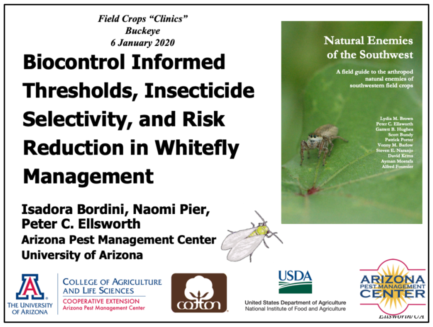
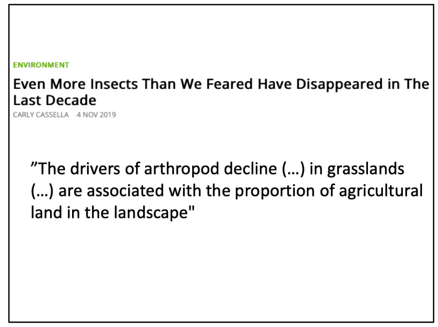


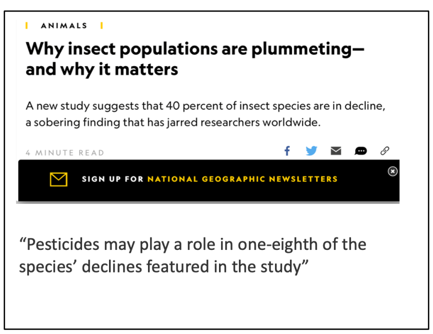
Today in Part 1, Isadora will talk about selective technologies in cotton and biological control, and how this contributes to the sustainability of the cotton industry.

In Part 2, Naomi will explore the concept of risk and how it is managed in our industry, especially as it relates to pesticide use and insect management.



Biodiversity conservation is one of the large issues that govern our science nowadays. Insects are species that must be protected because they are a primary food source for several species in the world, and provide significant ecosystem services, such as, pollination, biological control and decomposition.

However, the survival of these important organisms might be at risk. Research indicates a potential decline in insects' population. There is a lot of uncertainty regarding the factors leading to this potential decline. However, one factor that has been frequently pointed out is insect's habitat loss due to land use for agriculture and urbanization.



The use of pesticides may be associated with insects' population decline as well. This factor is particularly important when pesticides impact non-target organisms.

Pesticides may play a role in one-eighth of the species' declines featured in the study."

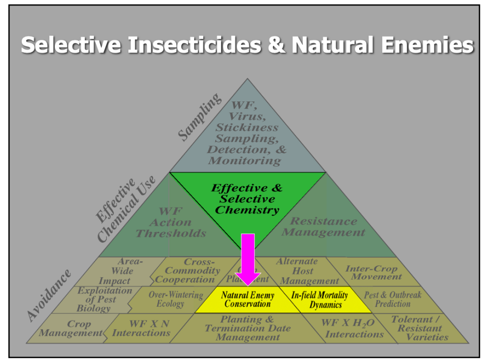
https://www.nationalgeographic.com/animals/2019/02/why-insect-populations-are-plummeting-and-why-it-matters/

Over the last years, consumers have become more aware of agricultural practices that might affect organisms and the environment. Thus, consumers along with industry have demanded sustainable practices in agriculture and other areas. Sustainability has become a key factor in the purchasing decisions of several consumers and industries in the world. Being able to produce cotton following sustainable practices will become even more important to be competitive, for access to different markets and to attend to the need for more sustainable practices.

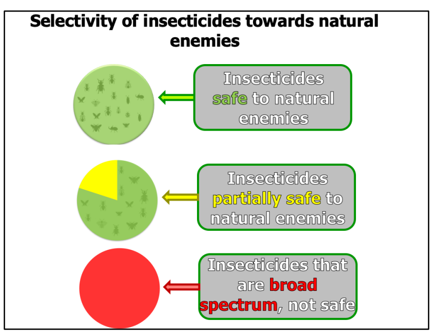
How does biological control help to achieve some of these demands?

- Conserve biodiversity
- Reduced insecticide use and toxicity
- Sustainability

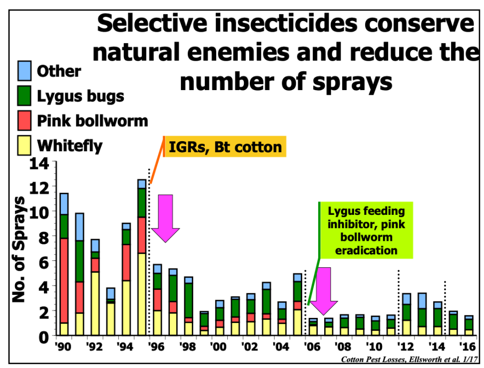
One of the goals of this presentation is to discuss with you how conservation biological control practiced in Arizona cotton has helped to achieve some of the demands for sustainability in agriculture within the context of pest management. I will explain how it has helped to conserve biodiversity in crop systems where insecticides are deployed; reduce number of sprays through the use of insecticides safer to natural enemies and other non-target organisms; and how it has enabled social, economic and environmental sustainability in cotton production.



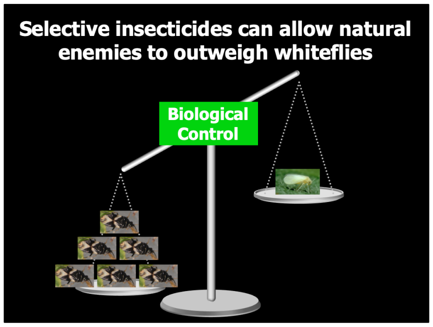
Conservation biological control can be achieved through the use of selective insecticides, which are safer towards natural enemies and help to preserve their ecosystem services. The compatibility of new cotton insecticides with natural enemy conservation is the key factor to avoiding pest problems in our highly developed cotton Integrated Pest Management (IPM) program.



We can classify insecticides based on their safety or selectivity towards natural enemies and other non-target organisms. In our system, insecticides that conserve the majority of natural enemies are called ”fully selective”. Insecticides that harm some natural enemies, but yet conserve the majority of them are called “partially selective”. However, insecticides that kill almost any insect are called “broad-spectrum insecticides”. “Fully” and ”Partially” selective insecticides are compatible with conservation biological control, because natural enemies are conserved after their application. However, broad-spectrum insecticides kill natural enemies. As a result, pest resurgence and secondary pest outbreaks may take place because pests are released from biological control.

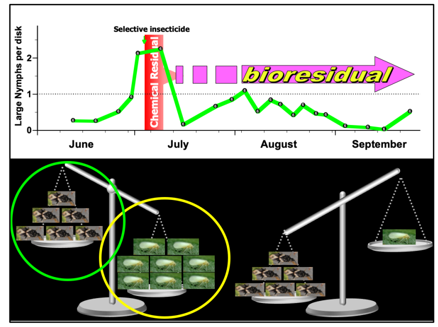


This chart represents the insecticide spray history in Arizona cotton. History has shown us with each major advance in selective approaches introduced to our system, such as Bt-cotton, whitefly-specific insect growth regulators (IGRs), and a Lygus-specific feeding inhibitor, has brought with it major gains in natural enemy conservation and insecticide use reduction.

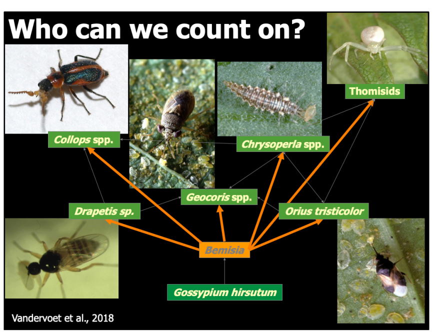


How do selective insecticides work in concert with biological control?

Selective insecticides reduce pest density while conserving natural enemies. This process allows natural enemies to outweigh pests, resulting in a functioning biological control of pests.



This chart shows the number of large whitefly nymphs per disk over time. Dashed grey line = large nymph threshold. A selective insecticide (green arrow) was sprayed once large nymphs were above threshold. When the insecticide was sprayed, there were lots of whiteflies, however, there was not a proportional number of predators to provide functioning biological control (left scale). The chemical residual lasts only for a few days (red rectangle). However, once this residual is gone, whiteflies remain below threshold, because the use of a selective insecticide favored biological control, reducing whitefly numbers while conserving natural enemies. As a result, natural enemies finally outweighed whitefly numbers & were able to provide functioning biological control (right scale). The period when pest control is exclusive due to natural enemies & other natural factors, after the application of a selective insecticide, is called Bioresidual.



These arthropods are key predators that dominate the relationship between whiteflies and their predation in the Arizona cotton. They include:

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

Collops beetle.

Big-eyed bugs.

Lacewings (only green lacewing larvae feed on whiteflies. The adult is a non-feeding life stage).

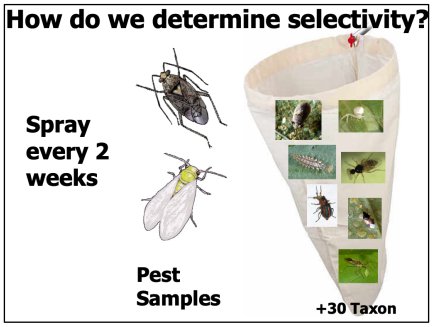
Crab spiders (though other spiders can also be present in large numbers).

Minute Pirate bugs.

Are novel insecticides selective for natural enemies in Arizona cotton?

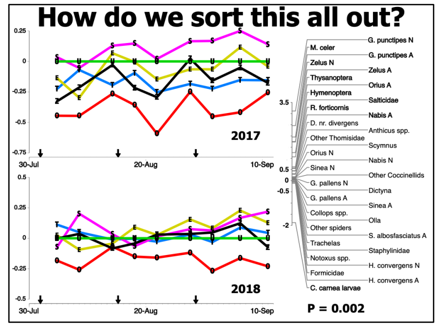
Chemical Common Name	Product Name	Chemical Group Name
Afidopyropen	Sefina	Pyropene
Cyantraniliprole	Exirel	Diamide
Flupyradifurone	Sivanto	Butenolide
Pyrifluquinazon	PQZ	Pyridine azomethine
Sulfoxaflor	Transform	Sulfoxamine

During Isadora Bordini's Master's degree, we examined the selectivity to non-target organisms, especially to key natural enemies in our system, of the insecticides listed above. In our cotton system, Sefina, Exirel, Sivanto and PQZ are insecticides used for whitefly control. Transform is used for Lygus control, however, it has a suppression effects on whiteflies. Sefina and PQZ were registered for the first time in 2019. Exirel and Sivanto have been registered for a short time, and Transform has been registered in our system for a few years.



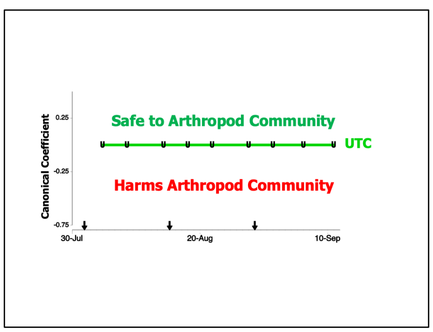
To determine the selectivity of insecticides to natural enemies, we used 60x60 ft plots. Insecticides were sprayed every 14 days for a total of 3 sprays at their highest labeled rates. Candidate insecticides were compared to a positive control (a broad-spectrum insecticide), and a negative control, the untreated check (UTC). We created a worse-case scenario by using the highest rates and applying 3 sprays at biweekly intervals. We sampled pests and non-target organisms (i.e., natural enemies), and we identified and counted more than 30 taxon.

Selective Insecticides, Predators & Risk
2020 Field Crops Clinics, January



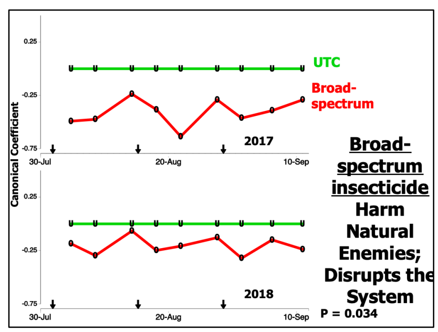
These charts are called principal response curves (PRC). PRC show trends in the whole arthropod community relative to an untreated check (y = 0 line) for each insecticide tested. The charts above display PRC during two growing seasons in Maricopa, AZ, where insecticides were sprayed three times (arrows). PRCs are accompanied by a species weight chart (right). The greater the species weight the more the response for that species resembles the trends shown in the PRC.

Selective Insecticides, Predators & Risk
2020 Field Crops Clinics, January

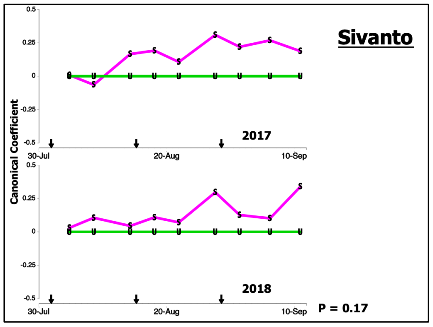


I would like to explain how to interpret PRC. The green curve is the untreated check (y = 0). In PRC, all insecticides are compared to an untreated check. Generally, insecticide curves above or that overlap the UTC curve are safe to a given arthropod community. However, curves below the untreated check might indicate that an arthropod community is being affected by an insecticide.

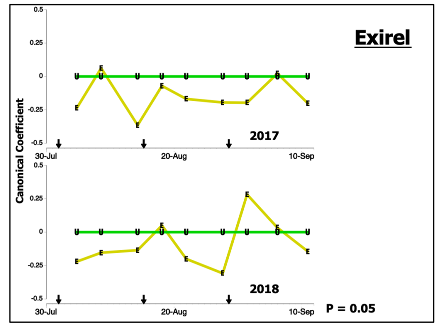
Selective Insecticides, Predators & Risk
2020 Field Crops Clinics, January



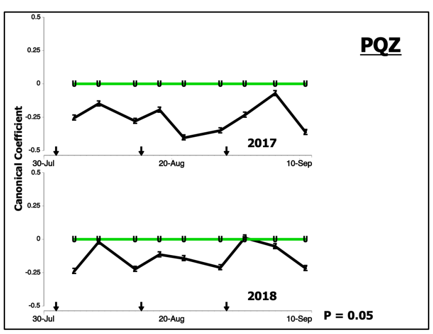
The broad-spectrum insecticide used as a positive control, acephate, harms the arthropod community as expected.



Sivanto is above the UTC most of the time in both years. Therefore, Sivanto is likely very safe towards the arthropod community in Arizona cotton.

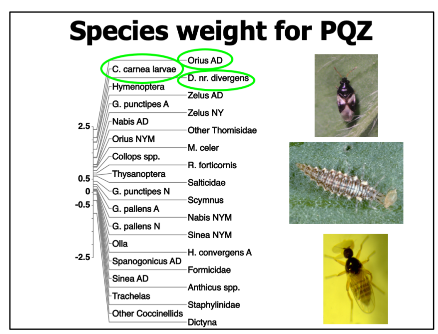


Exirel is above or overlapping the UTC in some instances, however, it remains below the UTC most of the time.

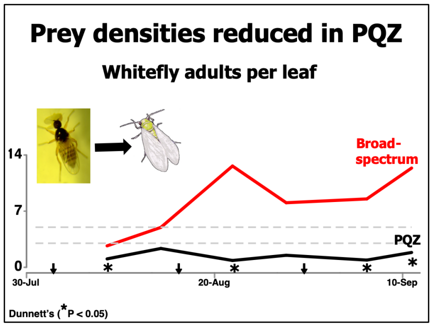


Similar to Exirel, PQZ is above or overlapping the UTC in some instances, however, it remains below the UTC most of the time.

The reduction in arthropod community does not necessarily mean that it is due to direct harmful or toxic effects of PQZ or Exirel. Likely, there was a change in the food web, mainly regarding predator to prey interactions. I will explain that next.

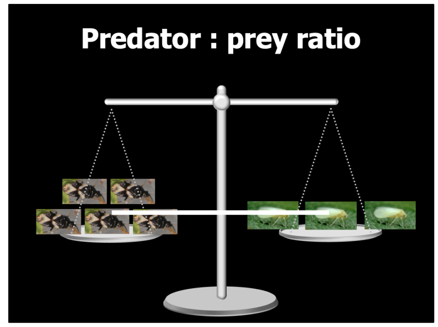


To explain the changes in the food web, likely responsible for reductions in arthropod community in the PQZ and Exirel treatments, I will be paying particular attention to these three species. PQZ will be used as an example.

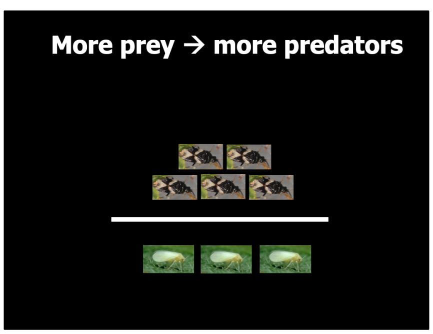


This chart represents the number of whitefly adults in the PQZ treatment over time. The dashed-grey lines represent the threshold for whitefly adults in Arizona cotton. PQZ was below the whitefly adult threshold throughout the whole season, meaning that the number of available prey (whiteflies) was very low.

Drapetis, one of the main species reduced in the PQZ treatment is known to feed exclusively on whitefly adults.



When we think about biological control mathematically, it is ratio between the number of natural enemies to the number of prey. There is a specific proportion between predator and prey that results in functioning biological control.



Because biological control is a proportion, it means that when there are more whiteflies, more predators can be supported.

However, when there are fewer whiteflies, fewer predators can be supported. Then, probably PQZ and Exirel are not harming predators. The reduction in the arthropod community in these insecticides is likely due to a reduction in prey availability, because they provided an excellent whitefly control.

Whitefly Large Nymphs			Predators per 100 Sweeps			
			Minimum number needed to provide biocontrol			
(1) Number of discs infested with large nymphs	(2) Percent infested discs	(3) Average per disc	(4) Big-eyed bug	(5) *Collops* beetle	(6) Crab spider	(7) *Drapetis* fly
4	13	0.2	Whitefly numbers are far too low; No need to spray or count predators			
5	17	0.3	1	1	2	14
6	20	0.3	1	1	2	14
7	23	0.4	1	1	2	18
8	27	0.5	1	1	2	22
9	30	0.6	1	2	3	27
10	33	0.7	1	2	3	31
11	37	0.8	1	2	3	36
12	40	1.0	1	2	4	44
13	43	1.1	1	3	4	49
14	47	1.2	1	3	5	53
15	50	1.4	2	3	5	62
16	53	1.6	2	4	6	71
17	57	1.8	Whitefly numbers are too high; Spray regardless of predator numbers			

Ellsworth/UA

In the IPM Short, "Counting Whiteflies & Predators", there are two tables to help interpret your predator's count data, and decide on a spray decision. This is the whitefly large nymphs and predators table.

Publication available at:

https://cals.arizona.edu/crops/cotton/files/PredatorToPreyRatios.pdf

Whitefly Large Nymphs		
(1) Number of discs infested with large nymphs	(2) Percent infested discs	(3) Average per disc
4	13	0.2
5	17	0.3
6	20	0.3
7	23	0.4
8	27	0.5
9	30	0.6
10	33	0.7
11	37	0.8
12	40	1.0
13	43	1.1
14	47	1.2
15	50	1.4
16	53	1.6
17	57	1.8

Ellsworth/UA

The normal threshold for large nymphs is 40% of leaf discs infested with 1 or more live, large nymphs (3rd or 4th instars). That's 12 leaves infested out of 30 total, and is equivalent to an average of 1 per disc.

ge Nymphs		Predators per 100 Sweeps			
		Minimum number needed to provide biocontrol			
(2) Percent infested discs	(3) Average per disc	(4) Big-eyed bug	(5) *Collops* beetle	(6) Crab spider	(7) *Drapetis* fly
13	0.2	Whitefly numbers are far too low; No need to spray or count predators			
17	0.3	1	1	2	14
20	0.3	1	1	2	14
23	0.4	1	1	2	18
27	0.5	1	1	2	22
30	0.6	1	2	3	27
33	0.7	1	2	3	31
37	0.8	1	2	3	36
40	1.0	1	2	4	44
43	1.1	1	3	4	49
47	1.2	1	3	5	53
50	1.4	2	3	5	62
53	1.6	2	4	6	71
57	1.8	Whitefly numbers are too high; Spray regardless of predator numbers			

There are 4 predator thresholds to go with your large nymph counts, one for big-eyed bug (specifically Geocoris pallens), one for Collops beetle (either species, C. vittatus or C. quadrimaculatus), one for crab spider, and one for Drapetis fly. These predator numbers indicate that you have functioning biological control proportional to the density of whitefly large nymphs in your field. Therefore, whitefly spray decisions might be delayed.

Whitefly Adults			Predators per 100 Sweeps			
			Minimum number needed to provide biocontrol			
(1) Number of leaves infested with 3 or more adults	(2) Percent infested leaves	(3) Average per leaf	(4) Lacewing larva	(5) Crab spider	(6) Minute pirate bug	(7) *Drapetis* fly
3	10	0.8	Whitefly numbers are far too low; No need to spray or count predators			
4	13	1.0	1	1	2	8
5	17	1.3	1	2	2	11
6	20	1.5	1	2	3	12
7	23	1.8	1	2	3	15
8	27	2.1	2	3	4	17
9	30	2.3	2	3	4	19
10	33	2.6	2	3	4	21
11	37	2.9	2	3	5	24
12	40	3.2	2	4	5	26
13	43	3.6	2	4	6	29
14	47	3.9	2	4	6	32
15	50	4.3	3	5	7	35
16	53	4.7	3	5	8	38
17	57	5.1	3	6	8	41
18	60	5.5	Whitefly numbers are too high; Spray regardless of predator numbers			

Ellsworth/UA

There is a table for adult whiteflies and predators, too.

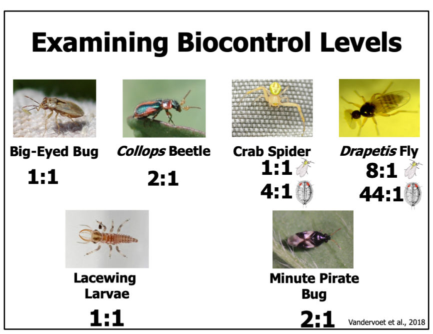
Whitefly Adults (1) Number of leaves infested with 3 or more adults	(2) Percent infested leaves	(3) Average per leaf
3	10	0.8
4	13	1.0
5	17	1.3
6	20	1.5
7	23	1.8
8	27	2.1
9	30	2.3
10	33	2.6
11	37	2.9
12	**40**	**3.2**
13	43	3.6
14	47	3.9
15	50	4.3
16	53	4.7

Ellsworth/UA

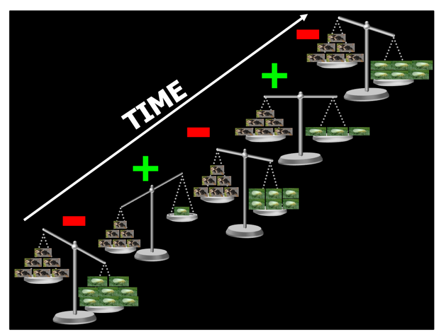
The adult threshold is 40% of leaves infested with 3 or more whiteflies (12 out of 30 here), which is equivalent to 3.2 adults per leaf…

Adults (2) Percent infested leaves	(3) Average per leaf	Predators per 100 Sweeps – Minimum number needed to provide biocontrol (4) Lacewing larva	(5) Crab spider	(6) Minute pirate bug	(7) *Drapetis* fly
10	0.8	Whitefly numbers are far too low; No need to spray or count predators			
13	1.0	1	1	2	8
17	1.3	1	2	2	11
20	1.5	1	2	3	12
23	1.8	1	2	3	15
27	2.1	2	3	4	17
30	2.3	2	3	4	19
33	2.6	2	3	4	21
37	2.9	2	3	5	24
40	**3.2**	**2**	**4**	**5**	**26**
43	3.6	2	4	6	29
47	3.9	2	4	6	32
50	4.3	3	5	7	35
53	4.7	3	5	8	38

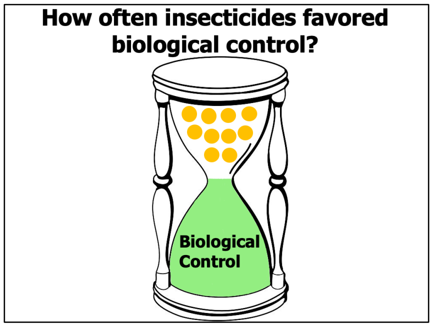
There are 4 predator thresholds to go with whitefly adult densities. These predator numbers indicate that you have functioning biological control proportional to the density of whitefly adults in your field. Therefore, whitefly spray decisions might be delayed.



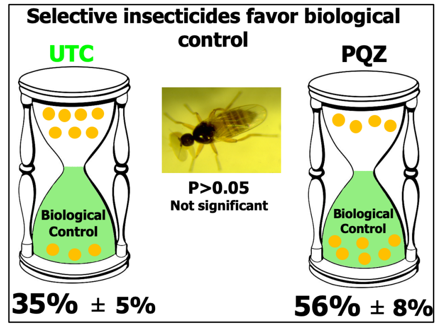
In summary, these are the eight ratios of key natural enemies relative to whitefly abundance that indicate functioning biocontrol found in previous research conducted by Vandervoet et al. (2018). Our next step in determining insecticide selectivity was to use these ratios as a metric to verify if the candidate insecticides were favoring or compromising these functioning biological control ratios.



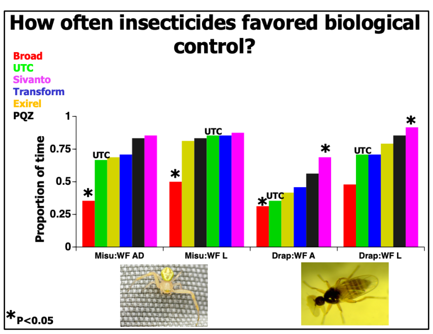
Functional biological control may not happen during the whole time in a cotton field. [This is why we need and use insecticides many times.] In this example, there was functioning biological control 2 out of 5 times.



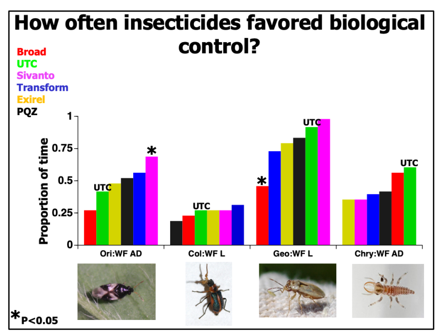
Based on the previous premise, we decided to investigate how often the candidate insecticides were able to favor functioning biological control.



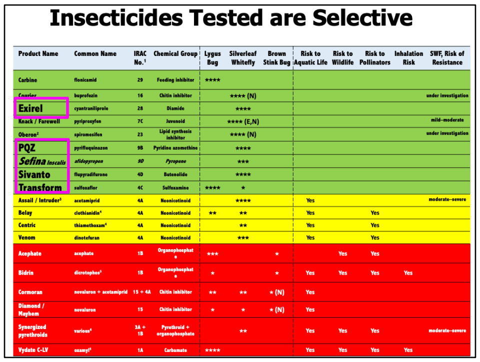
As an example, we looked at how often functioning biological control was being provided by Drapetis flies in the PQZ insecticide compared to the untreated check (UTC). PQZ was not significantly different from the UTC.
This fact re-enforces that reduction in abundance of the arthropod community may actually be a numerical response to lower prey densities in PQZ.



The broad-spectrum insecticide compromised ratios because of reduced natural enemies densities, but also because of higher whitefly densities in this treatment (acephate does not kill whiteflies in our system). The UTC had lower ratios often times because while natural enemies were unaffected (no spray), whitefly populations continued to grow more than in the insecticide treatments where whitefly efficacy is good (lowering whitefly densities). Sivanto, Transform, Exirel and PQZ were not significantly different from the UTC. This indicates these insecticides may be safe towards natural enemies and other non-target organisms in cotton in Arizona.



Sivanto, Transform, Exirel and PQZ were not significantly different from the UTC. This suggests that these insecticides may be safe towards natural enemies and other non-target organisms in cotton in Arizona. These results re-assure us again that reduction in abundance of the arthropod community may actually be a numerical response to lower prey densities in PQZ and Exirel.



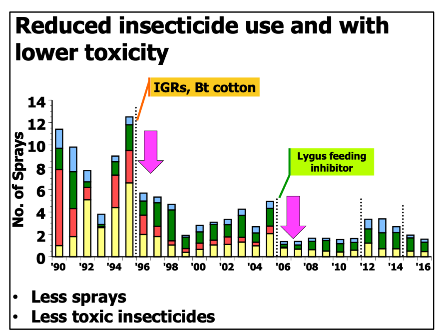
Insecticides Tested are Selective

Product Name	Common Name	IRAC No.[1]	Chemical Group	Lygus Bug	Silverleaf Whitefly	Brown Stink Bug	Risk to Aquatic Life	Risk to Wildlife	Risk to Pollinators	Inhalation Risk	SWF, Risk of Resistance
Carbine	flonicamid	29	Feeding inhibitor	****							
Courier	buprofezin	16	Chitin inhibitor		**** (N)						under investigation
Exirel	cyantraniliprole	28	Diamide		****						
Knack / Farewell	pyriproxyfen	7C	Juvenoid		**** (E,N)						mild–moderate
Oberon[2]	spiromesifen	23	Lipid synthesis inhibitor		**** (N)						under investigation
PQZ	pyrifluquinazon	9B	Pyridine azomethine		****						
Sefina Inscalis	*afidopyropen*	*9D*	*Pyropene*		***						
Sivanto	flupyradifurone	4D	Butenolide		****						
Transform	sulfoxaflor	4C	Sulfoxamine	****	*						
Assail / Intruder[3]	acetamiprid	4A	Neonicotinoid		****		Yes				moderate–severe
Belay	clothianidin[4]	4A	Neonicotinoid	**	**		Yes		Yes		
Centric	thiamethoxam[4]	4A	Neonicotinoid		**		Yes		Yes		
Venom	dinotefuran	4A	Neonicotinoid		***		Yes		Yes		
Acephate	acephate	1B	Organophosphate	***		*		Yes	Yes		
Bidrin	dicrotophos[5]	1B	Organophosphate	*		*	Yes	Yes	Yes	Yes	
Cormoran	novaluron + acetamiprid	15 + 4A	Chitin inhibitor	**	**	* (N)	Yes				
Diamond / Mayhem	novaluron	15	Chitin inhibitor	*	*	* (N)	Yes				
Synergized pyrethroids	various[6]	3A + 1B	Pyrethroid + organophosphate		**		Yes	Yes	Yes		moderate–severe
Vydate C-LV	oxamyl[5]	1A	Carbamate	****			Yes	Yes	Yes	Yes	

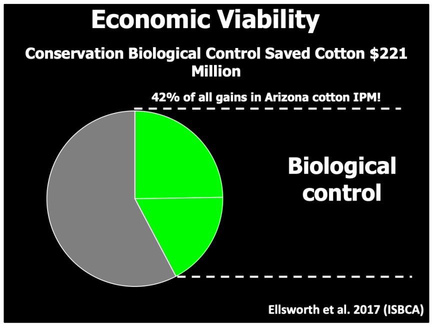
This table summarizes what we know about cotton chemistry and its efficacy and selectivity against our two key pests and the brown stink bug. The green color represents insecticides that are fully selective to natural enemies; the yellow color represents partially selective insecticides; and the red color represents broad-spectrum insecticides. From our research, we concluded that Exirel, PQZ, Sivanto and Transform are fully selective insecticides. We have only one year's worth of data for Sefina. However, our preliminary results suggest that Sefina is fully selective. More investigation on Sefina needs to be made in order to confirm selectivity to natural enemies.

I go back to this slide to summarize how you, PCAs and growers, have been contributing to these demands when conserving biological control through the use of selective insecticides.

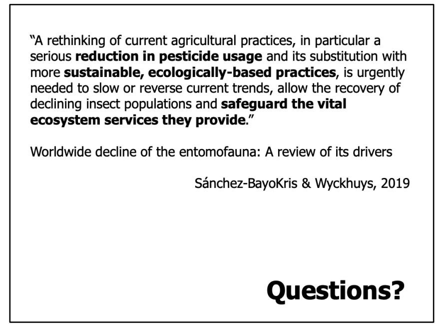
You have helped to conserve biodiversity every time you opted for selective insecticides, because they are safe towards our key natural enemies and other non-target organisms in cotton.



Since you have prioritized the use of selective insecticides, fewer sprays have been made in cotton. As a result, there is less toxicity in the environment. In addition, selective insecticides are generally less toxic to humans and the environment.



When we talk about sustainable practices, we need to verify their economic viability. Growers have benefited from the gains provided by biological control in our cotton system. Overall, biological control has contributed to 42% of all gains in cotton IPM, saving $221 million to cotton growers in Arizona.



The demand for more sustainable and ecologically-based practices in agriculture might seem like a recent demand, however, this demand has been noticed by the scientific community for about 60 years.

Arizona has made use of sustainable and ecologically-based practices through the integration of biological and chemical controls.

The lack of information on insecticide selectivity and research dedicated to measure biological control impedes advances in IPM in many different crop systems in the world.

I would like to close with thanks to the funding organizations and other supporters and collaborators that have been instrumental to our research and Extension programs, especially the Western SARE and Western IPM Center. I would like to thank the Entomology and Insect Science Department at UofA for their support during Isadora Bordini's Master's degree.

Substituting current agricultural practices with more sustainable, ecologically-based practices and reducing pesticide usage is a noble goal. However when making a decision to change a practice, these decisions cannot be made in a vacuum and should not be made willy-nilly without thought. Many times changes in behavior are made in the hopes of a more favorable outcome (that can be greater well-being, more money, healthier environment, etc.). Ultimately behavior changes are made in the face of avoiding or mitigating risks.

What is RISK?

Risk is a combination of factors that have the potential to harm

Ellsworth/UA

What is risk? Fundamentally it is a combination of factors that have the potential to cause harm to various entities, not only human health, but the environment and the economy. Risk comes in many forms and is something we deal with every day.

What is RISK?

Physical

Monetary

Toxicologic

Ellsworth/UA

Risk can come in several forms including physical, monetary, and toxicological.

What is RISK?

Physical
Property
Self

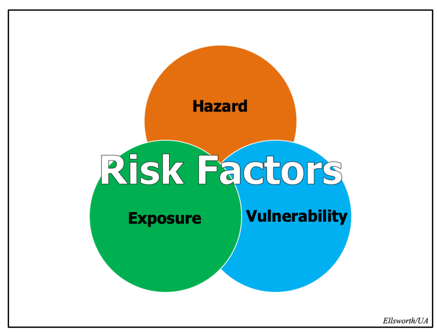
Monetary
Economy

Toxicologic
Environment
Human Health

Any Combination of the above

Ellsworth/UA

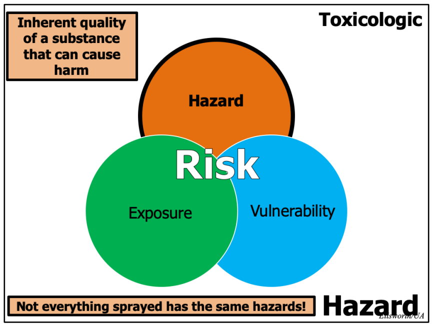
Physical can be thought of as a broken bone after falling off a bike, or a car damaged by hail, or maybe cotton damaged by adverse weather. Monetary can be the economy as a whole, or on an individual level. Toxicological risk is the risk often referred to when discussing pesticide usage. Risk can also include a combination of physical, monetary, and toxicological risks. For example, monetary risks are often associated with physical risk.



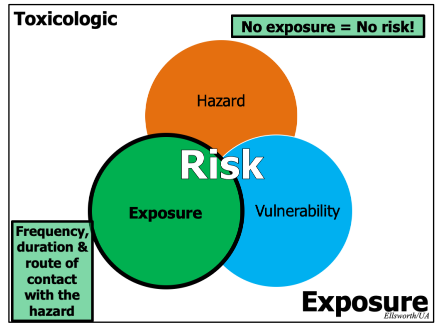
In dialogue of all types of risk, risk factors can be distilled down to three influences: hazard, exposure, and vulnerability. If any of these components are missing (are zero), then there will be no risk.

These three factors are present in our daily lives. A hazard can be a casino, online shopping, food, etc. Our vulnerability can be how we are feeling at the moment, how hungry one is, how bored one is, the possibilities are endless. If we don't have exposure to these hazards we have no risk, we are safe. If we aren't at a casino, we aren't at risk of using a slot machine, if we don't have access to the internet, we can't online shop.

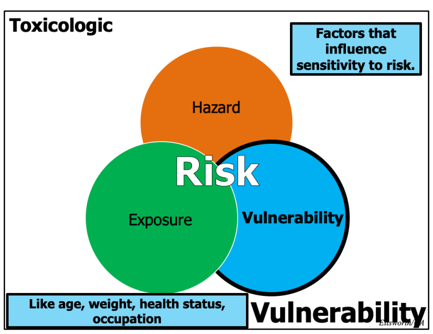
Today we will be focusing on toxicological risk as it deals with pesticides.



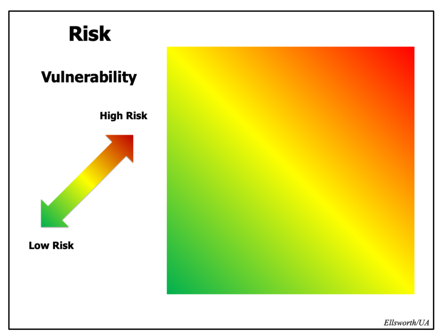
Hazard is the inherent quality of a substance that can cause harm. Something can be quite hazardous, but if it is never used in a significant dose the risk would be low. For example table salt. There is a hazard associated with salt; however, we do not commonly think of there being one. A large enough quantity of salt can be ingested to potentially kill an individual. Not everything sprayed in this industry has the same hazards. Some are considered to be "hotter" than others (those that are broad-spectrum and less selective).



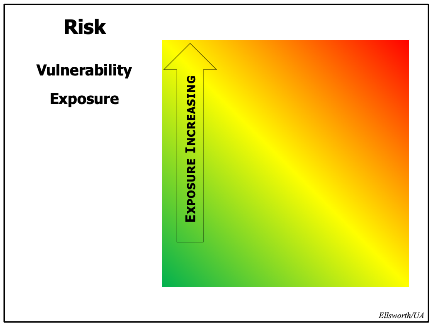
Exposure is the other component of risk. It is the frequency, duration, and route of contact with the hazard. If you have no exposure, the product of these three components will be zero and there will be no risk. If you don't swim in the ocean you are not likely to ever get killed by a shark.



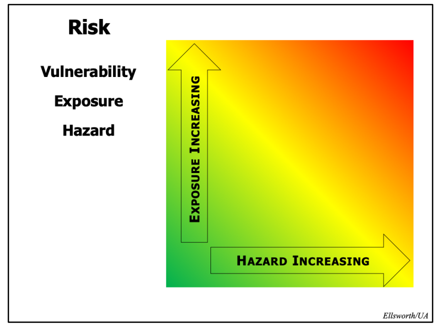
Vulnerability includes factors that affect your sensitivity to a product. When the EPA reviews pesticides they need to think of not only an average population, but the most sensitive populations. There are mitigation programs that only apply to very specific populations based on their unique vulnerabilities.



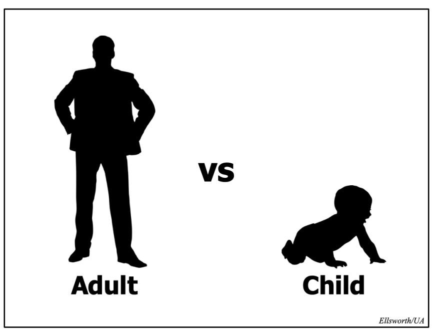
Risk is the color across the chart. High risk is the red zone, low risk is the green zone, and if you are at middle risk you are in the yellow zone. Vulnerability can shift the color across the diagonal gradient depending on the population. A more tolerant population will be depicted with more green (less risk) than a more vulnerable population.



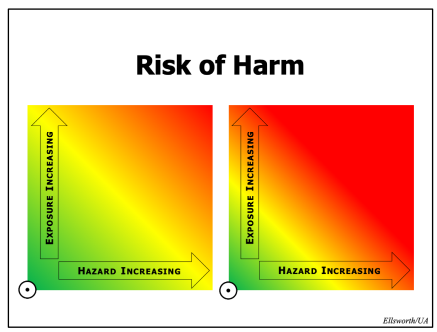
As exposure increases you are increasing the risk even with relatively safe products. A product may be more risky to a mixer and loader than a consumer because the mixer and loader is exposed to the product day after day.



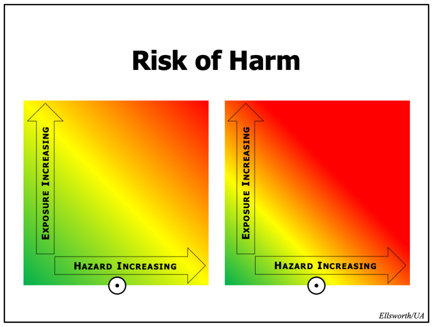
As the hazard increase, so does the risk.



For this example, think of an adult and a child population.

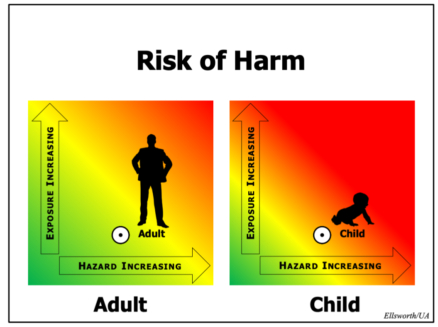


These are two very different populations with different vulnerabilities. Note how there is much more red in the right hand chart. The right hand chart is showing more vulnerability.

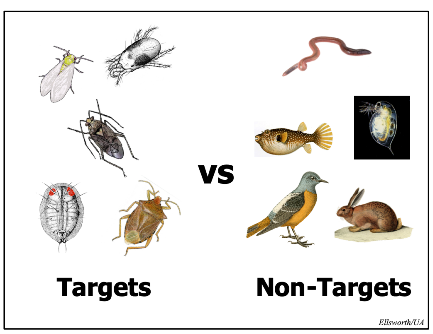


A chemical has a specific hazard, which is more or less toxic depending on the vulnerability of the population.

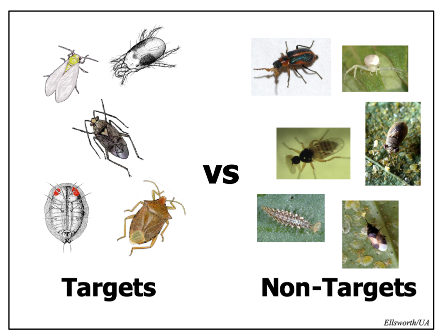
The exposure might be the same, but depending on the vulnerability of the population, the hazard may be more or less toxic. Notice how the hazard relates to the vulnerability. With the same hazard there is more vulnerability and greater risk to the population represented in the right hand chart. However, at this point exposure is at zero. What does that mean for both? It means that there is no risk to either population. As stated earlier, if a factor is missing or at zero, there is no risk in that particular situation.



For the same chemical (same hazard) and same exposure, the child will be more at risk than the adult (note the underlying color for both points on the charts). The adult is much more tolerant. This fact must be kept in mind when you are treating around areas with diverse populations.

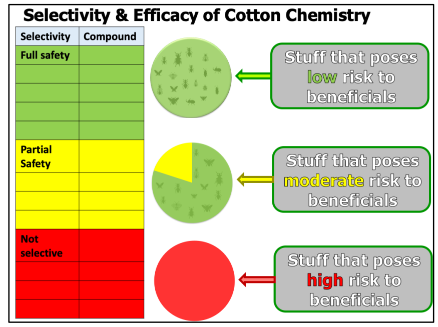


In our previous discussion and workshops we have mentioned our targets, in this case primary and secondary pests of crops (cotton) and those organisms that are not our targets (every other creature that isn't the pest, target organism).

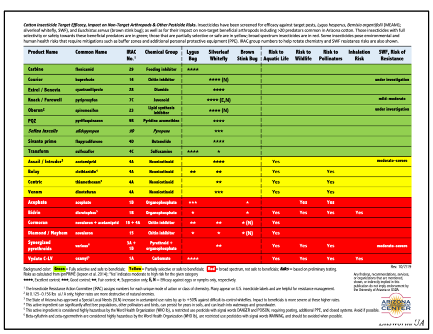


Bringing it back to our current discussions, we have our targets (the pest we want to get rid of) and the non-targets, which in this case are our beneficials we are looking to conserve to possibly delay sprays against whiteflies.

This image is an excellent example of risk. In this situation we are looking at the beneficials and chemistries used to control a primary pest. Among the plots, the targets and non-targets were exposed to selective chemistries, broad spectrum chemistries and no chemistries. As a result, the risk level varied across the field from no risk to high risk. The center plot shows a high risk scenario where a broad spectrum was used, which killed the beneficials in the process of killing the pests. This caused an outbreak of secondary pests (mites). A low risk scenario is where the selective chemistries were sprayed and a no risk scenario (where the hazard was missing) is present in the untreated check (UTC). No secondary outbreak of mites occurred in these places.



You have seen this table previously. Taking another look at it from a risk vantage point, fully selective chemistries pose a low risk, partially selective pose a moderate risk, broad-spectrum pose a high risk. This is all very intuitive and applies to not only beneficials, but in most cases, to other non-targets as well.



Cotton Insecticide Target Efficacy, Impact on Non-Target Arthropods & Other Pesticide Risks. Insecticides have been screened for efficacy against target pests, *Lygus hesperus, Bemisia argentifolii* (MEAM1; silverleaf whitefly, SWF), and *Euschistus servus* (brown stink bug); as well as for their impact on non-target beneficial arthropods including >20 predators common in Arizona cotton. Those insecticides with full selectivity or safety towards these beneficial predators are in green; those that are partially selective or safe are in yellow; broad spectrum insecticides are in red. Some insecticides pose environmental and human health risks that require mitigations such as buffer zones and additional personal protective equipment (PPE). IRAC group numbers to help rotate chemistry and SWF resistance risks are also shown.

Product Name	Common Name	IRAC No.[1]	Chemical Group	Lygus Bug	Silverleaf Whitefly	Brown Stink Bug	Risk to Aquatic Life	Risk to Wildlife	Risk to Pollinators	Inhalation Risk	SWF, Risk of Resistance
Carbine	flonicamid	29	Feeding inhibitor	****							
Courier	buprofezin	16	Chitin inhibitor		**** (N)						under investigation
Exirel / Benevia	cyantraniliprole	28	Diamide		****						
Knack / Farewell	pyriproxyfen	7C	Juvenoid		**** (E,N)						mild–moderate
Oberon[2]	spiromesifen	23	Lipid synthesis inhibitor		**** (N)						under investigation
PQZ	pyrifluquinazon	9B	Pyridine azomethine		****						
Sefina Inscalis	*afidopyropen*	*9D*	*Pyropene*		***						
Sivanto prime	flupyradifurone	4D	Butenolide		****						
Transform	sulfoxaflor	4C	Sulfoxamine	****	*						
Assail / Intruder[3]	acetamiprid	4A	Neonicotinoid		****		Yes				moderate–severe
Belay	clothianidin[4]	4A	Neonicotinoid	**	**		Yes		Yes		
Centric	thiamethoxam[4]	4A	Neonicotinoid		**		Yes		Yes		
Venom	dinotefuran	4A	Neonicotinoid		***		Yes		Yes		
Acephate	acephate	1B	Organophosphate	***		*		Yes	Yes		
Bidrin	dicrotophos[5]	1B	Organophosphate	*		*	Yes	Yes	Yes	Yes	
Cormoran	novaluron + acetamiprid	15 + 4A	Chitin inhibitor	**	**	* (N)	Yes				
Diamond / Mayhem	novaluron	15	Chitin inhibitor	*	*	* (N)	Yes				
Synergized pyrethroids	various[6]	3A + 1B	Pyrethroid + organophosphate		**		Yes	Yes	Yes		moderate–severe
Vydate C-LV	oxamyl[5]	1A	Carbamate	****			Yes	Yes	Yes	Yes	

Background color: Green = Fully selective and safe to beneficials; Yellow = Partially selective or safe to beneficials; Red = broad spectrum, not safe to beneficials; *Italics* = based on preliminary testing. Rev. 10/7/19

Risks as calculated from ipmPRIME (Jepson et al. 2014); 'Yes' indicates moderate to high risk for the given category

****, Excellent control; ***, Good control; **, Fair control; *, Suppression only; **E, N** = Efficacy against eggs or nymphs only, respectively.

[1] The Insecticide Resistance Action Committee (IRAC) assigns numbers for each unique mode of action or class of chemistry. Many appear on U.S. insecticide labels and are helpful for resistance management.
[2] At 0.125–0.156 lbs ai / A only; higher rates are more destructive of natural enemies.
[3] The State of Arizona has approved a Special Local Needs (SLN) increase in acetamiprid use rates by up to +50% against difficult-to-control whiteflies. Impact to beneficials is more severe at these higher rates.
[4] This active ingredient can significantly affect bee populations, other pollinators and birds, can persist for years in soils, and can leach into waterways and groundwater.
[5] This active ingredient is considered highly hazardous by the Word Health Organization (WHO Ib), a restricted use pesticide with signal words DANGER and POISON, requiring posting, additional PPE, and closed systems. Avoid if possible.
[6] Beta-cyfluthrin and zeta-cypermethrin are considered highly hazardous by the Word Health Organization (WHO Ib), are restricted use pesticides with signal words WARNING, and should be avoided when possible.

Any findings, recommendations, services, or organizations that are mentioned, shown, or indirectly implied in this publication do not imply endorsement by the University of Arizona or USDA.

ARIZONA PEST MANAGEMENT CENTER

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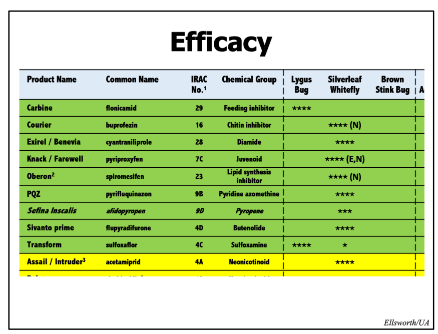
Taking a look at the selectivity table you have just been shown. This table is much more than a handy chart to show you what chemistries are the best for a specific target or the chemistries that pose the lowest risk to the natural enemies in your fields.



Efficacy

Product Name	Common Name	IRAC No.[1]	Chemical Group	Lygus Bug	Silverleaf Whitefly	Brown Stink Bug
Carbine	flonicamid	29	Feeding inhibitor	****		
Courier	buprofezin	16	Chitin inhibitor		**** (N)	
Exirel / Benevia	cyantraniliprole	28	Diamide		****	
Knack / Farewell	pyriproxyfen	7C	Juvenoid		**** (E,N)	
Oberon[2]	spiromesifen	23	Lipid synthesis inhibitor		**** (N)	
PQZ	pyrifluquinazon	9B	Pyridine azomethine		****	
Sefina Inscalis	*afidopyropen*	*9D*	*Pyropene*		***	
Sivanto prime	flupyradifurone	4D	Butenolide		****	
Transform	sulfoxaflor	4C	Sulfoxamine	****	*	
Assail / Intruder[3]	acetamiprid	4A	Neonicotinoid		****	

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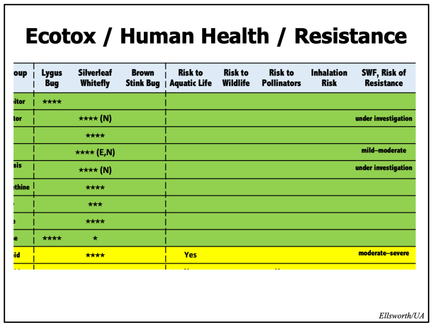
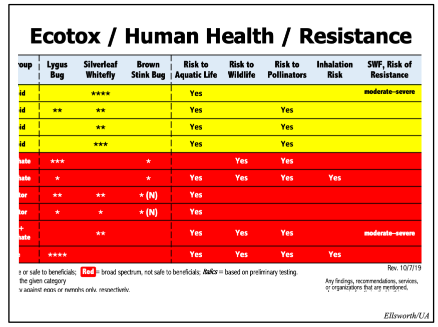
On the left hand side of the table you have the product name the active ingredient the mode of action class and chemical group. Along with the efficacy of a given product to the main cotton pests.



Take a look at the right side of the table. This shows the risk to other non-targets (including humans) and something we have not discussed today, the risk of whiteflies developing resistance. As can be expected, those chemistries that are highly selective and safe for natural enemies, are relatively low risk for other non-targets.



As you look farther down on the chart to the red zone, the broad spectrums, the risk to other non-targets become important. Those that are not safe to beneficials also tend to be less safe for other non-targets. However, do notice that with some products that are not safe to beneficials, there is low risk to other non-targets (i.e. inhalation risk).

What risk factor is missing from this chart? Economics. At times, economic risk is the overriding decision factor (and that is okay!). It's not all about cost or selectivity, it is a combination of a multitude of factors, including those listed on this chart. When making spray decisions, many factors will be considered, some more than others depending on the situation. It is important to weigh all your options (and risks associated with these options) before making a control decision that best fits the current need.

I'd like to close with thanks to the funding organizations and other supporters and collaborators that have been instrumental to our research and Extension programs.