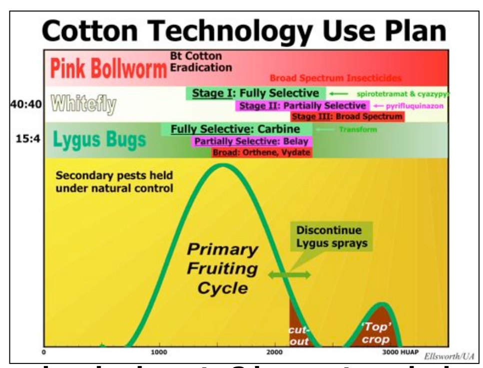
As cotton prices climb, the point at which the last



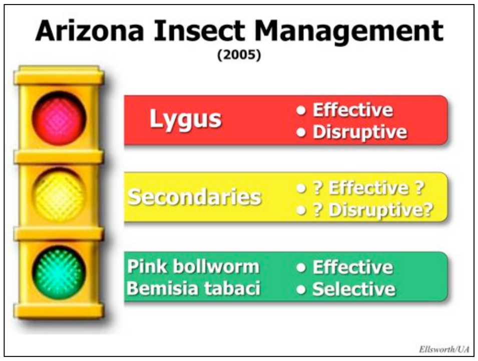
Our guidelines for Lygus control are based in sampling both adults and nymphs in 100 sweeps per field, in observing research-tested and commercially validated thresholds, and in responding with Carbine as the first selective option for control of Lygus that extends the period over which beneficials contribute to overall pest management.

These most recent guidelines provide research-based information on how to decide when to terminate Lygus controls based in planting date, variety and irrigation plans.

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

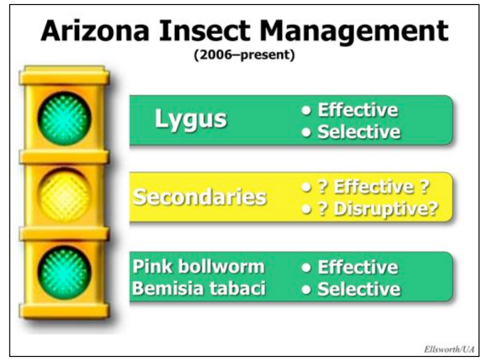


Our system breaks down to 3 key pests and a large array of secondary pests that never become significant, IF disruptions of natural controls do not occur. For PBW, Bt cotton is the ultimate biorational, and now with eradication, broad spectrum insecticides for its control are fading completely from our system. For whitefly, we have organized our insecticides into 3-stages based on selectivity, deferring all broad-spectrum inputs until the end of the season, if needed at all. For Lygus, we have one selective insecticide, flonicamid, and perhaps one partially selective compound, Belay, that was registered in 2010. Cotton IPM in AZ has become an exceptionally well-developed and selective system where conservation biological control is firmly established as a key element.

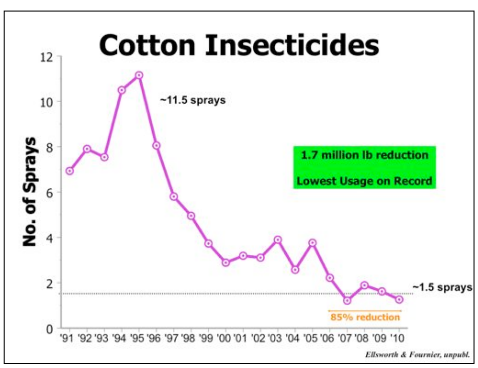


Our system breaks down to 3 key pests and a set of secondaries. For PBW and whiteflies we have very effective and selective technologies. At the other end of the spectrum, we did have effective technologies for Lygus (in 2005), but they were also quite disruptive and often implicated in secondary pest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

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

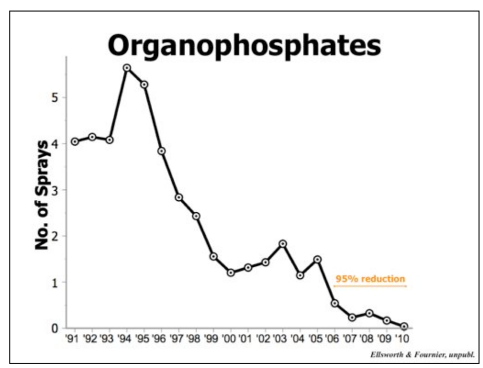


Today, with the addition of a strategic, selective feeding inhibitor for Lygus in Carbine, we have effective and selective options for our 3 key pests. Secondary pests can still derail our goals in keeping our system safe for beneficials. So controls against these pests must still be cautiously approached.

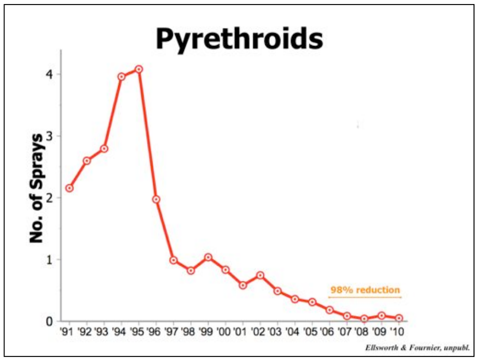


Striking trends in insecticide use are the result.

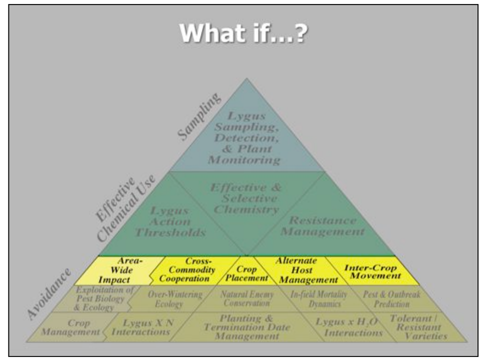
From a 30-yr high in 1995 of over 11 sprays used on average statewide for arthropod control to just 1.5 sprays in recent years. And virtually all pyrethroids, most organophosphates, all carbamates, and nearly all endosulfan uses have been eliminated in cotton in favor of reduced risk chemistries, mainly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



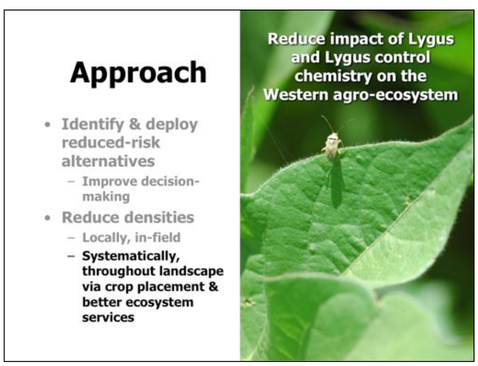
Organophosphates are another important group of insecticides used to control PBW, whiteflies and Lygus, especially chlorpyrifos, methyl-parathion, and acephate. This group has also declined to almost nothing. Carbine introduction has been very important to this continued trend in recent years as a selective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



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



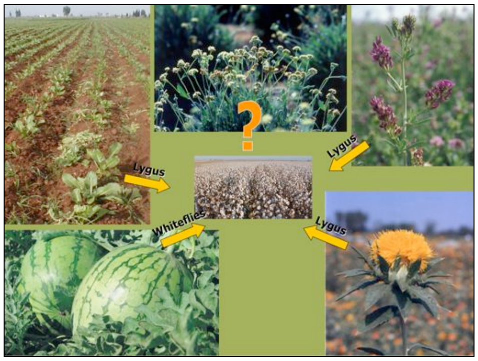
So everything we have covered thus far involves specific field practices for insect management. What if we were able to consider, understand and engage in a set of practices that have areawide consequence and impact on pest or beneficial populations? What if we could arrange crops over an area and actually minimize the damage potential or risk of infestation from a specific pest? These are the kind of advances that challenge the current generation of farmers who will be producing food and fiber for the world over the next 30 years.



Our approach involves opportunities for us to more systematically control the crop resources in a farmscape and in the larger community such that Lygus damage potential is minimized. In the future, we hope to amass enough research so that we can develop modules that predict whitefly risks as well as potential for maximizing colonization by beneficial insects like generalist predators.

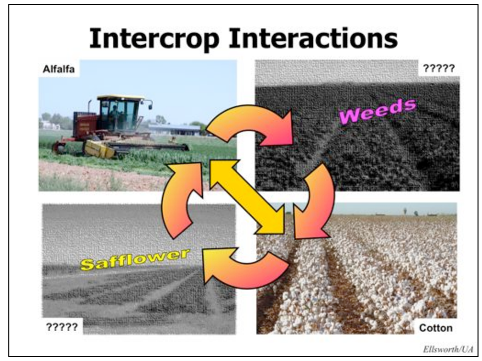
We are in a position now to capitalize on the many observations made by growers and scientists for decades. That is, if you are close to a source, your risk of invasion is greater. Generally around the cotton belt, we see examples where bollworms/budworms can be sourced from corn, sorghum, and peanuts; stink bugs from soybeans, peanuts, and wheat; and thrips and mites from wheat and corn, respectively.

But over what scale does this occur? Just from adjacent fields? From miles away? In most cases, we just do not know without the type of research we have conducted over the last 5 years.



In a more Western landscape, people have see whiteflies sourced from watermelons and melons, and Lygus sourced from sugar beets, alfalfa and safflower.

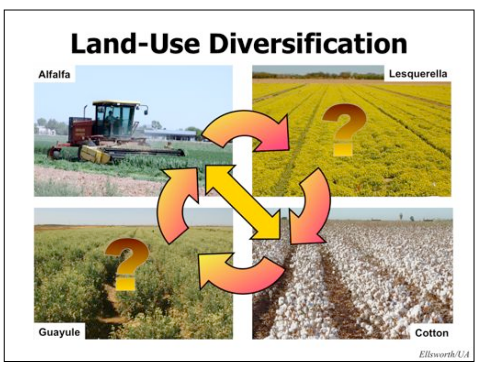
Guayule is an interesting sideline and case study. Here is a new crop! A good thing for most growers as it provides production alternatives. But have we considered what the addition of this crop resource will have on pest management generally? Or, on Lygus areawide? We know that Lygus feed on and reproduce in guayule. We also know that there is little measurable damage to the plant by this insect (so the guayule grower is unlikely to spray this potential cotton pest). What we have learned is that



We have known for decades some things about how Lygus use and move from different hosts. E.g., alfalfa grown for hay is alternately a source and a sink for Lygus depending on cutting status.

Other relationships have been noted in our desert ecosystem including winter weeds brought on by El Niño influenced winter moisture that host Lygus; or when safflower is planted, growers have long known that cotton immediately adjacent to this releasing source host is going to be damaged by Lygus.

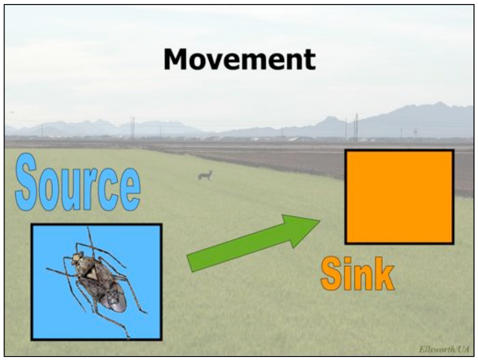
Damage to or protection of cotton is completely dependent on the proximity of the source or sink. But until recently, we just did not know enough to reliably advise growers, and our landscape is also



Land-use diversification is leading to brand new relationships representing new risks as well as new opportunities. After all, we want producers growing money (and not necessarily just cotton) and as markets change, crop mix will change including at times the introduction of new crops like Lesquerella and Guayule, both of which host Lygus. However, we may not know how these changes will impact Lygus movements and distribution without research. Some land-use changes might improve our ability to manage Lygus; others might make things worse.

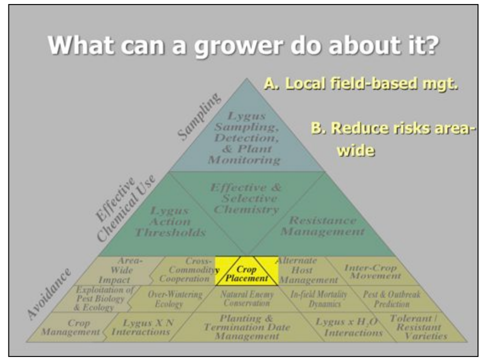
Guayule is commercialized and expanding; it does host Lygus. At least during the summer period, guayule serves as an opportunity as a sink for Lygus,

In thinking about Lygus, indeed all insect pests, it becomes clear quite quickly that it is an issue of "Abundance". Abundance is affected by Field-level processes, and a set of Broad-Scale processes. While there is not much we can do about the weather, a grower does control Local Management decisions on his/her own field or farm and we wish to continue to develop research to support this decision-making. However, insect abundance is also affected by one Broad-Scale Feature that we can control, host or crop and non-crop distributions in an area. It is these opportunities, both "great" and "small" in scale, that we wish to exploit for the benefit of agricultural pest management.



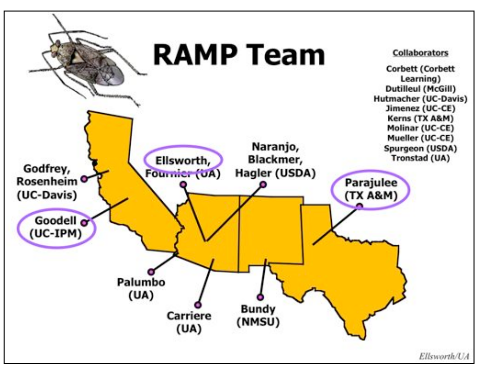
One cannot rationally control host or crop distributions without more information about how an insect moves and travels between different habitats. So Movement is very important. Insect pests and beneficials arrive to and depart from grower fields each year. Where they come from are “Sources”. Where they go are “Sinks”.

The research we conducted over the last 5 years helps us precisely define what the source and sink habitats are and how we can manipulate them for the benefit of the entire community.

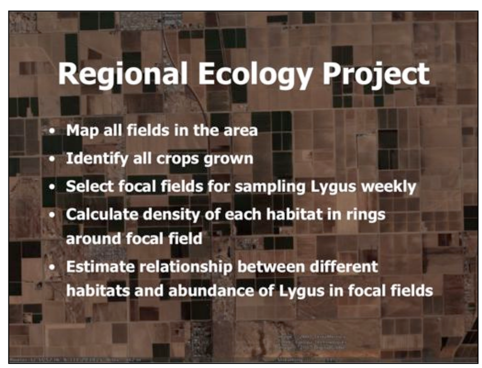


Right at the heart of our IPM strategy is “Crop Placement”. Crop placement is central to its availability to other pests. By strategically considering how we arrange and place our crops both in space and time, we can help to deny our crops as a resource for pest insects.

The problem until now is that we have had only very limited information on how to strategically arrange our crops to prevent or minimize damage from insect pests.

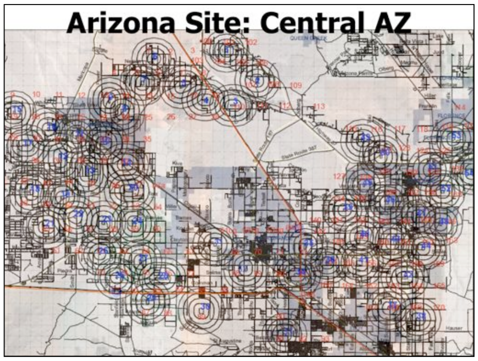


There are many projects in this grant designed to help us understand Lygus management and movement across the landscape. The large study that supported this Lygus simulation was conducted in the central valley of California under Dr. Goodell’s leadership, in west Texas under Dr. Parajulee’s leadership, and right here in central Arizona under my leadership. Analyses of the spatial data were conducted by Prof. Carriere’s and Prof. Dutilleul’s laboratories.

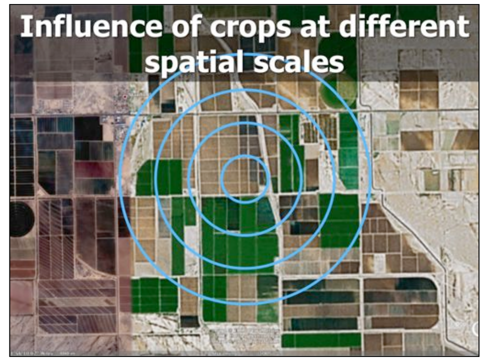


So we have developed an approach using new mapping, computer and analytical technologies that will allow us to ultimately advise growers how to minimize damaging Lygus populations through crop placement.

We did regional sampling for Lygus that followed these steps…



This was our experimental area, nearly all of Pinal County! There is about 100,000 acres of cotton in this area, similar in size to Mexicali Valley this year. Each set of rings surrounds a cotton focal field in which we took detailed measurements of Lygus numbers. We sampled about 55 fields for each of 3 years, 2007–2009.



So how is the cotton field in the center of these rings impacted by the cropping diversity in the rings that surround it?

This sort of effort is the kind of advance we need to reach higher levels of integration in IPM.

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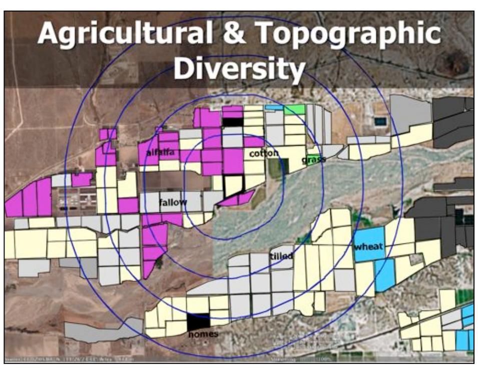
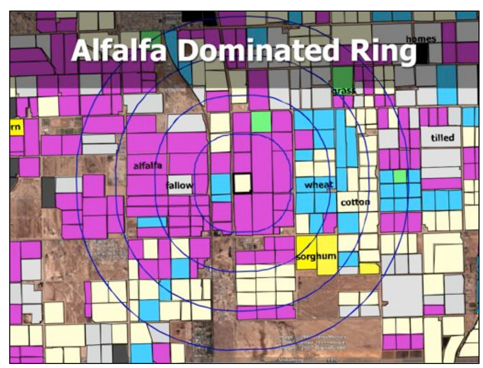


Arzona is both agriculturally and topographically diverse. So we looked at many situations so that we can compare them and identify the best arrangements for crops.

Alfalfa (in purple) is a consistent element of our system. Cotton is in light yellow, fallow and tilled ground are colored gray, wheat is light blue, and homes and other buildings are black.Each ring or donut depicted here represents a 0.75km slice progressively out to 3km around the field.

By examining Lygus densities in the focal fields and relating this to densities of different habitats in each successive ring, we can geostatistically correlate the rise and fall of bug densities with specific arrangements of surrounding habitat. When the correlation is strong and



In this example, alfalfa dominates the landscape around the focal cotton field and throughout the 3km area.

Is this a situation that protects or harms cotton with respect to risk of Lygus colonization and damage there?

By examining the donut slices, we can estimate how far these relationships extend, whatever they are.

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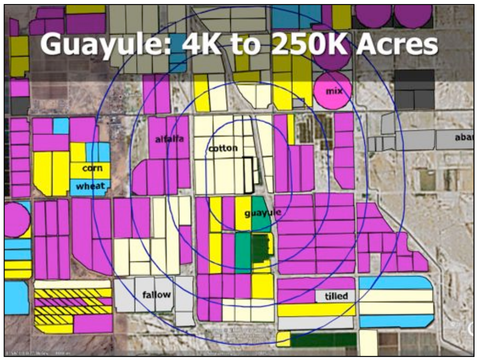

Guayule is a desert-adapted, commercial crop that may expand, with a projected western acreage of 250,000 A one day spanning W. TX to the SJV of CA. It is grown as a perennial and is a known reproductive host for Lygus. It was grown on about 4,000 A in AZ in 2007.

We did not have a lot of areas where we could test the influence of guayule; however, when we found an effect, it was serving as a sink for Lygus though over a relatively short range.

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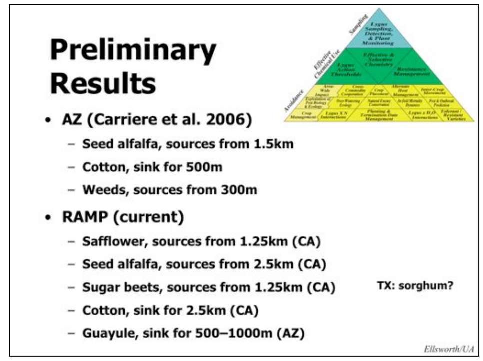


Here are some of the results that we consider in putting together the Lygus simulation that I will next describe. These numbers have since been revised and show even greater range for some of these sources and sinks.

We developed a landscape simulation of Lygus movement and distribution among cotton fields planted in large agricultural systems. Each grower has his/her own virtual cotton farm, 640 acres in size, that they can choose crops for planting and identify the locations for each. The overall community is roughly 10,000 acres in size, comparable to many AZ agricultural valleys.

All growers are networked together and the simulation takes all this information and predicts the distribution and damage caused by Lygus.

Profitability when no bugs are present is $100 per acre. This number is for purposes of illustration and not to be taken literally, but it does allow us the

In this screen, we added the bugs and you can see that the Farm in the center of the community lost 25% of his yield and sustained a 41% infestation with Lygus, reducing profitability down from $100 to $74 / A.

The farmer can examine the distribution of Lygus by looking at the pattern of shades of pink and red, with darker shades indicating heavier infestations in cotton. He/she can also note the distributions and strengths of sources in orange and sinks in blue.

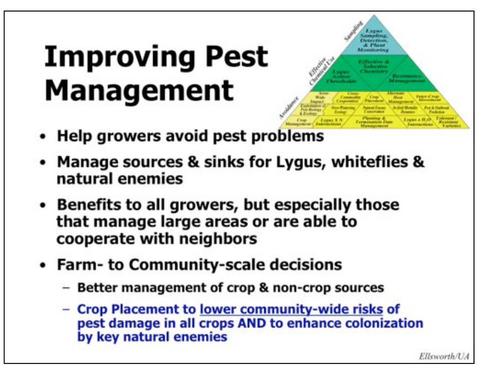
With only a modest change in the arrangement of crops, the community has lowered the infestation of Lygus to 39% and increased profitability from $74 to $93 / A.

The pattern of infestation shows lighter shades of red than before.

Further modifications helped the community to lower the infestation rate to 29% overall and further increase profitability to $94 / A. Note there are far fewer dark red cotton fields; more light pink ones indicating a reduction in the numbers of Lygus in the system.

Continued modifications helped the community to lower the infestation rate to 23% overall and further increase profitability to $97 / A. Note this was all accomplished with only modest changes to the overall acreages of each crop; just changes in where they were located within the farm and within the community.

Over successive plantings and re-arrangements, we can show the farmer his/her changes over time along with changes for the entire community. Usually this shows that what improves your own profitability will also help the overall community increase its profitability. This is a farmer – community win-win solution! But it can only occur after the grower achieves this basic understanding of Lygus source and sink relationships, <u>and</u> importantly that he/she communicates, if not cooperates, with neighboring farmers.



To summarize, our goal is to help growers avoid damaging Lygus populations right from the start. We hope to do this by giving them specific advice on how to manage the plantings of their many crops. By knowing what crop placements lead to more "sinks" for Lygus than "sources", a grower can become more profitable while reducing risks to the human health and the environment.

Any grower or entity who controls a larger region will benefit the most because they control a larger part of the landscape. But through even limited cooperation, even smaller farms can benefit from strategic planting practices, and clearly the whole community can benefit as a result.

Thank you for your attention.

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

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

Photo credit: J. Silvertooth