

Agricultural Biotechnologies Old & New Improve Food Safety & Public Health



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ICABR, Ravello, Italy – 9 July 2026

The context: climate change, food, health

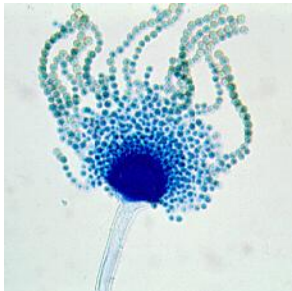


- Climate Action Tracker (2025): earth surface temperature will warm **2.7°C** by 2100 – beyond Paris agreement goal of 1.5°C
 - Global food security & safety → food production may increase, but **food safety risks will also increase**
- World Health Organization (2024): 733 million undernourished people worldwide: 1/11 people globally, 1/5 people in Africa
- Can agricultural biotechnology reduce risks?
 - Transgenic Bt corn (“old” biotech)
 - Newer biotech methods to improve crop yields & reduce **mycotoxins**, like **aflatoxin**
 - Genetically engineered (GE) bacteria to fix atmospheric nitrogen → reduce **phycotoxins**

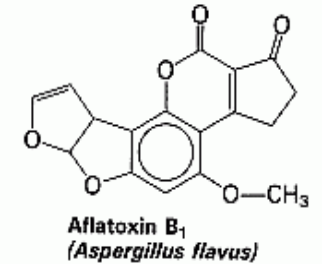
Mycotoxins: What are they?

- Toxic & carcinogenic chemicals produced by fungi
- Long history of mycotoxins affecting society
 - Leviticus 14:37
 - 11th c.: *Claviceps purpurea* produces ergot in rye → St. Anthony's Fire
 - Mysterious human & animal deaths in 1930s (Great Depression horses)
 - 1960 aflatoxin discovery: UK turkey deaths
 - Today: several dozen mycotoxins identified

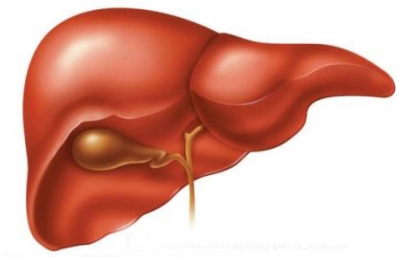




Aflatoxin



- Produced by fungi *Aspergillus flavus*, *A. parasiticus*
 - **Maize, peanuts**, pistachios, almonds, hazelnuts, seeds
 - **Warm climates**: Africa, Asia, Central America, US South
- Human health effects
 - **Liver cancer: >100,000 cases caused by aflatoxin/yr (Liu and Wu 2010, Liu et al. 2012)**
 - Synergizes with chronic hepatitis B or C viral infection: ~60X-70X higher cancer risk
 - Acute aflatoxicosis at high doses
 - Childhood stunting
 - Immune system dysfunction
- *A practical control strategy in some parts of the world...*



What is Bt corn?

- 2nd most commonly planted transgenic crop in world today



- “Bt” = *Bacillus thuringiensis*: soil bacterium produces proteins toxic to certain insect pests, but harmless to other species
- → **Bt corn produces its own pesticide**, contained within plant
- Benefit of reducing insect pests: improved yields, reduced pesticidal sprays, **reduced mycotoxins (including aflatoxin)**
- 82% of corn produced in US is Bt

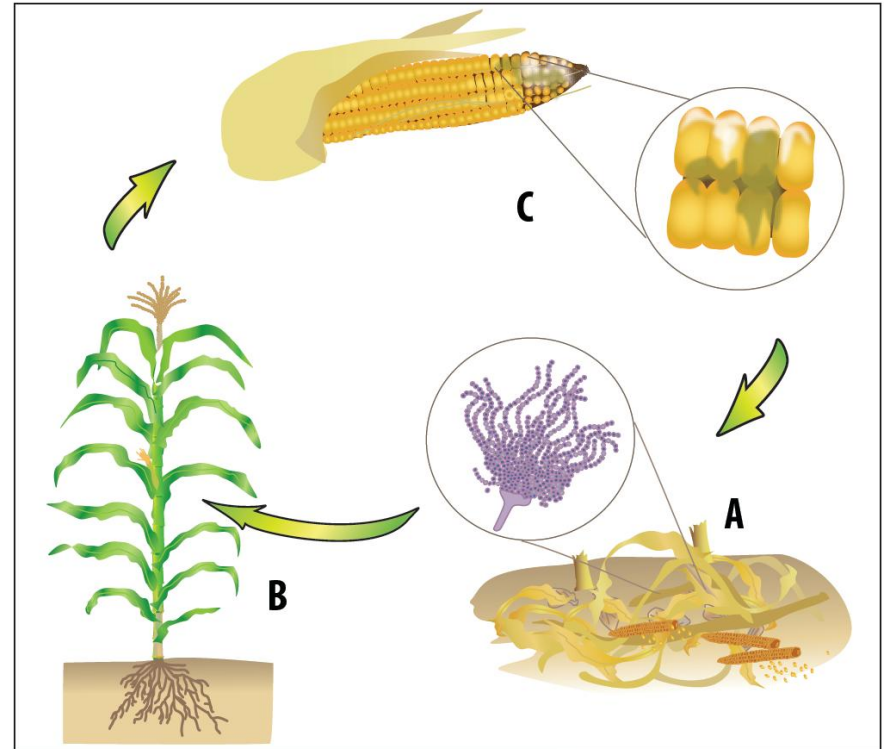
Abstract

Source: ISAAA, 2024



Bt corn can reduce fungal infection → can reduce mycotoxins

- Insect damage → fungal infection, mycotoxin production
- Bt corn reduces insect damage: lower mycotoxins
- Bt corn has lower risk of Fusarium ear rot than non-Bt isolines (Munkvold et al. 1997) → lower *fumonisin* levels than non-Bt isolines (Munkvold et al. 1999)
- **What about aflatoxin, which is even more toxic to humans?**



Source: Crop Protection Network,
<http://cropprotectionnetwork.org/corn/ear-rots/>

First: Will near-term climate change increase aflatoxin risk? **Insurance claims analysis**

- Our rationale:
 - 2005, 2006, **2012**: hot & dry summers → aflatoxin spreads to Corn Belt
- Many farmers buy *crop insurance*, which includes aflatoxin protection
 - Data: USDA Risk Management Agency (RMA)
- **Our work:**
 - Develop & validate model of aflatoxin risk as function of temperature, rainfall, & grower practices, 2011-2020
 - Project aflatoxin risk in US: 2031-2040
 - Averaged max/min daily temperatures May-Oct., rainfall, RH across 16 climate models
 - RCP 8.5



Figure 1. *Aspergillus* ear rot, caused by *Aspergillus flavus*. Photo: G. Munkvold.

What climatic conditions favor aflatoxin accumulation in corn?

- Hot, dry July – after silking
 - Reason: *Aspergillus flavus* “pollinates” silks
- Wet September – right before harvest
 - Reason: water remains in corn husks, perfect for fungal growth



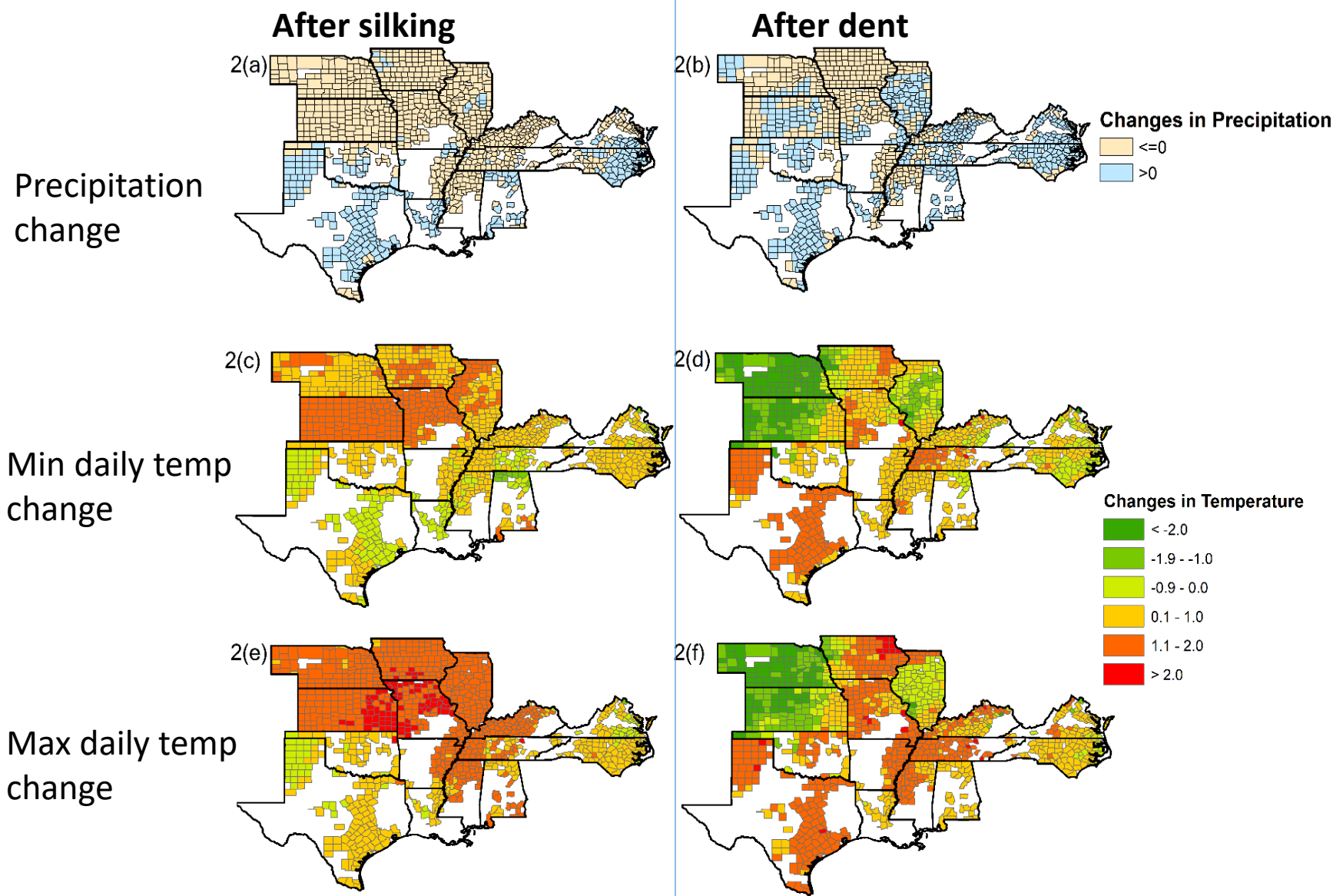


Figure 1 | Changes in precipitation, minimum temperature, and maximum temperature (°C) between two periods (2011-2020 and 2031-2040) during AS (left) and AD (right). 2(a): change in precipitation during AS. 2(b): change in precipitation during AD. 2(c) and 2(d): change in min temp during AS (left) and AD (right) respectively. 2(e) and 2(f): change in max temp during AS (left) and AD (right).

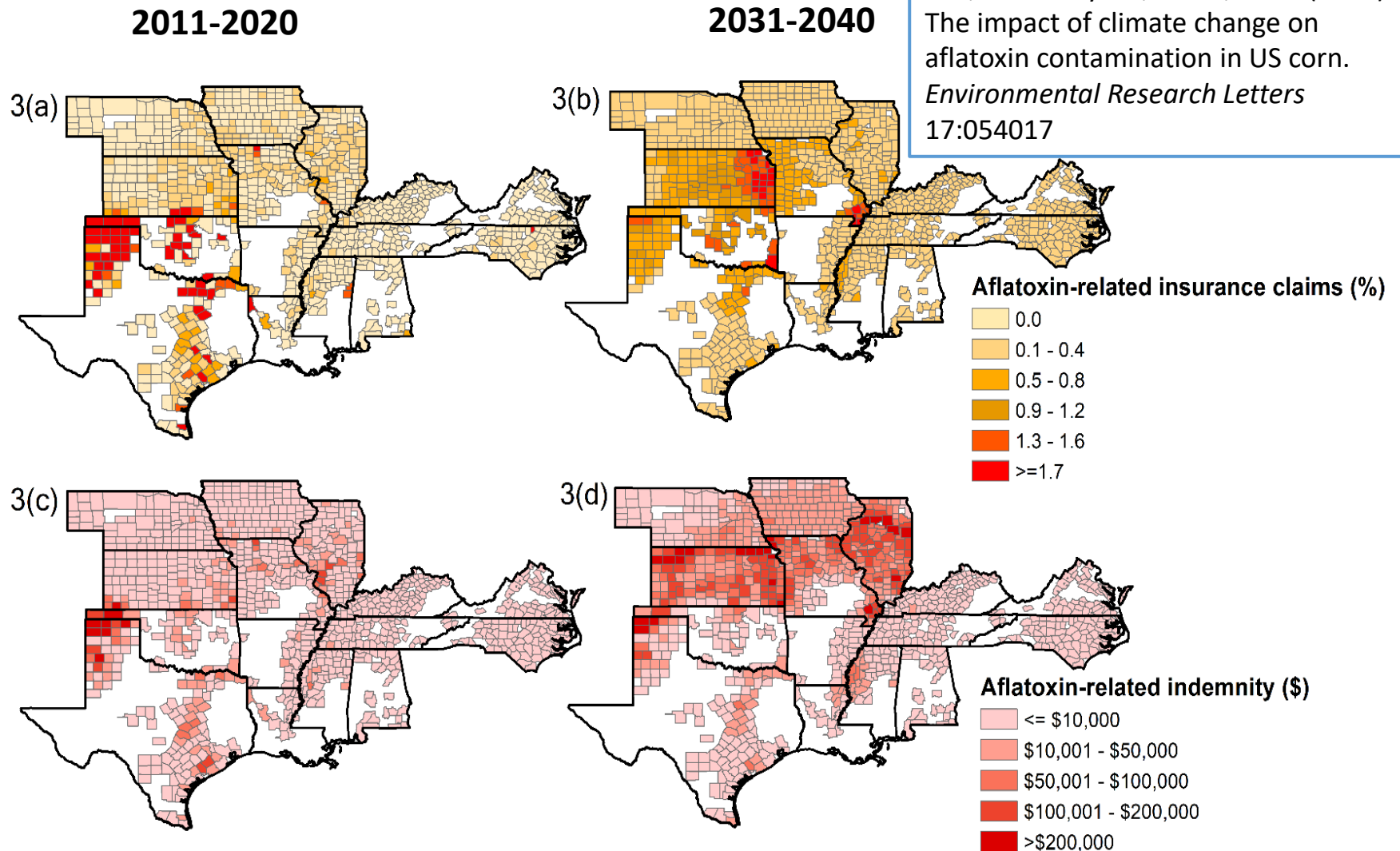


Figure 2 | Predicted aflatoxin risk measured by aflatoxin-related insurance claims per year (%) and aflatoxin-related indemnity. 3(a) is the aflatoxin-related insurance claims in 2011-2020; 3(b) is the projected aflatoxin-related insurance claims in 2031-2040; 3(c) is the aflatoxin-related indemnity amount in 2011-2020; 3(d) is the projected aflatoxin-related indemnity in 2031-2040.

Bt corn reduces aflatoxin risk: save \$200M/yr

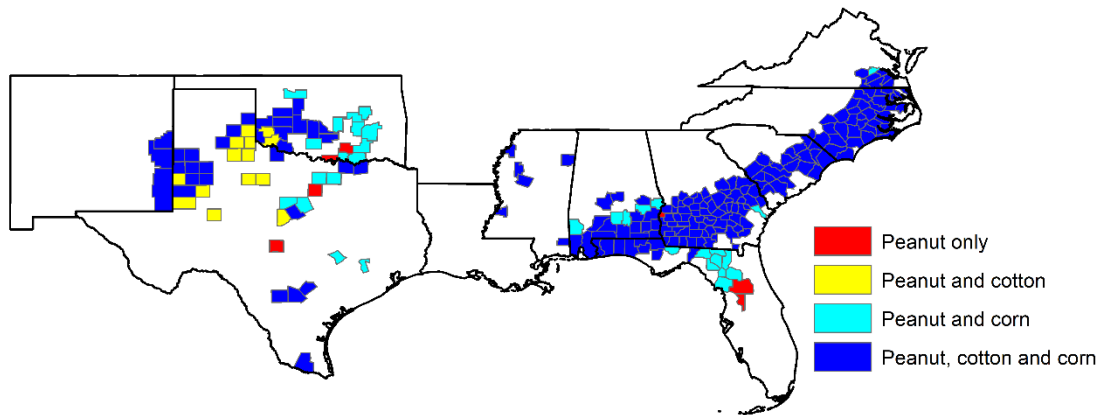
Variables	Coefficient	Marginal Effect
Bt maize adoption rate	-0.321*** (0.053)	-0.016*** (0.003)
Palmer Z index		
Palmer Z in June	-0.869*** (0.231)	-0.044*** (0.012)
Palmer Z in July	-0.807*** (0.221)	-0.041*** (0.011)
Palmer Z in August	0.110 (0.151)	0.006 (0.008)
Palmer Z in September	0.403*** (0.151)	0.020*** (0.008)
Temperature in June		
Range 32-40°C	17.885*** (3.791)	0.908*** (0.194)
Above 42°C	-62.819 (53.716)	-3.188 (2.727)
Temperature in July		
Range 32-40°C	6.399** (2.726)	0.325** (0.140)
Above 42°C	-13.305 (23.870)	-0.675 (1.210)
State Effects controlled	Yes	Yes
Year Effects controlled	Yes	Yes
Observations	12,127	12,127

Standard errors in parentheses,
*** p<0.01

Yu J, Hennessy DA, Wu F (2020). The impact of Bt corn on aflatoxin-related insurance claims in the United States. *Scientific Reports* 10:10046.

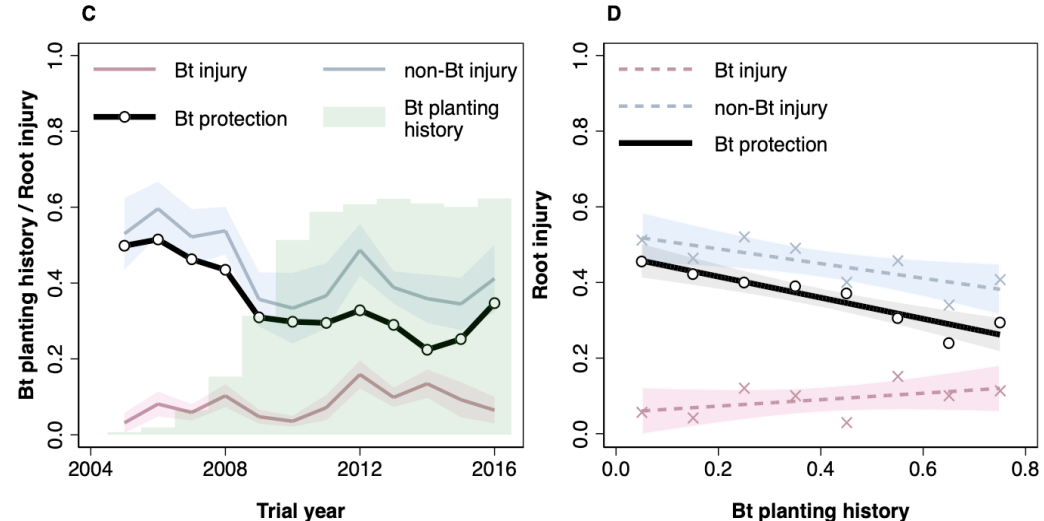
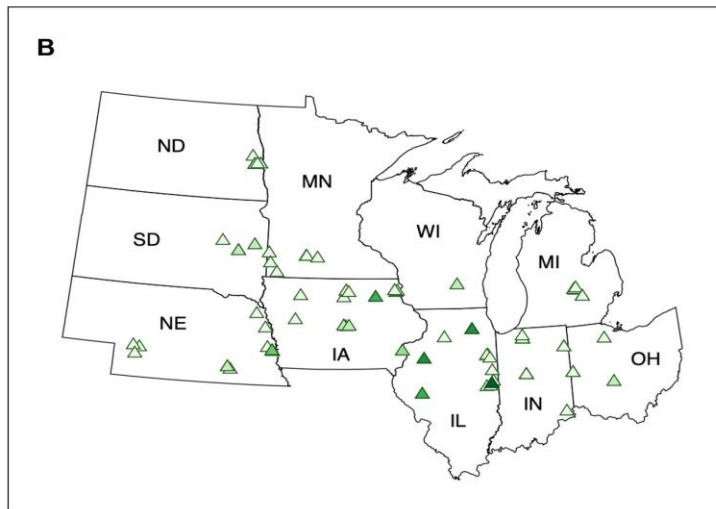
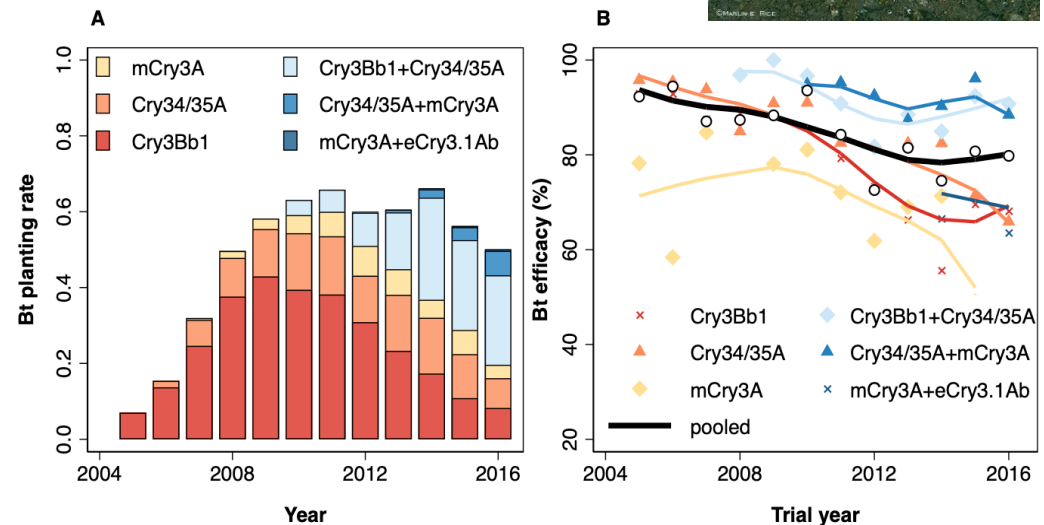
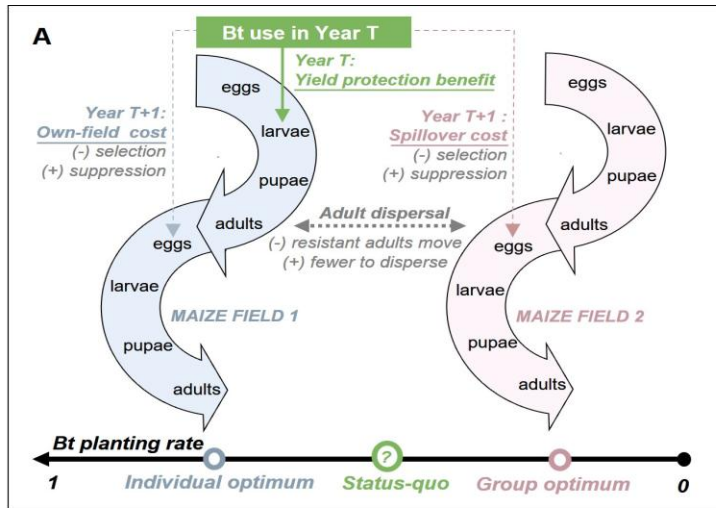
“Halo effect”: Bt corn & Bt cotton reduce aflatoxin even in peanuts, though there are no transgenic peanuts!

- The same pests – borers & weevils – affect corn, cotton, & peanuts (*Helicoverpa zea*, *Spodoptera frugiperda*, *Elasmopalpus lignosellus*)
 - → If Bt corn & cotton reduce pest populations, benefits neighboring crops, including peanuts
 - Insurance claim analysis: **controlling for other factors, Bt corn or Bt cotton planting in same county as peanut planting reduced aflatoxin-related & drought-related insurance claims in peanuts significantly**
 - Global implications for nations allowing Bt cotton but not other GMOs: Africa, south & southeast Asia, China



Yu J, Hennessy DA, Wu F (2024). Bt corn and cotton planting may benefit peanut growers by reducing aflatoxin risk. *Plant Biotechnology Journal* doi:10.1111/pbi.14425.

The problem: insects evolve resistance to Bt corn



Ye Z et al. (2025). Too much of a good thing: Lessons from compromised rootworm Bt technology in the US Corn Belt. *Science* 387, 984-9.

Nutrition: Golden Rice, gene editing



- Golden Rice first created in 1999 to provide beta-carotene to vitamin A deficient populations worldwide
 - Vitamin A deficiency → blindness, hearing loss, infectious disease, child mortality – South & East Asia, sub-Saharan Africa
 - Golden Rice Humanitarian Board provides technology for free; cost same as conventional rice
- 29% children suffer VAD worldwide: >200,000 excess deaths
- Multiple nations including US approve Golden Rice for consumption, but no nation yet for cultivation
 - Philippines allowed; the overturned for “biosafety” reasons
- Can gene editing be more accepted to introduce nutrients?

Wu F, Wessler J, Zilberman D, Russell RM, Chen C, Dubock A (2021). Allow Golden Rice to save lives. *Proceedings of the National Academy of Sciences*, 118 (51) e2120901118.

Pivot Bio PROVEN 40: GE soil bacteria to fix nitrogen from atmosphere

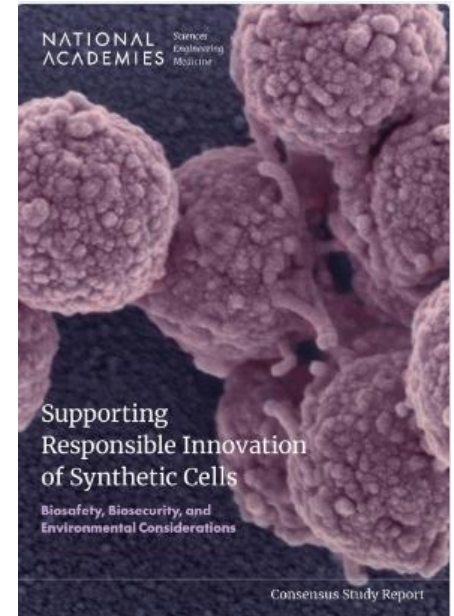


- GE *Klebsiella variicola* rhizobacteria fix atmospheric N at higher rates than other soil bacteria, & direct to crop roots
 - Bacteria live on roots of cereals: maize, rice, wheat
- Approved in US: used mostly in maize
- Goal: reduce fertilizer inputs
 - Globally, reduces major cost to farmers
 - Most N fertilizer can't be used effectively by crops: runs off into surface water, groundwater (methemoglobinemia: "blue baby syndrome")
 - Environmental benefits: less fertilizer runoff, fewer harmful algal blooms (HABs) → fewer fish kills, ***fewer phycotoxins in seafood***
 - Counteracts climate impacts of increased HABs & attendant risks



Synthetic cells may improve crop production & food safety

- Apply synthetic cells to soil to migrate to crop roots & produce nutrients locally
- Nutrients needed by crops from soil:
 - Nitrogen for leaf growth
 - Phosphorus for root & fruit development
 - Potassium for regulating photosynthesis & water uptake
- Conventional fertilizers applied broadly & inefficiently, causing water pollution problems
- Synthetic cells can be engineered to sense chemical signals from crop plant roots: release nutrients only then in precise, localized amounts



National Academies of Sciences, Engineering, and Medicine (Wu F, Co-Chair of Committee). 2026. *Supporting Responsible Innovation of Synthetic Cells: Biosafety, Biosecurity, and Environmental Considerations*. Washington, DC: The National Academies Press.

Summary



- Agricultural biotechnology *old & new* could address food safety risks, if commercialized
 - “Old” biotechnologies such as transgenic Bt corn could have halo effects not just to reduce mycotoxin risk, but to reduce problems at geographic scale
 - New biotechnologies could further improve food safety, nutrition, & food security for public health
- Applications extend far beyond food safety, & could benefit food security worldwide
 - But how accepted will they be worldwide?
- Thank you! fwu@msu.edu