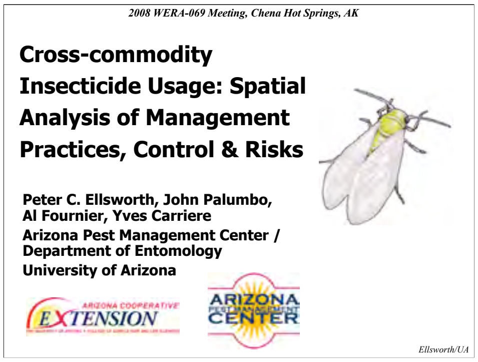
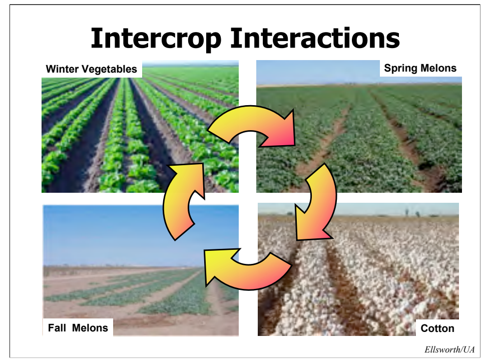


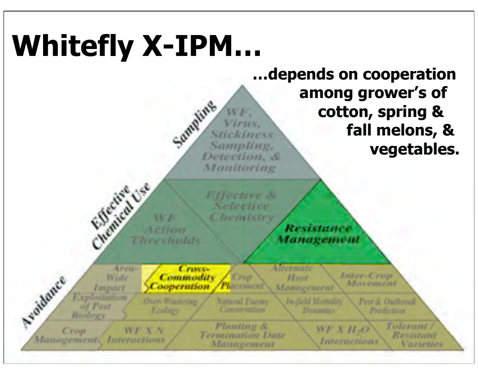
In Arizona, we are investing considerable IPM resources to research, develop, and analyze spatially-explicit data that can be used in advising clientele and in evaluating programs.

In one such program, we have a WR-IPM funded project to evaluate the adoption of cross-commodity IPM and resistance management guidelines for whiteflies by growers of cotton, vegetables and melons in Arizona.

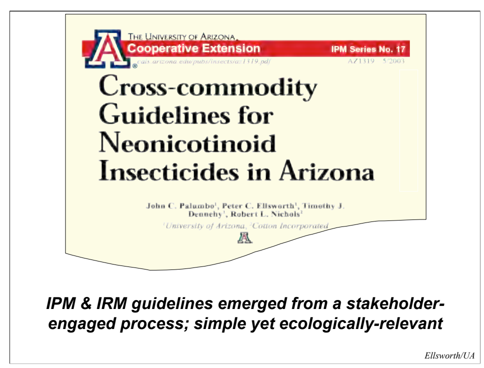


In AZ, our desert ecosystem is transformed by water into a very complex agroecosystem. AZ's year round growing season provides for a sequence of crop plants, winter vegetables like broccoli, lettuce, other cole crops, spring melons (esp. cantaloupes), summer cotton, and fall melons. These crop islands 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.

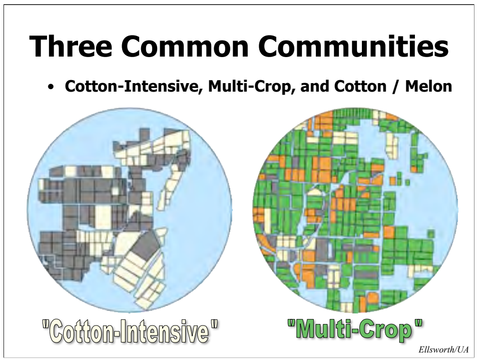
Photo credit: JCP



Singular attempts to deploy recommendations in one crop especially for a mobile, polyphagous pest seems futile, when registrations of key chemistries are broad across multiple crops. Thus, our cross-commodity effort concentrates on elements where we can integrate our practices across multiple crops. Resistance management is a shared responsibility that extends 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.



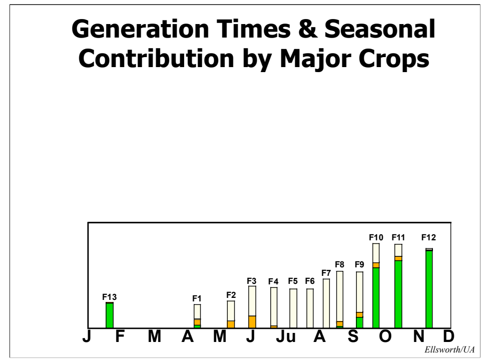
The specifics of the stakeholder process are beyond the scope of what I can cover in this presentation. However, I can say that this was not a desktop exercise limited to 1 or 2 people. Instead, these guidelines, which were published and disseminated in 2003, were the result of a year-long, stakeholder-engaged 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.



Neonicotinoids are critical to our whitefly control system. Yet real and perceived risks for resistance among growers of different crops within different communities in Arizona are not the same.

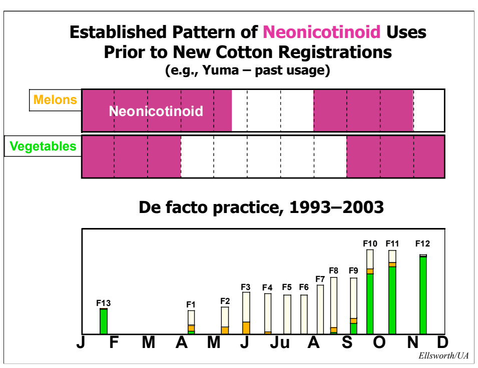
So rather than develop a single rule to be followed statewide, we attempted to develop guidelines that could be applied differentially according to cropping community and proportional to the inherent risks of whitefly problems and resistance.

Three cropping "communities" were identified and targeted for this approach: Cotton-Intensive, Multi-Crop, and Cotton/Melon (not pictured). White = cotton; orange = melons; green = vegetables (mostly lettuce); and gray = non-treated and/or non-whitefly hosts (mostly small grains, corn, sorghum, and alfalfa).



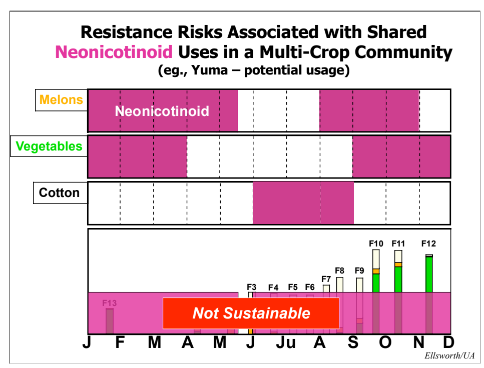
To illustrate the extreme risks of resistance in our most complex cropping system, we can break the system down into component parts. First, we view the generational production and relative abundance of whiteflies through time, again, where green represents the contributions of vegetables to overall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

From Palumbo et al. 2003



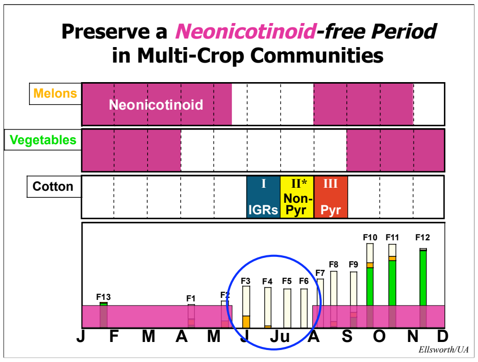
The second component is the established pattern of neonicotinoid usage, or really the periods during which residues are present, as shown here for vegetable and melon crops in Yuma valley. This pattern of usage was the de facto practice for 10 years while essentially only soil-applied imidacloprid was being used, and used ostensibly without problems of resistance. This latter fact was supported by the routine resistance monitoring that Dr. Tim Dennehy had 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, rather than making use of the newly available foliar neonicotinoids in cotton.

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

Sharing Neonicotinoids

Neonicotinoid Limitations:*

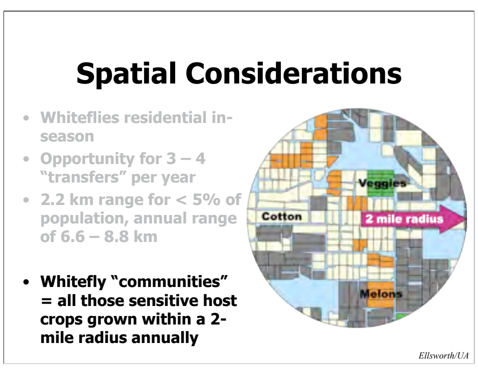
Maximum usage by crop per season

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.



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.

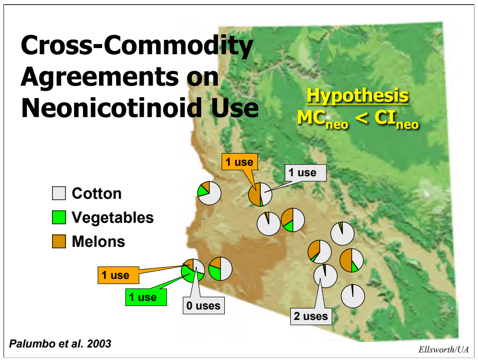
Cooperative Extension Model

- 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
- Develop feedback & make adjustments in research & education

Ellsworth/UA

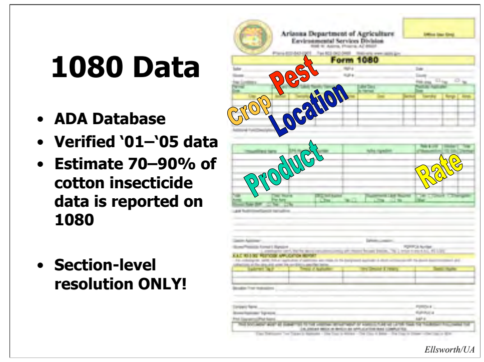
What I have detailed so far today, quickly, is the classic Extension model, where workers identify problems through stakeholder engagement and they develop solutions through applied research and education. These are time-tested standards in Extension. However, a modern program continues with formal assessments that measure impacts and changes in client behavior. With this information, we can benefit from feedback that helps us make needed adjustments in our research & education programs.

This funded effort is an opportunity for us to invest in the 2nd half of our approach: assess, measure, and develop feedback and adjust programs.



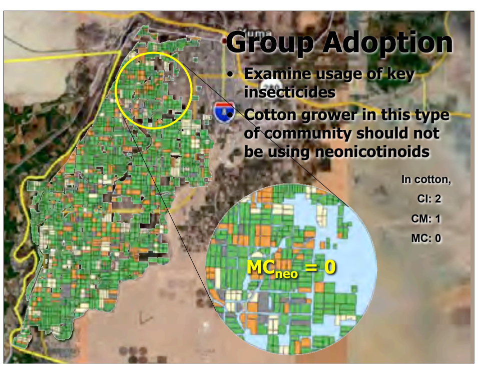
I want to emphasize that these guidelines did not come from a vacuum. They were developed in consultation with the industries they serve, cotton growers, vegetable and melon growers, professional crop consultants, and the affected agrochemical companies. Further, the ecological context is relevant to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

In particular, we can examine the hypothesis that cotton growers in Multi-Crop communities should be making less use (if any) of neonicotinoids relative to cotton growers in Cotton-Intensive communities within similar localities (to control for differences in pest pressures).



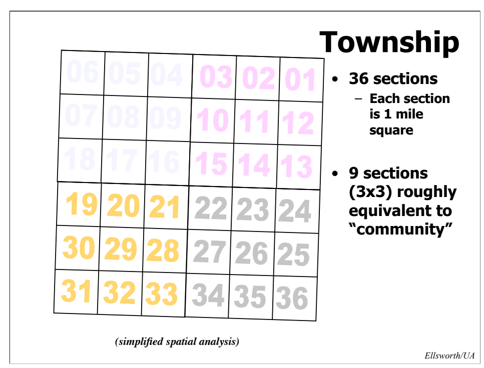
The tools we need to do this assessment include a rich database of pesticide use reporting data acquired from our own Arizona Department of Agriculture. We do not have 100% mandatory use reporting in AZ (as does CA). However, all custom-applied (for hire) and all aerial applications (upwards of 80%) and some other pesticides must be reported to the state via the L-1080 form. We estimate that for 70-90% of all cotton insecticide applications are reported to ADA. The data includes the crop, target pest(s), location (T.R.S.), and product and rate.

Our resolution is only down to individual sections, and not individual fields, as only the legal descriptions are captured in this reporting process.

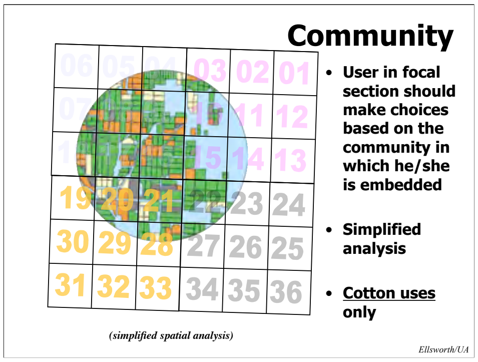


We also have access to detailed GIS-based crop maps statewide as maintained by a cotton-grower agency, the Arizona Cotton Research & Protection Council. Between these two datasets we are able to identify the cropping make-up of each section and beyond.

We wished to measure what incentives and constraints there are in complying with our cross-commodity guidelines. Because the unit of interest is a community, individual behaviors are not as important as the adoption by whole groups within each community. I will present you a simplified analysis that focuses mainly 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.

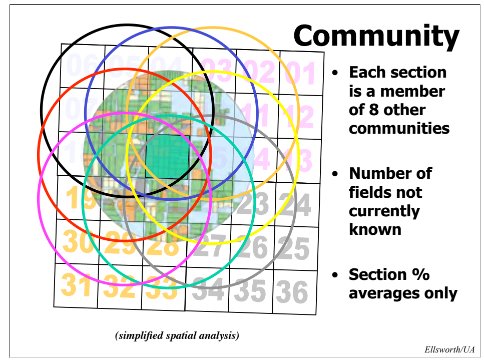


In the U.S., we are fortunate in that the landmass of this country is laid out on a grid that bears a legal description. One unit of this description is the "Township" which is 36 sq. miles in size made up of a 6 x 6 sectional grid. Each section is 1 mile square and numbered as shown. Nine sections (3x3) are roughly equivalent to a whitefly cropping "community" as defined in our guidelines.



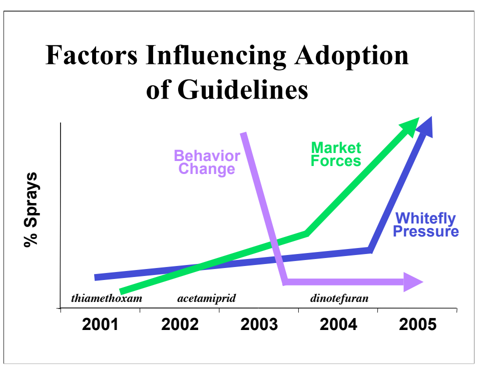
Each quadrant is a 3 x 3 section grid and roughly approximates an effective "whitefly community", which we defined, in guidelines, as the entire cropping community within a 2-mile radius. In this project, we examined communities and the section level pesticide records for those areas. In specific, we 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?

I.e., A user in a focal section should be making whitefly control product choices based on the community in which he or she is embedded.

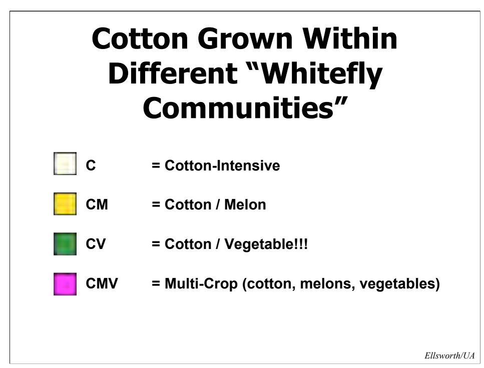


Bear in mind that one section can be a member of 8 other communities that might be variably defined. But that again, the user will make decisions based on the cropping pattern in the surrounding 8 sections plus in the focal section.

At this time, we have not quantified the number of fields per section. So all response variables discussed today will be Section % averages, rather than uses / field or total acres.

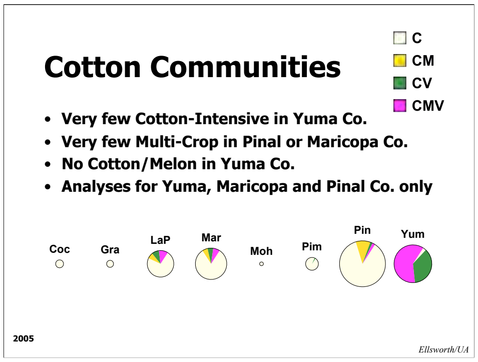


Documenting changes in behavior through time requires a clear understanding of competing forces & inherent change in the system. Market forces (new registrations) push users towards greater usage. In 2001, thiamethoxam was available, but by late 2002, acetamiprid became available as well. Still later (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. Whitefly pressures also change over time. In our case, pressures were low but increasing 2001-04 until 2005 when whitefly pressures were at a decade high. This pushes usage upward. Our impact on behavior should show some kind of decline in usage as a consequence of deployment of our educational programs for cotton growers in Multi-Crop communities.



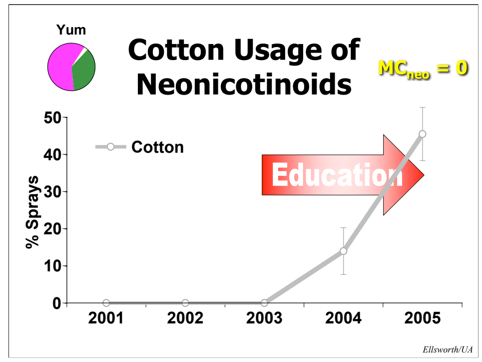
The next few charts will use the following color scheme to denote the FOUR cropping communities identified in the data. Note that cotton is grown in all four communities and that all data is with respect to what a cotton grower does in each of these communities: simple Cotton-Intensive through to the 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.



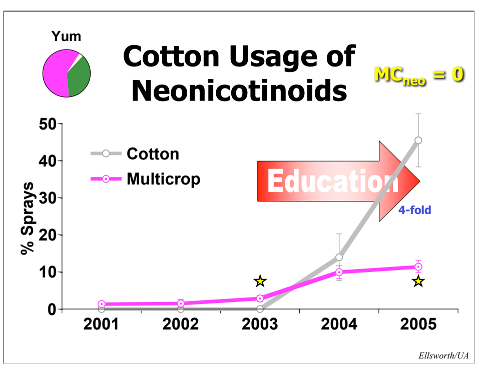
This bubble chart indicates the number and types of communities that grow cotton by county. As expected, there are very few Cotton-Intensive communities in Pinal county, but they do exist there! Conversely, there are very few Multi-Crop communities in Pinal or Maricopa counties, but again they do exist there.

Our analyses will focus on these larger agricultural counties where most of the whitefly applications are made each year.



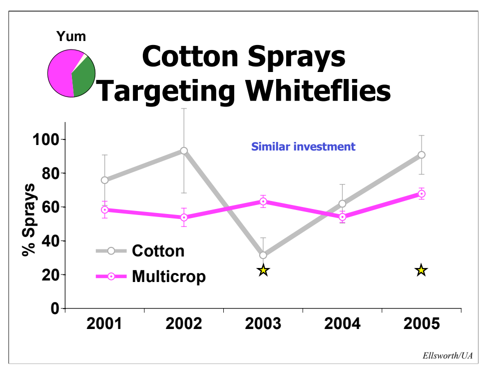
% Sprays that contained a neonicotinoid for cotton fields in Cotton-Intensive communities of Yuma Co. These growers should be limited to no more than two non-consecutive neonicotinoid sprays (gray line). Cotton neonicotinoid usage started at 0% in 2001-2003 and increased as acetamiprid use increased, topping out at ca. 45%.

Our guidelines were published in 2003 and our educational efforts were intense to begin with and then re-intensified in 2005 (red arrow).



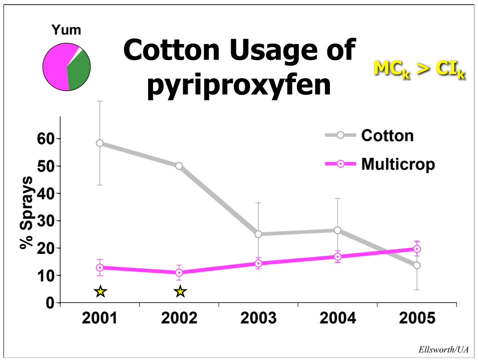
Cotton growers in Multi-Crop communities of Yuma Co. had very small usage of this class of chemistry in 2001-2002, and significantly higher usage in 2003. By 2005, the trend was reversed, presumably as a result of our education, showing a 4-fold reduction in neonicotinoid usage in comparison to cotton users in Cotton-Intensive communities.

Of course, the guidelines would have suggested no neonicotinoid usage in Multi-Crop communities. So ca. 10% of the applications made were at odds with the guidelines.



As a check to be sure that there are not large differences in pressure or spray investments for cotton by community, we can look at the % of Sprays that were targeting whiteflies. In general, both communities are spraying whiteflies about 60-80% of the time.

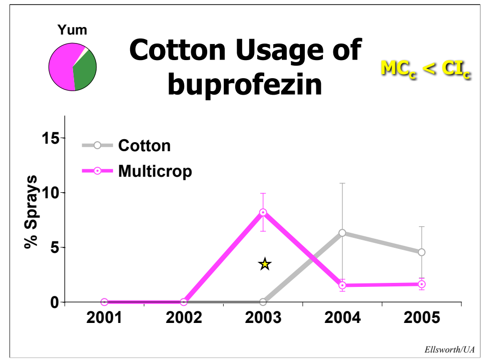
% Sprays (wf target) Yuma LSmeans



If neonicotinoid usage is going up through time, albeit at different rates, and whitefly control investments are stable, other chemistry must be changing. In this case, an IGR, pyriproxyfen has been steadily declining in usage in Cotton-Intensive communities, obviously in favor of neonicotinoid chemistry (usually acetamiprid). This is consistent with guidelines in general.

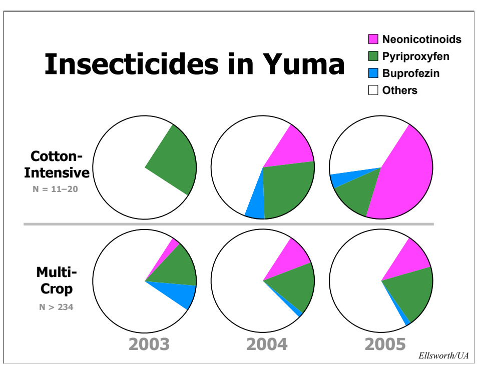
Also, there has been marginal increases in pyrproxyfen usage in Multi-Crop communities and this suggests that growers there are trying to make use of neonicotinoid alternatives.

% Sprays (Pyriprox) Yuma

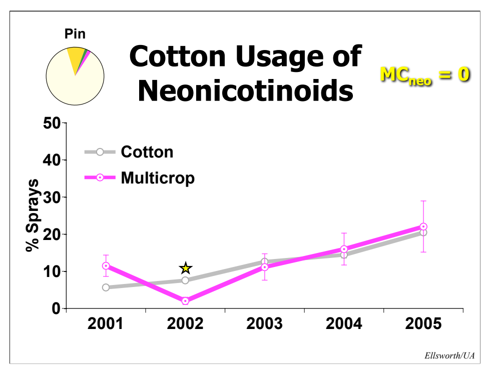


Buprofezin, another IGR, is not as popular in general, and is also subject to some cross-commodity constraints on usage in Multi-Crop areas (because of broad registrations). Here again, it appears that growers in Multi-Crop communities are minimizing their usage of buprofezin in comparison to Cotton-Intensive communities.

% Sprays (Bupro) Yuma

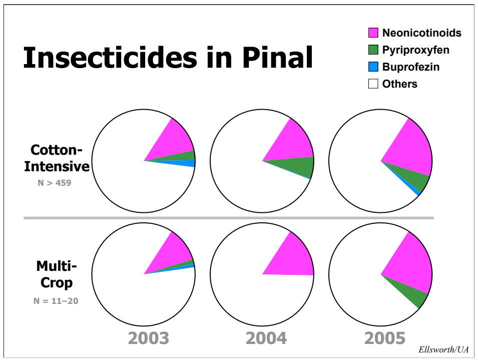


Reviewing the dynamics of major chemistries over time, we see all three trends simultaneously. Neonicotinoid usage has gone up in both community types over time, but less so in Multi-Crop communities. Pyriproxfen usage has remained steady in these same communities, but declined in Cotton-Intensive communities. Buprofezin is not used very much over this period, but in declining amounts in the Multi-Crop communities.

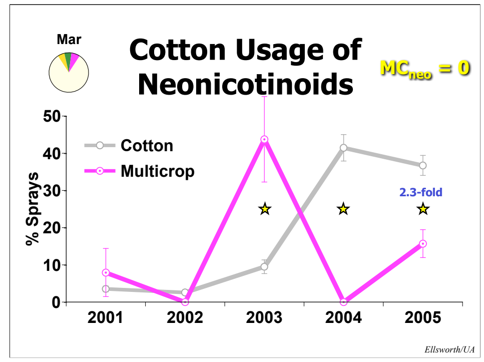


The conclusions are quite different as we move to the central part of the state and examine Pinal Co. usage data. Here it would seem that the clientele do not differentiate their usage of neonicotinoids by community type. The reasons for this are unknown at this time, but qualitative analyses of subject interviews should help us understand if this is a problem with the guidelines, perception of spatial dynamics, or perception of risk, among other potential factors. It could be as simple as growers not recognizing they are operating within a Multi-Crop community, for example.

% Sprays (Neonicotinoids), Pinal

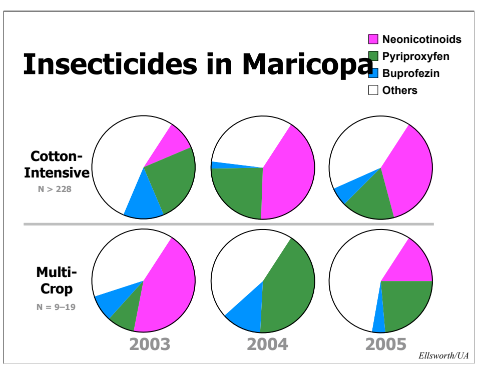


Usage dynamics over time: While other insecticides are used generally about 3/4ths of the time, neonicotinoid usage is consistent and undifferentiated by community type are time.

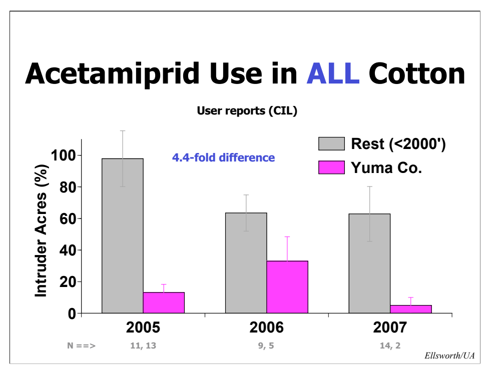


Maricopa Co. is another central AZ county and surrounds the city of Phoenix. Usage of neonicotinoids has changed over our key period, 2003-2005. Initially, cotton growers in Multi-Crop communities were using neonicotinoids at a much higher rate than cotton growers in Cotton-Intensive areas. This trend reversed abruptly in 2004 and continued in 2005 with a 2.3-fold reduction in use of neonicotinoids in Multi-Crop communities. This would suggest that practitioners were influenced by the guidelines, although there remained about 15% of sprays containing a neonicotinoid in cotton within Mult-Crop communities.

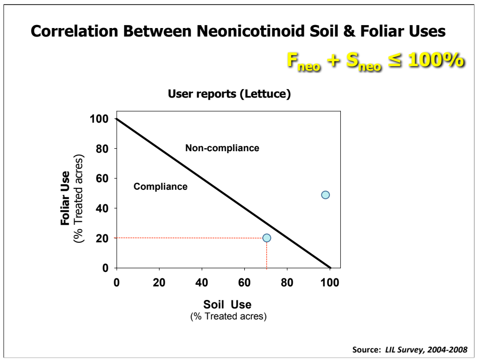
% Sprays (Acetam) Maricopa



Cotton in Cotton-Intensive communities expanded their usage of neonicotinoids, maintained usage of pyriproxyfen and reduced usage of buprofezin. Cotton in Multi-Crop communities minimized neonicotinoid usage in favor of pyriproxyfen, and buprofezin usage declined consistent with the guidelines.



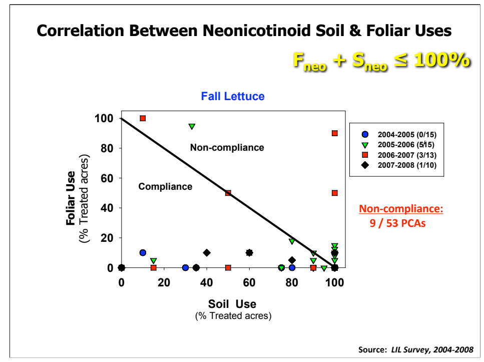
Data until now has all been from pesticide use reports maintained by ADA and only for 2001-2005. This dataset is different; it is from user reports in a Cotton Insect Losses process that we conduct each year with practitioners and brings our information forward to 2007. While we cannot separate communities spatially, we can contrast Yuma Co. (which is predominated by Multi-Crop communities) to the rest of the low desert of AZ (which is predominated by Cotton-Intensive communities). Here again, we see that on average, users use less neonicotinoids in cotton in mult-cropped areas in comparison to cotton-intensive regions. It would appear that the guidelines are observed in general. (Acetamiprid is the major cotton neonicotinoid and dominates this marketplace).



So far, we have examined exclusively cotton-growers behavior. In this chart we are showing how lettuce growers make use of the neonicotinoid class of chemistry as reported in user reports of our Vegetable Insect Losses workshops.

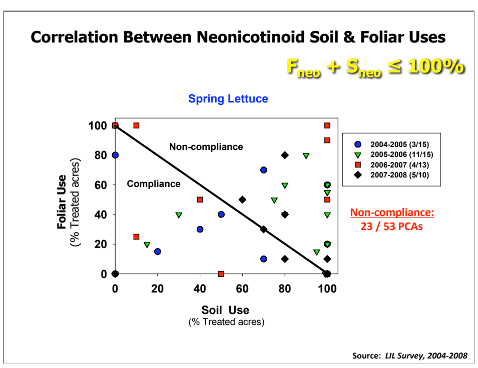
With foliar uses on one axis and soil uses on the other, we can test whether they are observing our guidelines and the labels of some products by not using foliar neonicotinoids over the top of crops that have already used a soil neonicotinoid. So a user reporting 70% soil use and 20% foliar use of this class could be in compliance (total 90%). However, a user who reports 100% soil use AND 50% foliar use is clearly outside the guidelines.

Data from Palumbo, unpubl.

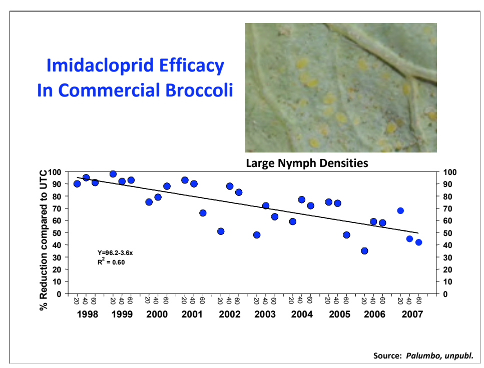


Looking at growers of fall lettuce from 2004-2007, we can see that the majority of pest control advisors (PCAs) are within the compliance zone. There are some examples where non-compliance is occurring, 9/53.

Data from Palumbo, unpubl.



Things looked good in the fall where they are battling whiteflies primarily. However, in spring lettuce, the picture changes and now shows closer to 50% non-compliance. Why is this? As it turns out, many of these neonicotinoid uses are likely targeting aphids rather than whiteflies, which are less of a concern in the spring crop. So perception of the resistance risk may be quite different between users in the fall vs. users in the spring.



John Palumbo has been doing systematic examinations of imidacloprid efficacy (soil uses) in broccoli for the past 10 seasons. Charting efficacy relative to a control shows rather marked reductions in efficacy in these studies. While users don't widely report problems with this use pattern <u>and</u> soil uses, especially in fall crops, are still almost universally practiced, this is a warning sign that we must re-consider our management program and decide whether further steps are needed to stabilize the control system. A dialog is currently underway with clientele through our Cross-Commodity Research and Outreach Program working group.

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
  - New data on imidacloprid performance; new products?

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.

Growers did in fact alter their insecticide use patterns as a result of our guidelines. However, resistance remains a threat to this and other chemistries. We will have to consider this along with other results in the generation of new research, new guidelines, and education.

Photo credit: J. Silvertooth

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. Carriére, 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.