Genetic Engineering and Agricultural Research in the United States:

Critical Choices and Troubling Barriers

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Points of Control: What's at Stake

✓ Research funding: The new NIFA competitive grant program

✓ Industry restrictions on access to research material (GMO seed)

✓ Examples where research decisions matter: Genetic engineering vs. other agricultural technologies for *yield* and *nitrogen use efficiency (NUE)*

Research For Industrial and Organic Agriculture at the US Department of Agriculture

- Grants under the National Institute for Food and Agriculture (NIFA)

  - Funding: $262 million

- Sustainable/organic research through SARE and OREI

  - Funding: about $37 million

Patents and the Restriction of Research

- Patents allow legal restriction of independent research

- Numerous incidents show that research on GMOs has been limited due to corporate restrictions on access to seed

Examples of Restriction of Independent Research

- Lappe soybean isoflavones, 1999
- Weed scientists, beginning in the 1990s
- Twenty six entomologists write to US EPA to complain -- *New York Times*, Feb. 2009
- More scientists come forward in "Under Wraps," *Nature Biotechnology*, Oct. 2009

“Outright written refusal is rare. Verbal is more common, and third is endless legal wrangling that costs…so much in legal fees they say no, or negotiations continue past planting date.” --Elson Shields, Cornell University

“I thought naively that that would be a courtesy and I could get a small sample [of GE seed]. But they really didn’t want to do that.” -- Paul Gepts, University of California, Davis

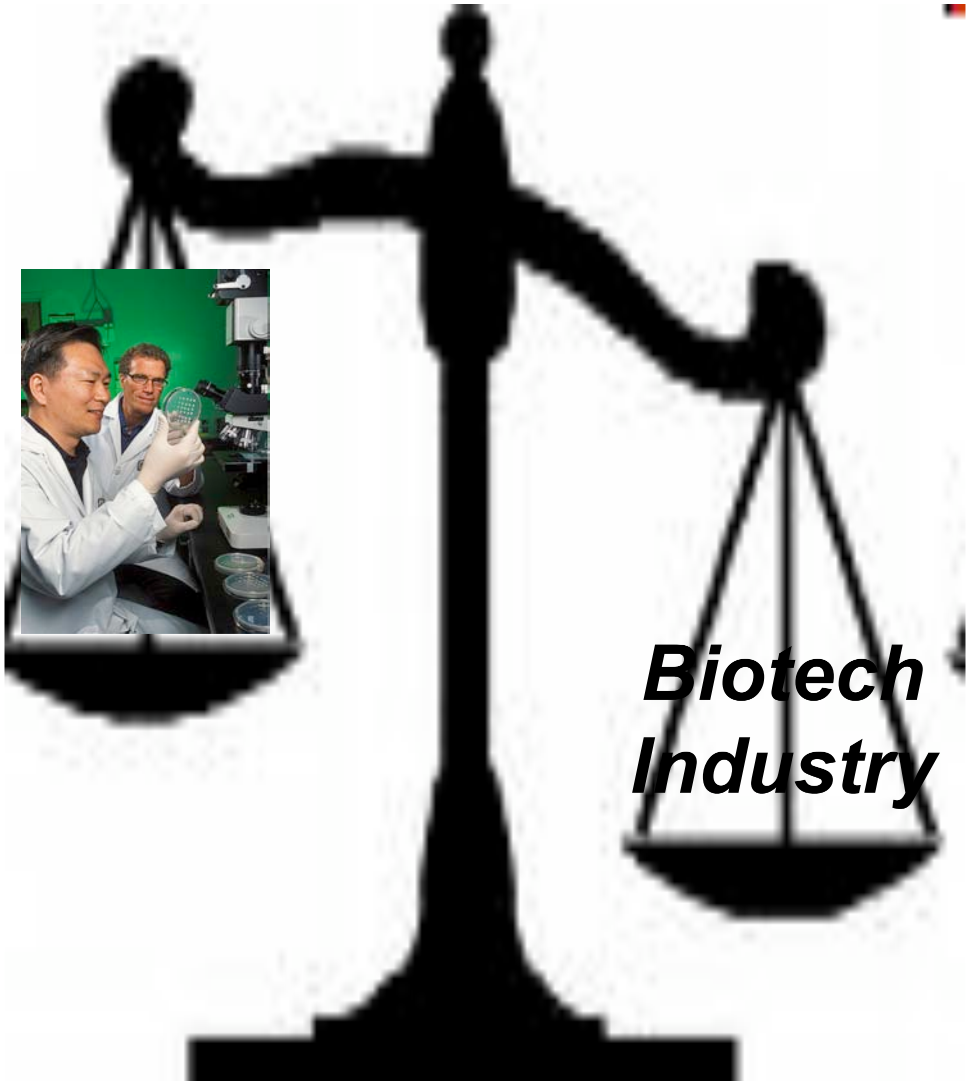
“I don’t think these events [GMOs] are being evaluated nearly as rigorously as they could be.” -- Christian Krupke, Purdue University

Current Status of Research Access

- The American Seed Trade Association is developing voluntary access guidelines in consultation with companies and academic scientists

An Asymmetric Relationship: Limits of Voluntary Industry Research Guidelines

- Ultimate decision rests with company -- no legal recourse for the scientist
- Company can indirectly prevent research by delay
- Company can use agreements with other companies as a reason to deny access
- Company obtains access to research protocols
- Publication may be delayed or restricted



Critically Important Research:
Crop Yield and Nitrogen Use Efficiency (NUE)

- GMO corn and soybeans were compared with non-GMO counterparts and with agroecological methods

- Prospects for GMOs to resolve big agricultural challenges like productivity and NUE are often less than for other methods

- Therefore, it is critically important to adequately fund research for other agricultural methods

Why Yield?
The Challenge of a Growing Population

- More mouths to feed
- Limits to land

Environmental Impacts of Synthetic Nitrogen Fertilizer

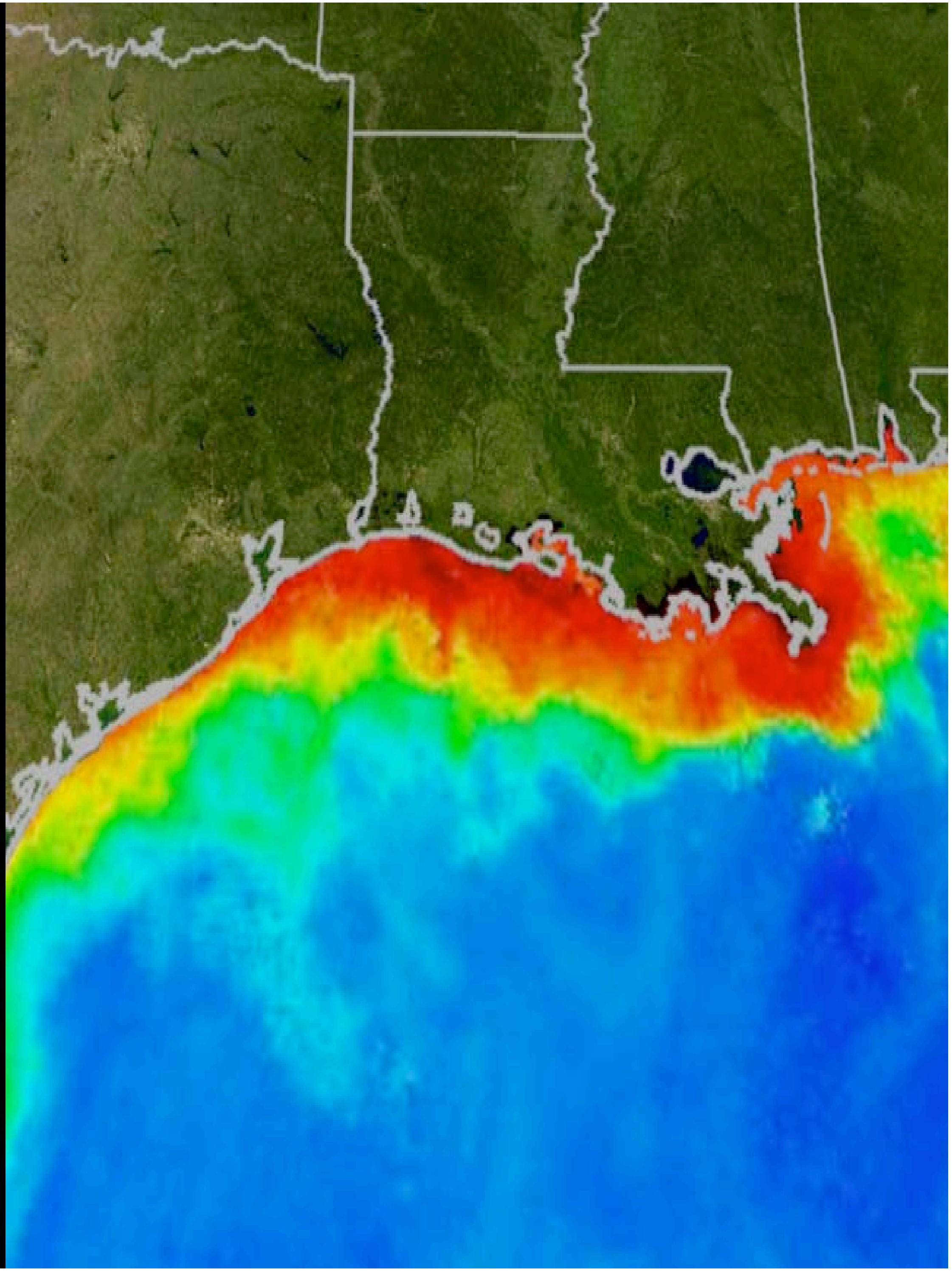
- Major source of water and air pollution
- Important source of climate-change emissions

Dead Zones

➢ Low oxygen caused mainly by agricultural nitrogen: fish cannot survive

- Dead zone in the Gulf of Mexico is the size of New Jersey

➢ Several hundred dead zones worldwide



Herbicide Tolerant (HT) GE Soybeans

- 5% reduction in yield potential compared to non-GE soy

- No yield benefit for HT corn

- Soybean yields have increased about 16% in the U.S. without GE since mid-1990s

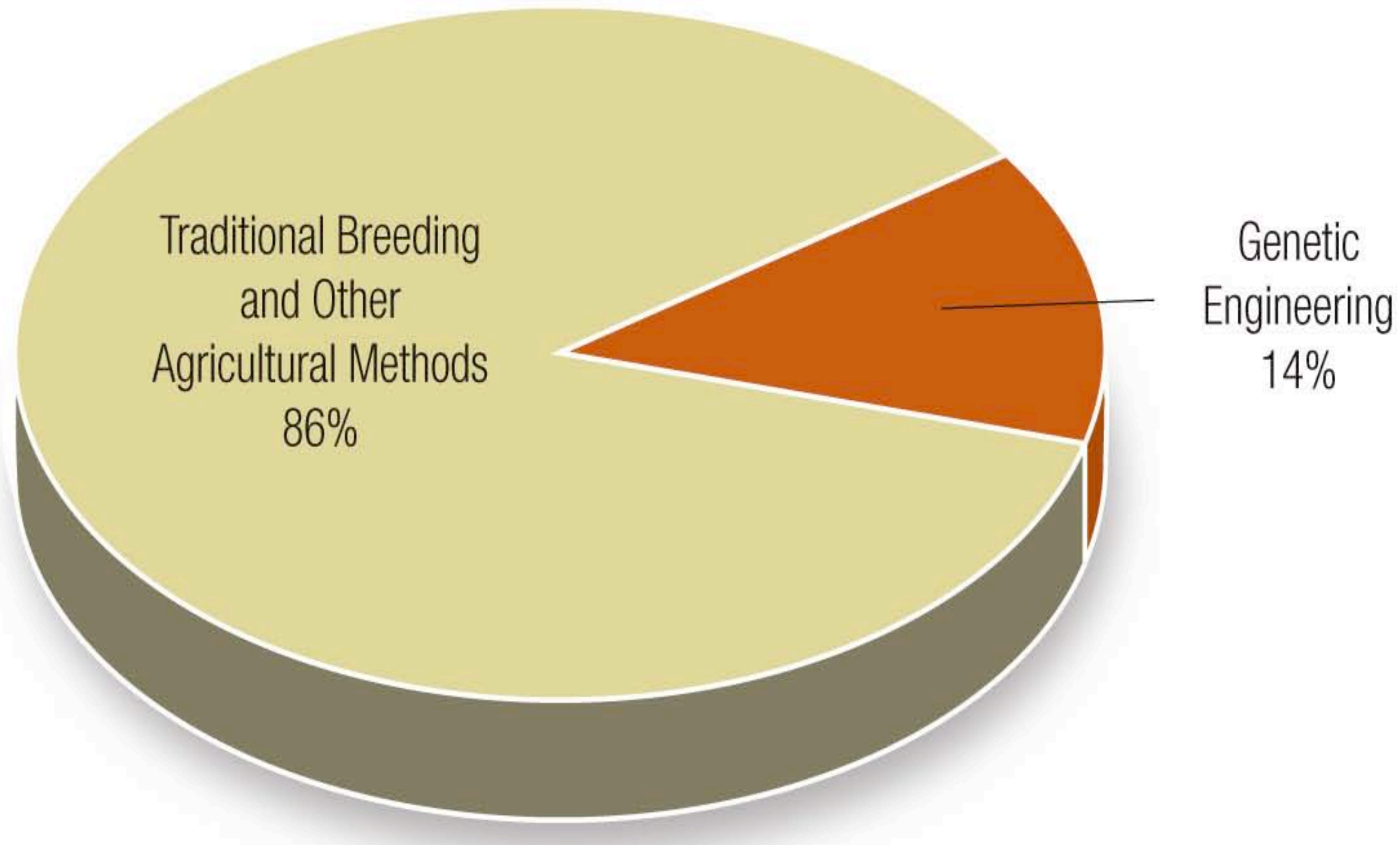
Bt Insect-Resistance Genes in Corn

- Average yield advantage: about 0-15% *where planted*

- Bt is *planted* on most corn acres – providing ~ 3% - 4% nationwide yield advantage

- During this period (1996-2008), corn yield increased about 28%

Contribution of Genetic Engineering to U.S. Corn Yield Increase, Early 1990s to Present



Field Trials of GE Crops for Yield: 1987 - 2000

Pest Traits: 1012

Stress traits: 41

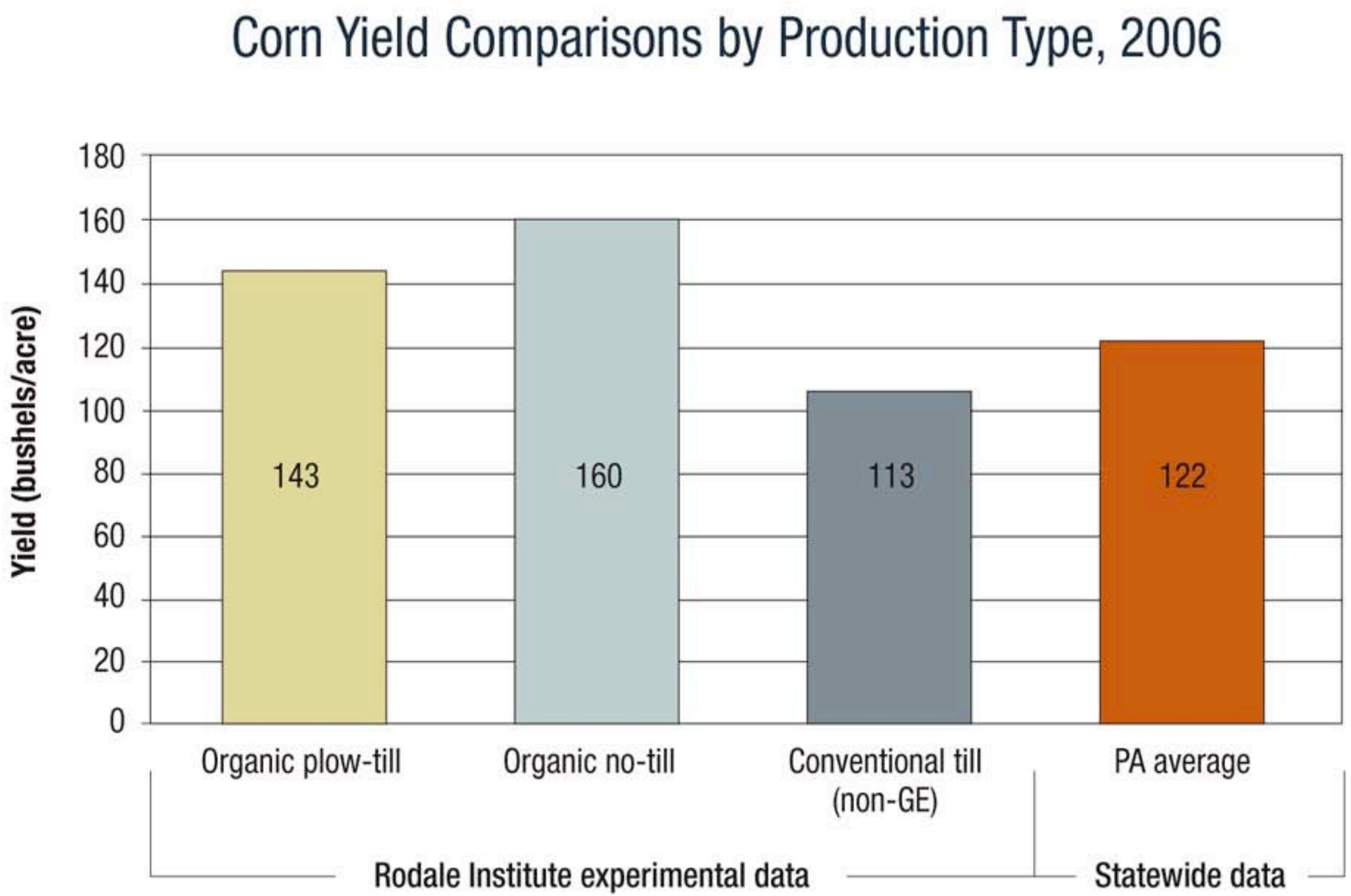
Intrinsic Yield traits: 55

Total 1108
(not including Bt and HT)

Successes: 0
(with several minor exceptions other than Bt)

Solutions that Need More Support

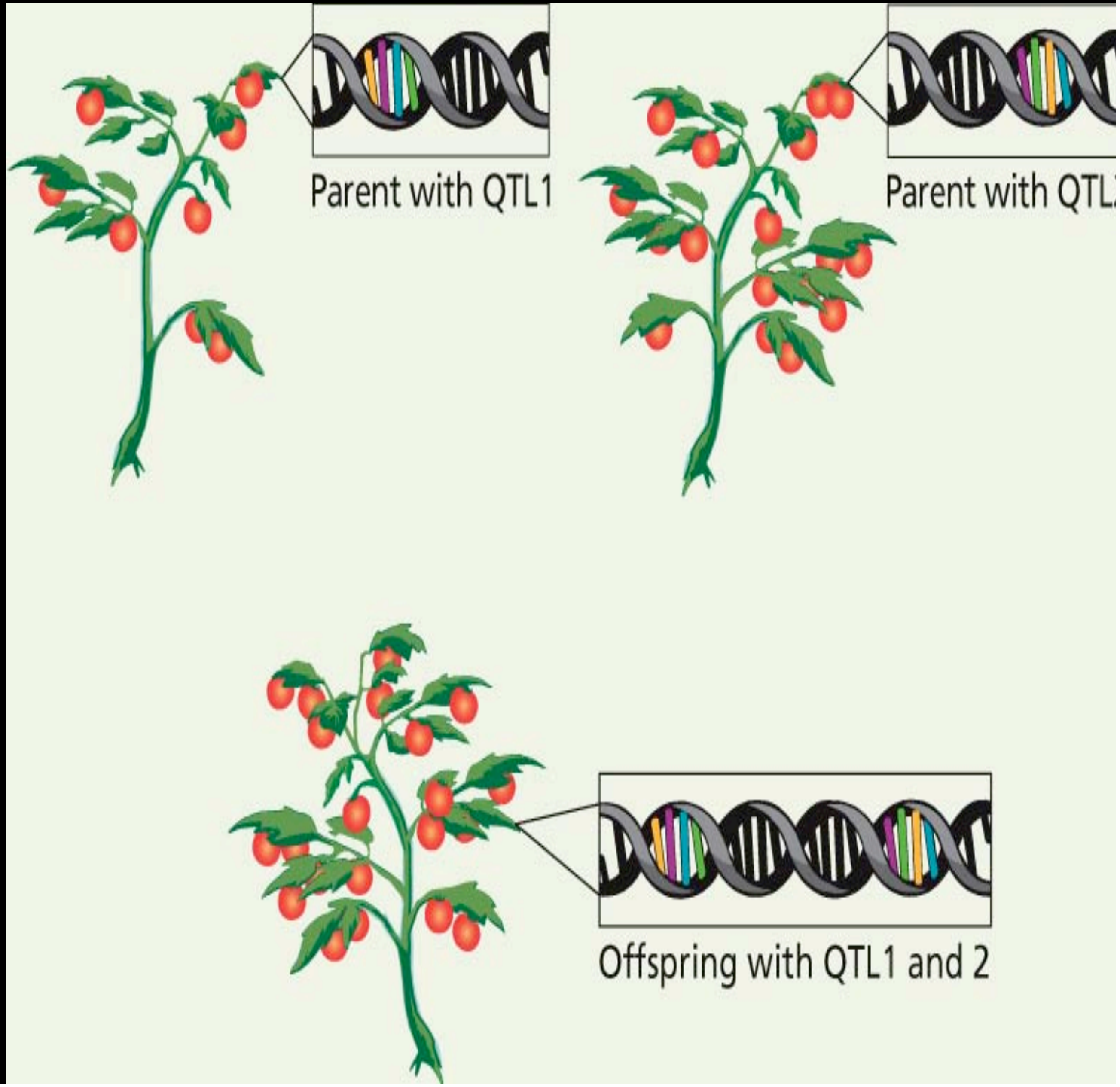
- **Conventional Breeding** - including genomics
- **Organic** - ~18 time fewer corn borer eggs than conventional farms
- **Crop Rotation** – Wheat preceding corn reduces corn rootworm damage


Corn Yield Comparisons by Production Type, 2006
Yield (bushels/acre)
180
160
140
120
100
80
60
40
20
0
143
160
113
122
Organic plow-till
Organic no-till
Conventional till (non-GE)
PA average
Rodale Institute experimental data
Statewide data

New Methods of Crop Breeding: Marker Assisted Selection (MAS)

- Better for complex traits than GE
- Faster than conventional breeding
- Fewer risks than GE
- Limited by plant genetics

E.g. Pioneer Co. soybeans: +6-10% yield increase



Drought Tolerance (pearl millet)

Before

With Marker assisted selection (MAS)

The Tally so Far: GE Impact on Yield in the U.S.

- ✓ Herbicide tolerance - 0
- ✓ Insect resistance, corn ~ 3% - 4%
- ✓ Disease resistance - insignificant
- ✓ Stress tolerance - 0
- ✓ Intrinsic yield - 0
- ✓ Crops other than corn or cotton - 0

Experimental

Genes Used to Improve NUE through Genetic Engineering

Gene	Gene Source (Gene/promoter)	Engineered Plant	NUE Improvement (Percent)	Grown in the Field?
Glutamine synthetase (GS)	Bean/rice	Wheat	10	No
Glutamine synthetase (GS)	Corn/plant virus	Corn	30	No
Glutamate synthase (GOGAT)	Rice/rice	Rice	80	No
Asparagine synthetase (AS)	*Arabidopsis*/plant virus	*Arabidopsis*	21	No
Glutamate dehydrogenase	*E. coli*/plant virus	Tobacco	10	Yes
Dof1	Corn/plant virus	*Arabidopsis*	Nitrogen content: 30; growth: ~65	No
Alanine aminotransferase (ALA)	Barley/canola	Canola	40	Yes
Alanine aminotransferase (ALA)	Barley/rice	Rice	31–54	Yes

Real-World

Improvements in Nitrogen Use Efficiency

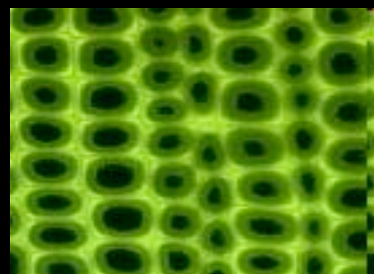
Crop	Time Frame* (Years)	Country	Source of NUE Gain	NUE Gain (Percent)	Reference
Wheat	35	Mexico	Breeding	42 (59 kg/ha/year)	Ortiz-Monesterio et al. 1997
Wheat	35	France	Breeding	29	Brancourt-Hulmel et al. 2003
Rice	~15	Japan	Unknown	32	Dobermann and Cassman 2005
Maize	~20	United States	Unknown	36	Dobermann and Cassman 2005
Cereal crops	15–20	United Kingdom	Unknown	23	Dobermann and Cassman 2005

Complex Rotations: Cover Crops Reduce N Pollution

- Cover crops reduced nitrogen losses into groundwater by about 40 to 70 percent.
  - Tonitto et al.
- Reduce erosion
- Add more-stable nitrogen to soil
- Sequester carbon, improve soil quality, control pests…

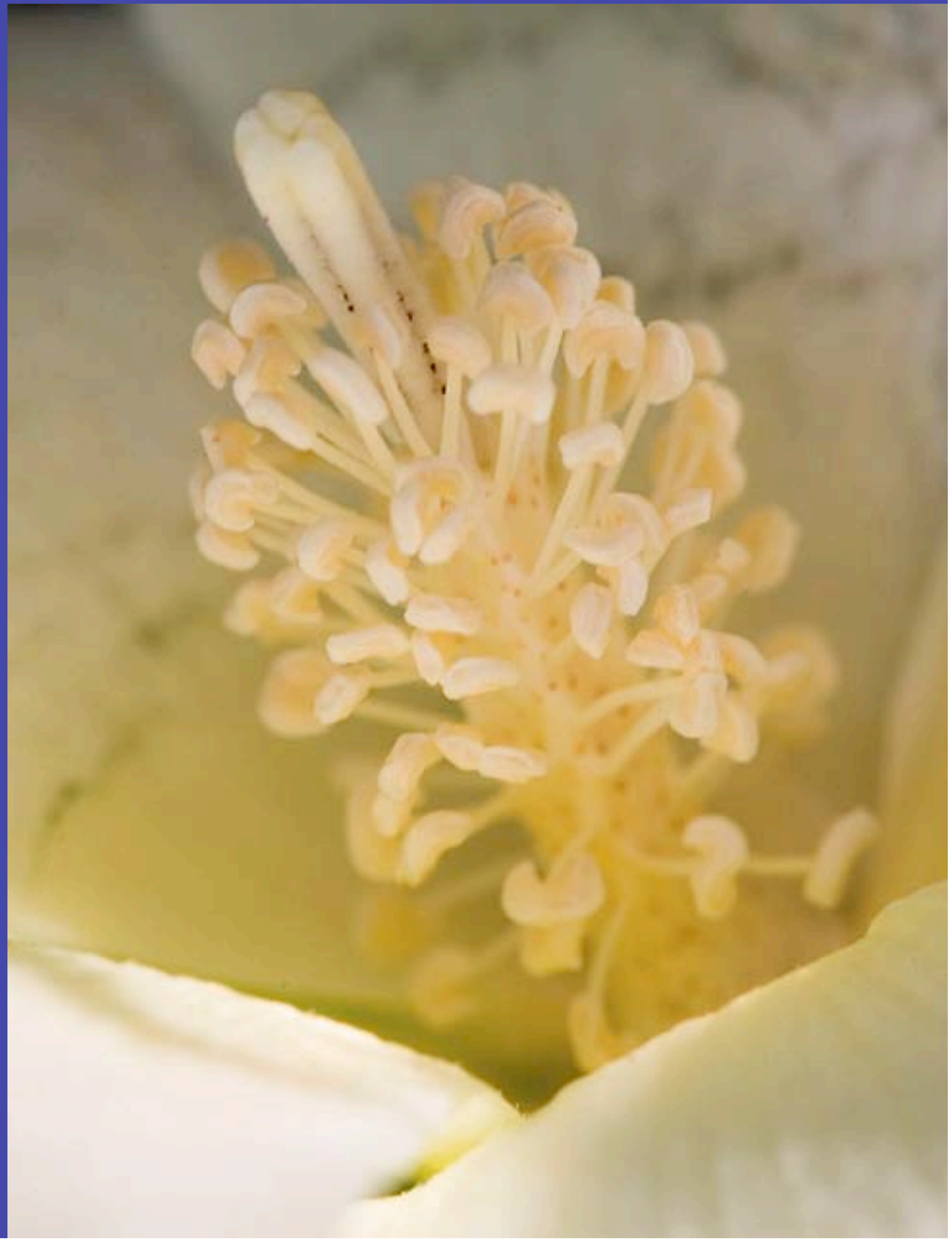
Looking Ahead:
Prospects for Improved Yield and NUE

New Yield and NUE Traits = Increased Genetic Complexity – One Gene, Many Unpredictable Effects



Examples: Intrinsic Yield Gene – *ap2*

✓ Produce larger seeds in wild mustard…but also controls flower development, seed oil content, and plant stress response



*era*1 Gene for Drought Tolerance

- Also controls the function of many proteins in the plant, including some involved with disease resistance

  -- The ***era1*** gene increases susceptibility to several plant diseases

Unintended Effects from NUE Genes

- ALA gene causes reduced function of several crop disease-defense genes

- GluD causes numerous changes in toxicologically important genes in tobacco

Summary

✓ GE has not been very successful so far at helping to solve the big challenges of industrial agriculture

✓ GE has not had commercial success with genetically complex traits

✓ GE is much more expensive, and not faster, than crop breeding

✓ Even where successful, GE is a piecemeal method rather than a systematic approach, unlike agroecology

✓ U.S. research and policy emphasis needs to support agricultural methods that have the greatest promise for sustainable production

✓ Unrestricted legal access to GE seed for research should be established