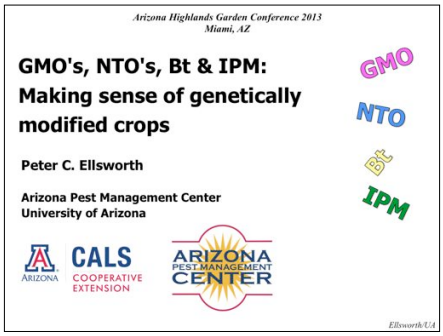
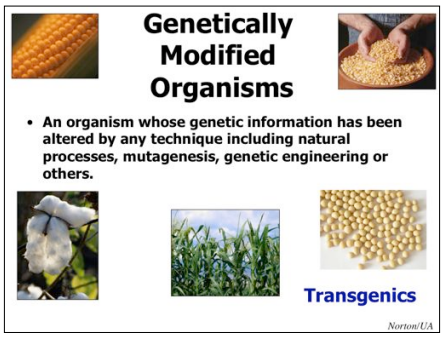


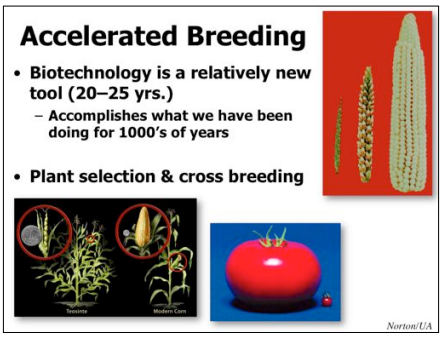
In this presentation, I hope to review the alphabet soup of terminology as it applies to the issues of genetically modified crops.

1 hr; 120 people

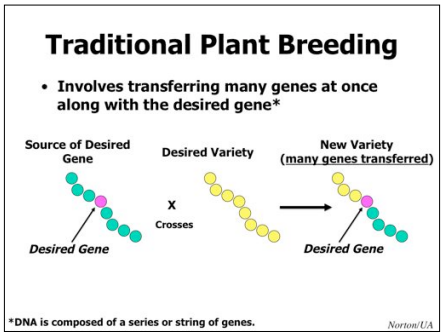
The first acronym, GMO, is of course genetically modified organism.



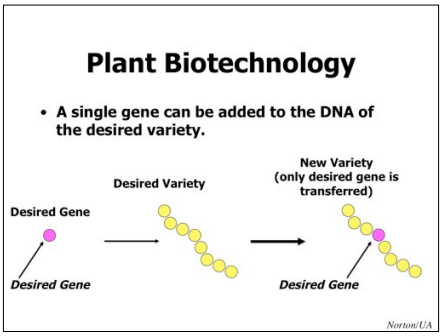
Interestingly while used by many different people and groups, this seems to be the term of choice for those that oppose biotechnology. In conversation with a grower recently, I mentioned that I would be talking about GMOs. He said, "Remind me again? What are those?", despite the fact that he had been growing GMOs (GM-cottons) for 17 years. When I communicate with producers, the more familiar term is "transgenics", which in many ways is really more descriptive and perhaps less cryptic than GMO.



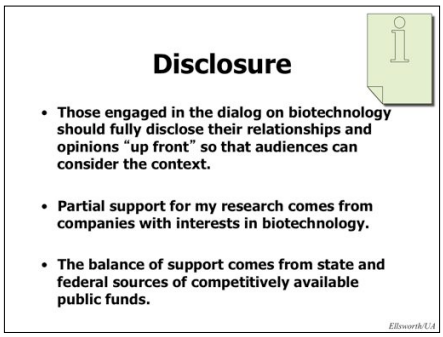
What is important to know about GMOs is that they can be produced through biotechnology and that this is a gateway to accelerating breeding efforts that have been ongoing for thousands of years. Tomatoes and corn today bear little resemblance to their wild ancestors.



Traditional plant breeding, practiced for millennia by human cultures, involves locating a source plant that contains a desired trait or gene conferring that trait and crossing it with a desirable variety. It works! But does so relatively imprecisely, because it drags along a set of non-target genes. The result, many genes are in the new variety that may be poorly known or confer undesirable crop characteristics.

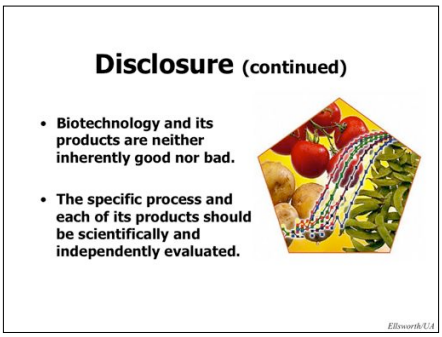


With biotechnology, it is possible to isolate a desirable gene in any organism (not just in other members of the target crop or species). Through processes we will not be discussing today, that singular gene or genetic material can be moved into a desired variety to produce a new variety with just this singular change. This level of precision avoids moving other genetic material that is brought forward in traditional plant breeding.



Before I go further, I need to provide this disclosure. GMOs and other issues are important to the social dialog regarding food production. Unfortunately, sources of information vary greatly in their accuracy and independence. Therefore, as a consumer of information, you should demand disclosure from people who speak on scientific topics so that you can understand the context of their comments from the beginning. You should not be surprised after listening to a speaker or supposed expert that they have a specific agenda or conflict that they failed to disclose.

Regardless of the support structure for my research, I receive my paycheck from the University of Arizona and owe no special allegiance to any group other than the citizens of Arizona.



In that disclosure, there should be a statement of relationship to the industry and the underlying science, as well as a straightforward statement of their summary view.

GM Controversies?

- Short- & long-term health problems
- Increased cancer risks
- Increased food allergies
- Lower quality / nutrition
- Lowered soil fertility
- Elimination of family farms
- Superbugs / superweeds
- Reduced beneficial insects

Ellsworth/UA

When searching for controversies of GMOs, one can quickly and easily assemble a list of potential concerns. As issues go, I am familiar with all of these but am only expert on the last two. Having said that, each of these issues has been examined and resolved or discarded as serious scientific limitations to the GM plants currently in production. These are, in fact, not scientific controversies for the current generation of GM plants.

GM Controversies

- Efficacy of gene
- Economics of control
- Performance of varieties
- Safety (risks)
- Resistance
- Impact of gene on plant
- Biodiversity
- Non-target effects

- Unintended consequences
  - Pest shifts

Ellsworth/UA

In fact, among scientists, these have tended to be the most important issues facing development of GM plants. And, these are all areas that I have investigated in the course of testing GM plants over the last 20 years. And here, too, these issues have all been resolved favorably in the current sets of GM technologies in use commercially today.

Lately, though, there continues to be the more generalized issue of "unintended consequences" of GM technology. What occurs that we have not considered as a result of broad-scale deployment of GM plants? One issue that has gained traction is that there will be a pest shift each time a pest-centric GM plant is deployed, greatly lowering its value.

Bt

Ellsworth/UA

Bt is next up in our alphabet soup. There are many people who use this shorthand including those that really do not know what it stands for.

Bacillus thuringiensis (Bt)

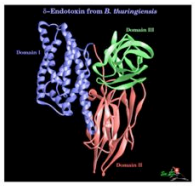
- Crystalline proteins are classified according to structure & have a specific nomenclature (e.g., Cry1Ac)
- Cotton has been transformed with Cry1Ac (narrow spectrum; Lepidoptera only)
- Protein binds with receptors in the insect gut causing pores which perforate the midgut & lead to cell leakage & insect death

Ellsworth/UA

***B. thuringiensis* is a common soil bacterium that is present in one or more varieties in virtually all soils all over the world. It naturally produces a crystalline protein that is toxic to various insects and their relatives. Bt's have been exploited and formulated as a natural insecticide in sprayable form by organic growers and others.**

Bt proteins have their own nomenclature. Most exploited Bt toxic proteins are crystalline in nature and therefore are referred to as Cry proteins.

Science or Emotion?



- Proponents and opponents of biotechnology have made ample use of both.
- However, emotion tends to rule in the court of public opinion.

Ellsworth/UA

When engaged in a dialog about GM technology or any scientific topic, it is important to be able to do so dispassionately so that emotional "feelings" don't interfere with true scientific understanding.

Public Opinion

- "Unintended consequences: pelicans nearly wiped out by DDT, massive radiation leaked at Chernobyl, now butterflies killed by genetically modified corn..."

Full page back cover of "blue" magazine; Patagonia, 2001

Ellsworth/UA

Several years ago as a full-page ad in a hiking magazine, Patagonia (a purveyor of clothing and outdoor gear) made rather emotional comments about GM technology. They did so while invoking some rather disturbing imagery.

Public Opinion

- "... The list of environmental damage caused by inadequately tested technologies is long. With genetic engineering unleashed on the world the list may grow much, much longer. We don't yet know all the impacts and dangers of genetic engineering. Shouldn't we find out the risks before we turn genetically modified organisms loose on the world, or eat them in our food?"

Ellsworth/UA

Their 'ad' states:

Are Scientists Mad?

"For the past decade, biotech's mad scientists have been telling consumers not to worry about Frankenstein foods....

...The biotech industry and governments have done almost no safety testing of GE foods....

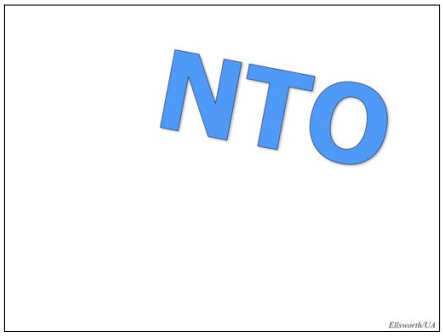
...Millions of acres of GE crops are spreading genetic pollution, creating superweeds and pests, disrupting the balance between pests and natural predators, and killing butterflies and beneficial soil microorganisms. The more we learn about Frankenfoods and crops, the scarier they appear."

From BioDemocracy News #40, "The Death of Frankenfoods", August 2002

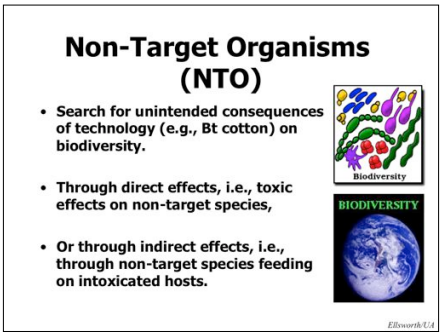
Ellsworth/UA

From another website during this time, similar rhetoric was provided, once again evoking disturbing imagery.

But what is the comment, killing butterflies, all about?



NTO is probably a much less mainstream acronym in the public discourse. But it is at the center of much of the debate. NTO stands for non-target organism.



So what are NTOs? In fact, we are a non-target organism for this technology. The targets of these technologies developed so far are either insect or weed pests. More specifically Bt cotton, for example, targets primarily two species of caterpillar pests with secondary targets being about a dozen or so other species of caterpillar pests.

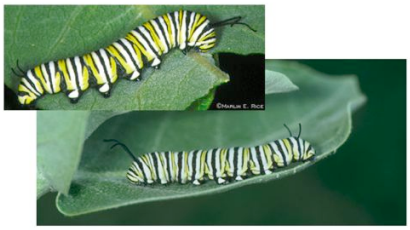
This issue, however, is central to the search for unintended consequences, because if poorly designed or deployed it may be possible to harm beneficial elements of biodiversity or the community of species that live in our agricultural fields.

So what is going on here? Why did Patagonia evoke imagery of dying butterflies and specifically Monarch butterflies? How does this even relate to IPM or to GM technology?

Monarchs overwinter in the mountains in Mexico after a harrowing cross-continent journey by the adult butterflies. There, they overwinter en masse. Those that survive, mate, and start the multi-generational return to the U.S. and Canada the following spring.

It is a biological and ecological marvel. A natural wonder!

Monarchs Feed on Milkweed



Ellsworth/UA

Where do milkweeds grow? There are many species of milkweeds, but throughout the upper midwest and Eastern seaboard, the common milkweed (*Asclepias syriaca*) dominates roadsides and other disturbed habitats. But there are other broadleaf milkweeds as well as desert adapted Asclepias with extreme, modified leaves that are reduced to a more stem-like appearance. Monarchs feed on all of these.

But where do they grow?

Bt Corn Sheds Pollen

- Some of which may fall on milkweed plants that serve as hosts for Monarchs.
- Bt corn pollen may contain some quantity of the Bt endotoxin.

Ellsworth/UA

They grow along side or near to corn fields at field margins and elsewhere throughout the midwest and elsewhere.

Should we expect milkweed to be present <u>in</u> corn fields of the midwest?

Monarchs Are Killed?

- Scientists have shown that larvae are killed when fed milkweed "dusted" with Bt corn pollen.
- But how realistic was this study?

Ellsworth/UA

A scientist from Cornell University decided to examine the potential risk to Monarchs that come in contact with the pollen produced by Bt corn.

What is wrong with this picture? The level of pollen deposition on the leaves of milkweed in this experiment was extremely high. Is this realistic?

He did show and identify a hazard. Monarchs could be killed in these lab experiments.

PNAS: Corn Pollen Deposits on Milkweed…

- Average 171 pollen grains per sq. cm. in corn fields
- Average 14 pollen grains per sq. cm. 6 ft outside of the corn field
- One rain removes 54-86% of the pollen
- Youngest leaves, the preferred food, have 50-70% lower pollen density than older leaves

From Pleasants et al., 2001

Ellsworth/UA

Densities of pollen fallen in corn fields is quite different than what results just outside the field margin.

Why is this fact important?

We will not review all the details of this study of the National Academy, but many researchers invested nearly $1M studying the potential of this newly described hazard. This included studies of pollen distributions in and around corn fields and how it might come in contact with Monarch caterpillars.

PNAS: Toxicity of Bt Proteins & Corn Pollen

Bt Toxin	1st instars on diet	1st instars on pollen on discs
Cry1F	Non-Toxic	Non-Toxic
Cry9C	Non-Toxic	Non-Toxic
Cry1Ac	Toxic	Non-Toxic
Cry1Ab	Toxic	Toxic (Event 176 only)

From Helmich et al., 2001

Ellsworth/UA

Turns out there were several different Cry proteins that were developed for use in corn. Even within a class of proteins (e.g., Cry1Ab), there were different "brands" or events that expressed differently in corn (e.g., event 176).

While some toxicity could be noted to very young Monarchs fed on a diet laced with the protein, this was only true for the one event (176), which had been withdrawn from the market. The others were non-toxic to even the smallest caterpillars.

PNAS: Field Impact of Cry1Ab (3 events)...

Exposure Density & Duration	Cry1Ab Event 176	Cry1Ab Bt11	Cry1Ab Mon810
22 gr. / sq. cm.	Weight loss (-18%)	--	--
67 gr. / sq. cm.	Weight loss (42%) & mortality (40%)	NOE	--
97 gr. / sq. cm.		NOE	--
500+ gr. / sq. cm.		NOE	--
In-field feeding for 14-22 d		NOE	NOE

Compared to lambda-cyhalothrin which killed most Monarch larvae

From Stanley-Horn et al., 2001

Ellsworth/UA

Three different "brands" of Cry1Ab were studied more intensively in the field. Here again, all studies showed no observable effect (NOE), except with the Event 176, which was removed from the market.

These researchers also noted that the insecticide most likely to be used in corn was far more toxic to Monarch than any of the Bt corn pollens.

PNAS: A Risk Assessment...

Hazard = Acute toxic effects of pollen

X

Exposure = Probability of larvae being exposed to toxic levels in and around corn fields

Risk = "This two year study suggests that the impact of Bt corn pollen from current commercial hybrids on Monarch Butterfly populations is negligible."

From Sears et al., 2001

Ellsworth/UA

So what is risk? How do we measure it scientifically?

Was a "hazard" identified?

Was "exposure" sufficient to create "risk"?

Note if one or the other is ZERO, the product or risk is ZERO.

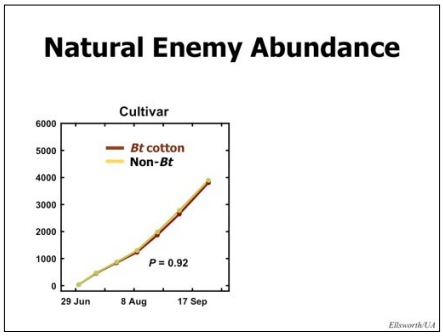
Biodiversity / NTO Studies

- The reports of Bt effects on Monarch butterflies have fueled much emotional debate on the use of biotech crops.

Ellsworth/UA

So while the Monarch issue turned out to be a red herring, a case where there really was no appreciable risk, this did re-energize efforts to identify non-target effects of importance to agriculture and the surrounding ecosystems.

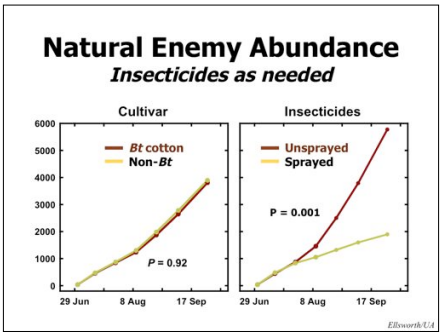
Note, net impact of Bt corn on Monarchs has likely been quite positive because of the large potential reduction in insecticide use in these systems.



Let's bring this a little closer to home and to a system that I have studied for over 20 years, cotton and Bt cotton.

We examined the presence of natural enemies (those beneficial arthropods — insects and their relatives) in Bt and non-Bt systems in replicated field experiments. Any way we looked at this, the lines for the two systems were identical, i.e., the same number of natural enemies in both systems.

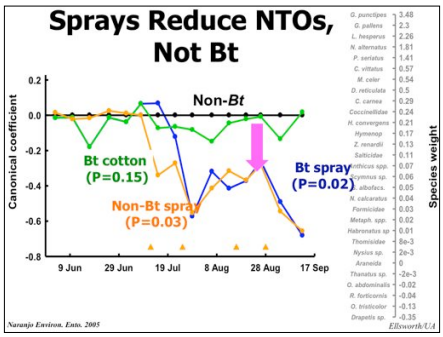
[In fact, further studies of all aerial, canopy, and soil-dwelling arthropods that we have done in Arizona has shown virtually no impacts on nearly 700 different species that are present in the average cotton field!]



In this same study where insecticides were used as needed to control lepidopteran pests in <u>non</u>-Bt cotton, we see the following patterns.

So what is a greater risk for natural enemies, Bt cotton or insecticides?

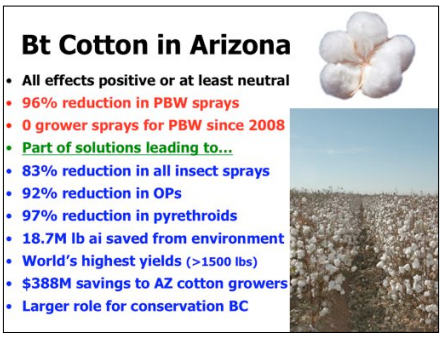
Clearly, the insecticides we are eliminating in our system and that were previously needed to control our key caterpillar pest are very damaging to the natural enemies in our system. Bt cotton enables our ability to make better use of natural controls.



My goal today is not to review these data in the finest detail or to make scientists of everyone listening. But it is to show you and assure you that there is a great deal of science behind the assertions made about this technology.

In this study, we examined all the beneficial species of arthropods on the right, about two dozen and including those bugs that are familiar to many gardeners like lady beetles, lacewings and assassin bugs, as well as the less apparent and less familiar.

The bottom line: Bt cotton is very good for our system; sprays that would otherwise be needed in non-Bt cotton are terribly damaging to these species and disruptive of our system!

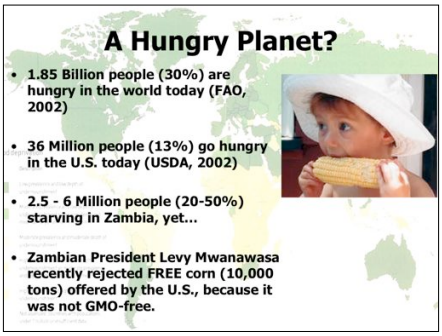


So where do we stand with respect to Bt cotton in Arizona? Here are the facts, not the emotions behind its deployment here.

Note, huge advances have been made in Arizona and Bt cotton is just a part of what we have accomplished. Notably, we now have a system that provides for a much larger role for conservation biological control or the use of natural controls in place of grower inputs like insecticides.

As the controversy about GM plants simmered, the world food crisis was looming even larger. Large portions of our world are plagued by serious issues of hunger and starvation.

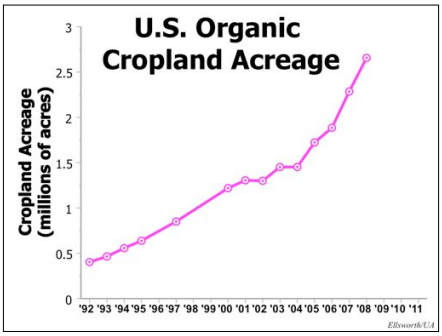
[Lighter greens and yellows indicate increasing levels of hunger and starvation.]



Most disturbing was a Presidential decision in Zambia not to accept food aid because it could not be guaranteed to be GMO-free! This corn was being offered to feed starving human populations there, not to grow and propagate. Yet, the issue was so white-hot and the rhetoric so inflammatory (recall the imagery) that decisions were governed by fear and not scientific or even in this case compassionate reason.

We have a serious, even grand, challenge facing us, your children and your grandchildren over the next 40 years. This is just one of the reasons why many in society have taken an interest in their food and where and how it is produced. We are all searching for answers, because we wish our children to enjoy the same safe and abundant food supply that we do.

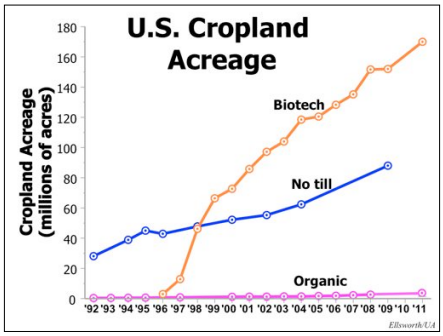
So what is the solution?



Here we see millions of U.S. acres dedicated to organic crop production. An impressive trend! Right?

Is this the answer to food shortages projected for the future?

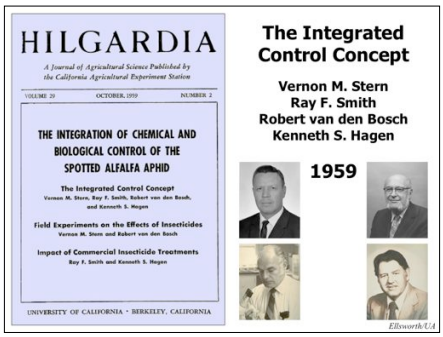
Many think so and organic proponents insist this should be the only solution.



This trend (note the magenta) is dwarfed by the larger trends in agriculture seen here. Orange shows the rapid adoption of biotech crops in the U.S.. Blue is the trend for no-till agriculture, something that is done to help control against soil erosion and off-site movement of nutrients, top soil, and other materials. This, too, is stimulated by the availability of biotech crops, specifically herbicide-tolerant crops.

Proponents of biotechnology cite this as the only answer. However, is this true? Is just how we produce our food the only or central to the problem?

Honestly, I have seen proponents or more accurately zealots of biotechnology suggest, "Yes!". However, more balanced view of the scope of this grand challenge would quickly point out that even biotechnology is no silver bullet, no panacea for all food production and availability problems facing the world today. Especially if one just considers the pest-centric solutions envisioned for biotechnology, we should be more sober in our views. As an entomologist, I am certain (in my beliefs) that cockroaches or their descendants and relatives are far more likely to be here 100 million years from now than humankind. Insects have and will adapt to technological breakthroughs no matter what technology produces them. That said, biotechnology offers us solutions that could not even be conceived of just a generation ago.



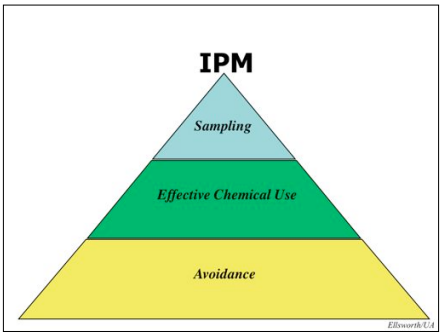
I suggest to you today that the solution is in the entire system and in no single technology. This is not a new idea. It was really first expressed as the Integrated Control Concept by Stern and his Californian entomology colleagues some 50 years ago. The insights provided in this paper form the conceptual basis for IPM today. This is REQUIRED reading for any student of IPM. I highly recommend it! It is an extraordinary piece with incredible insight into the basic ecology that underpins the control system. 1959 was a high-water mark for worldwide use of DDT, a very broad-spectrum insecticide. Yet, Stern could not reconcile what he was seeing with what needed to happen in the use of insecticides. He wished to see an integration of insecticides with the biological controls that were present in the field. He suggested that this could only be done with selective insecticides, a very foreign concept at the time.

Arizona was at the center of a controversy. Largely due to brave entomologists that preceded me in AZ, our state was the first in the U.S. to ban DDT. These IPM scientists saw risks associated with DDT residues that were ending up in milk, via alfalfa forage, which was a crop that did not have a label for DDT. This did not make them popular with growers of the time! And, the risk to raptor populations in particular was central to the issues that culminated in the first Earth Day celebration & in the formation of the EPA. This was also the location for the first federally supported IPM Demonstration by my immediate predecessor, Dr. Leon Moore, in cotton in central AZ. This along with the demo in NC on tobacco that same year was the birth of our federal Extension IPM program. The Growers Pest Management, Inc. was a non-profit scouting service that was spawned from this initial 1971 demonstration in AZ & has endured ever since.

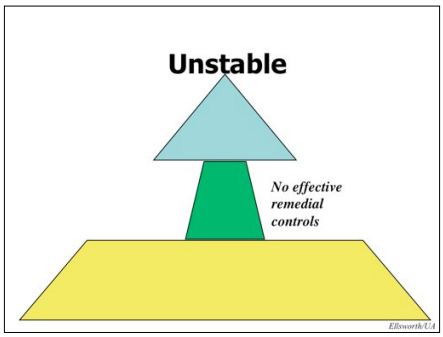
Photo by Tim Knight © http://homepage.mac.com/wildlifeweb/).

Which leads us to our last abbreviation, IPM for Integrated Pest Management. This systems science is the worldwide standard for the management of pests of all kinds in all systems, agricultural, natural, and urban. It is the evolution of Stern's original concepts into a sophisticated and strategic approach to the management of pests with lowest risks to society: economic, environmental and human health. IPM can and should operate in any production system regardless of its dependence on biotechnology or organic pesticides.

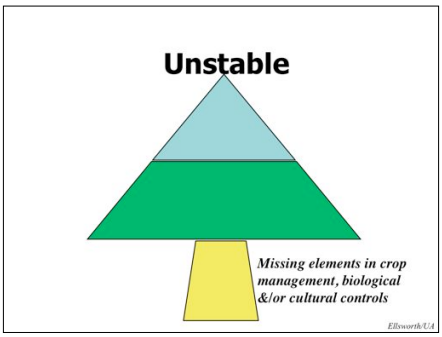
At its heart, however, is the integration of multiple tactics in a blended and optimized strategy to manage pest populations while limiting risks to people, property and resources.



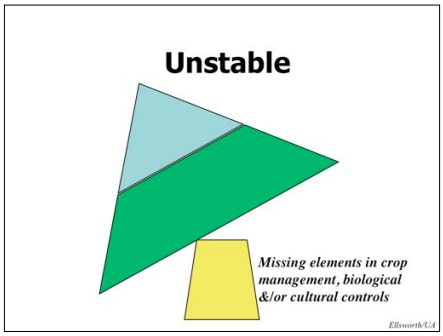
IPM for many systems can be represented by these 3 layers. They are interdependent. You must have sampling or detection systems to know when or if a pest is present as well as remedial controls, often chemical controls (even in organic systems) that can help you when all other prevention or avoidance tactics fail to maintain pests below economic levels.

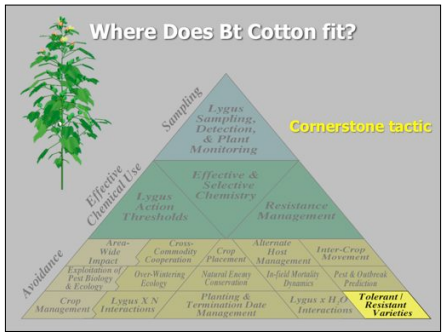


Even with the broadest and best foundation of avoidance tactics and ecological controls, there will be those scenarios where and when pests break-out and require control. If the technology arsenal is too narrow, the management becomes unstable.

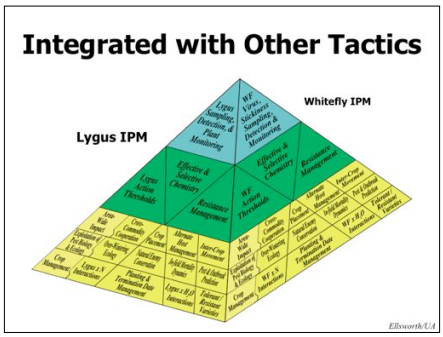


Even more seriously unstable are those systems where we have become over-dependent on the chemical tools (organic — and this does happen — biotechnological, or otherwise!) and where we lack the fundamental foundation of avoidance and prevention tactics of crop management, biological and cultural controls.

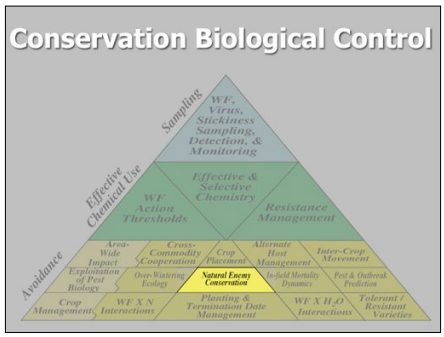




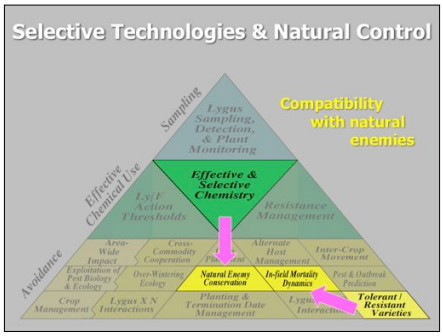
I like to begin any discussion by reviewing the overall structure of Cotton IPM as a means to understanding the potential role a new tactic may play in the system. So where did Bt cotton fit? As any student of plant breeding knows, the cornerstone to IPM is resistant varieties. It shapes the foundation for all else that we do in the production of cotton. Bt cotton for us in Arizona has been an all-important selective control tactic for pink bollworm, our key lepidopteran pest.



Think of each triangle as just a face of a larger structure that addressed the management system for each pest. It is critical in IPM to make sure all tactics are integrated and not antagonistic of each other.

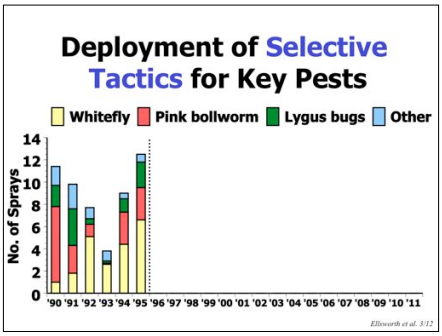


For AZ cotton, conservation biological control or those practices that foster the survival and function of the natural enemies in our system has become a key building block of our IPM system.

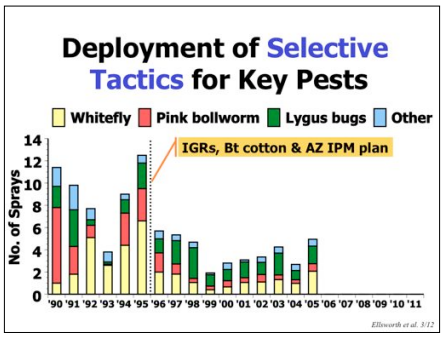


In AZ, we have shown that when selective options are available and effective, huge gains in both target and collateral control can be achieved due to much better natural enemy conservation and other natural mortalities. This ecosystem service is a foundational element of "Avoidance," and one made compatible with these specific and selective chemical controls in our system.

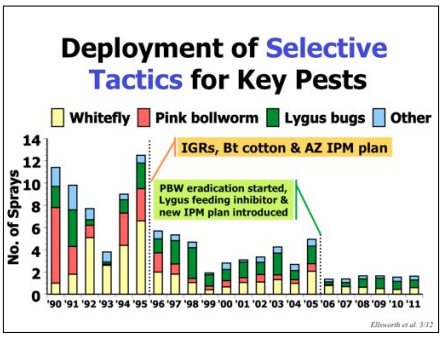
And this combination of tactics, chemical and biological control, was exactly what was suggested by Stern and colleagues over 50 years ago.



Let's review the history of deployment of selective tactics against key pests in our Arizona system. It is a striking history, where we can see the number of foliar insecticides used to control each of 3 key pests over time, whitefly, pink bollworm and Lygus bugs.

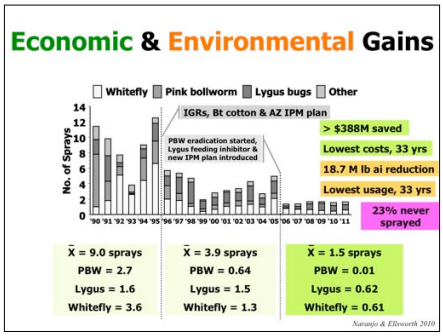


The results have been striking. A watershed of change occurred in 1996 with the introduction of very safe and selective Insect Growth Regulators (IGRs) for whitefly control, and transgenic Bt cotton, along with an IPM plan for whitefly management and comprehensive outreach campaign that consisted of extensive grower and pest manager education.



More recently, growers in collaboration with state agencies began PBW eradication in 2006. At the same time, we introduced flonicamid (Carbine) in 2006 as our first fully selective control agent, a feeding inhibitor, for Lygus.

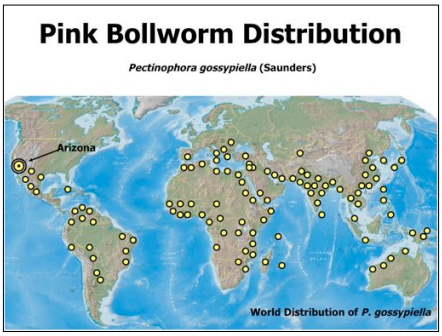
Adapted from Naranjo & Ellsworth 2009.



If we draw out information from these critical periods, we can see rather dramatic declines in overall insecticide use, as well as huge declines in PBW, Lygus and whitefly sprays made by growers.

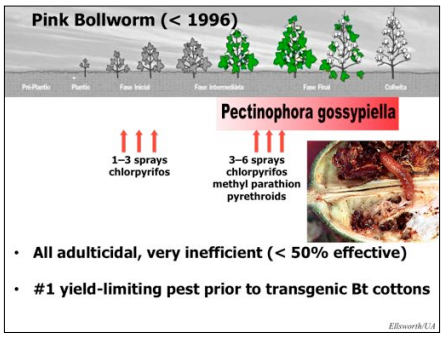
At one time, we averaged 9 sprays. Our 1996 programs cut that by more than half to ca. 4 sprays, and our 2006 programs have cut this by more than half again to just 1.5 sprays. In the process we are in the lowest foliar insecticide control costs in history, we're spraying less than at any time in history, and have saved growers cumulatively over $388M in 2011 constant dollars and prevented nearly 19M lbs of insecticide ai from reaching the environment.

On average today, ca. 23% of our acreage is never sprayed for arthropods, something we never thought would be possible on a single acre 20 years ago.

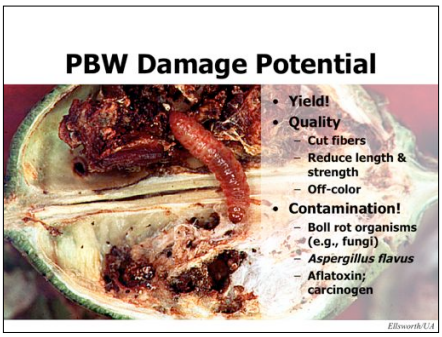


So let's examine the key pest, pink bollworm, that Bt cotton targets in our cotton system. This shows the historical record of distribution for PBW. It is everywhere PBW has been found.

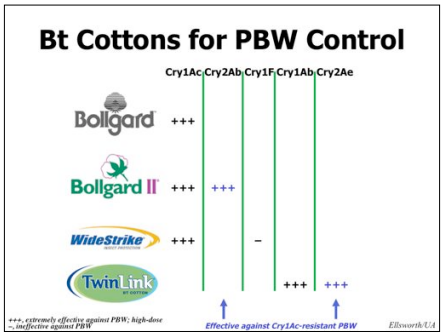
However, PBW has been more destructive in AZ than virtually anywhere else in the world through history. It had limited production here and cost growers millions in spraying very broad-spectrum insecticides.



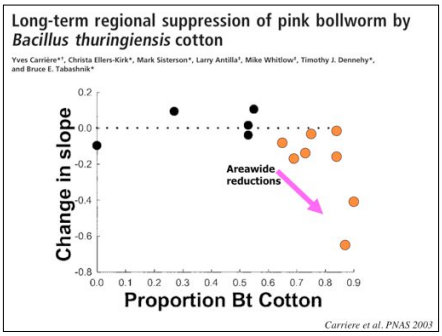
Prior to 1996, growers sprayed 3–6 times mid- to late-season, after having sprayed 1–3 times very early in the season, all in a very inefficient system to kill adult moths before they laid eggs in cotton.



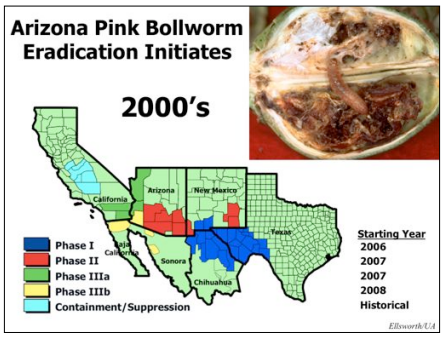
Yield losses were extreme at times. Quality, too. However, an area that many consumers do not think a great deal about was contamination. PBW helped introduce boll rot organisms that ruined bolls but more importantly contributed to the development of Aspergillus flavus, a common fungus in our environment. A. flavus produces a toxin called aflatoxin, one of the most potent mycotoxins and natural carcinogens known.



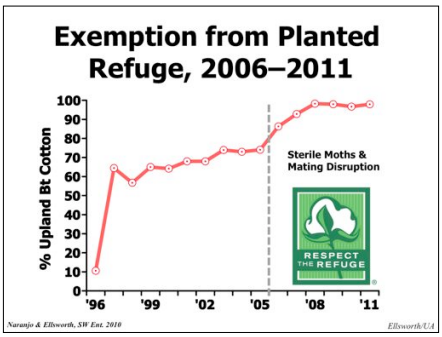
Bt cottons have been pivotal to our ability to stabilize the control system, starting with Bollgard, which is no longer marketed and based in the highly effective Cry1Ac protein, followed by the 2-gene Bollgard II where Cry2Ab is also highly effective against PBW, then by Widestrike which produces once again the highly effective Cry1Ac protein and TwinLink. Three different companies produce these Bt technologies, and we have done extensive testing of all of them under AZ conditions and found them to be effective against PBW without harming non-target species.



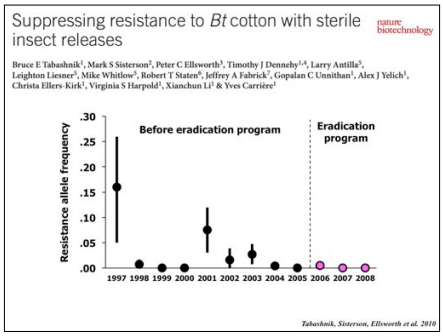
Researchers at UA found that as more growers adopted Bt cotton, the proportion of Bt goes up in local communities to a point at which pink bollworm populations decline regionally, thus providing benefits even to non-Bt cotton growers because of reduced pressures from this insect.



This fact has since been exploited as the central element of a large scale region-wide (multi-state and including northern states of Mexico) PBW eradication program instituted by cotton growers in Arizona. It phased in over time with the area bordering Mexico coming into the program in 2008. In all areas, adoption of Bt cotton as a major control tactic was encouraged.

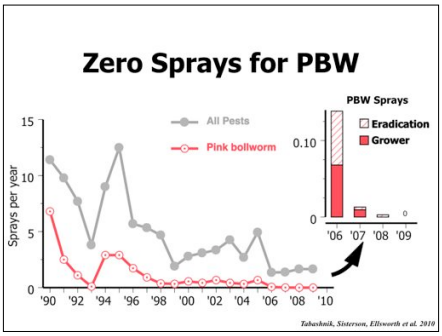


Normally as part of a resistance management program (to prevent PBW from developing resistance to Bt), growers had to plant a portion of their acreage to non-Bt. But as part of the eradication program, AZ was granted an exemption that permitted growers to plant 100% Bt without refuges. More than 95% of the acreage was (and continues to be) planted to Bt cottons.

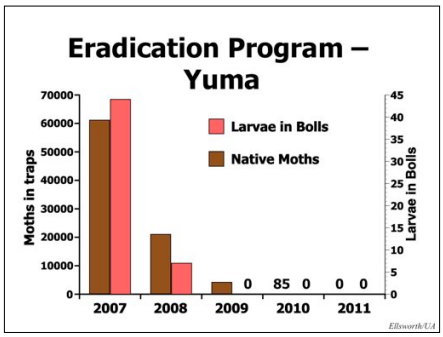


But what about "superbugs", those that become resistant to the technology. First of all, resistance should be thought of as inevitable, to biotechnology or conventional technology. However, measures can be taken to delay and even prevent this from having a major impact on the system.

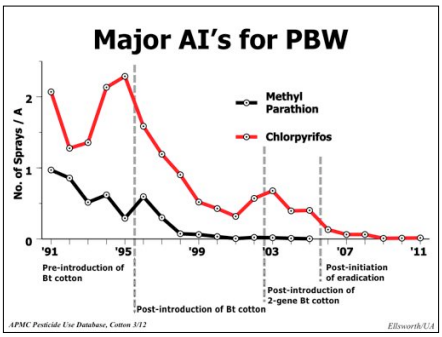
In our system, we have shown that the frequency of alleles that are associated with resistance in PBW have declined over time and gone to zero over the course of the eradication program.



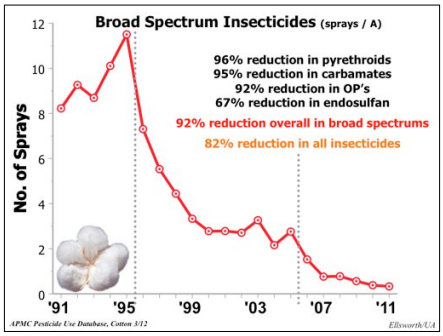
For the first time in over 40 years, Arizona cotton growers did not make a single spray against PBW in 2008–2013. Even when considering the programs over-sprays, we can see that no sprays of any kind have been made since 2009!



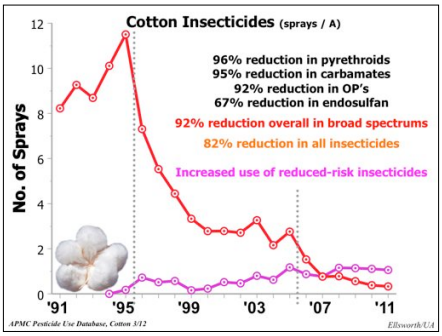
And, no native moth captures have been made since 2009 in Yuma and none in the last year over the entire 7-state region (4 U.S. states and 3 Mexican states).



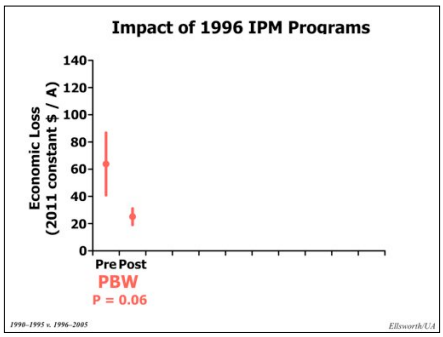
In terms of environmental risks, we have all but eliminated broad-spectrum insecticides in AZ cotton including uses of these key PBW insecticides.



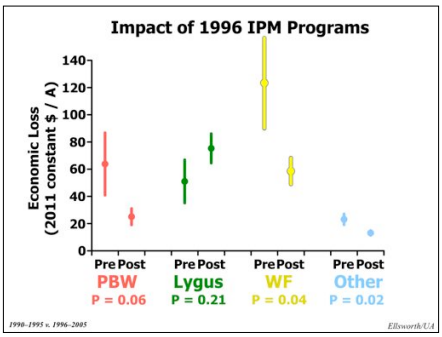
Looking at all insecticide sprays in cotton, we have documented dramatic reductions in the usage of broadly toxic, broad-spectrum insecticides.



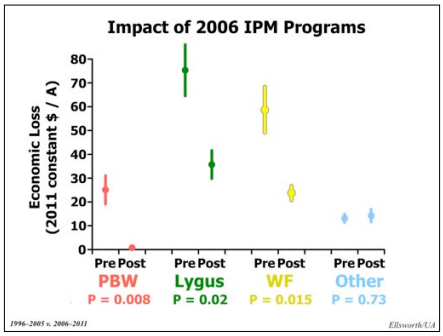
There has been a steady, yet sparing, increase in reduced-risk insecticides, ones that are safer to human and environmental health and that contribute to our programs to protect the natural enemies in our system.



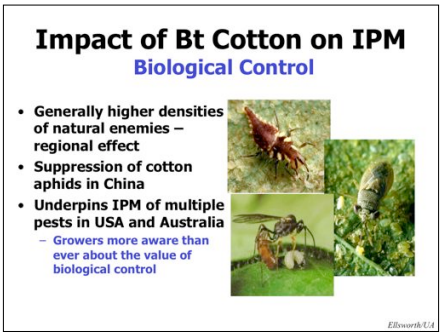
Economically, we can show huge impacts of our IPM programs. Before and after the introduction of Bt cottons (and other innovations and education) in 1996, growers saved nearly 40$ per acre.



And the benefits have spread to savings in whitefly and other insect control costs, too.



Then in 2006, we deployed technologies for the control of Lygus and used Bt cotton and other approaches to eradicate PBW. The result has been dramatic lowering of costs of control for PBW, Lygus, and whiteflies.



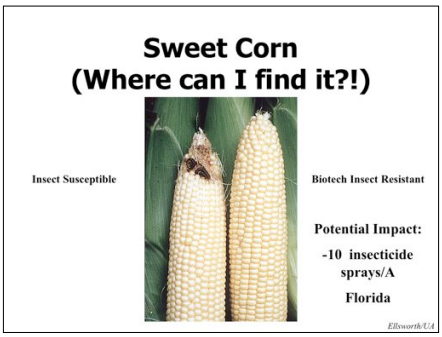
Finally, I want to emphasize the role of Bt cotton in biological control.

Several studies have documented generally higher densities of natural enemies, especially generalists, in Bt cotton and even the entire region over which Bt cotton is deployed

The reduction of insecticides in Bt cotton in China allows insecticide-resistant cotton aphid populations to be effectively suppressed by natural enemies.

Bt cotton is a foundation element in multi-pest IPM programs in several areas. The elimination of sprays for caterpillars contributes to the suppression of WF by natural enemies.

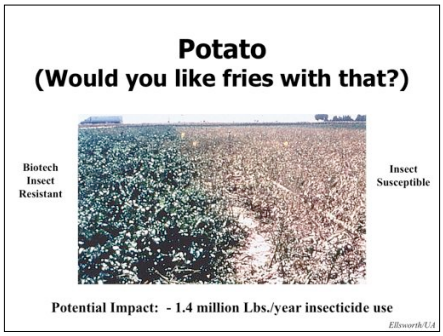
When we think of healthy, nutritious and delicious summer foods, we think of sweet corn! Yet, because of insect pests (corn earworm), this crop must be sprayed repeatedly through tasseling and silking, as much as once every 3 days, and typically with very broad spectrum insecticides. Depending on geography, this might mean 10 to 20 applications. Why?



Which corn would you rather eat? The one on the left where the grower had to spray 8, 10 or 20 (!) times and still sustained some corn earworm damage? Or, the one on the right produced with no insecticide on Bt sweet corn?

Turns out, despite its availability, Bt sweet corn is very rarely grown. And when it is, you can almost never find it identified as such. Why? Why wouldn't a grower like to advertise his corn as grown without excessive pesticides?

I want to know where to find it so that I can choose it over non-Bt corn! Unfortunately, you the consumer are in control. Your opinions and in general your fears are what cloister and hide the location of this nutritious and safe food that has the potential to eliminate so many sprays.



Colorado Potato Beetle is a major pest of potatoes responsible for millions of pounds of insecticide each year. Yet Bt potatoes can stop CPB completely without any insecticides!

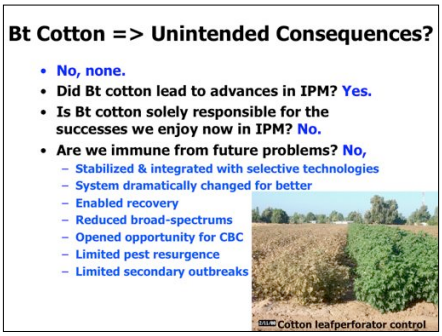
Is this biotech, GM crop grown today commercially?

If not, why not?

Who decides?

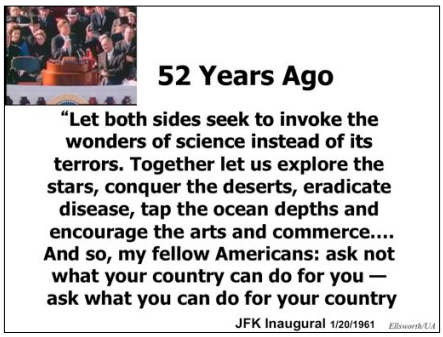
Who decided in this case?

Indirectly, you, the consumer decided, or, more appropriately the fear of consumer apprehension (emotionally driven) about GMOs. McDonald's, in fact, made the decision early on not to accept Bt potatoes in their french fries. So today, this biotech product sits on the shelf.



So where do we stand with respect to unintended consequences of Bt cotton in Arizona? Really, there are none, unless one wishes to count all of the dramatically positive achievements that have been possible as a result.

Importantly, despite this great success, it still is not a silver bullet and immune from any future issues or problems. However, we can say that it has dramatically improved our IPM system; it provides us a cornerstone tactic in resistant varieties, and has greatly reduced our need for broadly toxic insecticides. Probably most importantly, it has helped to enable an environment where conservation biological control can be practiced proactively to prevent other pests from becoming economic problems for our growers.



Thank you for the opportunity to address this conference. I'd like to finish with some very inspiring words and messages from history…

JFK provided this memorable quote (last sentence) during his inaugural just over 52 years ago. However, few have heard or read the words that preceded this now famous quote, and it has to do with the hope and promise of science and innovation in our society. These were hopeful, optimistic positive times, even despite the specter of the Cold War and the Soviet Union.

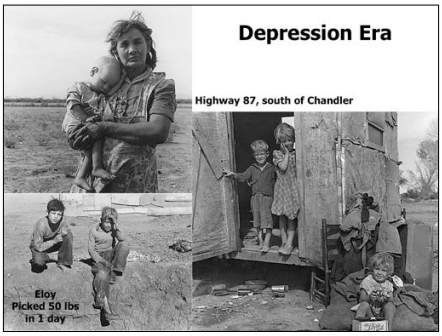
Recently, we celebrated the 50th anniversary of John Glenn's orbit of the Earth in Friendship 7, as the first U.S. astronaut to do so. This was an important moment in American history and one that signaled the dawning of a new technological age, and the beginning of the fulfillment of JFK's promise to the American people.

The time in history when this was happening was also a dangerous time, with friction mounting between the US and the Soviet Union and with Cuba, and the ultimate threat of technology in the atomic bomb.

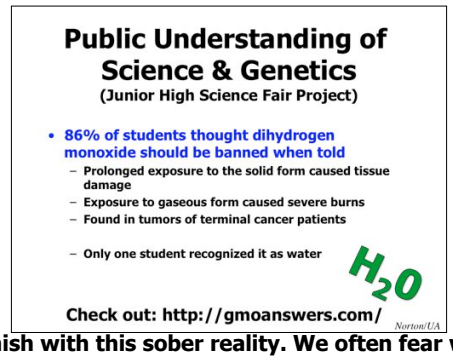
That same year in the fall, Rachel Carson's book Silent Spring was published. It may have gone less noticed if not for the pre-publication serialization of excerpts from that book in the New Yorker magazine which was read by thousands of Americans.

Many elements of Carson's book have since been challenged & debated by different parties. But, her general thesis that unbridled use of technology was inherently risky and potentially dangerous is an important one. This was the birth of an Environmental Age.

So very close in time, two different movements were started: a technological one and an environmental one. As part of the latter, many have recently called for a back to basics approach, shunning all use of technology in food production.



However, we've reached a time in history and in our culture (and some would say in hubris) where many are embracing a "get back to basics" attitude about food and agriculture especially, in an effort to be "green" and "sustainable". And, the fact that society is grappling with issues of food production and the processes involved is a wonderful new engagement of the public in an important dialog. However, I don't think anyone is suggesting discarding all technology and returning to a time where quality of life, standards of living, were very different and very, very difficult. These photos are from the area of AZ where I live and cotton is grown today. Living conditions were very difficult and young boys spent their days picking cotton.



I will finish with this sober reality. We often fear what we do not know / understand, a default, emotional behavior. This would not be so troubling if it only applied to fears of zombies / vampires or other denizens of the night that are subjects of popular culture. Unfortunately, it applies to these serious issues and makes us susceptible to flimsy arguments and fuzzy thinking.

While not an Extension website, for those looking for more balanced, evidence-based answers to their questions about GMOs, I refer you to this website. I also suggest that being skeptical of technology is fine and appropriate, but learn to ask questions of experts and dispassionately apply critical thinking. Challenge the agenda of anyone who speaks to you on this topic. Having society engaged in this dialog is great, but place a premium in educating our youth and ourselves in the sciences.

Thanks are given to the supporters of our IPM programs of research and education.

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

Photo credit: J. Silvertooth