

Chemical Control & Resistance Management

Building Capacity & Integration in Whitefly Management: Cross- Commodity Cooperation and Areawide Benefits

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4th International Bemisia Workshop December 6, 2006

A Processing / Marketing Disaster

Quality Loss



Ellsworth/UA

This presentation was invited by Rami Horowitz (Volcani Institute, Israel), as part of the 4th International Bemisia Workshop.

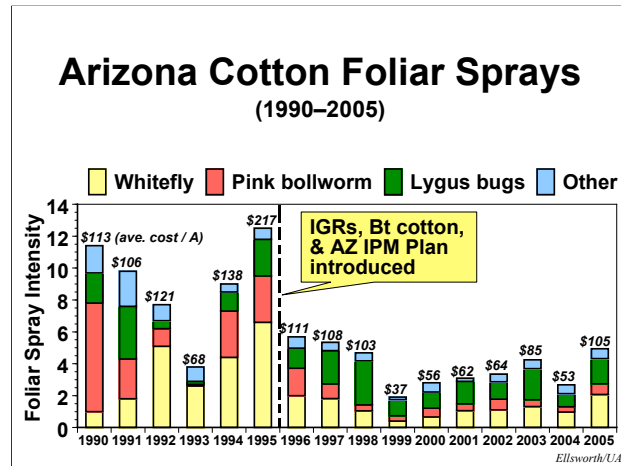
My thanks and acknowledgment to Dr. John Palumbo, UA Vegetable Entomologist, who has been instrumental in the development and deployment of the program that we describe here, as well as to Dr. Al Fournier, IPM Program Manager, who has been developing the pesticide use database and the program evaluation.

The "Arizona" program referred to in this and other presentations is the result of a large collaboration of the scientific, industry, & grower communities over a 10-yr period.

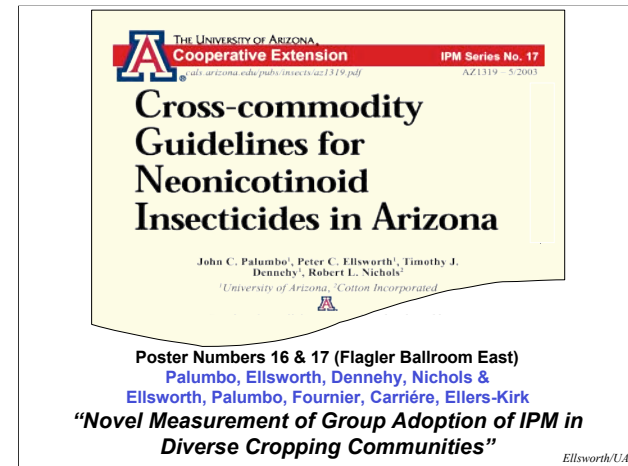
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While you will hear me reference all the whitefly-sensitive crops grown in Arizona, the orientation of this presentation is from the perspective of the cotton grower. It will become apparent why this is, but this scene sets the stage nicely. As a processing and marketing disaster for the cotton industry in the early 1990s, this memory is firmly entrenched in the minds of anyone who lived through this episode.

[Video shot in Maricopa, AZ, 1992].

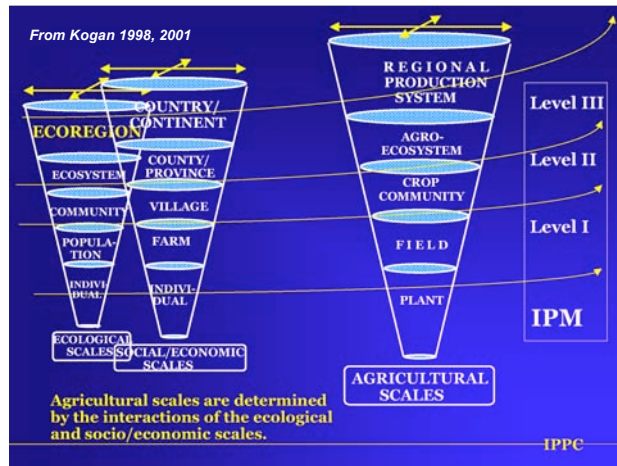


Dr. Tim Dennehy has already done an excellent job of introducing this talk by detailing the AZ situation, and by showing you this figure. I only wish to add that the disaster scene in the prior slide was accompanied by excessive insecticide use, 5-10 sprays per season, and excessive costs; however, our new IPM program, introduced first in 1996 along with 2 key sets of technologies, has produced a stability never seen before in AZ's cotton history. In fact, 1999 was the lowest foliar insecticide use in 27 years. I collect these data each year, and don't have 2006 yet, but believe that we will see a new all-time low in foliar insecticide use to less than 2 sprays season-long against the entire insect pest complex.



The specifics of the stakeholder process and even the guidelines themselves are detailed in two posters presented at this conference. However, I will touch upon these guidelines and our specific efforts to measure group adoption in this talk.

As this is a last minute substituted paper for a late cancellation, I was not intending to present these data for at least another 6-12 months. So bear with me as I work towards the limited analysis of data provided towards the conclusion of the talk.



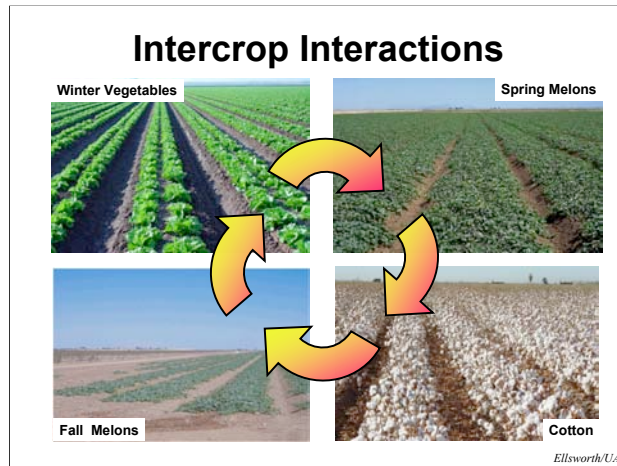
In Kogan's review of IPM (1998), he provided us a model for understanding organizational complexities across various scales: ecological, social/economic, and agricultural. While the schematic is complex, it synthesizes into a nominal categorization of "integration", which occurs at at least 3 organizational levels.

Levels of Integration in IPM (from Kogan 1998, 2001)

- Level I – "Species / population level integration"
 - The integration of control methods for single species or species complexes
- Level II – "Community level integration"
 - The integration of the impacts of multiple pest categories on the crop and the methods for their control
- Level III – "Ecosystem level integration"
 - The integration of multiple pest impacts and the methods for their control within the context of the whole cropping system

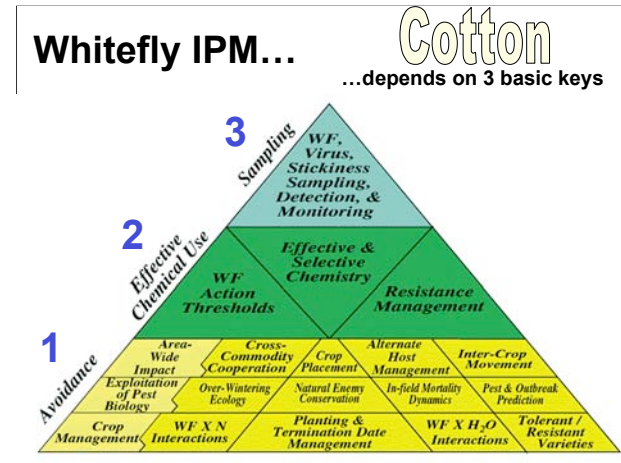
Ellsworth/UA

In summary form, Level I integration acts at the species or population scale; Level II at the community scale; and Level III integration operates at the ecosystem scale and should be what we aspire to develop, even if the science and practice cannot currently support it.



In AZ, our desert ecosystem is transformed by water into a very complex agroecosystem. AZ's year round growing season provides for a sequence of crop plants, winter vegetables like broccoli, lettuce, other cole crops, spring melons (esp. cantaloupes), summer cotton, and fall melons. These crop islands provide for perfect habitat for whiteflies, and our focus was on the intercrop interactions that were possible with this pest and that demanded a high level of integration in our IPM programs.

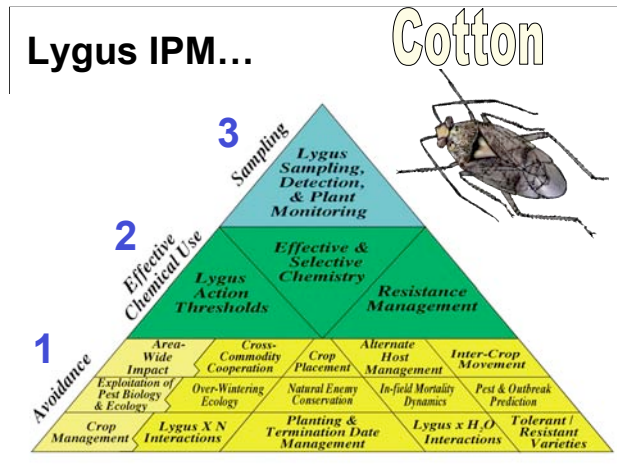
Photo credit: JCP



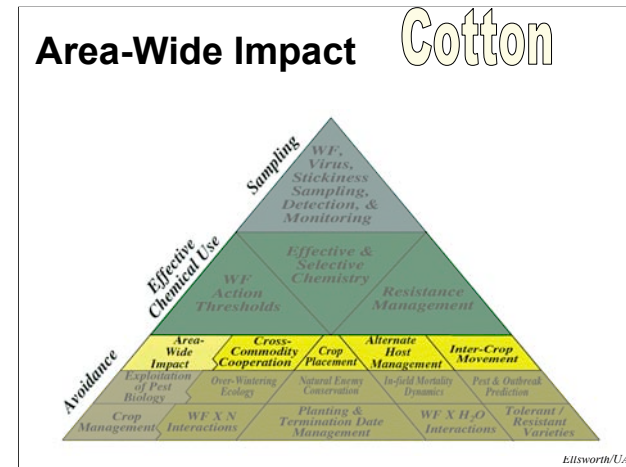
Several comments have been made about the "Arizona model" for management of whiteflies. I guess this is our best graphical representation of that program. At its simplest, it is Sampling & Effective Chemical Use, resting on a foundation of Avoidance, which is critical to stabilizing the system.

Bear in mind, once again, that this representation is cotton-centric and represents what we routinely teach to cotton growers and pest management professionals.

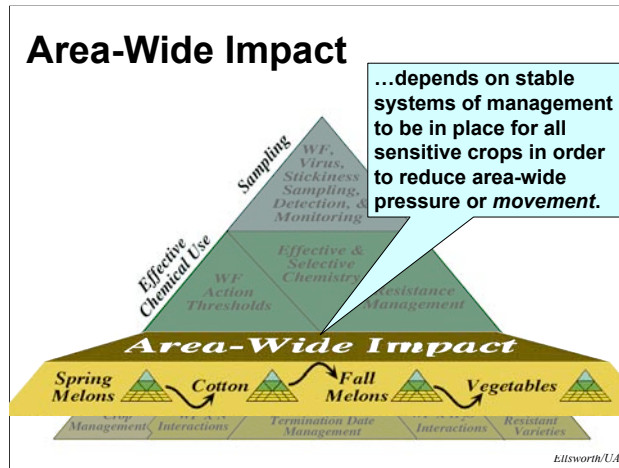
However, "IPM" is hardly integrated when solely focused on a single pest. One need only rotate this structure around...



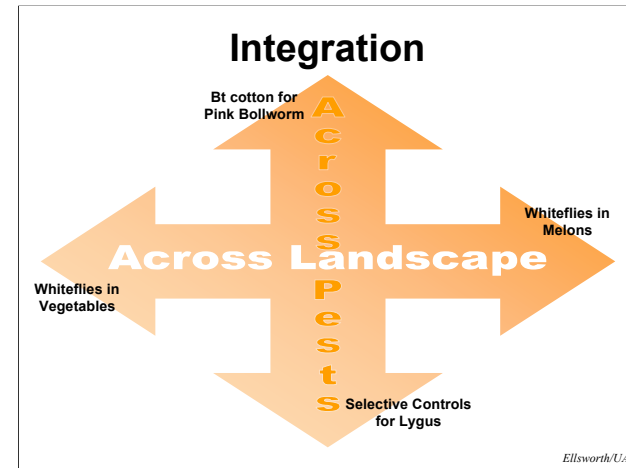
...to see that a similarly constructed system of management is needed in support of Lygus control. This additional level of integration is required in developing sustainable IPM systems, but also in effectively communicating with growers, who, after all, must manage a whole suite of pest problems.



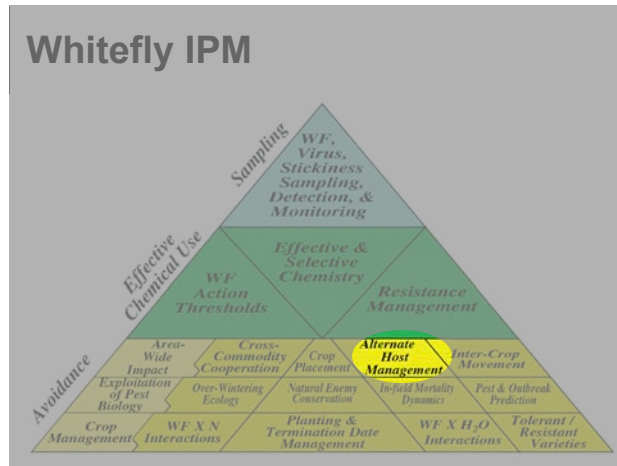
Shifting back to our Bemisia IPM model, we can focus on an important layer of "Avoidance"; I.e., those factors having Area-Wide Impact. Peering into this layer of management...



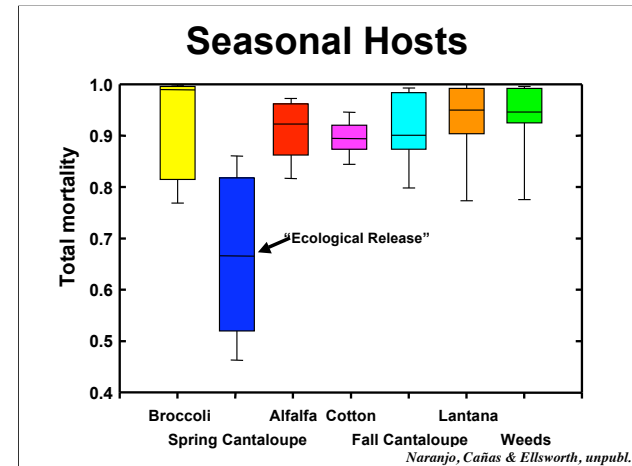
...we can see that the "cotton" plan must consider the stable function and management of multiple crops within the system. "Integration" is explicitly part of our Arizona program.



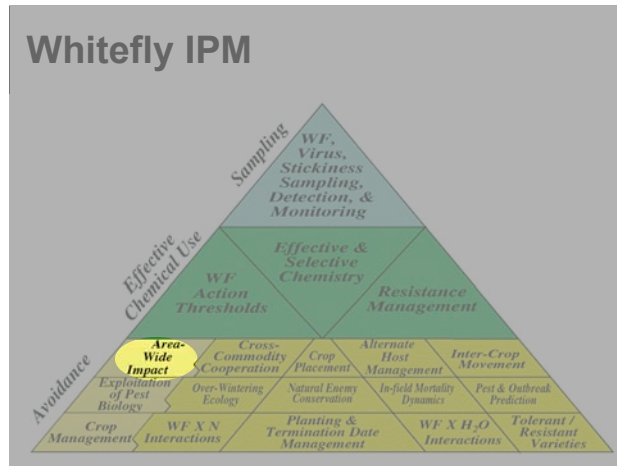
Integration can be thought of in at least two dimensions. Again, considering Bemisia in cotton as the central focus of our attention, we can see that vertically, within a crop, we must integrate our management programs with advances in controlling other cotton pests, particularly selective ones. At the same time, whiteflies in cotton are directly linked to whiteflies across the entire landscape, in space and in time, from vegetables to melons.



Just to point to a few examples of cotton’s explicit relationship to other crops, let’s examine evidence of the importance of alternate host management...

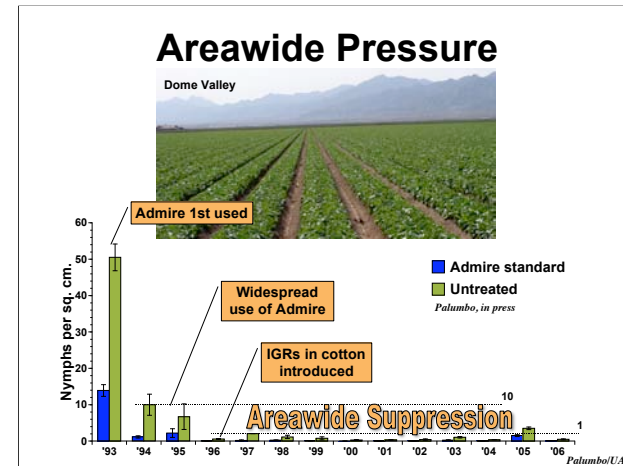


Steve Naranjo showed some of this data yesterday where we can see the total Bemisia mortality over a wide range of untreated crop and non-crop hosts in Arizona. High rates of natural mortality are obvious; however, Steve showed us in our work with Luis Cañas that spring cantaloupes are subject to much less natural mortality and as a result serve as an “ecological release” of Bemisia in our system.

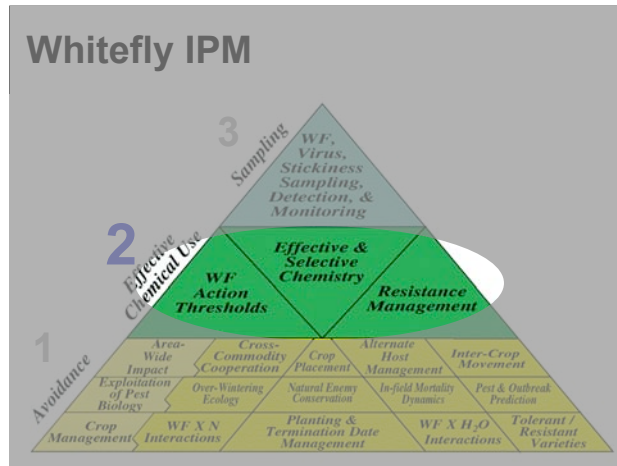


While our crop-specific model of IPM in cotton was not initially designed as an area-wide IPM plan, it does explicitly address fully exploiting tactics and information that have area-wide impact, all as critical elements to building a solid foundation in avoidance.

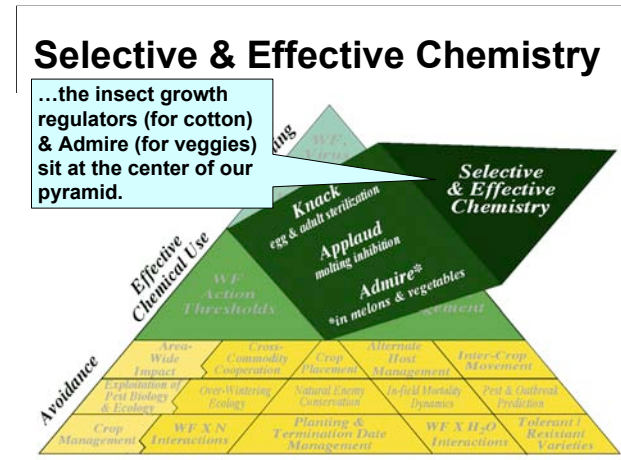
Let me show you tangible evidence of its importance...



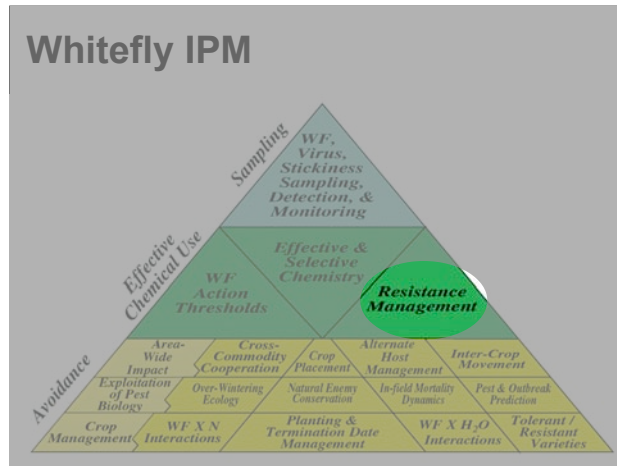
...in these data generated by Dr. John Palumbo. Starting in 1993, John had the foresight to initiate an "efficacy monitoring" protocol in commercial lettuce fields, where he established untreated blocks of lettuces within these commercially-treated fields with soil-applied imidacloprid. In this chart, we see total number of nymphs per sq. cm. (seasonal average), starting in 1993 when Admire was 1st used under a Section 18. Pressure was extreme as seen in the UTC green bar, but Admire did an excellent job at reducing these numbers. In 1994-1995, we see a period where widespread use of Admire was prevalent throughout the fall vegetable landscape and numbers were reduced in the UTC by nearly an order of magnitude. In 1996 through today, we enter a period where the IGRs were first registered and used in AZ cotton and used on a wide-scale. The result is another magnitude lowering in the overall whitefly density, and what we think of as area-wide suppression of whitefly populations. Photo credit: JCP



Of course, part of having a functional and stable management system is having the appropriate remedial controls and the technology and education to support them in place.



Central to these remedial controls is "selective and effective chemistry." The IGRs, pyriproxyfen and buprofezin, were absolutely key to our system when they were introduced under section 18s for cotton in 1996. However, imidacloprid, when used in the soil, is also a highly effective whitefly control agent that can also be fairly selective for natural enemies in our melon and vegetable crops. So again, despite this being the "cotton" IPM plan, a cotton-grower knows and acknowledges the importance of having effective tools operating in melons and vegetables.



The central role that our chemistry plays in our systems naturally leads us to concerns about resistance management, and Dr. Tim Dennehy has already reviewed the progress of resistance in an array of chemistry over the last decade. Resistance management has obvious implications for individual crops...

Neonicotinoids: A Major Class

A.I.	Product	Application	Crops Uses
Imidacloprid	Admire, etc.	Soil	Melons, Lettuce, Cole

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But at first blush, it might not be apparent why resistance management was needed to protect the neonicotinoid class, given that there was only a single member of this class for many years. In 1993, soil-applied imidacloprid or Admire was the only member of the neonicotinoids. Today, however, we have many additional potential members of this class with many registrations across multiple crops...

Neonicotinoids: A Major Class

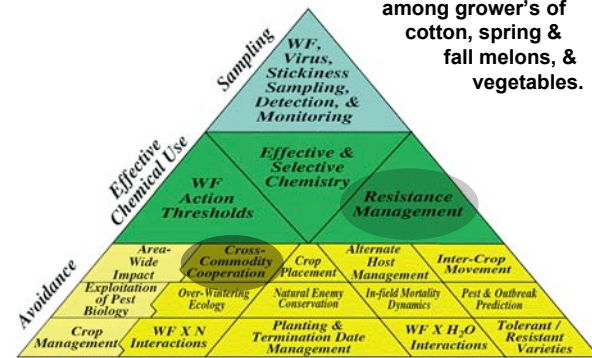
A.I.	Product	Application	Crops Uses
Acetamiprid	Assail	Foliar	Lettuce, Cole
Acetamiprid	Intruder	Foliar	Cotton
Dinotefuran	Venom	Foliar, Soil	All
Imidacloprid	Admire, etc.	Soil	Melons, Lettuce, Cole
Imidacloprid	Gaucho, etc.	Seed	Cotton
Imidacloprid	Provado, etc.	Foliar	Lettuce, Cole (Cotton)
Thiamethoxam	Centric	Foliar	Cotton
Thiamethoxam	Cruiser	Seed	Cotton
Thiamethoxam	Platinum	Soil	Melons
Clothianidin	Clutch/Poncho	various	?
Thiacloprid	Calypso	Foliar	?

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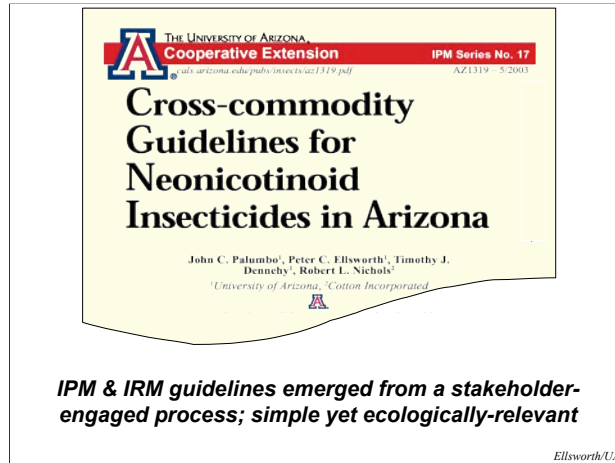
And now, Intruder (acetamiprid used foliarly) has rapidly become one of our most popular whitefly treatments in cotton. The potential for over-usage of this class of chemistry within our system gives us great concerns about future erosion of efficacy due to resistance. Rather than waiting to see what happens, we worked through our cross-commodity stakeholder process to develop proactive guidelines for the rational use of this class of chemistry and for management of whiteflies overall.

Whitefly X-IPM...

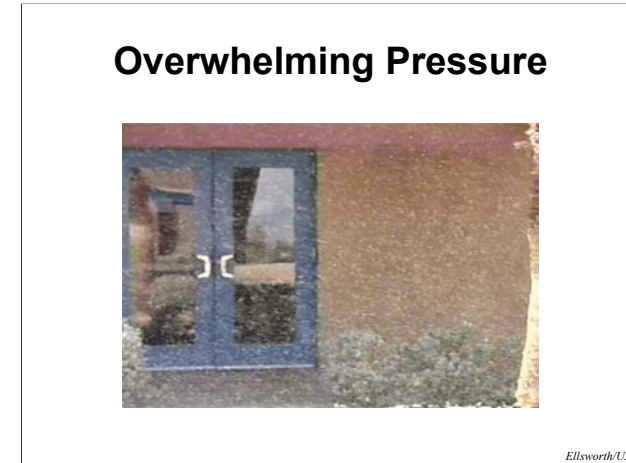
...depends on cooperation among grower's of cotton, spring & fall melons, & vegetables.



However, resistance management in our system could not be limited to or practiced in a single crop or commodity. That is, Level I integration for resistance management in a mobile, polyphagous pest seems futile, when registrations of key chemistries are broad across multiple crops. This shared responsibility extended across commodity borders. Cross-commodity cooperation can be key to the sustainability of a resistance management plan, and in Arizona, we have achieved some remarkable agreements among growers of several key whitefly crop hosts, which I will now detail.

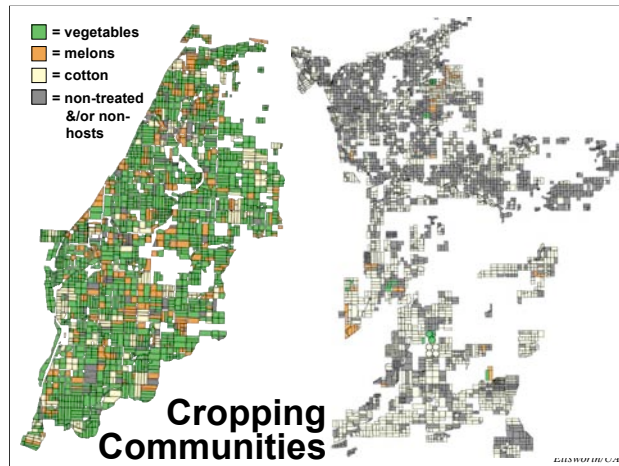


The specifics of the stakeholder process are beyond the scope of what I can cover in this presentation. However, I can say that this was not a desktop exercise limited to 1 or 2 people. Instead, these guidelines, which were published and disseminated in 2003, were the result of a year-long, stakeholder-engaged process spear-headed and led by Dr. John Palumbo. And while we did not and never do have perfect data or information, by engaging clientele directly in the development of these guidelines, we were able to forge a very simple set of rules for neonicotinoid usage. Yet through understanding of our system spatially, we also have ecologically-relevant guidelines as a result.

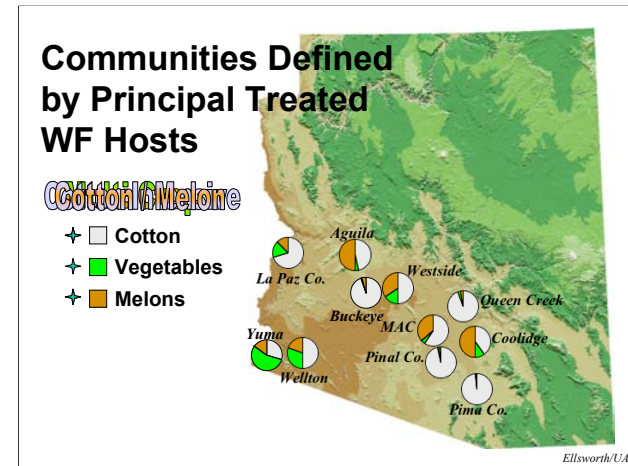


And we had a powerful incentive to cooperate, at least for those that remembered scenes like this from the early 1990s. Everyone recognized, grower, pest control advisor, scientists, and industry, that confronting these issues proactively was our best protection of all agricultural interests in Arizona. "Integration" across our landscape was paramount.

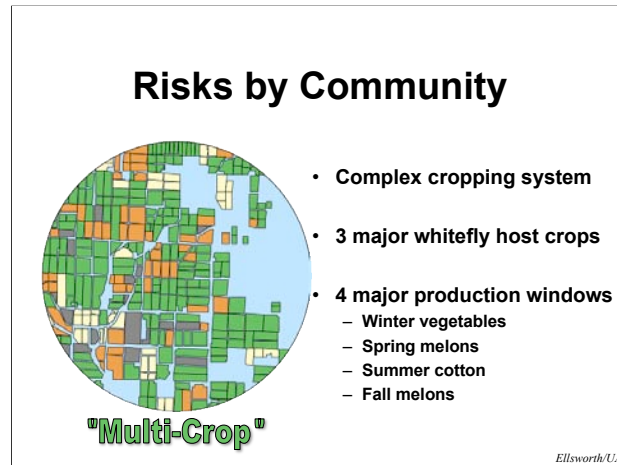
[This video was shot in 1992 on the campus of a community college located within the city limits of Phoenix. Truly this was everyone's problem.]



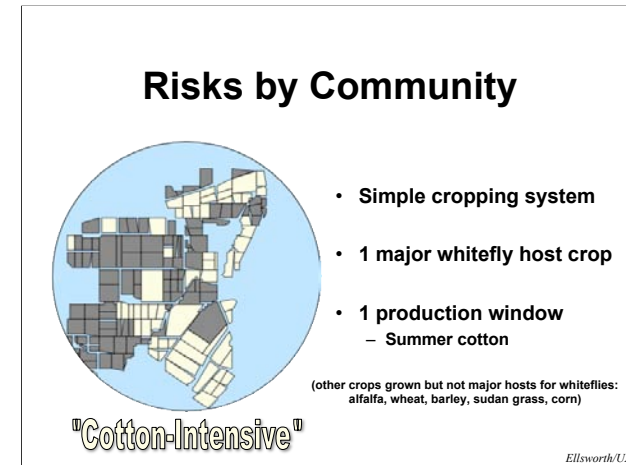
All cropping communities, agroecosystems if you will, are not the same in Arizona. In fact, where whiteflies are a key pest, the levels of host diversity and temporal complexity are quite different. Vegetable fields are shown in green; melons in orange, cotton in white, and non-treated or non-hosts in gray. On the left, Yuma Valley of Arizona, virtually every field is rotated to vegetables at some point in a 12 month period. And while cotton is grown in these communities, it is in a totally different context than we see on the right in central Arizona where cotton is grown more monoculturally with an array of untreated hosts, like alfalfa, and non-hosts like corn and small grains.



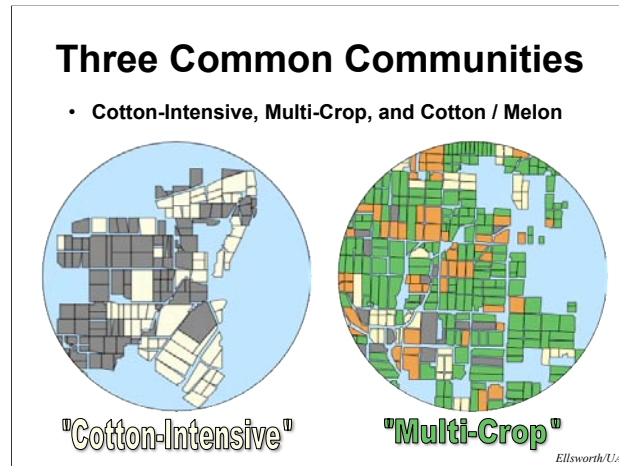
We have instances like in Yuma which are very complex and include significant acreages grown in melons, cotton and vegetables. We call this a "Multi-Crop" community. In other areas, the system is relatively simple and resembles a cotton monoculture as far as whiteflies are concerned, a "Cotton-Intensive" community. Then there are some places where a melon / cotton bi-culture exists, "Cotton/Melon" community. Hundreds of whitefly "communities" or ecosystems exist throughout the state.



Resistance risk, indeed risks of all sorts (insect pressure, economic loss, markets, etc.), are not all the same across AZ agricultural production. Some areas have extremely complex cropping systems, where 3 major whitefly host crops are grown, and 4 different production windows exist [winter vegetables (in green), spring melons (orange), summer cotton (white) and fall melons (orange)]. We refer to these areas as "multi-crop".

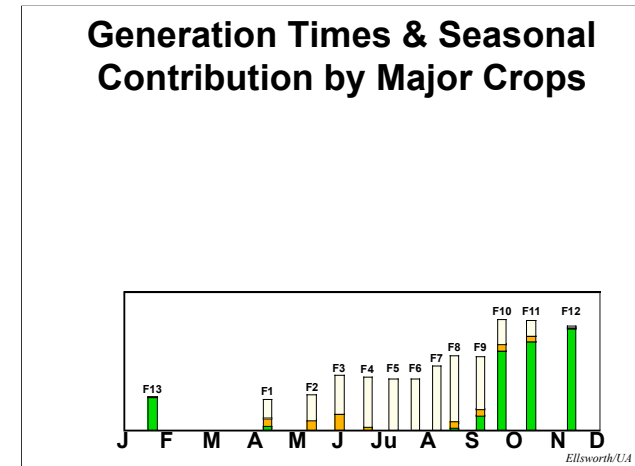


While still other communities have relatively simple cropping systems, only 1 major whitefly host crop and 1 production window, summer cotton (white). We refer to these communities as "Cotton-Intensive".



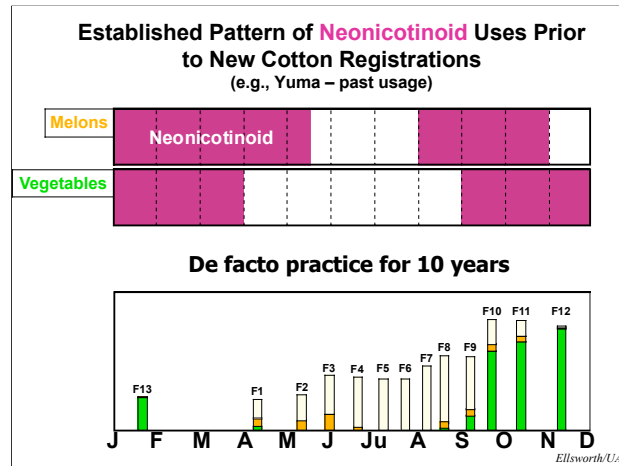
The risks of losing neonicotinoid chemistry are different between these two types of communities and with a 3rd one, not shown, where cotton and melons are grown in a summer bi-culture.

So rather than develop a single rule to be followed statewide, we attempted to develop guidelines that could be applied differentially according to cropping community and proportional to the inherent risks of whitefly problems and resistance.



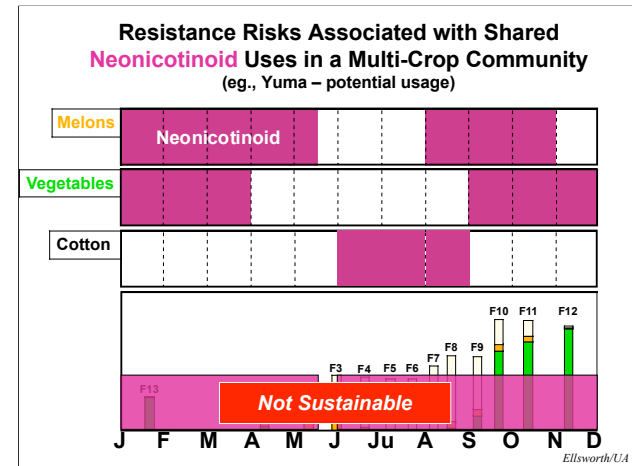
To illustrate the extreme risks of resistance in our most complex cropping system, we can break the system down into component parts. First, we view the generational production and relative abundance of whiteflies through time, again, where green represents the contributions of vegetables to overall whitefly abundance, white for cotton and orange for melons in this example for communities in Yuma.

From Palumbo et al. 2003



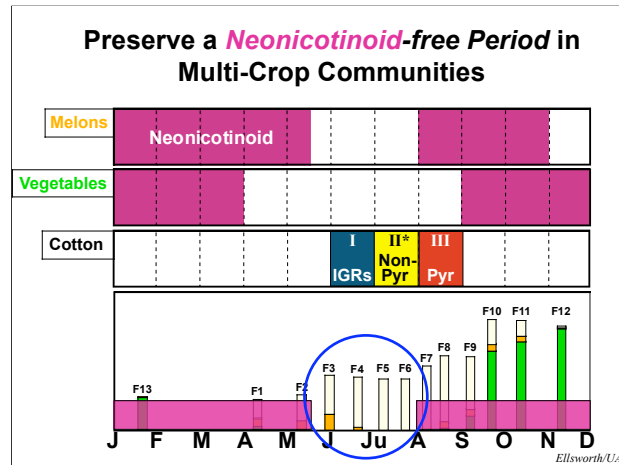
The second component is the established pattern of neonicotinoid usage, or really the periods during which residues are present, as shown here for vegetable and melon crops in Yuma valley. This pattern of usage was the de facto practice for 10 years while essentially only soil-applied imidacloprid was being used, and used ostensibly without problems of resistance. This latter fact is supported by the routine resistance monitoring that Dr. Tim Dennehy has done statewide over the last decade.

From Palumbo et al. 2003



If neonicotinoids were to expand to the cotton crops in these complex communities, these products would be depended on in the mid-summer window as well. Transposing these potential use patterns over whitefly generations, and the potential problem becomes apparent. This potential overall use pattern for neonicotinoids in this ecosystem is, we believe, not sustainable.

From Palumbo et al. 2003



Thus, we concluded that, despite new registrations of neonicotinoids, cotton growers should depend on the original 1996 plan that includes selective IGRs used first, and non-pyrethroid and pyrethroid insecticides as needed.

This effectively creates a neonicotinoid-free period that has been the de facto condition in these complex communities for the previous decade (1993-2003).

From Palumbo et al. 2003

Spatial Considerations

- Whiteflies residential in-season
- Opportunity for 3 – 4 “transfers” per year
- 2.2 km range for < 5% of population, annual range of 6.6 – 8.8 km
- Whitefly “communities” = all those sensitive host crops grown within a 2-mile radius annually



Ellsworth/UA

While the differential risks are obvious, some sort of spatial scale had to be defined. Without discussing the details today, we defined our whitefly “communities” (areas of potentially interbreeding and moving whiteflies) as all those sensitive host crops grown within a 2-mile radius annually. This happens to be an area that we believed that crop consultants (PCAs) could readily identify and anticipate production and insecticide use in a local area.

Sharing Neonicotinoids

Neonicotinoid Limitations: Maximum usage by crop per season*

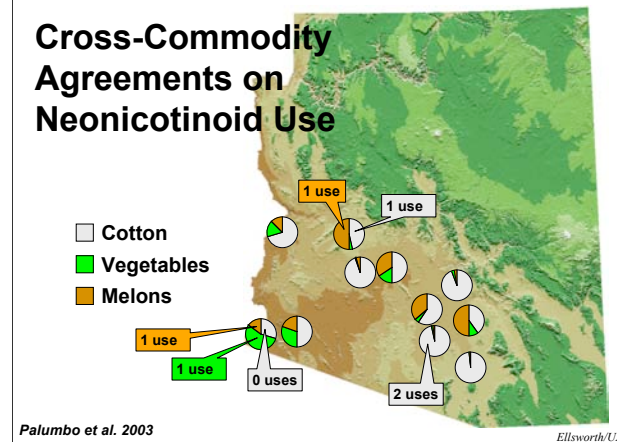
Community	Cotton	Melons	Vegetables
Multi-Crop	0	1	1
Cotton / Melon	1	1	—
Cotton-Intensive	2	—	—

*Seed, Soil, or Foliar

Ellsworth/UA

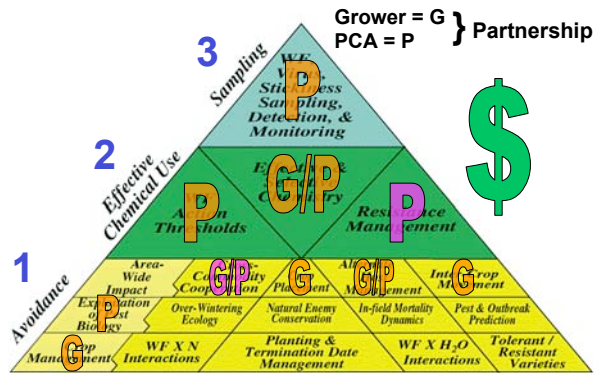
Under John Palumbo's leadership, we developed a stakeholder-driven set of guidelines that, in its simplest form, in essence, restricts neonicotinoids as a class to just two uses per cropping community. In a cotton-intensive community, growers of cotton there can use up to 2 non-consecutive neonicotinoids per season, while in cotton/melon communities, those two uses are shared between the cotton and melon grower. Perhaps most controversial, in the multi-crop community, the cotton growers there forego any usage of this chemical class, reserving the two uses to melon and vegetable growers there who are so dependent on this class for their whitefly control.

Cross-Commodity Agreements on Neonicotinoid Use



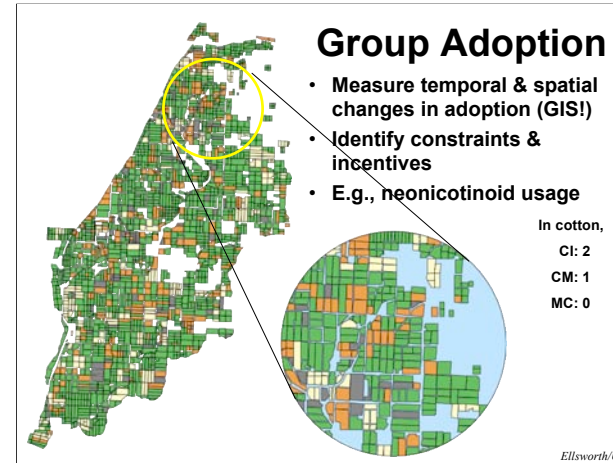
I want to emphasize that these guidelines did not come from a vacuum. They were developed in consultation with the industries they serve, cotton growers, vegetable and melon growers, professional crop consultants, and the affected agrochemical companies. Further, the ecological context is relevant to the key pest target. Compliance is voluntary, but we have a project to measure this explicitly in Arizona and I will share with you some of this preliminary data in the end of this talk.

Integrated “People” Management



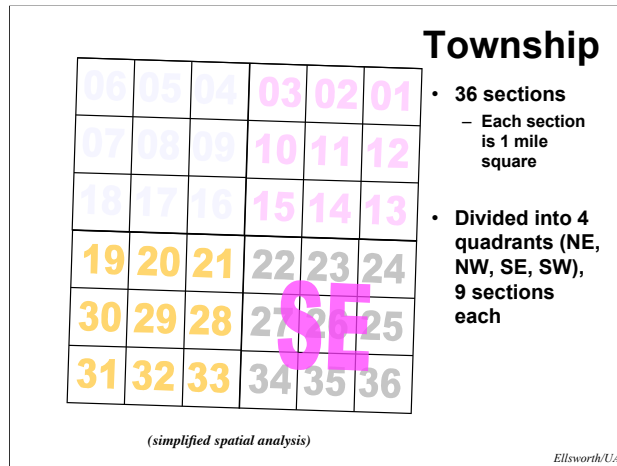
IPM becomes “integrated people management”, because Bemisia don’t make decisions, people do. Ultimately, this IPM system is an explicit partnership between grower and PCA. Some elements are clearly under the control of the PCA, while others the grower, and still others may be shared responsibilities of the PCA and grower. The difficulty therefore is making sure both parties have a clear understanding of their role in the efficient management of this pest. In terms of resistance management, the PCA tends to be the decision-maker. Growers, on the other hand, either alone or in concert with the PCA are key in cross-commodity cooperation. Ultimately, we have to remind ourselves that this is an economic system as much as it is an ecological system, and in the end, growers control the purse strings and \$ trumps everything.

Group Adoption

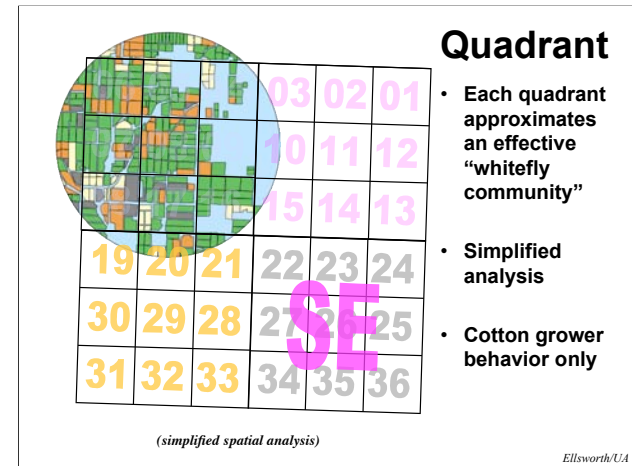


- Measure temporal & spatial changes in adoption (GIS!)
- Identify constraints & incentives
- E.g., neonicotinoid usage

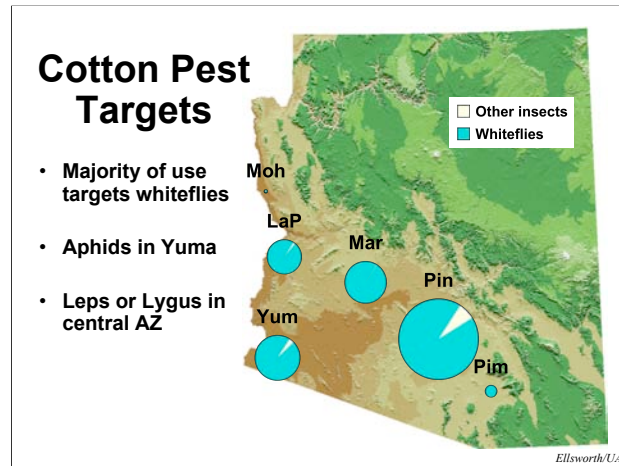
We hope to measure what incentives and constraints there are in complying with our cross-commodity guidelines through a new and innovative project to measure pesticide use both spatially and temporally across various cropping communities. Because the unit of interest is a community, individual behaviors are not as important as the adoption by whole groups within each community. We will do this work using a GIS approach, but the data are not ready for this yet. Instead, I will present you a simplified analysis that focuses, once again, on cotton-grower behavior only and on the usage of neonicotinoids. But before I show the data, I would like to briefly explain the approach we are taking.



In the U.S., we are fortunate in that the landmass of this country is laid out on a grid that bears a legal description. One unit of this description is the "Township" which is 36 sq. miles in size made up of a 6 x 6 sectional grid. Each section is 1 mile square and numbered as shown. In this project, we further subdivided these townships into 4 quadrants.

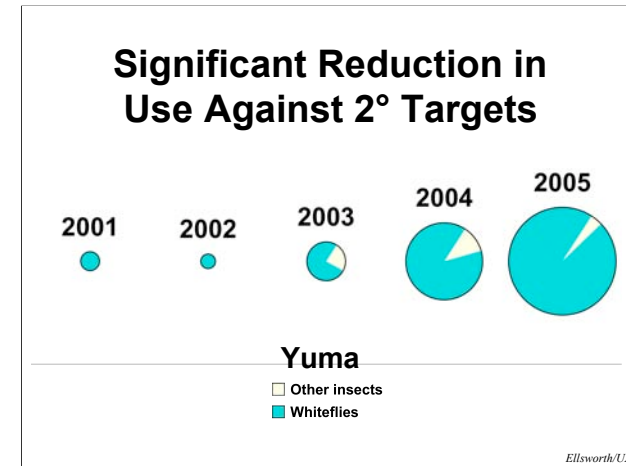


Each quadrant is a 3 x 3 section grid and roughly approximates an effective "whitefly community", which we defined, in guidelines, as the entire cropping community within a 2-mile radius. In this project, we will examine communities and the section level pesticide records for those areas. Again, today I will show a simplified analysis of cotton grower behavior only. In the future and with these data, we will measure changes in adoption both temporally and spatially using a geostatistical approach developed by Carrière and Dutilleul. In specific, we will examine neonicotinoid use by cotton growers in each of the 3 community types defined by the guidelines. Can a grower perceive "resistance risk" properly in his/her area and follow the applicable guideline?

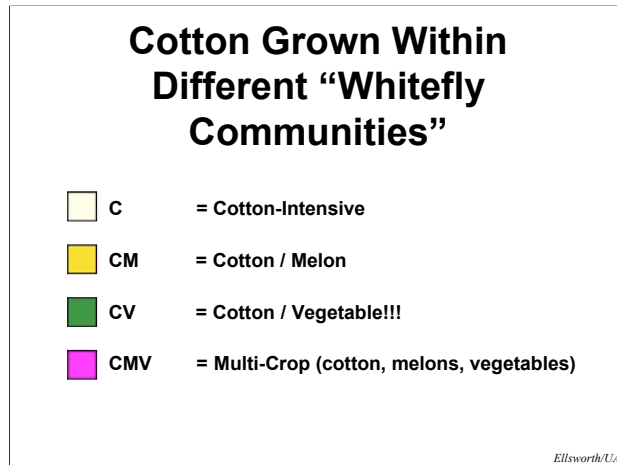


First, let's examine the pattern of use for neonicotinoids statewide. These bubble charts show proportional usage across the state (by county) and detail sprays targeting whiteflies and non-whitefly pests. In general, we suggest to growers that usage of this valuable class for non-whitefly pests is generally ill-advised. It is a matter of "wasting" a use.

This 2005 data shows that the majority of uses are in fact targeting whiteflies. A small amount of usage targets aphids in the Yuma area, only. And lepidopterans and lygus in central AZ.

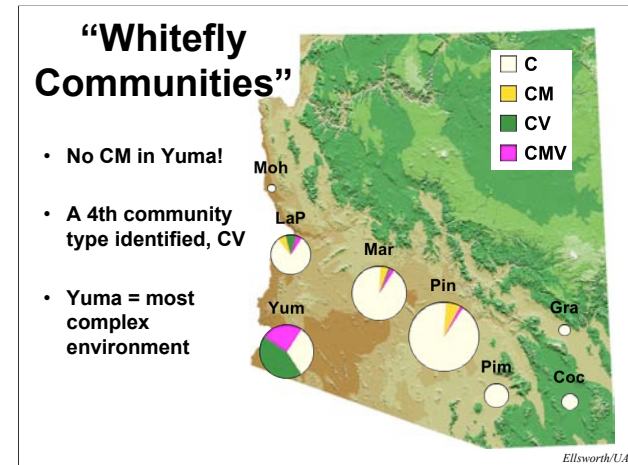


Isolating on "whitefly communities" in Yuma County, usage through time has increased in cotton as registrations developed and acetamiprid became more popular. However, there is a significant reduction in usage against non-whitefly targets from 2003 to 2005. This would suggest that growers there are carefully weighing the utility of using a neonicotinoid for anything other than whiteflies. In essence, they are not squandering their voluntary usage cap on other pests.



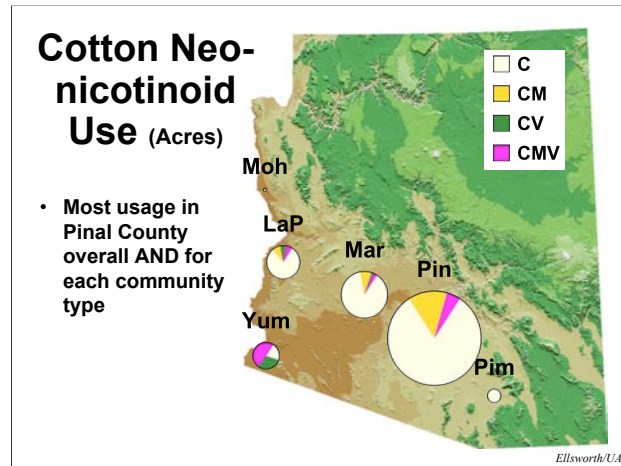
The last few charts will use the following color scheme to denote the **FOUR** cropping communities identified in the data. Note that cotton is grown in all four communities and that all data is with respect to what a cotton grower does in each of these communities: simple Cotton-Intensive through to the most complex Multi-Crop community where cotton, melons, and vegetables are grown.

Note that heretofore, we did not recognize the “cotton-vegetable” community as a distinct community type, and thus, there are no specific guidelines that dictate usage in this community type.

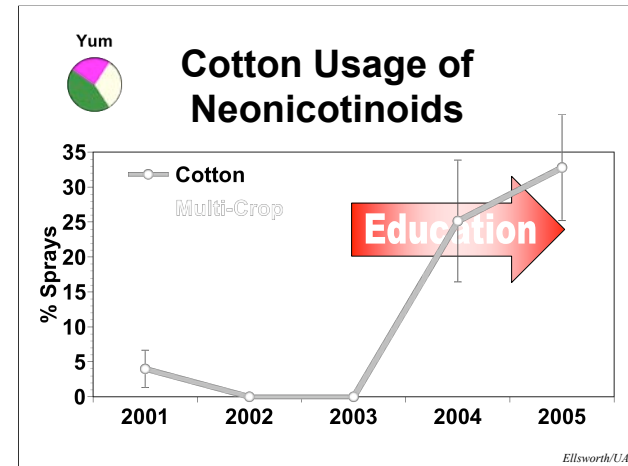


This first dataset shows the proportional number of “whitefly communities” present in each county by community type (used in the simplified analysis).

We found that the Cotton-Melon community does not operate in Yuma (at least based on this 2005 data). Further, the Cotton-Vegetable community is not only present but a major community type in the Yuma County area. Overall, too, it is clear that Yuma contains the greatest diversity of community types, including areas that qualify as “Cotton-Intensive.”

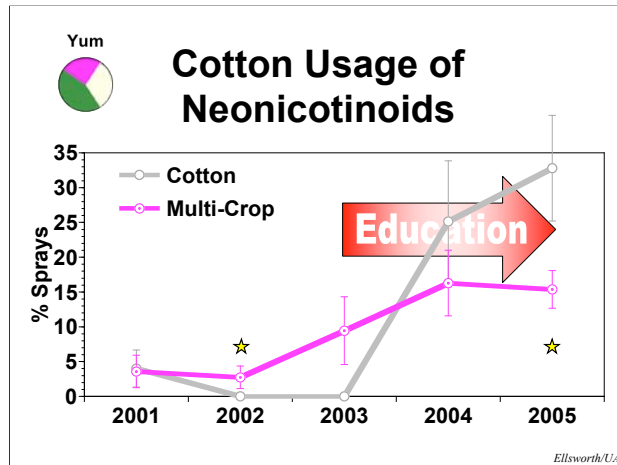


This plots cotton neonicotinoid use (in acres) across the state and among community types. Cotton neonicotinoid use in 2005 was greatest by far in Pinal County. This is a large acreage area, so this result was not surprising. However, it is interesting that even the cotton usage in the Multi-Crop communities of Pinal County is greater than the usage in the Multi-Crop communities in Yuma County.



Getting to the heart of the matter, we can examine cotton neonicotinoid usage in the more complex region of Yuma County by “whitefly community”. Here we see the percentage of neonicotinoid-containing sprays applied in the Cotton-Intensive communities located in Yuma County. In 2001, thiamethoxam was available, but by late 2002, acetamiprid became available as well. Still later (2004), dinotefuran was available to cotton growers. All the while, imidacloprid was available as a foliar spray either alone or in mixture with a pyrethroid.

Our guidelines were issued in 2003 along with intensive workshops and other communications. Educational intensity was reduced in 2004 but then re-intensified in 2005 as this was a difficult wf year.



Cotton growers in Cotton-Intensive communities of Yuma actually used significantly lower amounts of neonicotinoids in 2002 than the comparative cotton-growers in “Multi-Crop” communities. Usage increased as Intruder gained in popularity, at least to a point in 2004. Then, in 2005, we see the result we are looking for. That is, a cotton-grower growing in a more complex system (Multi-Crop) elected to use neonicotinoids with lower frequency than a comparable cotton-grower growing in the simpler Cotton-Intensive community. So this suggests that they are listening and trying to follow the guidelines, even in one of the worst whitefly years in a decade (see Palumbo area-wide data). At the same time, it does show that some growers use neonicotinoids in cotton even in multi-cropped areas.

Cooperative Extension Model

- Identify problem through stakeholder feedback
 - Stable whitefly management threatened by overuse of a key class of chemistry
- Develop solutions through applied research & education
 - Analysis of agroecosystem suggests variable risks; guidelines are generated, published & workshops conducted
- Assess & measure impacts and changes in client behavior
 - Cotton growers making insecticide use choices based ostensibly on guidelines
- Develop feedback & make adjustments in research & education
 - Cotton-Vegetable communities: what risk...?

Ellsworth/UA

What I have detailed today, quickly, is the classic Extension model, where workers identify problems through stakeholder engagement and they develop solutions through applied research and education. These are time-tested standards in Extension. However, a modern program continues with formal assessments that measure impacts and changes in client behavior. And with this information, we can benefit from feedback that helps us make needed adjustments in our research & education programs. One important outcome already is discovering a heretofore unrecognized “whitefly community”, Cotton-Vegetable. We will have to consider this along with other results in the generation of new research, new guidelines, and education.



A large group of people are involved in the larger effort to research, develop, and disseminate cross-commodity whitefly management programs [e.g., T.J. Dennehy, Y. Carrière, C. Ellers-Kirk (all UA); S. Naranjo, J. Blackmer, S. Castle (USDA-ARS); P. Dutilleul (McGill U.); R.L. Nichols (Cotton Inc.); AZ Cotton Growers Assoc., Western Growers Assoc., AZ Crop Protection Assoc.]. In addition, we thank the ADA and AZ-NASS for cooperating on the development of a pesticide use database; WRIPM & Cotton Inc. for providing grant support; and the Arizona Cotton Research & Protection Council for providing GIS mapping support.

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.