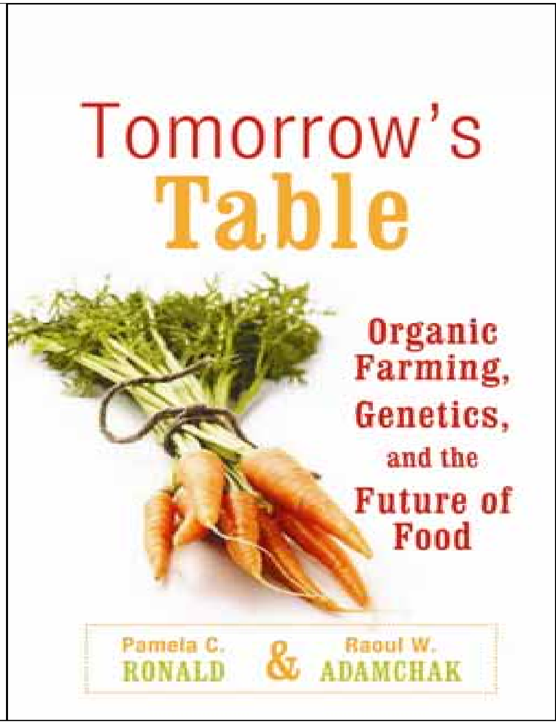
This is my husband Raoul Adamchak talking to his students. He has grown organic crops for thirty years. Here he on the certified organic farm on teh UCDavis campus descriiing organic production to his students.

YOu may think that geneticists and organic farmers represents polar opposits of the agricultural industry, Maybe you think that they dont even talk to each other. But we do and it is not difficutl because we both have the same goal: an ecologically based system of agriculture.

Over the years, many of our friends, family, and colleagues have asked us how GE will affect the environment and our food. Many of our scientific colleagues have asked us if organic framing can produce sufficient food to feed the world.



This book our response to these questions. Our intention is to give readers a better understanding of what geneticists and organic farmers actually do and also to help readers distinguish between fact and fiction in the debate about crop genetic engineering.

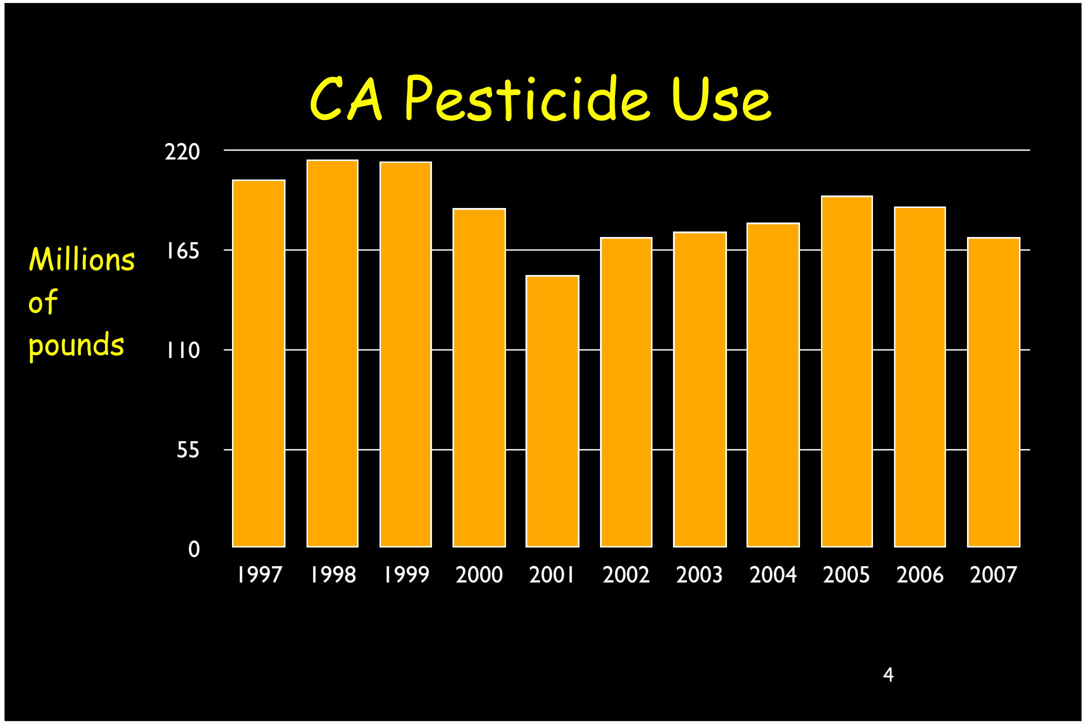
What kind of agriculture do we have?

-Overuse of harmful pesticides and soluble synthetic fertilizers.

What kind of agriculture do we want?
How can plant genetics help?

US agriculture is the most prodcutive in the wrld but the food is produced at severe environmental costs. These include..1. Problems generated by agricultural system.

2. Problems facing agriculture throughout the world.



180 million pounds pesticides used annually for past ten years.

1200 pesticide-related poisonings in 2004.

According to Eurostat, a general increase of pesticide use is observed in Europe and in most EU countries since 1996.

Already in 1995, a study by the European Environment Agency on environmental trends concludes that pesticide levels in groundwater are increasing and are estimated to exceed the target of maximum 0,5 µg/l (for total amount of pesticides) in 75% of agricultural land (PAN Europe 2002)

Long term health impacts--increased risk of prostate cancer, Parkinson's and other diseases.

Impacts on birds, fish, beneficial insects, and other animals.

3 million cases of severe pesticide poisonings each year

300,000 deaths

Image courtesy of R. Nelson

- Long term health impacts--increased risk of prostate cancer, Parkinson's and other diseases.
- Negatively affects birds, fish, beneficial insects, and other animals.

Another the problems of the current agricultural system is overuse of pesticides

This is a ppato farmer in peru.... This lack of safety precautions has led to 3 million...

read text. despite this well-reocgnixed facts, pesticide use continues. In california alone almost 200 million pounds of pesticides are used each year. 1200 pisiongin each year. Not only are humans affected but psticed devsate poulations of non-traget insects and kill millions of birds each year.

190 million pounds pesticides used in CA 2006; 1200 pesticide-related poisonings
CA dept of pesticide regulation

70,000 birds killed each year in the US alone
In the less developed country safe use of pesticides is even more difficult. World Health Organisation has estimated that between 3.5 and 5m people globally suffer acute pesticide poisoning every year

More than half the deaths occur ibn LDCs because not used safely

Data from teh world health organization

0-40% of potential global food, fiber and feed is lost to pest and disease.
60-70% of the losses are in the developing world at a cost of $300 billion/yr

CA Pesticide Use

180 million pounds pesticides used annually for past ten years.

1200 pesticide-related poisonings in 2004.

Conventional agriculture uses and enourmous amount of synthetic fertilzers. There are three problems with this: First, fertilzer synthesis represents 1% of global energy consumption. It takes the equivalent of 30 gallons of gasoline to make the synthetic fertilizer used on an acre of corn. Second, fertilizer is expensive, Finally, Soluble nitrates and phoshates leach into water supplies and become food for aquatic organisms.

{Synthetic nitrogen, phosphorus, and potassium fertilizers}

This slides shows highly turbid waters on the **left** that form each summer from the mouth of the Mississippi River all the way to the Texas coast. Bacteria thrive off excessive organic matter and use oxygen, the same oxygen that fish, crabs and other sea creatures rely on for life. The result is a Dead zones -an areas of water so devoid of oxygen that sea life cannot surivive.

This is Summertime satellite photo of from Nasa shows highly turbid waters from the mouth of the Mississippi River all the way to the Texas coast. In this image, reds and oranges represent low oxygen concentrations. Each year, a 6500 sq mile dead zone forms at the mouth of the Mississippi River

25% of nitrogen run-off comes from Iowa

Imagine...the world your children will live in 50 years from now if we make no changes to our agricuttularl prodcition

If we continue with current farming practices, vast amounts of wilderness will be lost, millions of birds and billions of insects will die, farm workers will be at increased risk for disease, and the public will lose billions of dollars as a consequence of environmental degradation. Clearly, there must be a better way to resolve the need for increased food production with the desire to minimize its impact.

Raoul and I start from this point, recognizing that there are problems with agriculture that need to be solved.

Criteria for Sustainable Agriculture

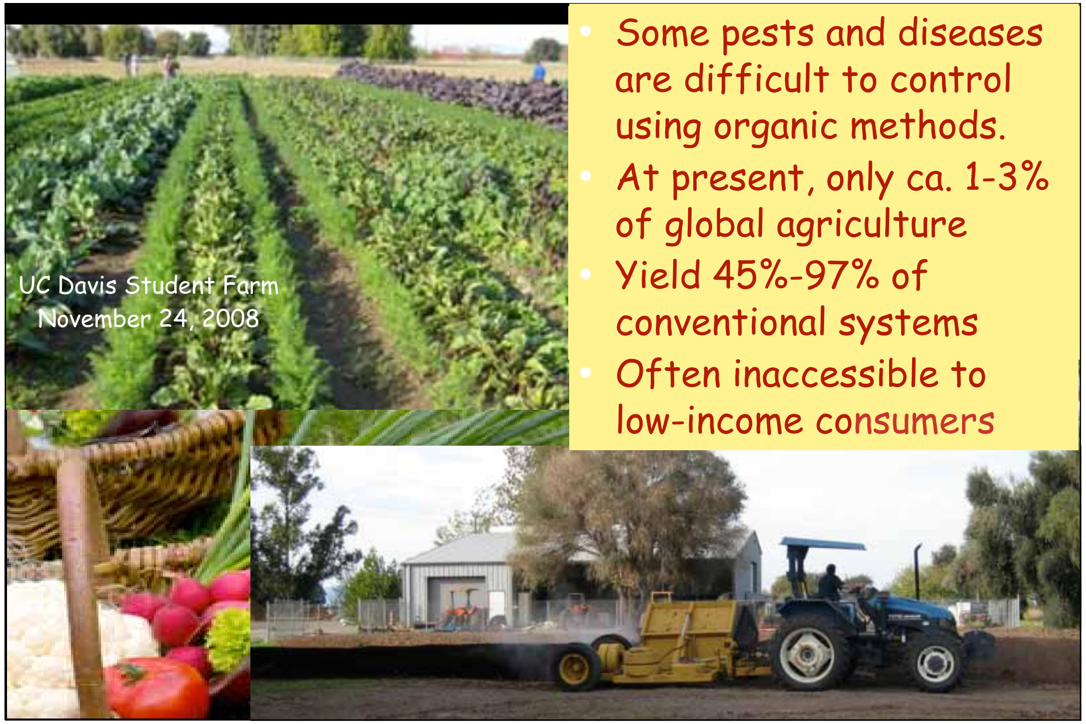
- Provide abundant, safe and nutritious food
- Reduce harmful environmental inputs
- Reduce energy use and greenhouse gas emissions.
- Foster soil fertility and reduce soil erosion
- Enhance crop genetic diversity
- Maintain the economic viability of farmers and rural communities
- Protect biodiversity
- Improve the lives of the poor and malnourished

It is time to step back and create a new vision for agrilcuture. These are the criteria that Raoul and I put together.

Organic agriculture began as a response to the problems of conventional agriculture. In the US the USDA certifies farms as organic based on specific criteria.

Must have 3 years with no prohibited material and be inspected on an annual basis by a USDA accredited certifier to be certified organic.

The current USDA regulations prohbit genetically engeineered crops.



What are the principles of organic agriculture? Organic agriculture focuses on the health of crops, animals, farmers, environment, and consumers

15. Organic farmers Controls pests through crop rotation, support and enhancement of beneficial organisms that prey on pests, use of seed carrying genetic resistant varieties, and naturally occurring pesticides.

16. Organic farming fosters soil fertility through use of compost. This is jeff on the compost spreader. He gathered food waste from the coffeehouse, manure from the stables// etc, let it ferment at x degreses with x moisture ofr x weeks and then spread it because…
Less soluble than synthetic nitrogen fertilizers and energy comes from sun rather than fossil fuels.

17. Organic farming builds soil through use of cover crops (fix nitrogen in the soil). This reduces nutrient run-off and soil erosion. This slide shows clover??? In the sring. In the fall it will be tilled in.

18. Yields can be comparable to conventional farms depending on the crop and location, but for some key crops such as rice, yields are often lower.
Some pests are difficult to control using organic methods
Presently comprises only ca. 3.5% of all agriculture.
Higher prices of organic food reduces availability to low income consumers. Losses to abiotic stresses not reduced with organic practices.
Losses to environmental stresses are difficult to reduce with organic practices.

Organic agriculture is a production system that:
Places a priority on health of crops, animals, farmers, environment, and consumers
Doesn't use synthetic pesticides (97% less pesticide than conventional systems).
Controls pests through crop rotation, support and enhancement of beneficial organisms, resistant varieties, and naturally occurring pesticides.
Focuses on building soil through use of compost and cover crops (less soluble and energy comes from sun.) This reduces nutrient run-off and soil erosion.
compost has nitrogen phosphours,, potassium and wide range of micronutrients.

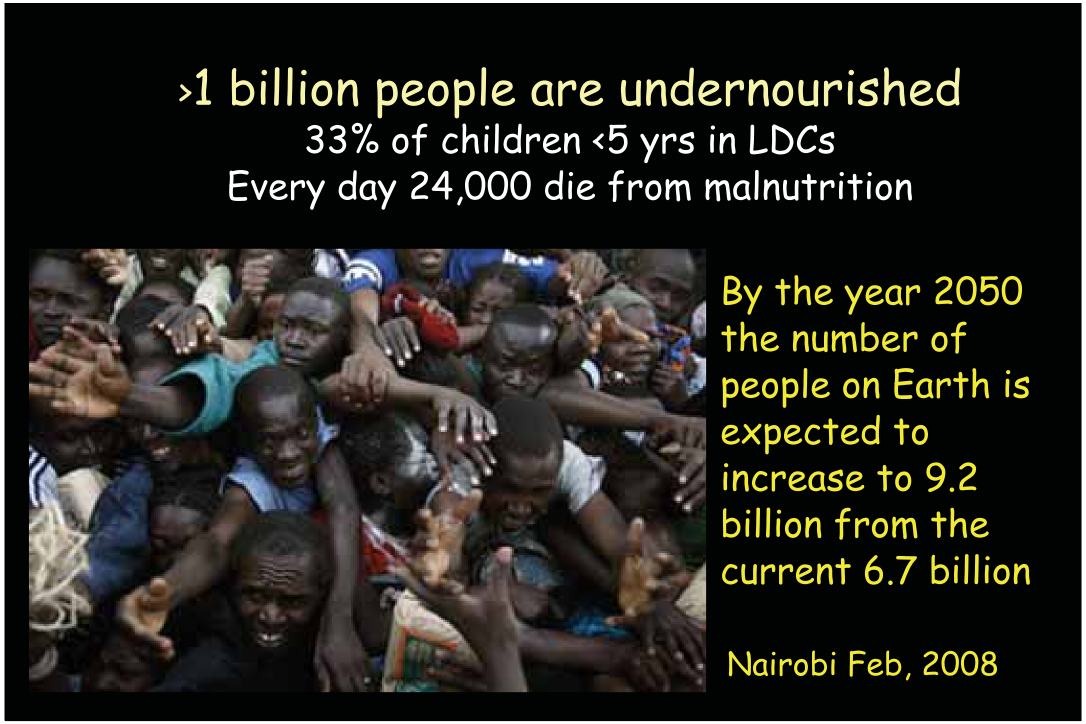
Integrates crop and animal agricultur

Is Organic Agriculture enough? Is the problem solved?

Organic practices and inputs need to evaluated on a case-by-case basis to determine if they meet standards for sustainable agriculture

Yields can be comparable to conventional farms depending on the crop and location, but for some key crops such as rice, yields are often lower.
Some pests are difficult to control using organic methods. This is one of the reasons that organic ag presently comprises only ca. 2-3% of all agriculture.

So clearly organic Ag can contribute to sustainable agriculture but it is not enough. So how have people in the past enhanced yields and reduced pests?



And there are many more low income consumers than high income consumers.

At least 80% of humanity lives on less than $10 a day.Source 1 (http://www.globalissues.org/article/26/poverty-facts-and-stats)

More than 80 percent of the world's population lives in countries where income differentials are widening.Source 2 (http://www.globalissues.org/article/26/poverty-facts-and-stats)

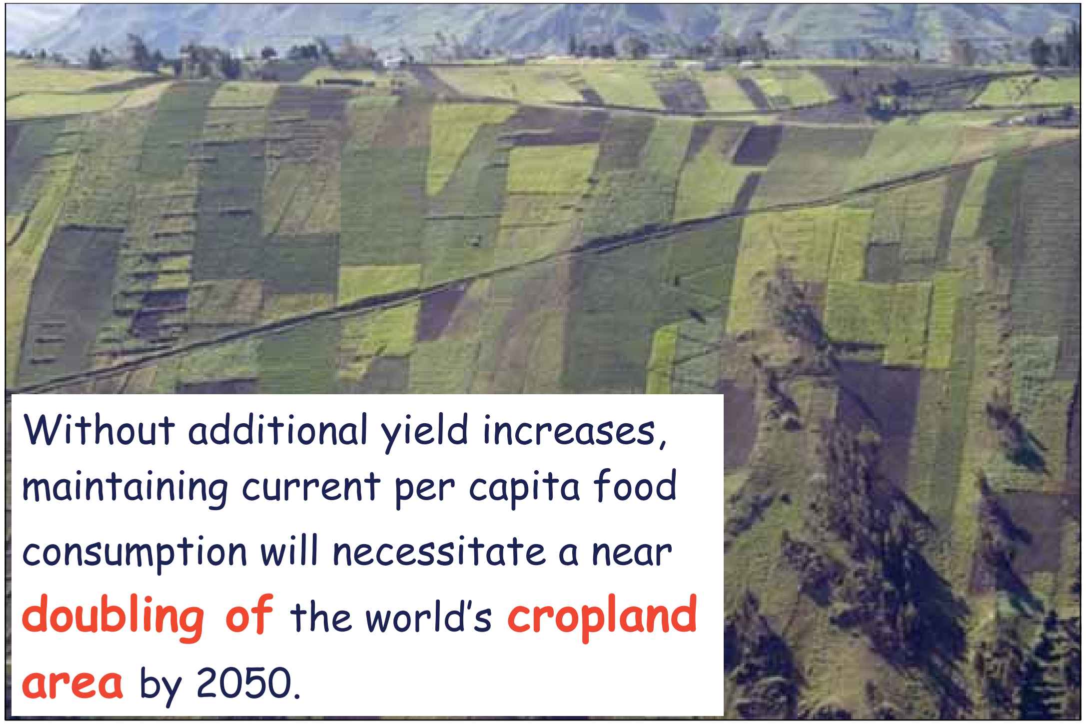
Despite the use of this intensive agriculture (One person in six! Are undernourished
(182 million children)
Rocketing food prices — some of which have more than doubled in two years — have sparked riots in numerous countries recently.
People push to receive food distributed by the Kenyan Red Cross in the Mathare slum in Nairobi. Time magazine Feb 27th 2008

What is the best way to produce enough food to feed all these people?

The consequences:
Conflicts over food?

In 2008 there were food riots in Haiti and Bangladeshi . the UN and other experts are concerend that these riots will become icnrasinly prevlanet unless we increase our gloabl food supply. Not only do we have a humanitarian duty to feed the hungry but we have global conflicts simmering

How are we going to grow more food?



We cannot produce more food by plowing more land. Already most of Most aerable land has been farmed. Patchwork fields on steep hills near Ambato, Ecuador. Thus, the increased demand for food and fiber must be met primarily by increasing production on land already under cultivation.

****

If we continue with current agricultural practices, We have to produce minor food on the same amount of land. Thus, the increased demand for food and fiber must be met primarily by increasing production on land already under cultivation. One alternative is to eat less meat. It is estimated that we vast areas of land would be freed for cultivation if everyone became a vegetarian. Unfortunately the trend is going the other way, with more and more people demanding meet.

We also know that we must increase yield.

Imagine that the earth will look like in 40 years if we do not change our farming practices. Imagine Camden or your local community with twice as much wilderness put to farmland. Imagine the consequences of plowing twice as much land. Speices biodiviersy will be lost beause every time you plow whethr it i organic arming or onentional farming, you damage habitat. Water supplies will be further constrained; soil erosion will increas.

If we hadn't genetically modified our crops by conventional methods over the last 50 years, we would be using twice as much of the Earth's surface to grow the same amount of food. In the future, if we don't increase yields, we'll need to use double the amount of land to produce the same amount of food. Sparing land from becoming farmland, is the greatest benefit to biodiversity. For this reason, some ecologists see the application of GE as a way to spare even more land from destruction by enhancing yields (Qaim and Zilberman 2003; Snow et al. 2005).

The a U.K.-based consulting firm recently released a report saying that GE crops reduced pesticide spraying by 359 million kilograms from 1996-2007 If no GE crops had been grown in 2007, an area equivalent to about 6 percent of the arable land in the U.S.,would have had to be brought under cultivation in order to achieve the same global production levels. (The report, by Graham Brookes and Peter Barfoot, is entitled: "GM crops: global socio-economic and environmental impacts 1996-2007.)

DO.meb.9B.cxxsAfter hunting dragonflies in a rice field with a homemade bamboo whip tipped with sticky jack fruit sap, an Indonesian boy treats himself to a short swim under a waterfall, Batuan, Bali, Indonesia.(Man Eating Bugs pa

Can we cope with the future demands on water?

Approximately 40% of the world's food is produced from irrigated land,DAG and 10% is grown with water mined from aquifers. There is growing competition for water between cities and industry, with agriculture being the user of lowest value and last resort. Thus, the projected doubling of food production must largely take place on the same land area and using less water. More effective management of water requires a series of institutional and managerial changes in addition to a new generation of technical innovations that includes advances in genetic engineering of plants. (Somerville and brisoce Sciene 292, 2001 p 2217)

What kind of agriculture do we want?

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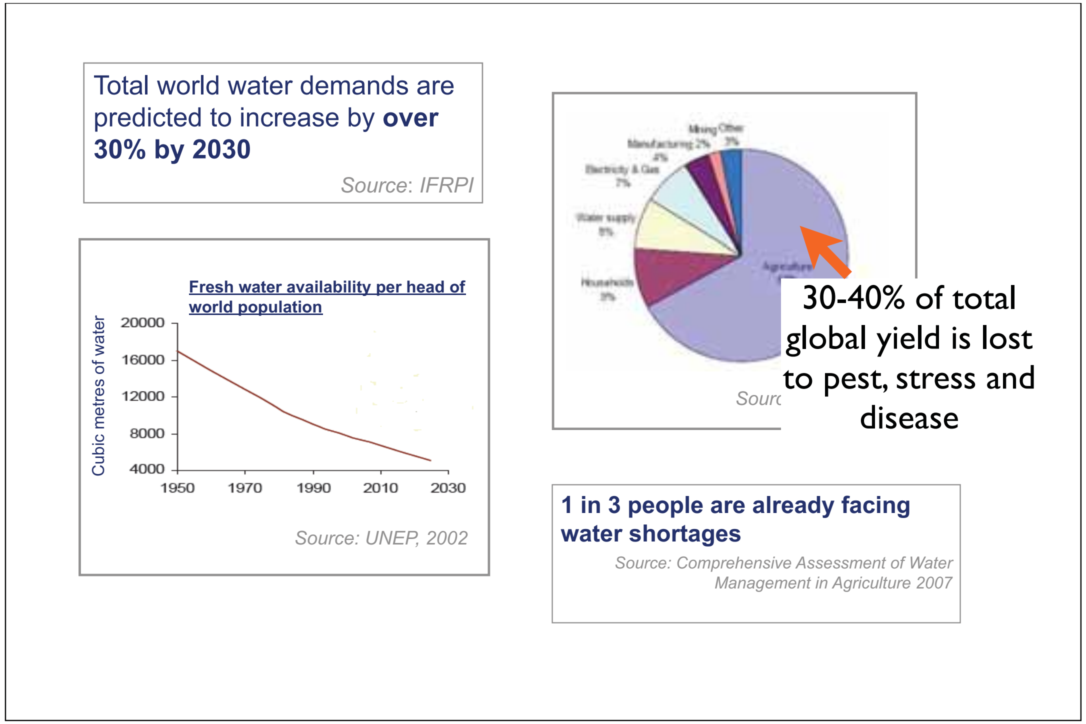
- Reduce harmful environmental inputs
- Foster soil fertility and reduce soil erosion
- Maintain the economic viability of farmers and rural communities
- Protect insect, plant and microbial biodiversity
- Improve the lives of the poor and malnourished

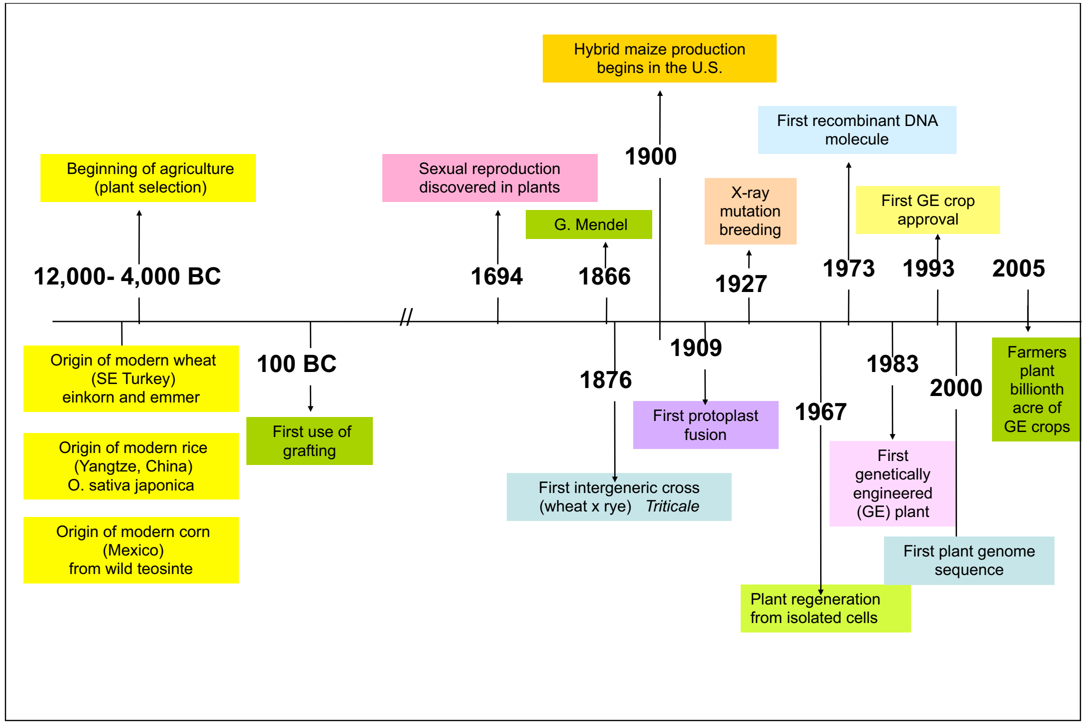


Four fold decrease in per capita water availability over the last 60 years. Of the water that is available for use, about 70% is already used for agriculture. It has been estimated that up to 40% of plant productivity in Africa and Asia, and about 20% in the developed world, is lost to pests and pathogens. Approximately one-third of the losses are due to viral, fungal, and bacterial pathogens, and the remainder is due to insects and nematodes. Much of the loss occurs after the plants are fully grown: a point at which most or all of the water required to grow a crop has been invested. Thus, reducing losses to pests and pathogens is equivalent to creating more land and more water.

Modern genetic approaches such as genetic engineering can help reduce losses to pests, stress and disease

17

so what can GE contidbute to sustianable ag in faxce of these large problems, which challenge us as much and are linked to climate chnage,



What seed you use has a huge impact in the yield you get and the survival of the plants in various environmental conditions.
All the information for traits that farmers need- for yield, flavor nutrition- is contained in the seed.

Our ancestors knew this.

The first genetically improved plants- that is they differed from their wild progneitors -were found in Turkey (wheat), China (rice) and mexico (corn) and 13,000 years ago. ...you can see for the first 13,000 years improvements through primitive plant selection were slow. After the discovery by Mendel that traits in seeds were encoded by genes, more precise breeding was introduced. In 1900, hybrid seed production, in 1927 inudced mutation by mutageneisis. All these methods were radical in their time but were accepted. Ge is a new and distinct process that some people consider to be the natural next phase in crop domestication and others see as completely unnatural.

This is a timelline...yoyu can see for the first 13,000 years improvements through prmivit pplant selection were slow.

10K years ago
Einkorn Triticum monococcum (diploid)
Emmer T. turgidum (tetrapolid)

Spelt, T spelta and T simopheevil were ancient forms of wehat developed by the late neotlithi, neither which have much a a markte today.

Main difference is that domesticated forms ahe larer seeds and a non-shattering Rachis- the stem that keeps the wheat shafts togetehr

Today, rice (Oyrza species) feeds more than half the world's population, and accounts for 20 percent of the world's total calorie intake. It grows on every continent in the world except Antartica, and has 21 different wild varieties and two cultivated species: Oryza sativa, domesticated in south Asia at least 10,000 years ago, and Oryza glabberima, domesticated in west Africa between about 1500 and 800 BC.

According to the latest molecular studies, Oryza sativa was domesticated at least twice: O. sativa japonica, developed in south China (probably the Yangtse valley), and O. sativa indica, developed in eastern India or Indonesia. Both of these were domesticated from the original plant called Oryza rufipogon. Rice farming at this early date was dryland cultivation; rice paddies were not developed until about 2500 BC.
The History of Rice in China

The best known evidence for early domestication is japonica. Rice phytoliths (some of which are identifiable to japonica) were identified in the sediment deposits of Diaotonghuan Cave, located near Poyang Lake in the middle Yangtse river valley radiocarbon dated about 10,000-9000 years before the present. Additional soil core testing of the lake sediments revealed rice phytoliths from rice of some sort present in the valley before 12,820 BP (although these were not necessarily domesticated). Shangshan, a Neolithic village in the lower Yangtse valley dated to about 10,000 BP contained ceramic sherds tempered with charred plants, including rice and containing fan-shaped phytoliths. By about 7,000 years ago, japonica is found throughout the Yangtse valley, including large amounts of rice kernels at such sites as TongZian Luojiajiao (7100 BP) and Hemuda (7000 BP).
Earliest Evidence

Four grains of rice were recovered from the Yuchanyan site, a rock shelter in Dao County, Hunan Province in China. They seem to represent very early forms of domestication having characteristics of both japonica and sativa, and are said to be dated between 12,000 and 14,000 years ago, although there is no discussion of what exactly was dated in the very preliminary report.

An astonishing discovery in the Rio Balsas region of Mexico has pushed the domestication of corn—or rather, American corn or maize—back to at least 7,000 BC. Maize (Zea mays—and decidedly not teosinte) starch granules and opal phytoliths from squash dated to more than 9,000 years ago have been found in a rockshelter in the Rio Balsas valley of Mexico, where teosinte is believed to have originated. The new findings were reported in the March 23 issue of the Proceedings of the National Academy of Sciences by a team led by Dolores Piperno.

Teosinte at the Jardín Etnobotánico in Oaxaca City, Oaxaca
Teosinte at the Jardín Etnobotánico in Oaxaca City, Oaxaca. Photo by Jerry Friedman

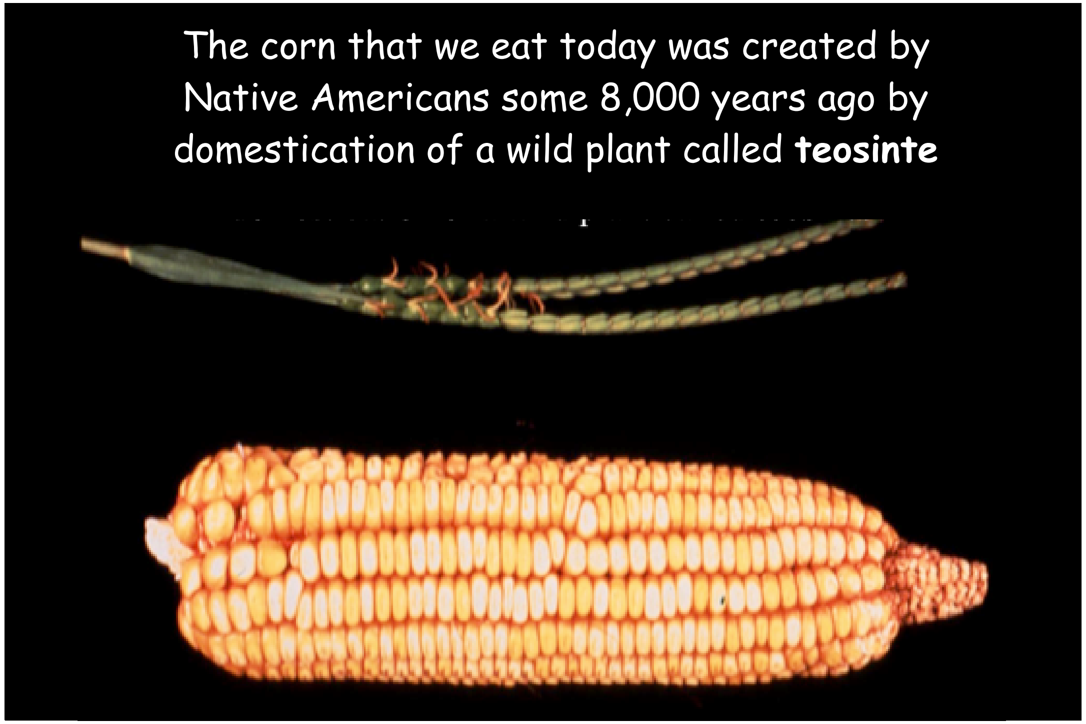
At a rockshelter site called Xihuatoxtla in the state of Guerrero, five stratified layers contain occupational debris between 1000 and 9000 cal BP, or between about 7000 BC and AD 1000. Each of the layers contain millstones or hand stones and the majority of those stones—including the Archaic and Paleoindian layers—had either starch granules from domesticated maize and/or phytoliths from domesticated squash (cucurbits).

The squash and maize are on stone tools and in the sediment layers of even the lowest layer, which includes a Pedernales point base and another lanceolate point, clearly an Early Archaic or Paleoindian occupation. Before the discoveries at Xihuatoxtla shelter, the earliest maize was noted at Archaic period Guila Naquitz (5400 RCYBP) and Coxcatlan Cave (5960 BC).

What this all means

First of all, its important to note that the starch is from domesticated Zea mays, not the wild form of teosinte (Zea mays spp. parviglumis) thought to be its progenitor. Interestingly enough, teosinte is thought to be native to the Rio Balsas valley—so the Xihuatoxtla rockshelter could well be near the location of the first domestication of corn, which had to have taken place before 9,000 BP.

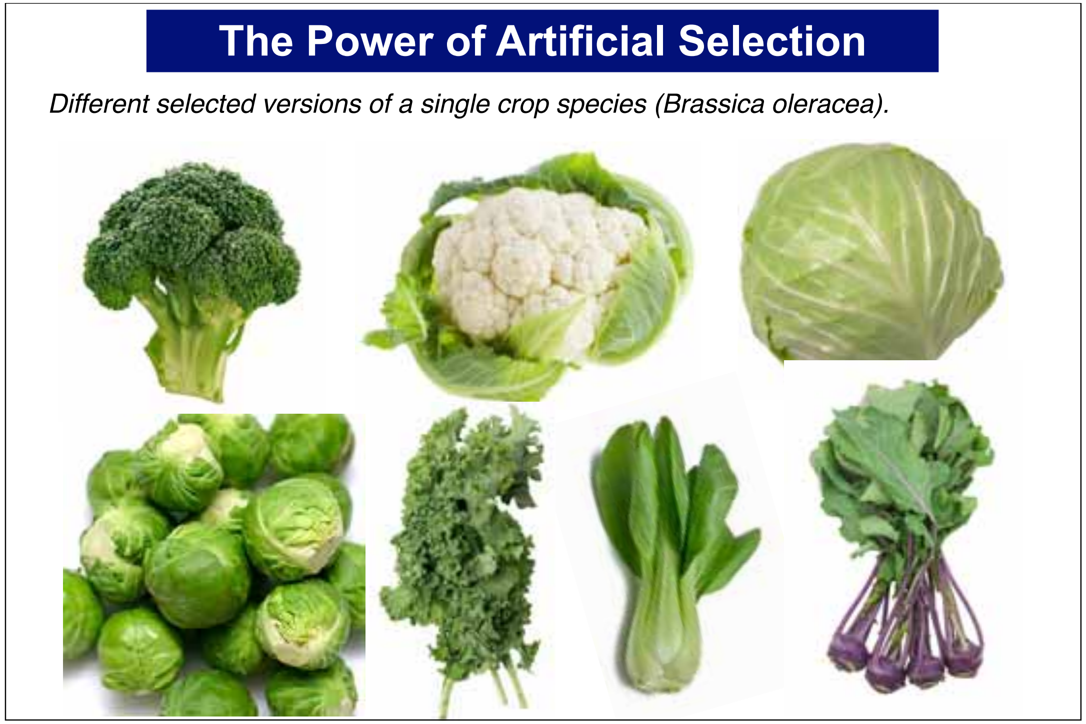
Further, the discovery of domestic corn and squash in Paleoindian/Early Archaic settings suggests that we need to seriously rethink our ideas of what a "typical" hunter-gatherer lifestyle is. The notion that hunter-gatherers only collect or at most tend to stands of crops is clearly no longer viable with this discovery.



. First lets see what sorts of genetic changes our ancestors accomplished. On the top: This is an ancient ancestor of modern-day corn, called Tripsacum. (Teosinte) It comes from a plant that doesn't look anything like a modern corn plant; it looks more like a type of grass, with long, thin blades. Also its seed structure, the primary source of nutrition from corn, is different in the way it is formed and what it contains. It is born on the end of one of its stalks, instead of on the body of the plant. Tripsacum produces 10 or 20 seeds per plant and the seeds of Tripsacum are much less nutritious. It requires a hammer in order to break the seed coat of the wild relative's grain to expose the nutritious kernel; something that most of our stomachs are not equipped to do.

On the bottom: This is an ear of modern corn; it contains the seeds that the plant produces in order to be able to insure a next generation. The modern hybrid corn will produce several ears each bearing in excess of 1000 seeds. Before hybrid corn 20 bushels an acre. With hybrid corn farnmers are getting 150 bushels an acre.

If we had to depend on the wild relative for feed stock for animals, we would have to plant 100's, if not 1000's, of times more plants. That would take 100's or 1000's of times more acres, in order to get the same amount of seed. -This is not the case just for corn. Every single food that you eat each day has been genetically improved in some way. It is all domesticated



Here is another example of conventional breeding. All these vegetables are produced from the same species of Brassica (oleracea). Much of this diversity produced within historic times in Europe within the last 800 years. You can see the great diversity generated by conventional methods of genetic improvement.

>>>>>>>>
It's called a selective sweep.

These are all Brassica oleracea

Cauliflower is the newcomer at about 1200 AD and brussel sprout might have a similar time of origin. The others are known from Greek and Latin texts so much older. I found this info on Wikipedia and it fits my recollection from NW Simmonds book the Evolution of Crop Plants. So they have all been around for 800 years. They are all Brassica oleracea. Take a look at

http://en.wikipedia.org/wiki/Brassica_oleracea

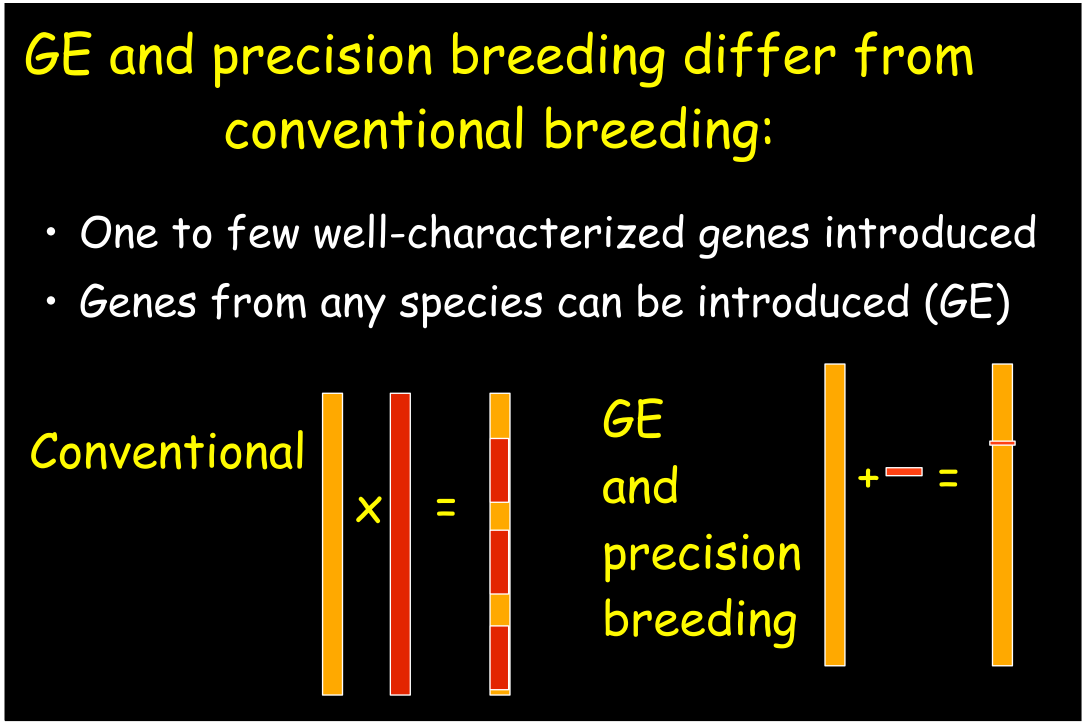
There are a few crops varieties with more recent origins. Mutation breeding (xray mutagenesis) has been used since the 1940s (?) but you'd need to do some digging to find a concrete example. Triticale, a wide cross, is a recent crop. I think the commercial strawberry is a post columbian hybrid of american and european species.

What is GE?
Pam: GE is a modern form of plant breeding that does not require pollination. It differs from conventional breeding in two basic ways:
Conventional plant breeding allows gene transfer only between closely related species.
With genetic engineering, genes from the same species or from any other species, can be introduced into a plant.

Plant breeding mixes large sets of genes of unknown function, whereas genetic engineering generally introduces only one to a few well- characterized genes at a time.
People have been domesticating crops for thousands of year. Improve for better tasting yield etc. It is human nature.
Ge is a new and distinct process that can be considered to be the next phase in human domestication.

Both conventional approaches and GE results in a genetically modified crop that produces seed Farmer can still save seed.

Why is there so much excitement about GE? Let me tell you the story of papaya



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Why is there so much excitement about GE? Let me tell you the story of papaya

Both conventional and modern approaches result in a genetically modified crop that produces seed that can be saved by the farmer

Precision breeding and GE can address problems difficult to solve with conventional breeding: drought, flood tolerance, pest resistance, nitrogen assimilation

I recognize that there is the general anxiety about genetic engineering, and often teh science itsul f is not trusted.. It seems that to successfully make decisions on how to use GE for the betterment of humankind and the environment, the public will need to understand the scientifi c process and learn to distinguish high-quality scientifi c research that has stood the test of time and can largely be relied on from simple assertions or unsubstantiated rumors.

Examine the primary source of information.
Is there a reference to the source of information? If not, it cannot be verifi ed. If so, is the source reputable? In the case of the boy and the mice, I found that the reference given for the boy's work was to another Web site, and that that web site referred to even another Web site (Ho ☒☒☒☒). It turned out that the only documentation of this "experiment" was a chance meeting with the boy's mother, who was the source of the "scientifi c information." "Mum Guusje is very proud of her son. . . ." I wonder why someone would cite a conversation with a boy's mother as a good scientifi c reference? Either the authors of the book and the Web site lack a basic understanding of science and cannot assess the accuracy of the work, or they simply do not care, or both. But they should care; for this kind of deception only confuses and frightens people. And laws are being passed based on this kind of silliness.
Ask if the work was published in a peer-reviewed journal
☒. . Peer review is the standard process for scientifi c publications. Peer-reviewed manuscripts have been read by several scholars in the same fi eld (called peers), and these peers have indicated that the experiments and conclusions meets the standards of their discipline and are suitable for publication. In the absence of peer-review the signifi cance and quality of the data cannot be assessed. With no peer-reviewed, published record of the boy's subjective experiment, it is doubtful that normal standard scientifi c methods were applied.
Check if the journal has a good reputation for scientifi c research.
☒. If a peer-reviewed paper is cited, where was it published? Is the journal widely respected? One tool that is commonly used for ranking, evaluating, categorizing, and comparing journals is the frequency with which the "average article" in a journal has been cited in a particular year or period. Th e frequency of citation refl ects acknowledgment of importance by the scientifi c community. High-impact and widely respected journals include Science and Nature. Th erefore, a citation in Science generally suggests scholarly acceptance, whereas publication in a nonscientifi c or little-known journal does not.
Determine if there is an independent confi rmation by another published study.
☒. Even if a study is peer-reviewed and published in a reputable journal, independent assessment is critical to confi rm or extend the fi ndings. Even the best journals or scientists will occasionally make mistakes and publish papers that are later retracted. Sometimes there may be outright fabrication that is overlooked by the reviewers and not detected until later (Kennedy ☒☒☒☒). In other cases, the scientifi c report may be accurate but its signifi cance may be misrepresented by the media. A good example is that of genetically engineered corn and the monarch butterfl y controversy that erupted in ☒☒☒☒. A Cornell entomologist, John Losey, published a short paper in the scientifi c journal Nature reporting that monarch butterfl y larvae died after eating milkweed plants dusted with pollen from GE corn (Losey et al. ☒☒☒☒). Th e paper generated intense national and international news coverage transforming the monarch butterfl y overnight into a dramatic symbol of what some consumers saw as the dangers of agricultural biotechnology. Subsequent scientifi c studies, including fi eld trials, showed that the exposure of monarchs to GE corn is fairly small and that the threat to monarchs pales in comparison to risks presented by conventional pesticides (Pew Initiative on Food and Biotechnology ☒☒☒☒). Such misrepresentations or errors are usually discovered by other researchers because most reports, especially if it is exciting news such as a suggestion that genetic engineering kills monarch butterfl ies or makes mice sick, will be rapidly retested by other scientists. If the data are challenged, the fi rst author then has the opportunity to write another paper refuting the challenge. Although it is a slow process to establish a scientifi c "truth," a particular scientifi c conclusion will eventually either gain broad acceptance or be discarded.
Assess if a potential confl ict of interest exists.
☒. Most people would agree that a mother usually believes the best about her son, and that pesky details such as lack of scientifi c training may not bother her. Th erefore, a mother's recommendation represents a clear confl ict of interest in such a case. Studies tainted by such undisclosed confl icts of interests are a major concern in the debate about genetic engineering. If governmental regulators were to rely solely on data supplied by parties whose primary concern is not the public good but private interest, then the public would have reason to question the integrity of the research. Similarly, if a person with a strong stance on the use of GE in agriculture is an employee of a for-profi t biotechnology or organic industry, such employment should be disclosed because a confl ict of interest may exist. (Full disclosure: neither Raoul nor I presently have fi nancial relationships with for-profi t food biotechnology or organic industries.. Transparency is a wonderful disinfectant when honesty is needed.

Assess the quality of institution or panel.
Does the report emanate from a University accredited by the U.S. Department of Education or equivalent society? Such information is generally more reliable than that issued from a single individual putting information out on the web. In the United States, government research arms such as the National Science Foundation and the National Institute of Health and professional scientifi c societies generally provide up-to-date, high-quality information. For example, the American Society of Plant Biologists is a nonprofi t professional society devoted to the advancement of the plant sciences. It publishes two world-class journals and organizes conferences and other activities that are key to the advancement of the science. Th e National Academy of Sciences (NAS) is "an honorifi c society of distinguished scholars engaged in scientifi c and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare." (NAS ☒☒☒☒). Election to the Academy is considered one of the highest honors that can be accorded a U.S. scientist or engineer. Th ese types of nonprofi t organizations provide a public service by working outside the framework of government to ensure independent advice on matters of science, technology, and medicine.
Examine the reputation
☒. of the author. Do the author(s) have training in science? If so, have they had formal training leading to an advanced degree such as a Master's degree or doctorate, and have they published widely in reputable journals? If not, then are they working with a reputable scientist(s) to evaluate the data? In the case of the boy and the mice, a university affi liation is hinted at, but it seems that the "experiment" was carried out at home and reviewed primarily by his mother.

The science is clear. The current GE crops are safe to eat. The fact is that there is not a shred of any evidence of risk to human health from GM crops. Every academy of science, representing the views of the world's leading experts—the Indian, Chinese, Mexican, Brazilian, French and American academies as well as the Royal Society, which has published four separate reports on the issue—has confirmed this. Independent inquiries have found that the risk from GM crops is no greater than that from conventionally grown crops that do not have to undergo such testing.

The commercialized GE crops are safe to eat (NAS, Royal Academy, French..).

No scientific basis for ruling out GE

Each new crop must be evaluated on a case-by-case basis. Sometimes a GE crop will be the most appropriate technology to address a particular problem and sometimes not.

In other words there have been more harm from hoes than transgenic plants

Conclude: To put it in another way the science indiating that GE crops are safe to eat is a broadly accepted as the science that says our earth is warming. The diffrence is that the political right protested the science of global warming. With GE it is the political letft.It is critical to move beyond politics and address these major challenges of our time: Developing a sustainable productive agirulcutral sytesm is as important ot our future as is reducing global warming.

fr In 2001, the research directorate of the EU commission released a summary of 81 scientific studies financed by the EU itself—not by private industry—conducted over a 15-year period, to determine whether GM products were unsafe or insufficiently tested: none found evidence of harm to humans or to the environment.

If you are making policy it is wise to go with tehopnion of the bil of the part of the scientific community that has tsudied the particular questions. This was true wtih climate change and is true with ag biotechnology. The mainstream view is just as i have stated. If I were a policy makers betting the publics welfone on an intereprestaion of scinece, I would go with teh mainstream.

Bollworm egg hatching

Cotton uses approximately 25% of the world's insecticides to control this pests

The Environmental Protection Agency considers seven of the top 15 pesticides used on cotton in 2000 in the United States as "possible," or "known" human carcinogens

In the 1990s, varieties of cotton genetically engineered to protect itself against insects was developed. The plants carry a protein called Bt, a favorite insecticide of organic farmers because it kills pests but is nontoxic to mammals, birds, fish, and humans.

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The bacterium Bacillus thuringiensis produces an insecticidal protein called Bt

Used since the 1930s, Bt sprays are a favorite tools of organic farmers

Bt gene cloned and introduced into crops.

Presently only commercialized transgene for insect resistance in various crops

In Arizona, growers cut their insecticide use in half while maintaining the same yield as their neighbors. Insect biodiversity increased as measured by the diversity of beetles and ants in the field.example of arizona cotton?

This is f rom a vriginia tech magazine

With a goal to add value to the state's cotton crop, Professor of Biological Systems Engineering Foster A. Agblevor has developed the manufacturing processes that can extract glucose and xylose from cotton gin residue, which can then be used to make ethanol, potentially an automobile fuel, and xylitol, a sugar. "Our work shows a manufacturing process for extracting both products simultaneously from the cotton residue so in the future it is possible that a manufacturing company could produce both the ethanol and xylitol products," Agblevor said. An Iowa firm that produces ethanol from corn is interested in developing the technology.

Punjiben, cotton farmer, Gujarat, India

(Photo from Fairtrade Foundation)

In India, yields increased 80 percent on small farm plots compared with neighboring plots growing conventional cotton

China is the world's leading producer of cotton, with an output of 6.73 million tons per year. BEGINNING IN 1997, an important change swept over cotton farms in northern China. By adopting Bt cotton, growers found they could spray far less insecticide over their fields. Within four years they had reduced their annual use of the poisonous chemicals by 156 million pounds - almost as much as is used in the entire state of California each year. Cotton yields in the region climbed, and production costs fell. Strikingly, the number of insecticide-related illnesses among farmers in the region dropped to a quarter of their previous level. By 2001, Bt cotton accounted for nearly half the cotton produced in China.

>>>>>>>

Bundled against the wind, a group of women picks cotton in China. The Asian nation is the world's leading producer of cotton, with an output of 6.73 million tons per year. Farmers can't keep up with the burgeoning textile industry, however, which uses about 13 million tons of cotton a year. The Chinese often rely on imports to close the gap, which drives up textile prices for consumers worldwide.

(Photo shot on assignment for, but not published in, "Chasing the Wall," January 2003, National Geographic magazine)

BEGINNING IN 1997, an important change swept over cotton farms in northern China. By adopting new farming techniques, growers found they could spray far less insecticide over their fields. Within four years they had reduced their annual use of the poisonous chemicals by 156 million pounds - almost as much as is used in the entire state of California each year. Cotton yields in the region climbed, and production costs fell. Strikingly, the number of insecticide-related illnesses among farmers in the region dropped to a quarter of their previous level.

This story, which has been repeated around the world, is precisely the kind of triumph over chemicals that organic-farming advocates wish for.

But the hero in this story isn't organic farming. It is genetic engineering.

The most important change embraced by the Chinese farmers was to use a variety of cotton genetically engineered to protect itself against insects. The plants carry a protein called Bt, a favorite insecticide of organic farmers because it kills pests but is nontoxic to mammals, birds, fish, and humans. By 2001, Bt cotton accounted for nearly half the cotton produced in China.

For anyone worried about the future of global agriculture, the story is instructive. The world faces an enormous challenge: Its growing population demands more food and other crops, but standard commercial agriculture uses industrial quantities of pesticides and harms the environment in other ways. The organic farming movement has shown that it is possible to dramatically reduce the use of insecticides, and that doing so benefits both farm workers and the environment. But organic farming also has serious limits - there are many pests and diseases that cannot be controlled using organic approaches, and organic crops are generally more expensive to produce and buy.

To meet the appetites of the world's population without drastically hurting the environment requires a visionary new approach: combining genetic engineering and organic farming.

But relying on a GE approach alone cannot solve the pest problem

After seven years of reduced insecticide use in China, populations of other insects increased so much that farmers resumed spraying certain kinds of pesticides.

The key to Bt cotton's continued efficacy may well be the use of refuges – patches of non-Bt cotton intermingled with the fields of Bt cotton.

Tabashnik et al 2008, Nature Biotechnology, 26:199.

After seven years of reduced insecticide use in China, populations of other insects increased so much that farmers resumed spraying certain kinds of pesticides

Biologists have know for 50 years that high levels of pesticides leads to resistant pests. 400 insect species have evolved resistance to insecticides. This is supported by filed-evolved resistnace to sprays of Bt toxins in diamonbath moth (1990s)

BT corn and cotton grown on a cumulative total of 200 million hecatres worldwide, more than enough to cover teh entire states of Texas, california and Iowa.

Still in the first decades no resistance was observed in insect pests targeted by BT coprs in most countries. This result exceeded teh expectations of most scientists.An exceoption is the resistance observed in 3 species. Why? thoruhg that failire to intoreuce crop genetic diversity (refuges) enhanced resistance. REfuges: patches of conventional cotton intermingled with the fields of Bt cotton.

Conclusion: sustainable farming practices combined with GE crops has dramatic benefits for farmers and the environment.

****

Bt cotton has been planted in Arizona since 1996. Now more than half of the state's 256,000 acres of cotton fields are planted with the biotech plants. Without the protection provided by Bt cotton, some fields can have 100 percent of plants infested with pink bollworm caterpillars, which live inside the cotton boll, destroying the crop.

Dennehy said, "In an extreme infestation, you can have every single boll in the field infected." The caterpillars eat the seeds and damage the developing cotton fibers.

In contrast, when the caterpillars eat Bt cotton, they die.

Before the use of Bt cotton became widespread, pink bollworm was one of the top three insect pests of cotton in the Southwest. In 1995, losses from pink bollworm in Arizona cotton were estimated to be $8.48 per acre, totaling $3.4 million statewide. Cotton is grown in eight Arizona counties: Cochise, Graham, La Paz, Maricopa, Mohave, Pima, Pinal and Yuma.

"Moreover, the harsh insecticides used to control pink bollworm resulted in a host of other insect pests becoming more serious problems," Dennehy said.

Everything changed in 1996, he said, when Bt cotton and two other "soft" insect control tactics replaced a large amount of the harsh pesticides used on cotton crops. Spraying less chemical insecticides means more beneficial insects survive, further reducing the need for spraying.

By 2004, pink bollworm losses had fallen to nearly half of earlier levels, $4.34 per acre.

Tabashnik said, "Some of the other pests are not so much of a problem because we're not killing their natural enemies with insecticides."

Dennehy added, "These soft toxins plus the good bugs acting together have driven pesticide use to historic low levels ... this is a wonderful success of integrated pest management."

Since widespread adoption of Bt cotton in 1997, insecticide use on Arizona's cotton crops is down 60 percent, said Tabashnik. The reduction in chemical pesticide use saves growers about $80 per acre. According to the Arizona Agricultural Statistics Bulletin, the value of Arizona's cotton crops for 2004 was estimated at $207 million.

The key to Bt cotton's continued efficacy is the use of refuges – patches of traditional cotton intermingled with the fields of Bt cotton.

The refuges ensure that the few pink bollworm moths that are resistant to Bt are most likely to mate with Bt-susceptible pink bollworm moths that grew up in the refuges. The offspring from such matings die when they eat Bt cotton.

In contrast, if all of Arizona's cotton was Bt cotton, only pink bollworm caterpillars that were resistant to the Bt toxin would survive. If resistant pink bollworm moths mated with each other, their offspring would be resistant and could feed on Bt cotton. Bt cotton would then become useless against pink bollworm.

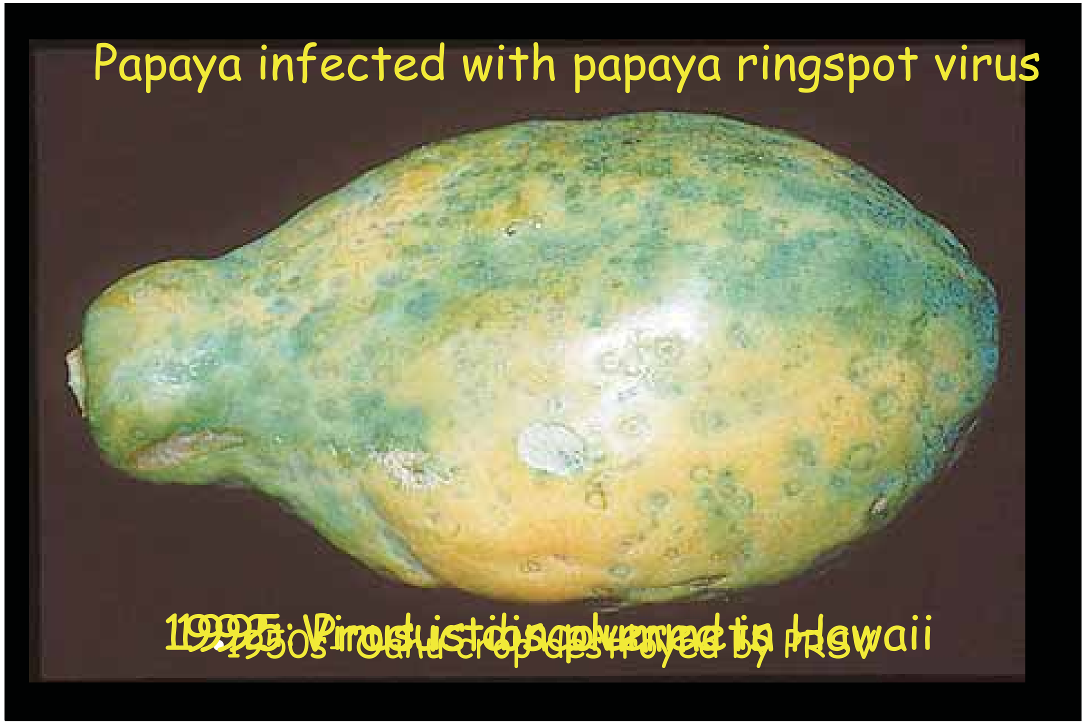
The UA team used a combination of field surveys, laboratory testing and mathematical modeling to determine if pink bollworm had become resistant to Bt cotton.

The team did find Bt-resistant pink bollworm caterpillars in the field, but they were rare.

Tabashnik said that doesn't mean the insects won't bite back in the future. "It's not that pink bollworm can't beat Bt toxin, but that it hasn't beaten Bt toxin so far."

There's a new variety Bt cotton now available that has two different Bt toxins, he said. The team's next step will be to determine how to best use that combination of toxins to stay one step ahead of the pink bollworms.

The a U.K.-based consulting firm recently released a report saying that GE crops reduced pesticide spraying by 359 million kilograms from 1996-2007 (The report, by Graham Brookes and Peter Barfoot, is entitled: "GM crops: global socio-economic and environmental impacts 1996-2007.)



This is a papaya. Like humans, plants are also vulnerable to viral disease. THis pap infected with papaya ringspot virus.

You can see the ring spot symptoms on fruits. \

In the 1950's, the entire papaya production on the Island of Oahu was decimated by papaya ringspot virus. There was no way to control the disease so farmers were forced to abandon the island.

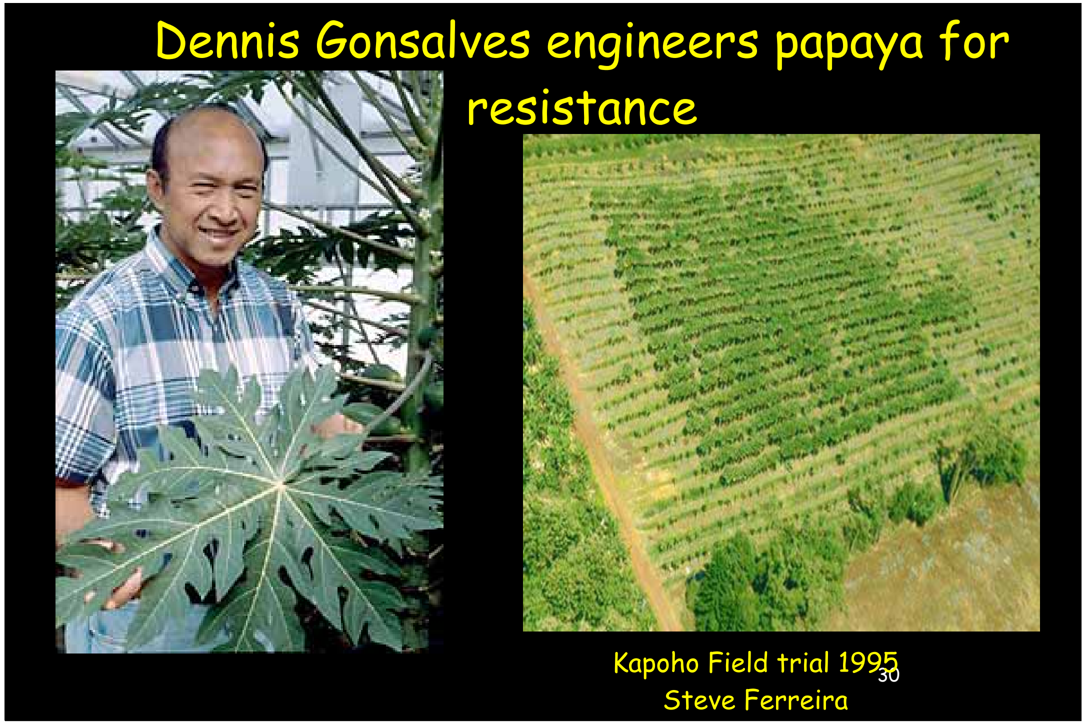
In 1992, the virus was discovered in the papaya orchards on the island of Hawaii (by 1995 the disease was widespread), creating a crisis for Hawaiian papaya farmers. By 1998 papaya production had dropped to 26 million pounds.

Notes:
Most damaging viral disease of papaya
Developing countries produce 98% of the crop
Brazil, Mexico and India largest world producers
Hawaii largest US producer

1950s- Oahu crop destroyed by PRSV
1992 PRSV found in Puna, hawaii

1978 Gonsalves began research
1986 Gene encoding PRSV coat protein cloned
1990 Papaya transformed
1992 PSRV hits island of Hawaii
1992 Field trials
1995 PSRV widespread. Production plummets.
1998 Transgenic papaya distributed free to growers
2001 Industry rebounds

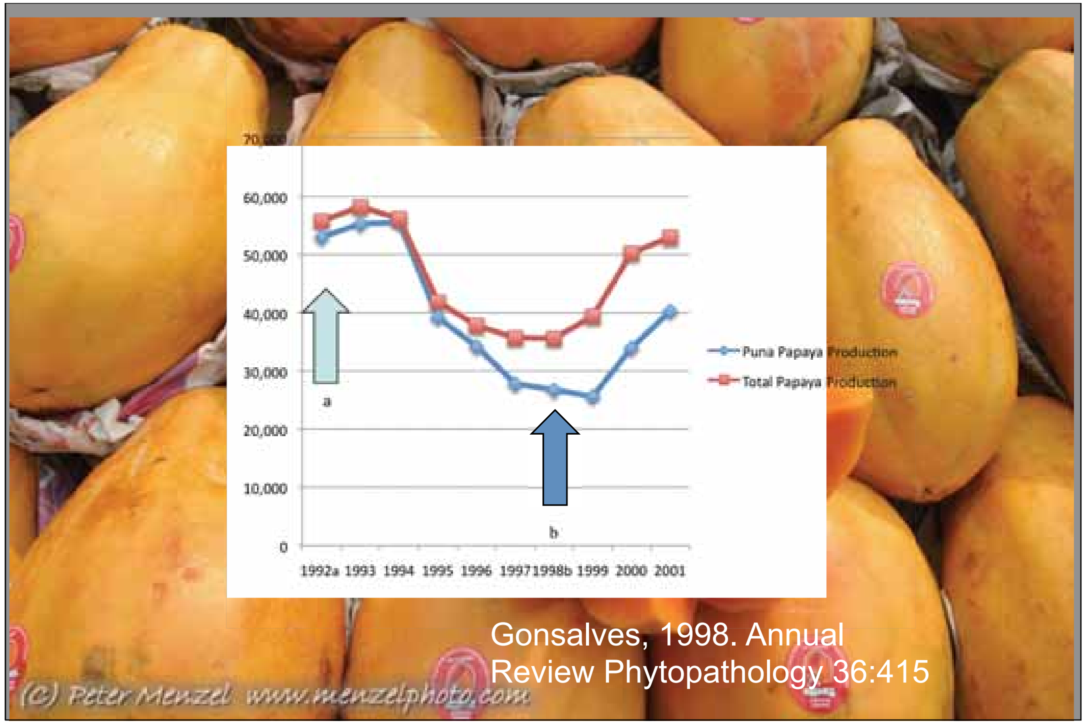
Gonzsalves, 1998. Ann Rev phytopath. 36:415



There is hero to the story . This is Dennis Gonsalves, in 1978, a native of Hawaii, and coworkers initiated research to develop strategies to control the disease. Fortunately, geneticists were able to develop papayas resistant to the virus by using genetic engineering.

Gonsalves' group spliced a small snippet of DNA (made from viral RNA; called RNA interference; from a mild strain) into the papaya genome. Similar to human vaccinations against polio or small pox, this treatment immunized the papaya plant against further infection.

Aerial view of transgenic field trial in Puna that was started in October 1995. The solid block of green papaya trees are 'UH-Rainbow' while the surrounding papaya trees that are nearly dead are nontransgenic papaya trees severely infected by PRSV.



After the intorductino of papaya, the ipapaya orchards rebounded with a 20X increase in yield

By 2003, 90% of all papaya was transgenic

Occurrence of PRSV drastically decreased; benefits organic growers

MEX03.5843.xf1bPapayas on display, Cuernavaca municipal market, Mexico. (Supporting image from the project Hungry Planet: What the World Eats.) /// Grocery stores, supermarkets, and hyper and megamarkets all have their roots in village market areas where farmers and vendors would converge once or twice a week to sell their produce and goods. In farming communities, just about everyone had something to trade or sell. As transportation became more efficient (especially refrigerated transport), and farms became huge, big corporations moved into the food business to take advantage of scale, especially in the United States. Now the convenience of one-stop shopping has made this business even bigger. Even the smaller supermarkets are being bought up or run out of business by the larger concerns. Some small town markets still exist today throughout much of Europe, although to a lesser degree there as well. Small markets are still the lifeblood of communities in the developing world, and, for better or worse, will remain so until they are numerous and big enough to attract the conglomerates' attention. Coming full circle, farmers markets have come back into vogue in some places in the USA where they had largely disappeared.

Now I will turn to some of my own work in rice. Genetic improvement to rice will have profound impacts because rice feeds more than half the world's population, and accounts for 20 percent of the human's total calorie intake. It grows on every continent in the world except Antartica,

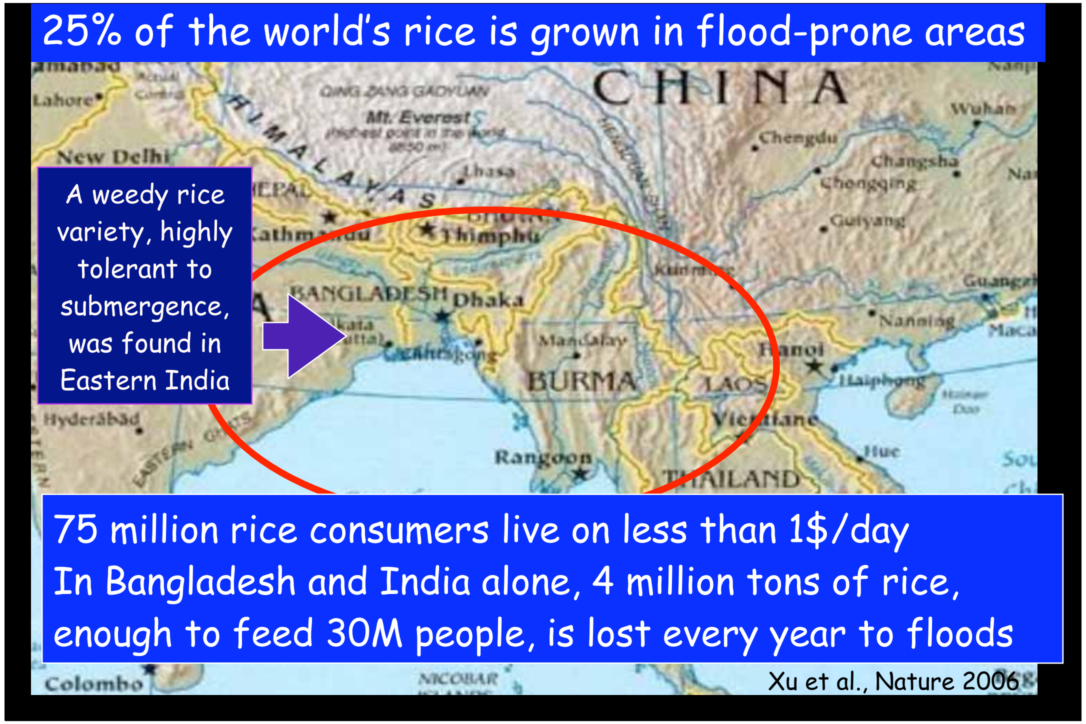
this photo is in the village of Kouakourou, Mali, on the banks of the Niger River.

>>>>>>>>>
Mal.mw.21.xxsNatomo family dinner of rice porridge cooks on the hearth over a wood fire. Published in Material World, Meals of the World gallery, page 176. The Natomo family (Soumana Natomo, his two wives—Pama Kondo and Fatoumata Toure—and 7 children) lives in two mud brick houses in the village of Kouakourou, Mali, on the banks of the Niger River. {{They are grain traders and own a mango orchard. According to tradition Soumana is allowed to take up to four wives; he has two. Wives Pama and Fatoumata are partners in the family and care for their many children together. They have separate households but share meals in the courtyard of Pama's house. The older children help care for the younger children and help with sweeping the mud brick courtyard, and dish washing and clothes washing in the Niger River. Family members are:Soumana Natomo (39, father); Pama Kondo (28, first wife); Fatoumata Toure (26, second wife); Pai Natomo (11, daughter of Soumana and Pama); Kontie Natomo (9, son of Soumana and Pama); Mama Natomo (6, son of Soumana and Pama); Mamadou (3, son of Soumana and Pama); Toure Natomo (5, daughter of Soumana and Fatoumata); Fatoumata Natomo (3, daughter of Soumana and Fatoumata); Mama Natomo (1, son of Soumana and Fatoumata). From Peter Menzel's Material World Project that showed 30 statistically average families in 30 countries with all of their possessions.}}

Most of the worlds production is carried out on small farms by people with little technology.

Planting rice near Alexandria, Egypt.

man cultives his terrace rice fields near Ubud at Penatahan in Bali, Indonesia.



Many people assocaite agrilcutral biotehcnologyw tihw large multnational coproratinos and and wealthy farmers. I would like you to now turn your attention to less developed countries.

Nearly all rice varieties die within 1 week of submergence
1/4 of the global rice cropland is prone to flooding (10-15 M ha).
Flashfloods are unpredictable and can occur several times/year.
Yield losses range from 10% to total destruction
Nearly $1 billion/year loss

These losses disproportionately affects the poorest farmers in the world. The people of Bangladesh get about two-thirds of their total calories from rice

140 million people at risk of flooding damage to their farms ibnn Bangladesh and 5 states in eastern india. 45% of these people are living in poverty (les than 1$ a day) . These areas have the highest concetnration of very poor of any place in the world.

when the rice crops fail, people starve, like after the great floods of 1974. "That year, nearly all the places got submerged and that is why there [was] no rice production, and people had no work, so a lot of people died."

In fact, nearly a million people died. Since then, scientists have been trying to create rice that survives flooding.

Monsoon floods are a recurring problem as shown in this newspaper articl ein August 2007, describing the ferocious weather last year in Asia.
Monsoon rains have inundated countries from the Philippines to Nepal. Super typhoons slammed into China and Japan. And a heat wave in Pakistan pushed the temperature to 125 degrees Fahrenheit. All of this is bad for rice. And what's bad for rice is especially bad for Bangladesh. In Norhtern India and Bangladesh, millions of poor familes lost crops, livestockand family members.

- FR13A has poor grain and yield qualities but is unusual in its ability to endure complete submergence for ~ 14 days
- Attempts to breed tolerance into rice varieties favored by growers failed
- In 2006, my lab isolated the gene called Sub1 that confers tolerance to flooding and engineered a tolerant rice
- Precision breeding carried out with multiple varieties (Mackill, IRRI)

To find out how the farmers and families liked the new variety we visited India and Bangaldesh last year.

her job is seeding the rice and transplanting, She likes the swarna variety best.

She also said it tastes very good.

I wil be in this field next week. NOt a good week for C diet. And it doesn't get any more real than northern Bangladesh, where the vast Brahmaputra River often spills over its banks and into the fields of struggling rice farmers. The people of Bangladesh get about two-thirds of their total calories from rice

Dr. Md Abdul Mazid, of the Bangladesh Rice Research Institute, stands in a field of flood-resistant rice.

Ocrober 2007 NPR:

The field was under water for eight days. Gobindra says that usually after eight days, the crop would be damaged. But the sub-1 rice is still thriving… Gobindra says his neighbors are amazed by what they've seen in his paddy. Standing in a semi-circle in front of a shed made of bamboo and corrugated sheet metal, they line up to talk about Gobindra's rice. Men stand up front. Women farther back. And little boys climb on anything tall enough to give them a better look.

Many of the farmers can't read or write. But when it comes to rice science, they're at the cutting edge. And every single one in Gobindra's village now plans on planting the sub-1 variety

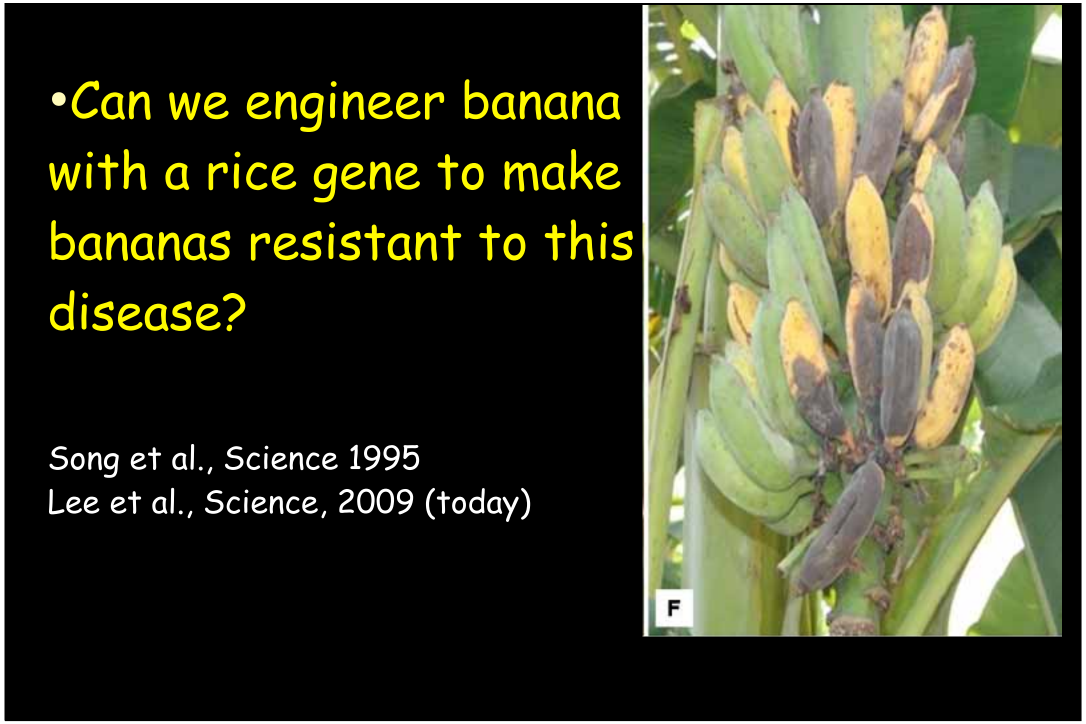
So where are we now? With all this new knowledge, It seems nearly inevitable that genetic engineering will play an increasingly important role in agriculture. The question is not whether we should use genetic engineering, but more pressingly, how we should use it - to what responsible purpose. Agriculture needs our collective help and all appropriate tools if we are to feed the growing population in an ecological manner. Consumers have a significant opportunity to influence what kinds of plants are developed and to address the key agricultural challenges. Let us direct attention to where it matters - the need to support the use of seed and farming methods that are good for the environment and for the consumers.

- 100 million people rely on banana as a staple food source.
- Banana wilt attacks all banana varieties causing complete crop loss.
- Conventional breeding not an option

caused by *Xanthomonas campestris* pv. *musacearum*

First reported in Uganda in 2001.
The disease has also been reported in DR Congo, Rwanda, Tanzania, Kenya and Burundi.

East Africa is the largest banana producing and consuming region in Africa.
BXW is causing an annual loss of over US$ 200 million in Uganda.
BXW attacks all banana varieties resulting in absolute crop loss.
Resistance has been the best and most cost-effective method of managing bacterial diseases.
No source of germplasm exhibiting resistance against *Xcm* has been identified.
Transgenic technologies for banana may provide a timely alternative solution to control the BXW pandemic.



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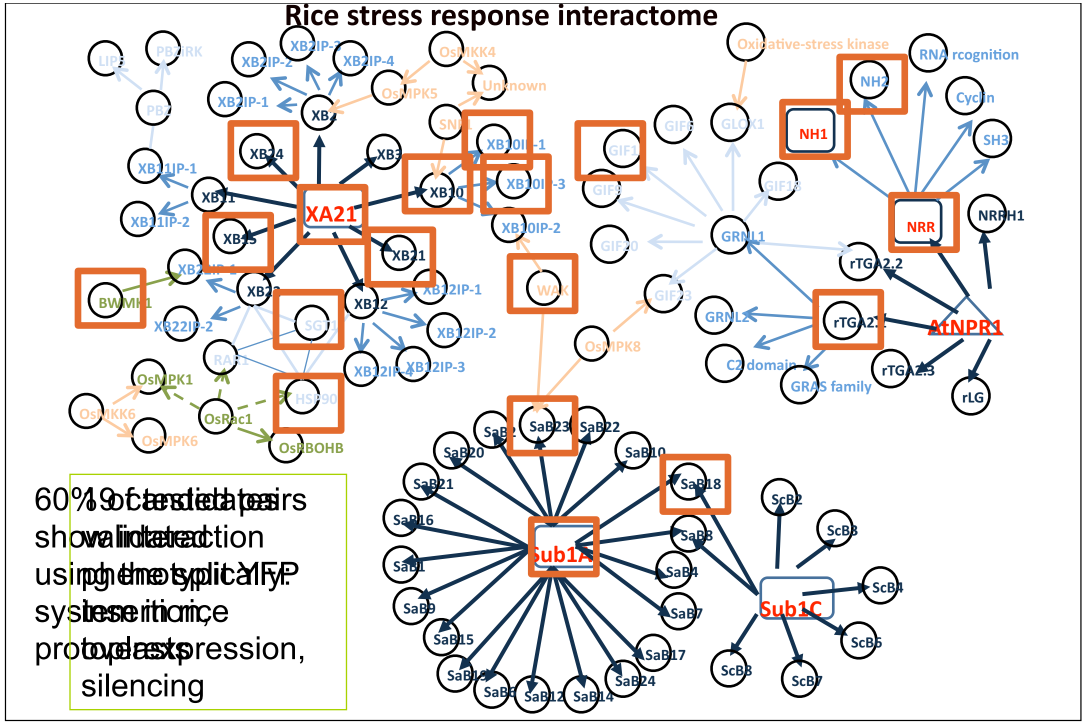


First, we need to identify all the component sin the pathway. For this we have used the Y2H to identify interacting proteins.

NPR1 is a master regulator of the systemic acquired resistance response that is induced after a local infection and confers resistance throughout the plant. Induction of SAR requires accumulation of the endogenous signaling molecule SA which activates gene expression.

EG> WAK1 - we have already validate that it is required for Xa21 mediated resistane, now testing submergence.

######

Exogenous application of SA triggers translocation of NPR1 to the nucleus. Once in the nucleus NRPR1 interaction with TGA transcription factors to mediate gene expression. A class of genes called pathogenic related proteins (PR genes) which encodes small secreted of vacuole targeted proteins with antimicrobial activities. Over-expression of Arabidopsis *NPR1* or the rice *NPR1 homologue 1* (*NH1*) in rice results in enhanced resistance to the pathogen *Xanthomonas oryzae* pv. *oryzae* (*Xoo*), suggesting the presence of a related defense pathway in rice. We investigated this pathway in rice by identifying proteins that interact with NH1.

In monocots, SAR was shown to be induced by BTH in wheat and by *Pseudomonas syringae* in rice (Smith and Metraux, 1991). BTH can also induce disease resistance in rice (Schweizer et al., 1999; Rohilla et al., 2002) and maize (Morris et al., 1998), although it is not clear whether the resistance was SAR.

Intensive investigations have shed some light on how NPR1 mediates SAR. NPR1 contains a bipartite nuclear localization sequence and two potential protein-protein interaction domains: an ankyrin repeat domain and a BTB/POZ domain (Cao et al., 1997; Ryals et al., 1997). Nuclear localization of NPR1 protein is essential for its function (Kinkema et al., 2000). Without induction, NPR1 protein forms an oligomer and is excluded from the nucleus. Redox changes mediate SAR induction, causing monomeric NPR1 to emerge and accumulate in the nucleus and activate *PR* gene expression (Mou et al. 2003).

Although rice has attracted great research interests upon the completion of it genome sequence, relatively little is known about pathways and mechanisms leading to disease resistance, including the *NH1*-mediated pathway. Rice is different from tobacco and Arabidopsis in that it has very high basal levels of SA and no changes in SA levels were detected after interactions with avirulent or virulent pathogens (Silverman et al., 1995).

The *npr1* mutant also displays enhanced disease symptoms when infected with virulent pathogens and is impaired in some *R* gene-mediated resistance, suggesting that NPR1 is important for restricting the growth of pathogens at the site of infection

Genes encoding proteins that interact are often coexpressed in a given tissue or in response to a treatment. The coexpressed genes are known to be involved in the same biological pathway in many cases [62]. In this context, we tested the expression level of the 28 genes that encode for proteins detected in the *Sub1A* and *Sub1C* interactome. We sampled the sensitive M202 and tolerant M202(*Sub1*) plants before submergence (0 d) and after 1 d and 6 d of submergence. Using a q-PCR assay, we found at least 16 of the 28 interactome genes to respond to submergence treatment at 1 d or 6 d of stress.

Analyzed ~50 millions data points

23 types of data sets from 5 different species

551,886 links / 18,129 genes (~45% of the 41,203 non-TE related genes in *Oryza sativa*)

A probabilistic functional network of yeast genes (Lee and Marcotte, Science 2005)

A probabilistic integrated gene network of *C. elegans* (Lee and Marcotte, Nat Genetics 2008)

Lee, Seo, Ronald and Marcotte, in prep

Marcotte group applied probabilistic functional gene networks to yeast and worm to identify new genes in involved in cellular responses.

In particular, RNAi-mediated phenotypic analysis in worm revealed that 20% (10 out 50) in computational core interactors and 5% (6 out of 124) in computational non-core intreractors from network are functionally validated in retinoblastoma tumor suppressor pathway.

Instead of fully modeling the mechanistic details of gene relations—for example, physical interactions—marcotte modelsl "functional coupling", a high-level abstraction of gene relationships.

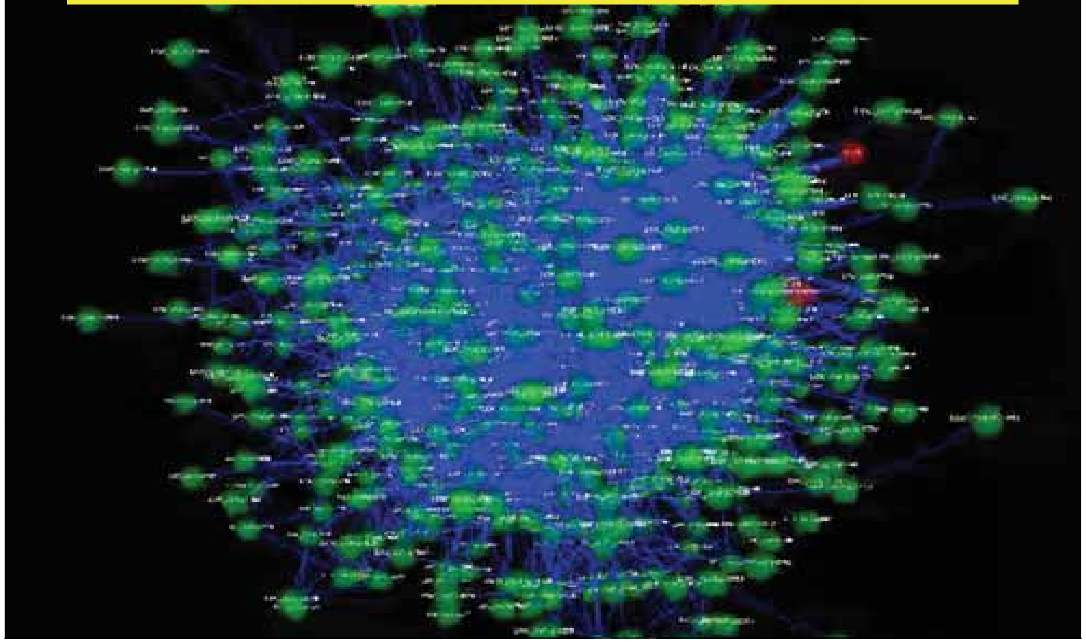
). Thus, a major aspect of reconstructing a functional gene network is to quantify the quality of the data, especially the strength of functional inferences that can be drawn (e.g., using a Bayesian probabilistic approach that Marcotte lab developed [38]), then to combine these diverse classes of functional data into a composite network that is larger and more accurate than that from any individual dataset. Such integration increases the accuracy and significance of cellular network models considerably

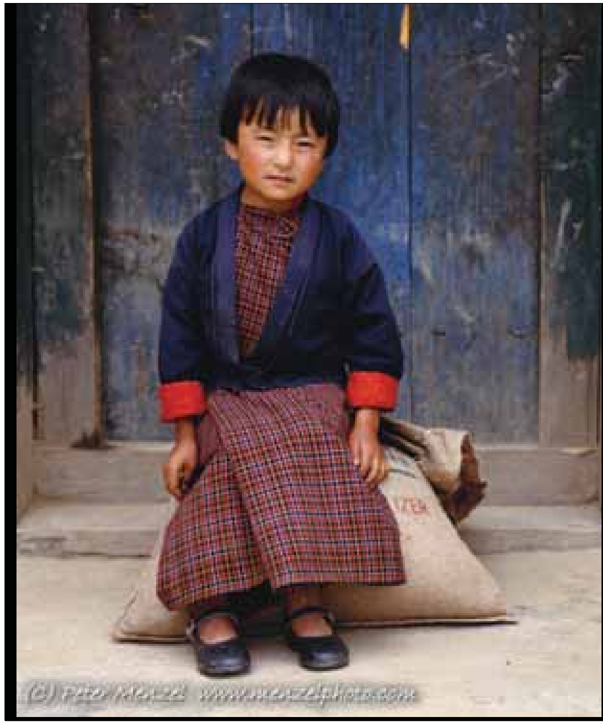
ARANET: 1,062,222 links / 19,647 genes (~73% of genome

We have developed a new network platform, called a probabilistic functional gene network [38]. This new network framework was designed to improve (1) completeness, (2) data integration efficiency, and (3) predictive power of systems models. Instead of fully modeling the mechanistic details of gene relations—for example, physical interactions—we model "functional coupling", a high-level abstraction of gene relationships. As many data types indicate functional coupling, this improves network completeness and integration efficiency. We use a Bayesian probabilistic framework to score each gene-gene relationship—this step is critical, as data (e.g. protein-protein interaction data derived from Y2H assays) may contain considerable noise, but which we can filter at this step [78]. Scoring each association allows simple data integration and more reliable predictions for genes' functions or pathway memberships. We successfully demonstrated proof-of-concept initially for a unicellular organism, yeast [38,45,78], next a multi-cellular animal, worm (*C. elegans*) [39], and most recently for mouse [29,55]. Each network model was highly predictive of gene function, and where tested in yeast and *C. elegans*, for organismal phenotype following gene perturbation [39,43,45,48,78,137,145,146]. Our results indicate that we can efficiently gain new functional knowledge by prioritizing genes for a given biological role based upon the networks, then testing these candidates using available reverse genetics resources.

In contrast to yeast and animals, there is a paucity of tools available for network analysis in plants. Thus development and validation of such a network for rice, an important model for crop species and staple food for humans, will dramatically advance our ability to make sense of the vast amount of proteomic, genomic and transciptomic information that is now available. For example, large gene expression data sets for rice subjected to diverse biotic and abiotic stresses are available and proteomics data sets are fast emerging [7,8,9,12] Clearly there is a need to develop computational and experimental pipelines that will move researchers beyond the initial stages of gene expression or proteomics analyses to efficiently and accurately assign function to the diverse components of the stress signaling network.

Identification of additional components of the rice stress response using RiceNet and 16 validated seed genes





The judicious incorporation of two important strands of agriculture—agricultural biotechnology and organic farming—is key to helping feed the growing population in an ecologically balanced manner.

Agriculture needs our collective help and all appropriate tools if we are to feed the growing population in an ecological manner.

Pitting genetic engineering and organic farming against each other only prevents the transformative changes needed on our farms. There seems to be a communication gap between organic and conventional farmers and between consumers and scientists. The stakes are high in closing that gap. Without good science and good farming, we cannot even begin to dream about establishing an ecologically balanced, biologically based system of farming and ensuring food security.

This idea is anathema to many people, especially the advocates who have helped build organic farming into a major industry in richer countries. As reflected by statements on their websites, it is clear that most organic farming trade organizations are deeply, viscerally opposed to genetically engineered crops and seeds. Virtually all endorse the National Organic Standards Board's recommendation that genetic engineering be prohibited in organic production.

But ultimately, this resistance hurts farmers, consumers, and the planet. Without the use of genetically engineered seed, the beneficial effects of organic farming - a thoughtful, ecologically minded approach to growing food - will likely remain small.

Despite tremendous growth in the last 15 years, organic farms still produce just a tiny fraction of our food; they account for less than 3 percent of all US agriculture and even less worldwide. In contrast, in the same period, the use of genetically engineered crops has increased to the point where they represent 50 to 90 percent of the acreage where they are available. These include insect-resistant varieties of cotton and corn; herbicide-tolerant soybean, corn, and canola; and virus-resistant papaya.

After more than a decade of genetically engineered crops, and more than 30 years of organic farming, we know that neither method alone is sufficient to solve the problems faced - and caused - by agriculture.

Pitting genetic engineering and organic farming against each other only prevents the transformative changes needed on our farms. There seems to be a communication gap between organic and conventional farmers and between consumers and scientists. The stakes are high in closing that gap. Without good science and good farming, we cannot even begin to dream about establishing an ecologically balanced, biologically based system of farming and ensuring food security.

It seems nearly inevitable that genetic engineering will play an increasingly important role in agriculture. The question is not whether we should use genetic engineering, but more pressingly, how we should use it - to what responsible purpose. Agriculture needs our collective help and all appropriate tools if we are to feed the growing population in an ecological manner. Consumers have a significant opportunity to influence what kinds of plants are developed and to address the key agricultural challenges. Let us direct attention to where it matters - the need to support the use of seed and farming methods that are good for the environment and for the consumers.

What we can hope for is a future in which farmers use the best organic farming methods to grow the most beneficial engineered crops. Any effective approach in feeding the world in a sustainable manner will require us to embrace more than one great new idea.

Bhutan
Bhu.mw.748.120.xxsA young Bhutanese girl sits on a sack of rice in Gaselo, Bhutan. Published in Material World: A Global Family Portrait, page 6. {{From Peter Menzel’s Material World Project that showed 30 statistically average families in 30 countries with all their possessions.}}

"A truly extraordinary variety of alternatives to the chemical control of insects is available. Some are already in use and have achieved brilliant success. Others are in the stage of laboratory testing. Still others are little more than ideas in the minds of imaginative scientists, waiting for the opportunity to put them to the test. All have this in common: they are biological solutions, based on understanding of the living organisms they seek to control, and of the whole fabric of life to which these organisms belong. Specialists representing various areas of the vast field of biology are contributing—entomologists, pathologists, geneticists, physiologists, biochemists, ecologists—all pouring their knowledge and their creative inspirations into the formation of a new science of biotic controls."

Rachel Carson, 1962

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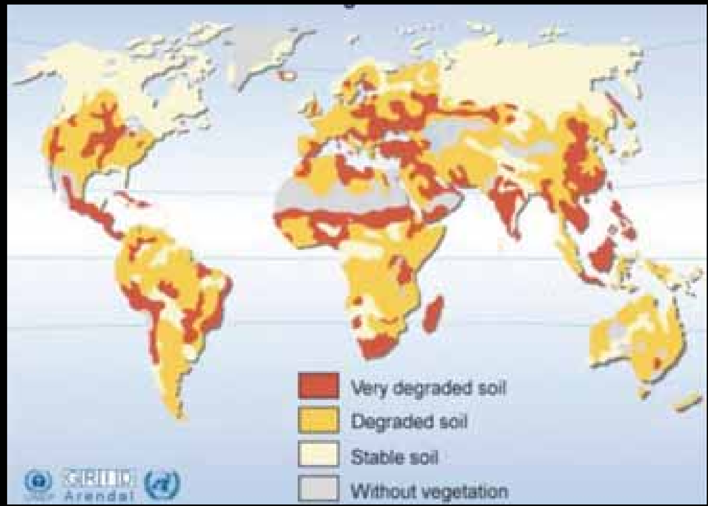
Farms of the future must produce enough affordable food to feed all the people in a manner that relies less on herbicides, pesticides, inorganic fertilizers and surface irrigation.

Organic production systems and GE crops can make a major contribution to reaching these goals, just as plant breeding was of crucial importance to increased food production in the 20th century. Each application must be looked at on a case by case basis.

END, extra slides follow

Agricultural tillage causes soil erosion



30 percent of the world's arable land has become unproductive.

60 percent of eroded soil ends up in rivers, streams and lakes

United Nation
Environmental Program

The vast majority -- 99.7 percent -- of human food comes from cropland, which is shrinking by more than 10 million hectares (almost 37,000 square miles) a year due to soil erosion, Soil erosion by water, wind and tillage affects both agriculture and the natural environment. tillage reduces vegetation cover on the surface of the soil and disturbs both soil structure and plant roots that would otherwise hold the soil in place.
 * The United States is losing soil 10 times faster -- and China and India are losing soil 30 to 40 times faster -- than the natural replenishment rate.
* As a result of erosion over the past 40 years, 30 percent of the world's arable land has become unproductive.

Because soil is formed slowly, it is essentially a finite resource.

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 * The United States is losing soil 10 times faster -- and China and India are losing soil 30 to 40 times faster -- than the natural replenishment rate.
   * The economic impact of soil erosion in the United States costs the nation about $37.6 billion each year in productivity losses. Damage from soil erosion worldwide is estimated to be $400 billion per year.
   * As a result of erosion over the past 40 years, 30 percent of the world's arable land has become unproductive.
   * About 60 percent of soil that is washed away ends up in rivers, streams and lakes, making waterways more prone to flooding and to contamination from soil's fertilizers and pesticides.
   * Soil erosion also reduces the ability of soil to store water and support plant growth, thereby reducing its ability to support biodiversity. 1.8 million tons lost in U.S in 2006
   * Erosion promotes critical losses of water, nutrients, soil organic matter and soil biota, harming forests, rangeland and natural ecosystems.
   * Erosion increases the amount of dust carried by wind, which not only acts as an abrasive and air pollutant but also carries about 20 human infectious disease organisms, including anthrax and tuberculosis.

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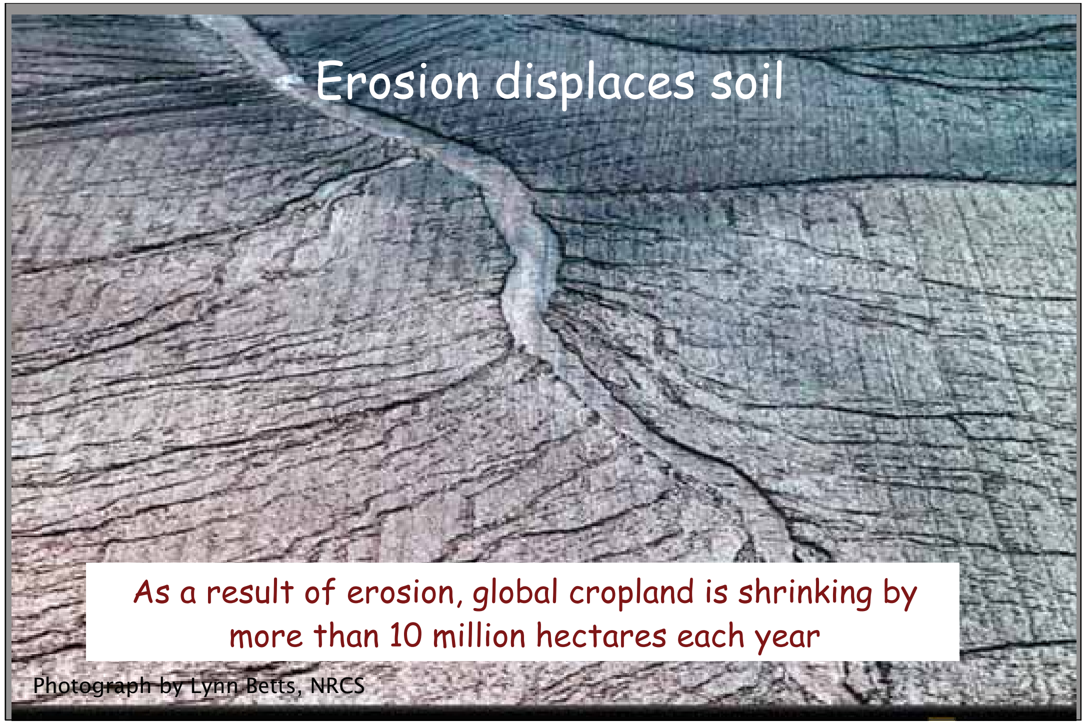

This slides shows a scarred farmland in northwest Iowa after Heavy rains washed away soil,. This type of erosion, occurs when there is insufficient vegetation to hold soil in place. As rain falls, it forms sheets of surface water that transport soil away. As more water accumulates, it forms runoff channels called rills, which further displace soil.

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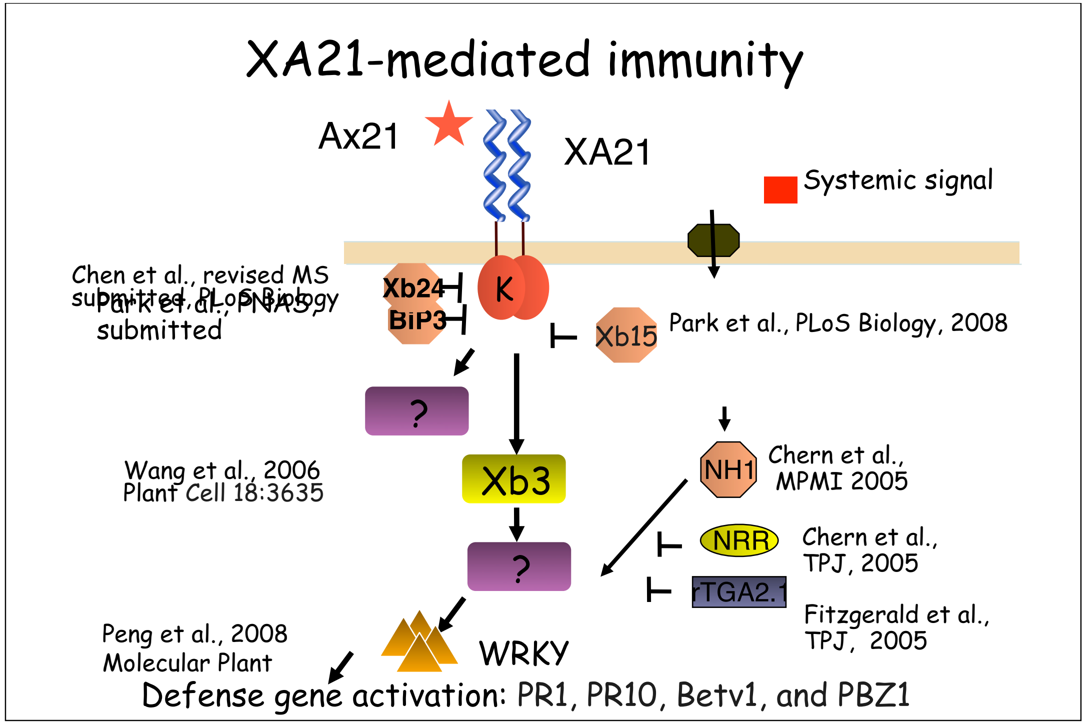
efuse to settle for the status quo and tha ag policies and pracites that have held us back for5 years and pollute the ivnroment. This means we must that works across the globe so that we can pass on to our children and grnahchlden not just abdundant and nutiritous food, but a cleaner planet.

I hope I have convinced you of the need for a more sustainable farming systems and demonstrated ways that both organic farming and ag biotechnology can contirbute to such a system. Establiing a ssutainable agirucltural systems is one of the major challenges that science and society must addrss in the comin gyears.



The XA21 protein is present on the plasma membrane, where it recognizes the Ax21 PAMP. XB24 physically associates with XA21 and uses ATP to promote phosphorylation of specific Ser/Thr sites on XA21, keeping the XA21 protein in an inactive state. Upon recognition of Ax21, the XA21 kinase becomes activated, triggering downstream defense responses. The mechanism(s) for XA21 activation following perception of Ax21 likely requires removal of the XB24-promoted phosphorylation. When XB24 is over-expressed, the XB24 inhibitory effects cannot be readily overcome, instead leading to rapid degradation of the XA21 protein.

XB3, an E3 ubiquitin ligase, functions as a substrate for the XA21 Ser and Thr kinase and is necessary for full accumulation of the XA21 protein and for *Xa21*-mediated resistance [25]. XB10 (OsWRKY62) functions as a negative regulator of innate immunity in rice, modulating both basal and XA21 mediated race-specific defense responses [23]. XB15, a PP2C phosphatase dephosphorylates autophosphorylated XA21 and negatively regulates the XA21-mediated innate immune response [24]. Our results that XB24 promotes XA21 autophosphorylation and inhibits XA21-mediated immune response to the Ax21 PAMP, further demonstrates that the phosphorylation state of XA21 is critical for XA21-mediated signaling. Phosphorylation of certain residues (such as T705, T769, S967, S985, S987 and T997) on XA21 negatively regulates XA21 function whereas phosphorylation on other residues may be required for activation of XA21 function. These latter residues are likely dephosphorylated by XB15 to downregulate XA21 activity. The S697 site in the JM domain of XA21 is required for both XB15 [24] and XB24 interaction with XA21 suggesting that there is a competition between XB15 and XB24 for XA21. The physical association between XB24 and XA21 is compromised while the physical interaction between XB15 and XA21 is enhanced upon recognition of Ax21 [24], suggesting that the regulation by XB24 occurs before Ax21 recognition while regulation by XB15 accurs after Ax21 recognition.

First of all, BiP is induced after Xoo treatments. It makes sense because plants need more BiPs under ER stress condition such as defense response. So, after Xoo inoculation, increased BiP will sequester XA21 and send the XA21 protein to ERAD efficiently.
Second, the interaction between XA21 and BiP was significantly increased after Xoo treatments. Again we'd better consider that the negative regulation by BiP is a survival way of plants undergoing too much ER stress to release the ER stress.
So your model fits to what we described in the BiP MS
Below is what we said in the BiP discussion (last Fig).
"We hypothesize that if unfolded and/or misfolded proteins over-accumulate after Xoo infection, then ER stress will be prolonged. In this case, cells can either initiate ER-associated cell death or attenuate the signal transduction pathway causing the ER stress. Our results indicate that BiP3 attenuates the XA21-mediated signaling pathway."

NRR inhibits PR gene expression by serving as a transcriptional repressor in a nuclear complex containing NH1 and TGA factors

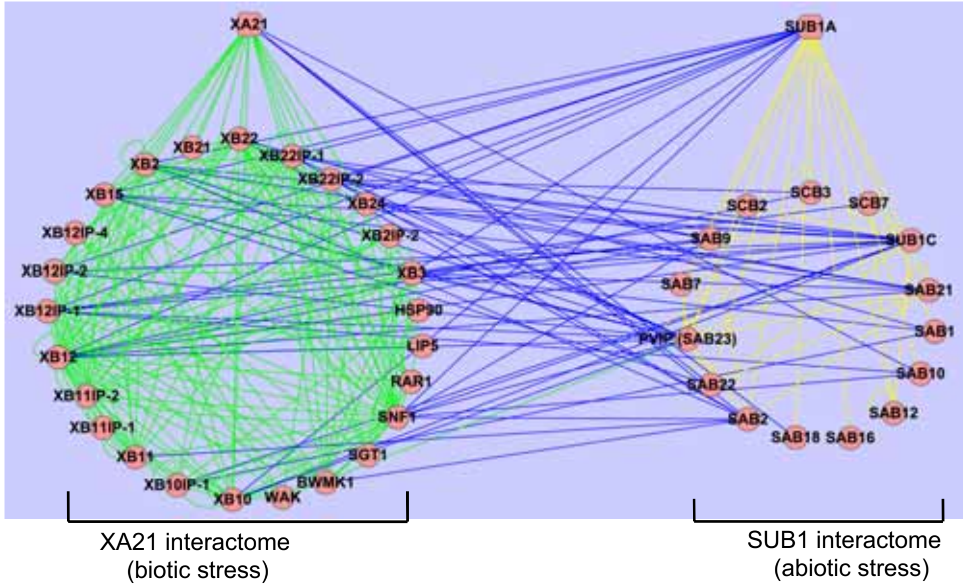
We now have the genetic, computational and proteomics tools to fully characterize the XA21-mediated response and to determine how the components of this response intеact with those that transudce the abiotic stress response.

++++

Several studies have shown that WRKY subgroup IIa members have both positive and negative effects on plant innate immunity. Characterization of *Arabidopsis* WRKY IIa family members (*AtWRKY18*, *AtWRKY40* and *AtWRKY60*) revealed that although constitutive expression of *AtWRKY18* enhances resistance to *P. syringae*, co-expression of *AtWRKY18* with *AtWRKY40* or *AtWRKY60* compromises resistance to both *P. syringae* and *B. cinerea* (Chen and Chen, 2002); (Xu *et al.*, 2006b). In barley, two WRKY IIa members HvWRKY1 and HvWRKY2 have been identified to act as repressors of both PAMP-triggered basal defense and the polymorphic barley *mildew* A (*MLA*) R genes-specified immune responses to *B.graminis* (Shen *et al.*, 2007). Identification of OsWRKY62 as a negative regulator of defense responses in rice plants provides another evidence of the existence of a repressor function conserved between the monocot and the dicot in innate immunity.

By not limiting our selection criteria to a single method we have developed a robust and integrated approach to discover genes that are highly likely to contribute to stress tolerance of rice.

Components of the rice stress response interactome were validated by pair-wise tests

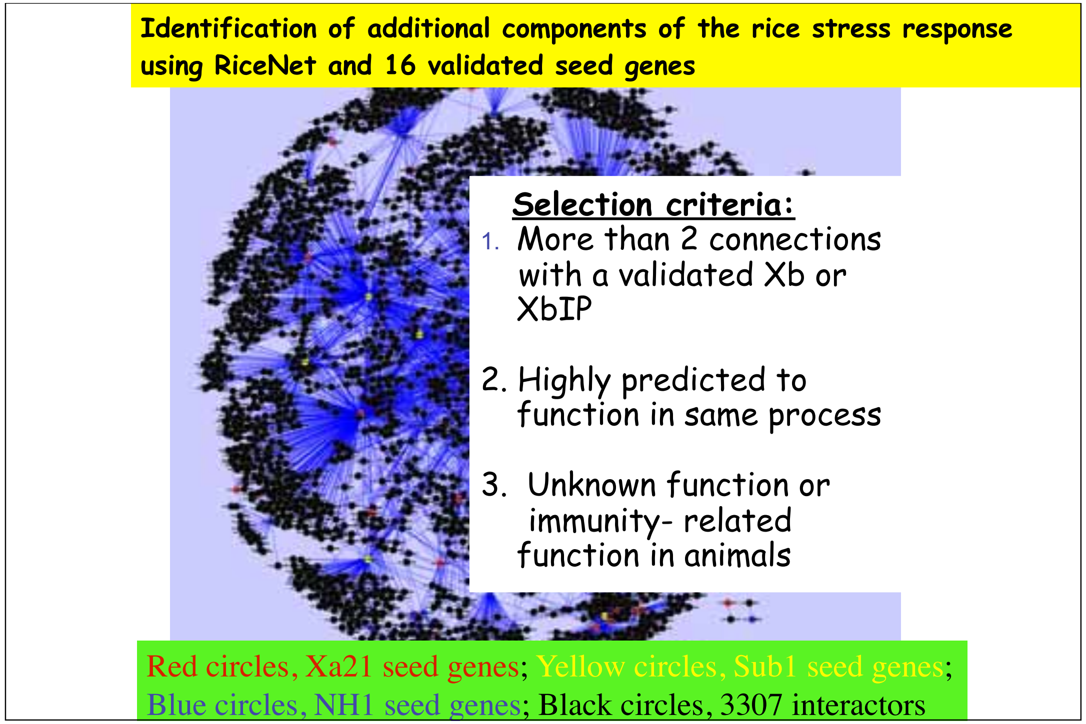


Young-Su Seo

The number of pairwise Y2H with Sub1 x Xa21
is (16x26)

Thus, The number of pairwise Y2H with Sub1 x Xa21
is (Sub1 x Xa21 = 16 x 26 = real 416 interactions)
and We got 64 (15.3 %)real interation out of 416 tested pairs.

Pair-wise protein protein interactions (PPIPs) in XA21-Sub1 interactome. 26 FL cDNAs from 34 components of XA21 interactome were cloned and 16 FL cDNAs from 29 components of Sub1 interactome were cloned. PPIPs were performed within Xa21 (Green edge colors, 146 PPIP from 26 FL genes) or Sub1 interactome (yellow edge colors, 38 PPIP from 16 FL genes). Furthermore, PPIP were carried out between XA21 (26 FL genes) and Sub1 (16 FL genes). 64 PPIP between XA21 and Sub1 (blue colors) were identified.



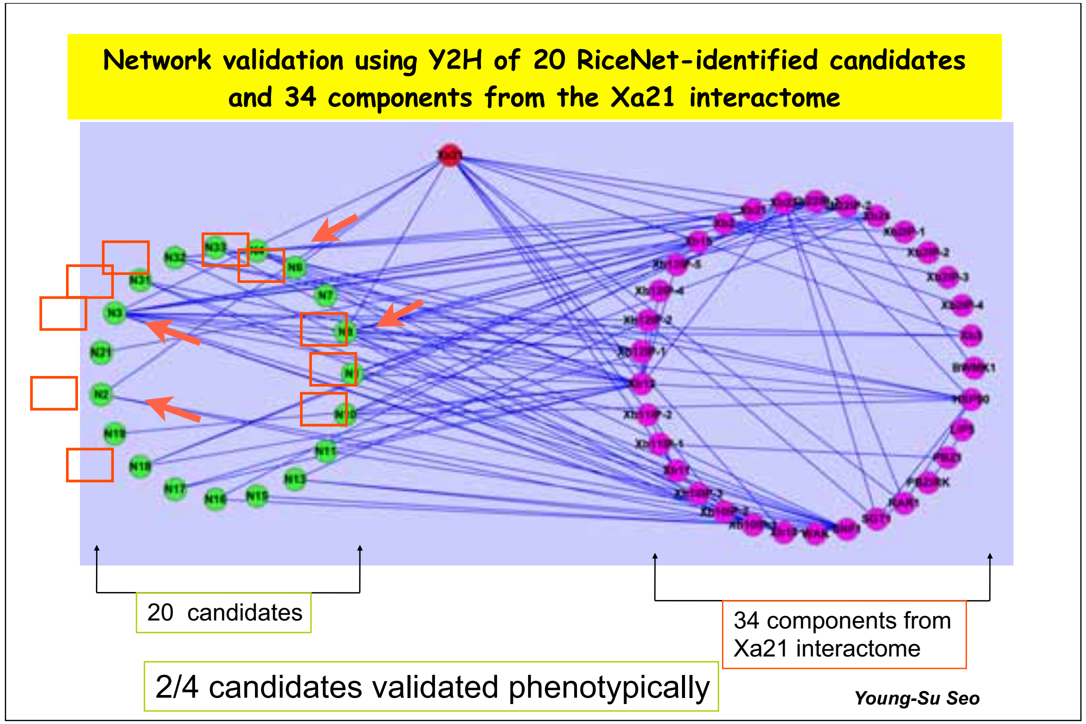
Note the hubs. This is contrast to human diseasome. These hubs hae not yet been tested for lethality.
By guilty-by-association analysis on our RiceNet with the selected seed genes, we will prioritize genes to identify additional defense response pathway candidates.

We have developed the general framework for evaluating the intrinsic predictability of a set of seed genes (by using cross-validation and ROC analysis; Figure 1), ranking order the genes by the *naive* Bayesian probability of belonging to the same pathway as the seed set genes [39,45] and measuring the predictability as the area under a ROC curve (AUC).

We can evaluate the intrinsic predictability of this pathway by rank ordering all genes in the network by their connectivity to the red genes, performing the analysis using cross-validation by omitting each red gene from the seed set for the purpose of evaluating it. A plot of the true positive rate vs. the false positive rate —a standard analysis known as ROC (receiver operating characteristic) analysis—reveals that the red genes are most strongly connected to each other and are ranked most highly (red line), and thus each is predictable knowing the others. The most likely additional candidate genes (green circles) for operating in the same pathway can be identified by their connections to the known set.

Core links have >1.5 fold higher likelihood (measured by bootstrapping) than random chance (*i.e.*, >60% accurate)

The methodology for network modeling is thus in place. It is based upon measuring the conditional probabilities (formally, log likelihood ratios) for pairs of genes to participate in the same biological processes, conditioned on the available data. The result is an undirected graph in which each gene-gene linkage indicates the probability for the linked genes to function together in the organism [78]. We have demonstrated excellent predictive power for these networks for loss-of-function phenotypes [39,43,45,48,78,137,145].



The number of pairwise Y2H with RiceNet x Xa21
is (20x24)

The number of tested pairwise Y2H with RiceNet x Xa21
is (Sub1 x Xa21 = 20 x 24 = 480)
and We got 70 (14.6 %) real interactons out of 480 tested pairs.

The Future of Food

- Farms of the future must produce enough affordable food to feed all the people in a manner that greatly reduces toxic inputs, minimizes nutrient run-off and soil erosion.
- Organic production systems and GE crops can make a major contribution to reaching these goals, just as plant breeding was of crucial importance to increased food production in the 20th century.

Raoul pg 164 is ge a new tool for farmers?”

Stephen Chu
US Secretary
of Energy

“people are entitled to their own opinions, but they are not entitled to their own facts".

Western Governors' Association (WGA) annual meeting in Utah
14-16 June

> "A truly extraordinary variety of alternatives to the chemical control of insects is available. Some are already in use and have achieved brilliant success. Others are in the stage of laboratory testing. Still others are little more than ideas in the minds of imaginative scientists, waiting for the opportunity to put them to the test. All have this in common: they are biological solutions, based on understanding of the living organisms they seek to control, and of the whole fabric of life to which these organisms belong. Specialists representing various areas of the vast field of biology are contributing—entomologists, pathologists, geneticists, physiologists, biochemists, ecologists—all pouring their knowledge and their creative inspirations into the formation of a new science of biotic controls."
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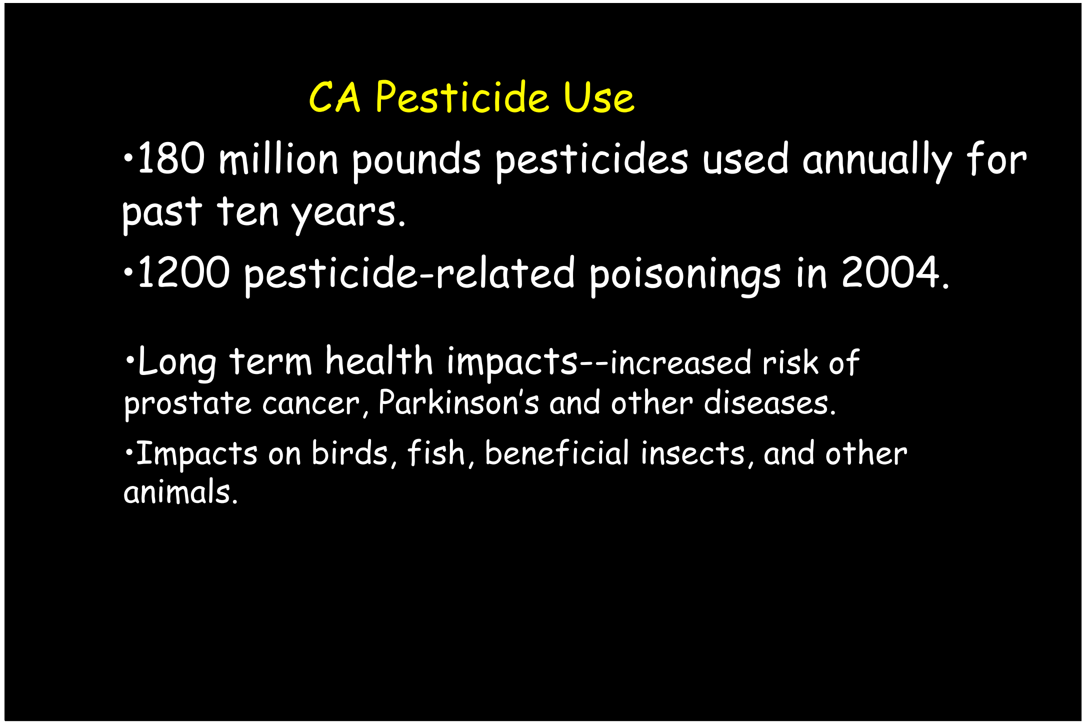
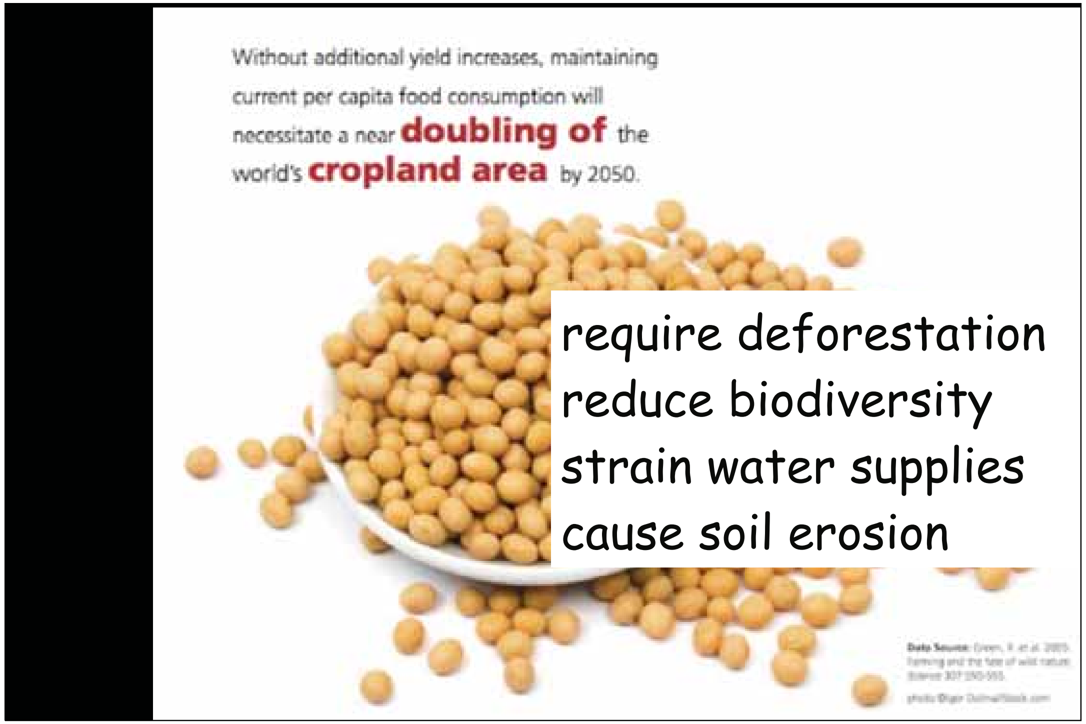


First of all we use a lot of pesticides in the US.



We also know that we must increase yield.
 Imagine that the earth will look like in 40 years if we do not change our farming practices. Imagine Camden or your local community with twice as much wilderness put to farmland. Imagine the consequences of plowing twice as much land. Speices biodiviersy will be lost beause every time you plow whethr it i organic arming or onentional farming, you damage habitat. Water supplies will be further constrained; soil erosion will increas.

If we hadn't genetically modified our crops by conventional methods over the last 50 years, we would be using twice as much of the Earth's surface to grow the same amount of food. In the future, if we don't increase yields, we'll need to use double the amount of land to produce the same amount of food. Sparing land from becoming farmland, is the greatest benefit to biodiversity. For this reason, some ecologists see the application of GE as a way to spare even more land from destruction by enhancing yields (Qaim and Zilberman 2003; Snow et al. 2005).

If no GE crops had been grown in 2007, an area equivalent to about 6 percent of the arable land in the U.S.,would have had to be brought under cultivation in order to achieve the same global production levels.

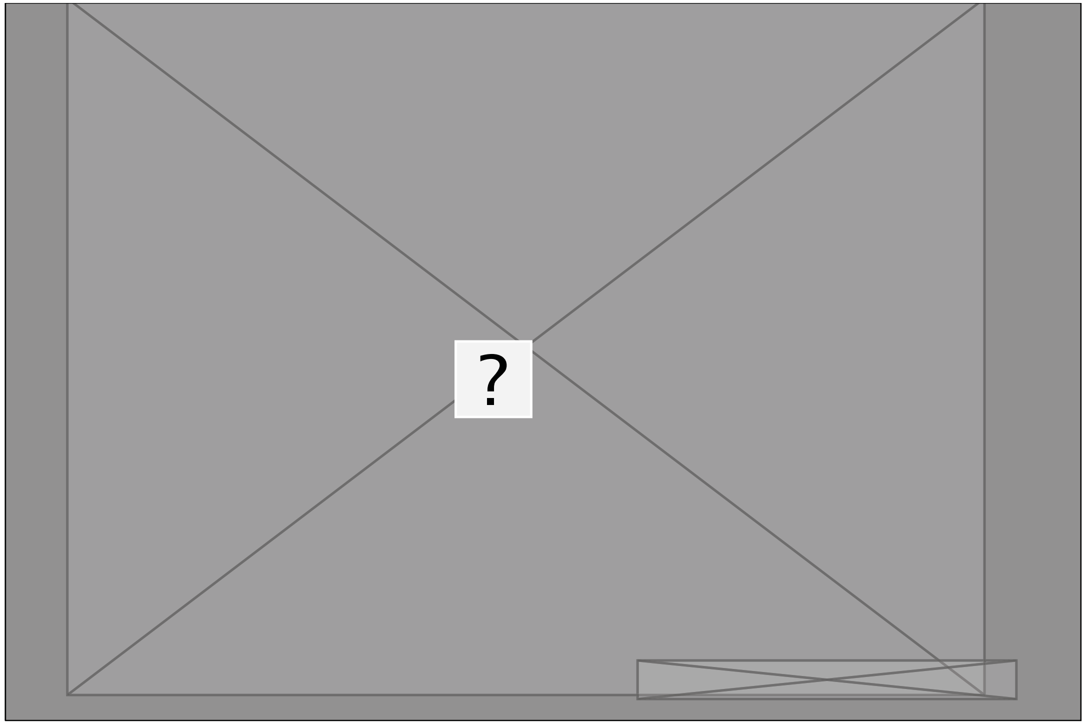
The reduced greenhouse gas emissions that resulted from the planting of GE crops in 2007 was equivalent to removing nearly 6.3 million cars from the road for one year;

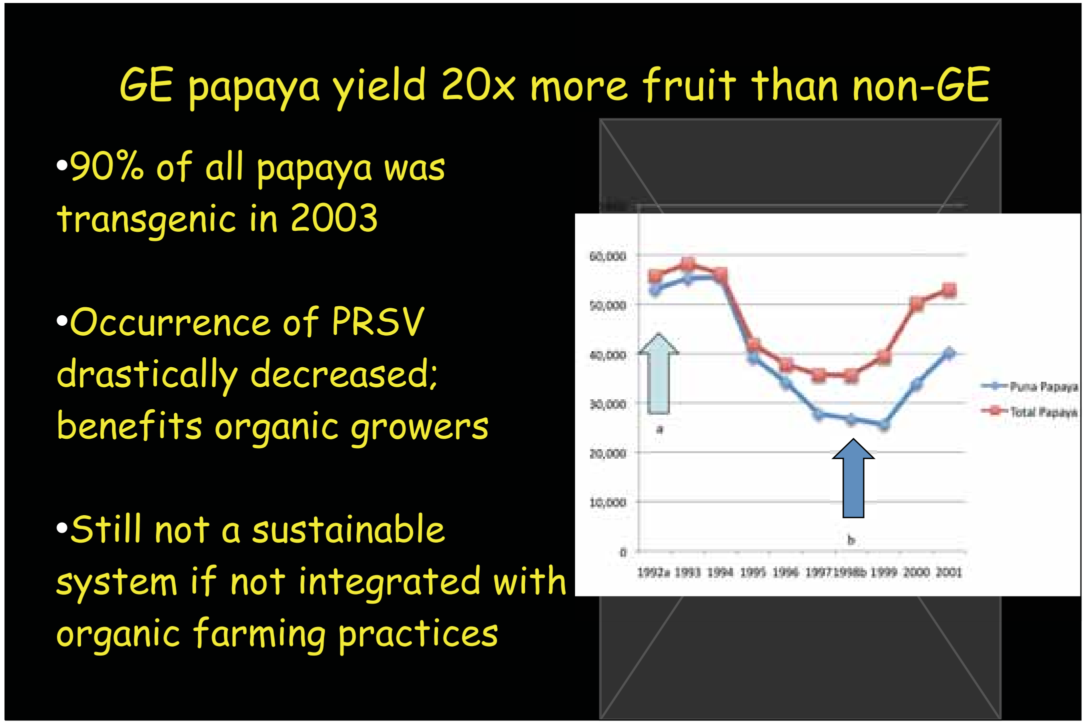
GE crops reduced pesticide spraying by 359 million kilograms from 1996-2007

- Graham Brookes and Peter Barfoot, is entitled: "GM crops: global socio-economic and environmental impacts 1996-2007.

The U.K.-based consulting firm PG Economics has released a new report saying that genetically modified (GM) crops increase farmers' incomes globally, raise yields, and promote environmental sustainability. The report, by Graham Brookes and Peter Barfoot, is entitled: "GM crops: global socio-economic and environmental impacts 1996-2007." According to the report, in 2007 the net farm level economic benefit from the adoption of GM crops was US$10.1 billion, equivalent to adding 4.4 percent to the value of the global production of the four main GM crops (soybeans, corn, canola and cotton). Farmers in developing countries are said to have gotten 58 percent of these farm level income gains. For farmers in developing countries the total cost of accessing GM technology in 2007 was equal to about 14 percent of total technology gains, the report says, whilst for farmers in developed countries the cost was 34 percent of the total technology gains. GM crops, on average, result in higher yields, the report says. Production of GM soybeans, corn, cotton and canola in 2007 was, respectively, 29.8 percent, 7.6 percent, 19.8 percent, and 8.5 percent higher than if non-GM varieties had been grown instead, the report finds. It says that if no GM crops had been grown in 2007, an area equivalent to about 6 percent of the arable land in the U.S., or 23 percent of the arable land in Brazil would have had to be brought under cultivation in order to achieve the same global production levels. In addition, the report says: 1) the reduced greenhouse gas emissions that resulted from the planting of GM crops in 2007 was equivalent to removing nearly 6.3 million cars from the road for one year; 2) GM crops have reduced pesticide spraying (1996-2007) by 359 million kilograms over the 1996-2007 period; and 3) herbicide tolerant GM crops have facilitated the adoption of enviro The U.K.-based consulting firm PG Economics has released a new report saying that genetically modified (GM) crops increase farmers' incomes globally, raise yields, and promote environmental sustainability. The report, by Graham Brookes and Peter Barfoot, is entitled: "GM crops: global socio-economic and environmental impacts 1996-2007." According to the report, in 2007 the net farm level economic benefit from the adoption of GM crops was US$10.1 billion, equivalent to adding 4.4 percent to the value of the global production of the four main GM crops (soybeans, corn, canola and cotton). Farmers in developing countries are said to have gotten 58 percent of these farm level income gains. For farmers in developing countries the total cost of accessing GM technology in 2007 was equal to about 14 percent of total technology gains, the report says, whilst for farmers in developed countries the cost was 34 percent of the total technology gains. GM crops, on average, result in higher yields, the report says. Production of GM soybeans, corn, cotton and canola in 2007 was, respectively, 29.8 percent, 7.6 percent, 19.8 percent, and 8.5 percent higher than if non-GM varieties had been grown instead, the report finds. It says that if no GM crops had been grown in 2007, an area equivalent to about 6 percent of the arable land in the U.S., or 23 percent of the arable land in Brazil would have had to be brought under cultivation in order to achieve the same global production levels. In addition, the report says: 1) the reduced greenhouse gas emissions that resulted from the planting of GM crops in 2007 was equivalent to removing nearly 6.3 million cars from the road for one year; 2) GM crops have reduced pesticide spraying (1996-2007) by 359 million kilograms over the 1996-2007 period; and 3) herbicide tolerant GM crops have facilitated the adoption of environmentally beneficial no/reduced tillage production systems in many regions, especially South America. The report is available online at the link below.

http://www.pgeconomics.co.uk/Biotech%20crops%20making%20important%20contributions%20to%20sustainable%20farming.htm nmentally beneficial no/reduced tillage production systems in many regions, especially South America. The report is available online at th



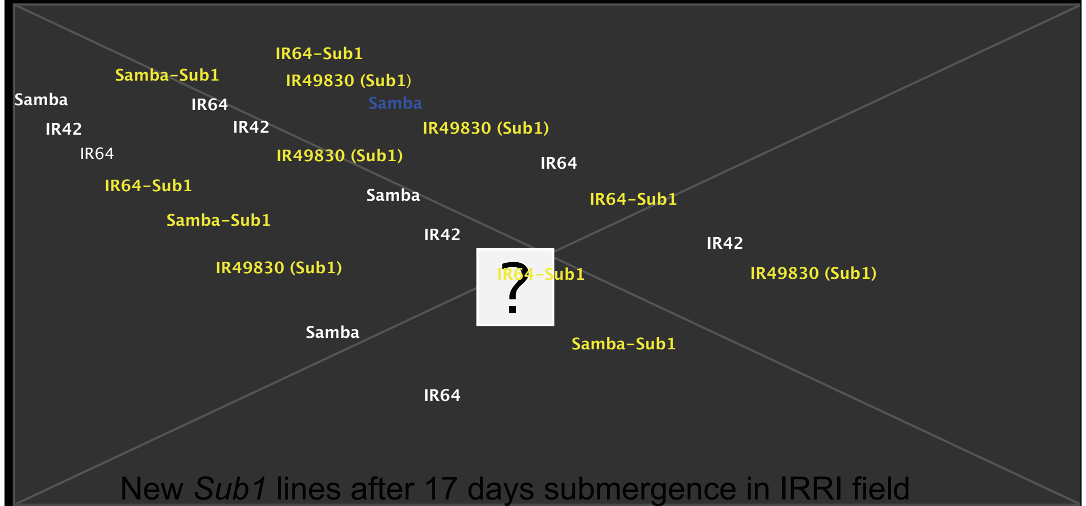


After release of GE papaya to farmers in May 1998, production rapidly increased with a peak of 40 million pounds in 2001.

a=PRSV first observed in Puna in May 1992
b=Transgenic seeds were released to farmers in May 1998

The story of the Hawaiian papaya is an example where GE was the most appropriate technology to address a specific agricultural problem. There was no other technology then to protect the papaya from this devastating disease, nor is there today.

Sub1A is sufficient to confer tolerance to nearly all intolerant varieties (5-6 fold yield increase)



New *Sub1* lines after 17 days submergence in IRRI field

Xu et al., Nature 2006; Slide Courtesy of D. Mackill

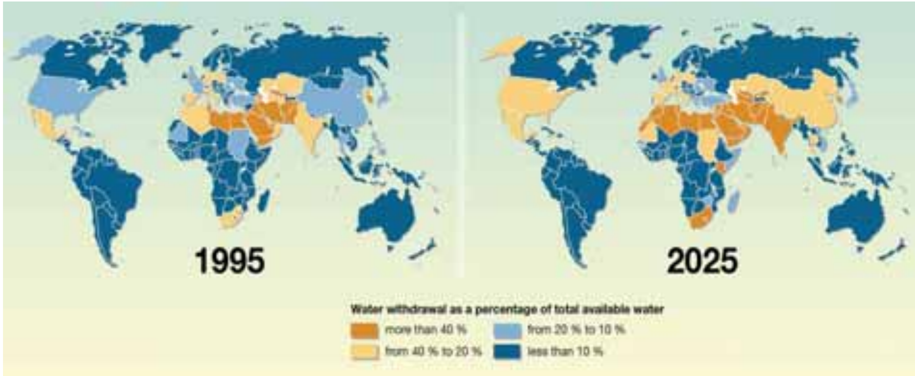
Organic Ag for Developing Countries

- Organic agriculture requires fewer external inputs, including energy, and may be more suitable for locations where inputs are too costly or not available.

In sub-Saharan Africa, synthetic fertilizers cost 2 to 6 times as much as those in Europe or North America. The use of nitrogen-fixing legumes or biomass transfer of nutrient-accumulating shrubs has been shown to be effective in providing nutrients for plants and increasing soil organic matter. (Sanchez, Pedro. 2002.)

Increased global water scarcity and stress

Predicted water scarcity and stress in 2025



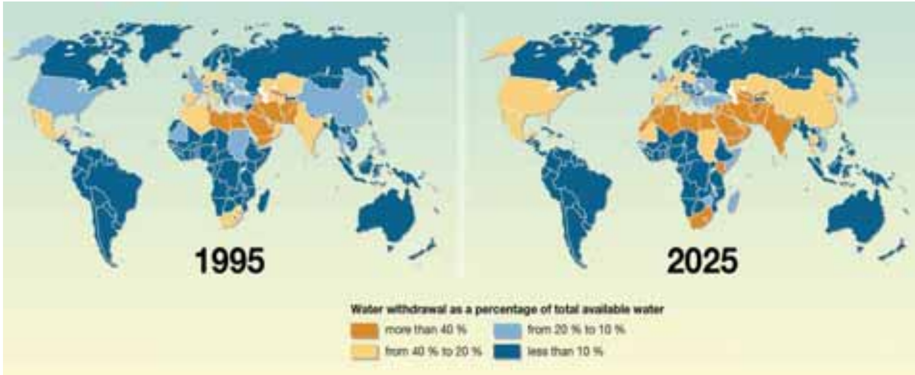
Source: UNEP 2008

Source: John Beddington; UNEP 2008

Total world water demands are predicted to increase by **over 30% by 2030** *Source: IFRPI*

Increased global water scarcity and stress

Predicted water scarcity and stress in 2025



Source: UNEP 2008

Source: John Beddington; UNEP 2008

Total world water demands are predicted to increase by **over 30% by 2030** *Source: IFRPI*

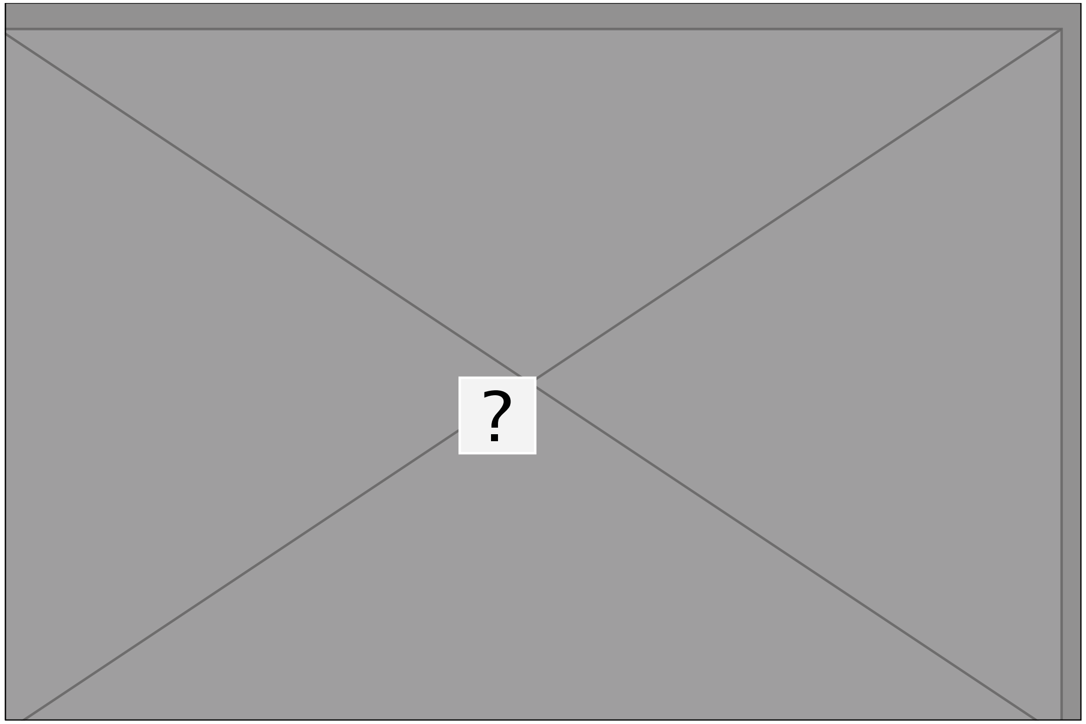
On the left shows the water availablity in 1995. On the right are the predictions o f2025. The areas in oragen are regions werhe more than 40% of the total available water has been withdrawn

In addition to the limitations of intrinsic yield and available land, there is a significant water problem. Of the water that is available for use, about 70% is already used for agriculture.* Water systems are under severe strain in many parts of the world. Many rivers no longer flow all the way to the sea; 50% of the world's wetlands have disappeared; and many major groundwater aquifers are being mined unsustainably, with water tables in parts of Mexico, India, China, and North Africa declining by as much as 1 m per year.

Model System

- Corn/Soybean System compared to Corn/Soybean/Small Grain/Alfalfa System.
- Synthetic N was reduced 74% and herbicide use by 82%. Net returns for this system exceeded the corn/soybean system.
- Liebman, et al. Agronomy Journal, Volume 100, Issue 3, 2008

Matt Liebman, et al. from Iowa State Univ. designed a cropping system to replace the existing corn/soybean system. It added more diversity to the rotation, corn/soybean/small grains/alfalfa.



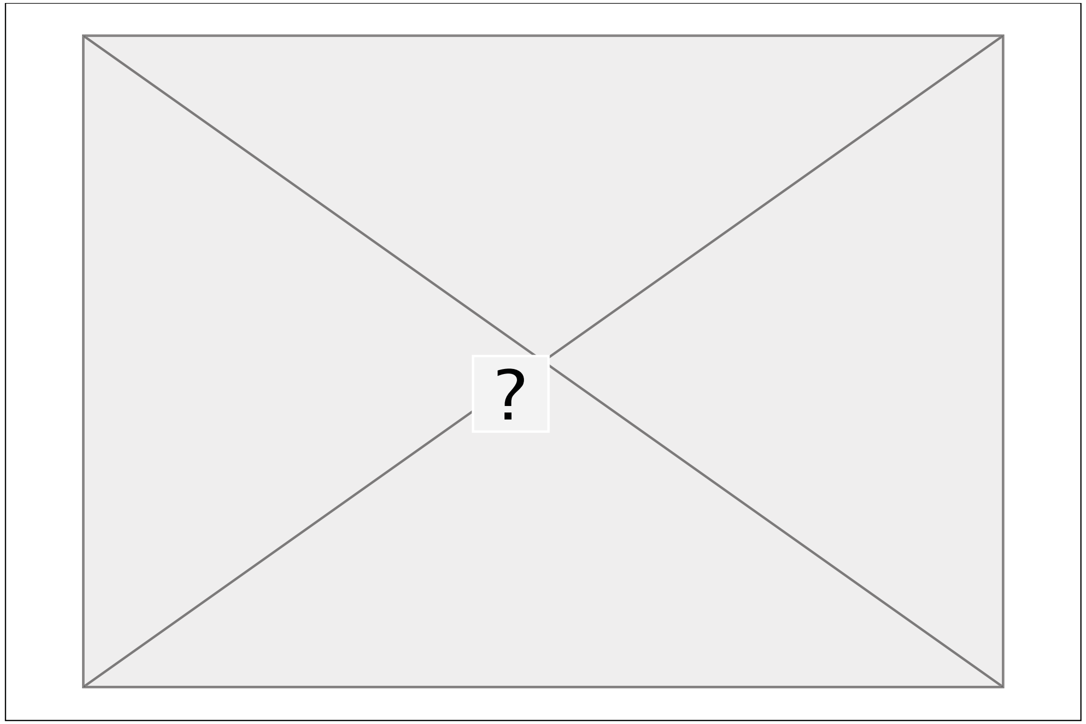
USA_AG_CRPD_03_xsCrop dusting. Spraying cotton prior to harvest with defoliant (Paraquat) in Kern County, California, USA.

Conventional Agriculture Depends on Synthetic Fertilizers

This is Anhydrous ammonia fertilizer applicator.

Conventional agriculture uses and enourmous amount of synthetic fertilzers. There are three problems with this: First, fertilzer synthesis represents 1% of global energy consumption. It takes the equivalent of 30 gallons of gasoline to make the synthetic fertilizer used on an acre of corn. Second, fertilizer is expensive, Finally, Soluble nitrates and phoshates leach into water supplies and become food for aquatic organisms.

{Synthetic nitrogen, phosphorus, and potassium fertilizers}



Sustainable management approaches enhances effectiveness of BT crops

Resistance evolves quickly without refuges; slowly or not at all with refuges

Photo credit: Timothy Dennehy. 2005

Cotton fields in Parker Valley, Ariz. Bt cotton is the greener field in the foreground. The whiter swath of cotton in the background is a refuge field of non-Bt cotton.

Biologists have know for 50 years that high levels of pesticides leads to resistant pests. 400 insect species have evolved resistance to insecticides. This is supported by filed-evolved resistnace to sprays of Bt toxins in diamonbath moth (1990s)

BT corn and cotton grown on a cumulative total of 200 million hecatres worldwide, more than enough to cover teh entire states of Texas, california and Iowa.

Still in the first decades no resistance was observed in insect pests targeted by BT coprs in most countries. This result exceeded teh expectations of most scientists.An exceoption is the resistance observed in 3 species. Why? thoruhg that failire to intoreuce crop genetic diversity (refuges) enhanced resistance. REfuges: patches of conventional cotton intermingled with the fields of Bt cotton.

Conclusion: sustainable farming practices combined with GE crops has dramatic benefits for farmers and the environment.

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Bt cotton has been planted in Arizona since 1996. Now more than half of the state’s 256,000 acres of cotton fields are planted with the biotech plants. Without the protection provided by Bt cotton, some fields can have 100 percent of plants infested with pink bollworm caterpillars, which live inside the cotton boll, destroying the crop.

Dennehy said, "In an extreme infestation, you can have every single boll in the field infected." The caterpillars eat the seeds and damage the developing cotton fibers.

In contrast, when the caterpillars eat Bt cotton, they die.

Before the use of Bt cotton became widespread, pink bollworm was one of the top three insect pests of cotton in the Southwest. In 1995, losses from pink bollworm in Arizona cotton were estimated to be $8.48 per acre, totaling $3.4 million statewide. Cotton is grown in eight Arizona counties: Cochise, Graham, La Paz, Maricopa, Mohave, Pima, Pinal and Yuma.

"Moreover, the harsh insecticides used to control pink bollworm resulted in a host of other insect pests becoming more serious problems," Dennehy said.

Everything changed in 1996, he said, when Bt cotton and two other "soft" insect control tactics replaced a large amount of the harsh pesticides used on cotton crops. Spraying less chemical insecticides means more beneficial insects survive, further reducing the need for spraying.

By 2004, pink bollworm losses had fallen to nearly half of earlier levels, $4.34 per acre.

Tabashnik said, "Some of the other pests are not so much of a problem because we’re not killing their natural enemies with insecticides."

Dennehy added, "These soft toxins plus the good bugs acting together have driven pesticide use to historic low levels ... this is a wonderful success of integrated pest management."

Since widespread adoption of Bt cotton in 1997, insecticide use on Arizona’s cotton crops is down 60 percent, said Tabashnik. The reduction in chemical pesticide use saves growers about $80 per acre. According to the Arizona Agricultural Statistics Bulletin, the value of Arizona’s cotton crops for 2004 was estimated at $207 million.

The key to Bt cotton’s continued efficacy is the use of refuges - patches of traditional cotton intermingled with the fields of Bt cotton.

The refuges ensure that the few pink bollworm moths that are resistant to Bt are most likely to mate with Bt-susceptible pink bollworm moths that grew up in the refuges. The offspring from such matings die when they eat Bt cotton.

In contrast, if all of Arizona’s cotton was Bt cotton, only pink bollworm caterpillars that were resistant to the Bt toxin would survive. If resistant pink bollworm moths mated with each other, their offspring would be resistant and could feed on Bt cotton. Bt cotton would then become useless against pink bollworm.

The UA team used a combination of field surveys, laboratory testing and mathematical modeling to determine if pink bollworm had become resistant to Bt cotton.

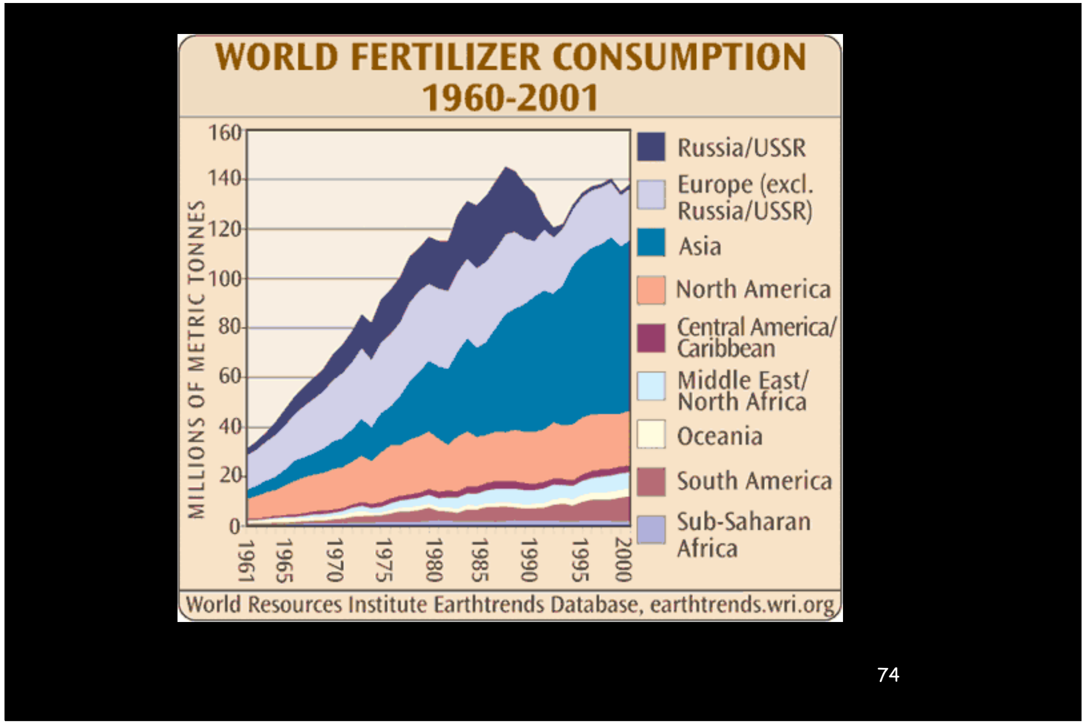
The team did find Bt-resistant pink bollworm caterpillars in the field, but they were rare.

Tabashnik said that doesn’t mean the insects won’t bite back in the future. "It’s not that pink bollworm can’t beat Bt toxin, but that it hasn’t beaten Bt toxin so far."

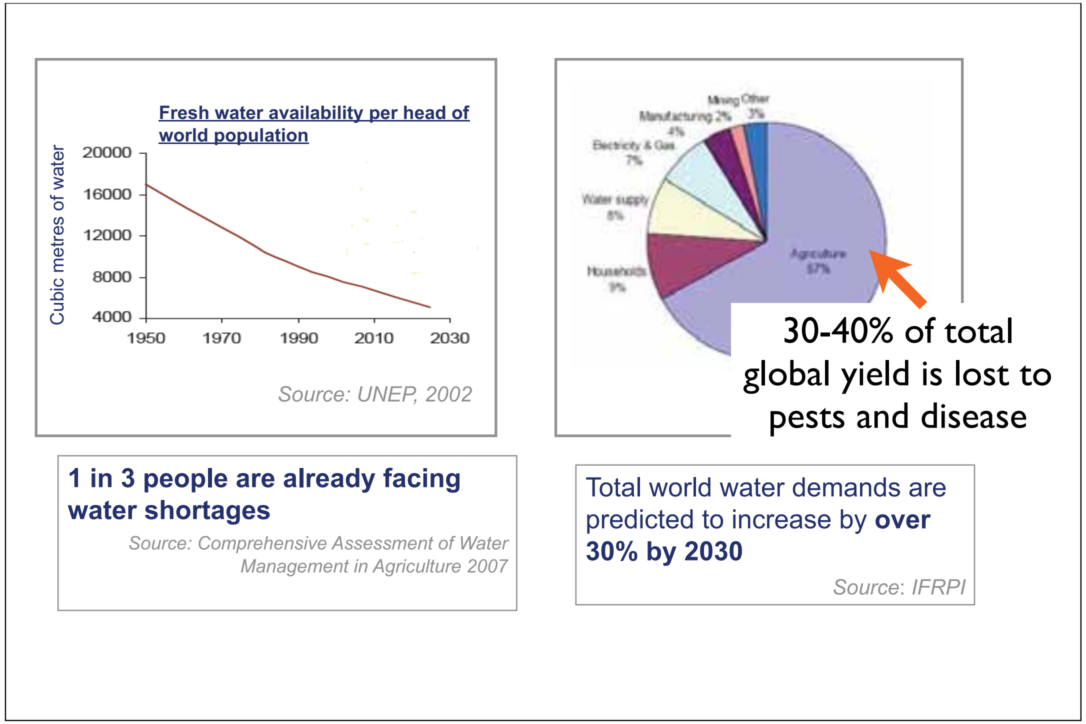
There’s a new variety Bt cotton now available that has two different Bt toxins, he said. The team’s next step will be to determine how to best use that combination of toxins to stay one step ahead of the pink bollworms.

It seems nearly inevitable that genetic engineering will play an increasingly important role in agriculture. The question is not whether we should use genetic engineering, but more pressingly, how we should use it - to what responsible purpose. Agriculture needs our collective help and all appropriate tools if we are to feed the growing population in an ecological manner. Consumers have a significant opportunity to influence what kinds of plants are developed and to address the key agricultural challenges. Let us direct attention to where it matters - the need to support the use of seed and farming methods that are good for the environment and for the consumers.

The reduced greenhouse gas emissions that resulted from the planting of GE crops in 2007 was equivalent to removing nearly 6.3 million cars from the road for one year;



Nitrogen fertilizer use is increasing. Use in Russia has rebounded. The highest use is in Asia.



It has been estimated that up to 40% of plant productivity in Africa and Asia, and about 20% in the developed world, is lost to pests and pathogens. Approximately one-third of the losses are due to viral, fungal, and bacterial pathogens, and the remainder is due to insects and nematodes. Much of the loss occurs after the plants are fully grown: a point at which most or all of the water required to grow a crop has been invested. Thus, reducing losses to pests and pathogens is equivalent to creating more land and more water.

Knowledge of the mechanisms by which plants naturally resist pests and pathogens is rapidly increasing.As knowledge about the molecular mechanisms for such resistance or susceptibility advances, it will become possible to transfer the genes responsible for resistance mechanisms from one species to another. The success of the genetically modified insect-resistant corn and cotton plants grown on a large scale in the United States provides a first example of the feasibility of the approach. Plants engineered for pest and pathogen resistance could be distributed without cost to subsistence farmers in the developing world by the International Crop Research Centers. The benefits of such developments would be substantial in terms of income and food for the poor, reduced demand for water, and limiting the expansion of land area under cultivation, all of which would also generate environmental benefits.

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Editorial
Genetic Engineering and Water
Chris Somerville and John Briscoe