Genetic Modification and Genome Editing in Plants

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01

Introduction to GMOs

What are GMOs?

- Genetically modified organisms
- The genetic information of an organism is being modified through genetic engineering
- Genetic modification consists of DNA being inserted into the genome of an organism
- New DNA would then be transferred into plant cells

History of BT Crops

- BT as insecticide derived from the bacterium Bacillus Thuringiensis was used since the 1920s, however, with increased pesticide resistance and increased awareness of the harmful effects an alternative had to be developed

- In the 1980s with the advent of more biotechnology developments the genes from the bacterium were inserted into plants so that pests would die off as a result of eating the plant

- This lead to many ethical issues including the environmental impact, economic and social issues, impact on human health, industry control, as well as labelling and consumer choices

02

Stakeholders & Interested Parties

Stakeholders and Interested Parties

In favor of

- **Farmers** - use to prevent crop loss, pest resistance, increased crop yields
- **Consumers/general public** - many consumers enjoy the improved nutritional value, longer shelf life, lower prices, greater food security
- **Biotech companies** - develop and produce the products
- **Food industry** - many food companies use genetically modified ingredients in their products

Against

- **Consumers/general public** - some are concerned about the safety of GMOs and believe they may cause diseases and other long term effects
- **Environmental groups** - may negatively impact the agricultural ecosystem, have caused biodiversity loss, development of pest resistance

Neutral

- **Regulatory agencies (USDA, EPA, FDA)** - government agencies oversee the regulation and safety of agricultural and biotech products
- **Scientists/researchers** - study and research the effects of genetically modified products

03

BT Cotton

What is BT Cotton?

- BT cotton is a genetically modified to be resistant to bullworms/moth insects
- Bull Worms have caused significant damage to multiple crops particularly cotton as they eat through the cotton to the seeds
- The worldwide cotton industry is worth $38.5 billion dollars as of 2021 and is expected to grow 4% by 2027
- The industry also provides income for 250 million people worldwide and makes up 7% of all labor in developing countries
- This is a very large market and lucrative market highly dependent on the plants themselves

Case Study of BT Cotton

Sustainable agriculture and GM crops: the case of Bt cotton impact in Ballari district of India

This case study aims to look at the long term effects of BT cotton particularly in a specific portion of india

The study took into account 320 households that were randomly selected and different variables were tested to see the implications of BT cotton over the span of 15 years

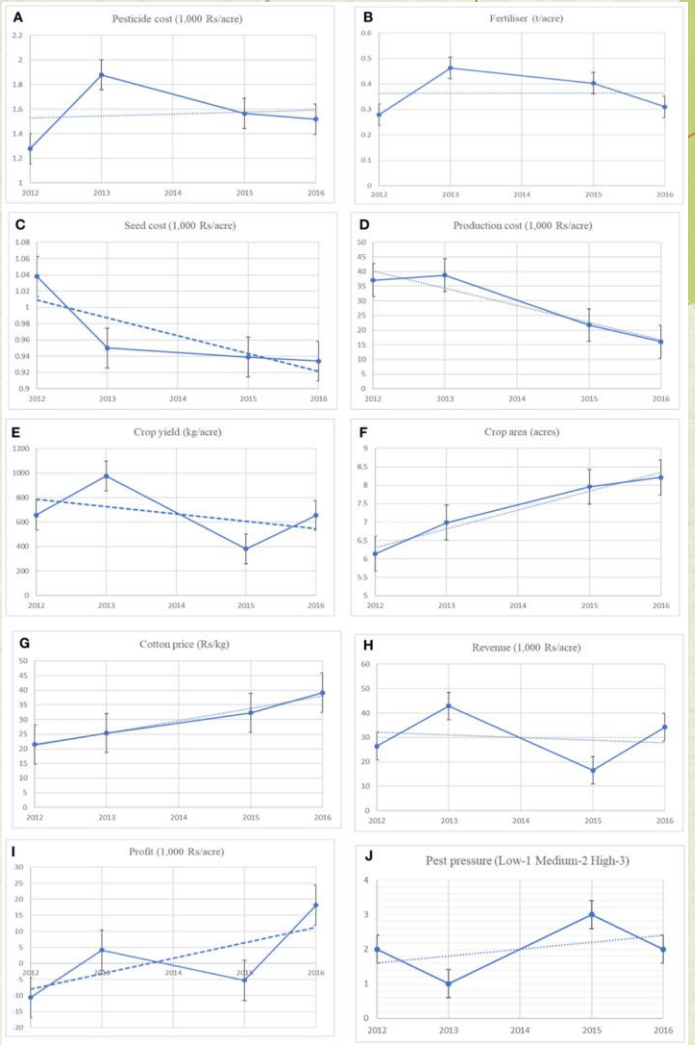
- These variables included: seed cost, seed rate, pesticide cost, yield rate, revenue etc

This study also took into account the pest rate and the relative pest severity and analysed these rates along with the other variables

The data was then analyzed to observe if any long term benefits were found of introducing BT cotton

Plot level information	2002-2004	2006-2008	2012-2013	2013-2014	2015-2016	2016-2017
	(1)	(2)	(3)	(4)	(5)	(6)
Seed cost (1,000 Rs/acre)	1.60 (0.43)	0.91 (0.32)	1.038 (0.225)	0.954 (0.186)	0.939 (0.103)	0.934 (0.284)
Seed rate (g/acre)	490.72 (114.23)	570.75 (160.93)	1163.262 (435.553)	1069.781 (488.353)	924.001 (410.335)	1025.701 (267.135)
Pesticide cost (1,000 Rs/acre)	1.43 (1.57)	1.07 (1.38)	1.278 (1.101)	1.879 (1.318)	1.564 (1.109)	1.518 (1.327)
Fertiliser (t/acre)	0.26 (0.16)	0.25 (0.15)	0.279 (0.191)	0.463 (0.298)	0.403 (0.283)	0.310 (0.139)
Fertiliser cost (1,000 Rs/acre)	n.a	n.a	3.811 (2.732)	6.754 (4.720)	6.258 (4.667)	4.453 (2.096)
Micronutrients (1,000 Rs/acre)	n.a	n.a	0.035 (0.132)	0.066 (0.166)	0.184 (0.295)	0.146 (0.117)
Yield (kg/acre)	705.40 (360.41)	829.03 (341.08)	657.321 (430.693)	975.551 (488.202)	380.342 (219.701)	654.627 (228.533)
Profit (1,000 Rs/acre)	6.14 (6.89)	10.32 (7.73)	-10.639 (44.162)	4.145 (31.591)	-5.248 (11.964)	18.178 (10.162)
Production cost (1,000 Rs/acre)	7.65 (2.94)	9.03 (5.12)	37.027 (46.891)	38.758 (28.098)	21.741 (9.381)	16.082 (5.545)
Revenue (1,000 Rs/acre)	13.79 (7.32)	19.35 (8.42)	26.388 (17.924)	42.904 (23.391)	16.493 (9.519)	34.261 (11.832)
Crop area (acres)	6.20 (6.73)	5.79 (4.60)	6.138 (5.159)	6.984 (7.687)	7.957 (9.731)	8.214 (8.872)
Cotton price (Rs/kg)	19.52 (2.69)	23.31 (4.05)	21.452 (13.921)	25.401 (16.772)	32.284 (26.872)	39.173 (32.312)
Share of cotton area in total cultivated area	n.a	n.a	0.680 (0.286)	0.681 (0.284)	0.678 (0.313)	0.718 (0.309)

Columns (1) and (2) are taken from Kathage and Qaim (2012). Mean values are shown with standard deviations in parentheses. "n.a" in columns (1) and (2) refers to "not available" because Kathage and Qaim (2012) do not report this in their paper. One acre is equal to 0.405 hectares.



Results and Implications of the Study

As the data was analyzed it was found that at a micro level there was benefit of growing BT cotton, however, there are minimal benefits over the course of a decade

The study states:

> "More specifically, despite Bt technology that is claimed to be protecting from pink bollworms, farmers suffered massive yield losses from the pest. It represents a significant threat to the livelihoods and the very lives of millions of subsistence Indian cotton farmers."

This raises a multitude of ethical issues many of which directly impact the farmers involved in the production process of cotton along with the companies that produce cotton seeds

Ethical Issues of BT Cotton

- Issues with growth
    - Historically BT cotton was designed to work in environments that are cooler and have less pest infestations such as the US, the technology is less effective in hotter environments such as india which has more pests than just the bullworm. This leads to government push for BT cotton adoption however, farmers suffer the same loses as seen by the study
    - BT cotton therefore impacts small farmers greatly and does not provide much economic gain for them long term
    - The push for BT adoption only stresses farmers out further leaving them without proper regulation and rights
    - It is estimated that between 1995 and 2018 400,000 thousand farmers have taken their lives due to bad crops and increased government pressure

Ethical Issues of BT Cotton

- Company Monopoly
    - While BT cotton has been shown to be much less effective in India, the company Monsanto which owns the BT cotton seeds in india has been pushing for more adoption
    - Monsanto itself has been involved in many scandals and is known for prosecuting farmers for technology infringement and harassing them with lawsuits.
- Environmental Effects
    - Since BT cotton is less effective, to combat the other pests found in countries such as india heavy pesticides are still used which pose a hazard to both human health and the farmers health

Obligations and Choices

Companies and Stakeholders

It's the company's responsibility to consider the farmers rights and abilities and provide the correct information and products

Scientists and Researchers

As seen by the study, certain gmo crops in this case BT cotton can be less effective depending on the environment In the case for india, they would have to develop crops that are effective in combating a multitude of pests not just bullworms

Regulatory Agencies

Since farmers often lack autonomy in voicing their opinions due to socioeconomic issues, it is the regulatory agencies responsibility to ensure justice and accountability for companies and the government

General Public

It is also on the general public to boycott and raise awareness for the injustices that farmers might face

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BT Corn

BT Corn: A Breakthrough in Agricultural Biotechnology

- "BT Corn addresses challenges posed by the European corn borer."
- "Innovative blend of genetics and agriculture."
- "Genetic engineering using Bacillus thuringiensis DNA."
- "Significant reduction in pesticide use."
- "Enhanced crop yield and efficiency."
- "Revolutionizes traditional corn farming methods."
- "A sustainable approach to pest management."
- "Marks a shift towards eco-friendly farming practices."

Navigating the Ethical Landscape of BT Corn

- "Health concerns about Cry proteins in BT Corn."
- "Potential allergenic reactions, a subject of debate."
- "Impact on ecological systems and non-target species."
- "Risks of developing pest resistance to Cry proteins."
- "Genetic pollution: Transgenic DNA found in Mexican corn."
- "Balancing agricultural benefits with environmental risks."
- "Socioeconomic implications for farmers and consumers."
- "Global regulatory challenges and frameworks."
- "Need for ongoing research and monitoring."
- "Ethical responsibility in biotechnological advancement."

BT Corn: Pioneering and Controversial

- "BT Corn as a symbol of agricultural innovation."
- "Catalyst for ongoing ethical and environmental discussions."
- "Highlights the complexity of genetic modification."
- "Diverse perspectives from scientists, farmers, and advocacy groups."
- "Importance of comprehensive research and understanding."
- "Regulatory frameworks essential for safe implementation."
- "Debate reflects evolving attitudes towards GM crops."
- "Responsibility to balance technological progress with ethics."
- "A call for informed decision-making in agricultural biotech."
- "Emphasizes the need for a balanced approach to future innovations."

04

BT Potatoes

Background of BT potatoes

- Developed to resist pests, notably the ***Colorado potato beetle***.
- This modification dates back to the late 20th century, leveraging Bacillus thuringiensis (BT) bacteria's natural pesticidal properties.
- The timeline of BT potatoes mirrors the broader history of GMOs, marking a shift towards biotechnological solutions in agriculture.

- The modification process involves inserting a gene from BT bacteria into the potato's DNA.
- Enable potatoes to produce a toxin harmful to specific insects but safe for human consumption.
- Enhance crop resilience and open the door to future advancements like improved resistance to diverse pests and adaptation to climate change.
- These ongoing innovations continue to broaden the potential applications and benefits of BT Potato technology.

Ethical Aspects

- Considerations about the environmental impact, such as potential effects on non-target species and local biodiversity
- Concerns regarding human health and the long-term ecological consequences.

- **Stakeholders** in this narrative range
  - Farmers
  - Consumers
  - Biotech firms
  - Environmental groups

05

Choices & Consequences

Choices & Consequences

Reducing the Environmental Impacts of GMOs

- Isolation and Containment Measures between GMO & Non-GMO crops
  - Spatial Separation + Buffer Zones → reduces risk of gene contamination + gene flow
- Public Education and Awareness
  - Conduct education programs to inform farmers, communities, and consumers about the environmental benefits & potential risks of GMOs

Economic Equity

- Empowerment of small-scale farmers
  - Provide resources and support to small-scale farmers to adopt and benefit GMO technology

Choices & Consequences

Health & Safety

- Long-Term Monitoring and Surveillance
  - Invest in research and development
  - Establish programs to track environmental, animal, human health, and socioeconomic impact of GMOs over time
- Regulatory Oversight
  - Enforce and update regulations that govern the release, cultivation, and labeling of GMOs
  - Ensure that regulatory frameworks prioritize environmental safety and sustainability
- Transparency and Information Sharing
  - Provide clear & accessible information of GMO development to the public
  - Transparency in labeling & risks associated with consumption → gain public's trust

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Conclusion

GMOs

- Wide range of GMOs from BT crops to genetically engineered commercialized fruits (i.e. non-browning apples, mosaic virus resistant papayas, pink-fleshed pineapples)

- Benefits:
  - increased crop yields
  - pest + disease resistance
  - improved nutritional content
  - extended shelf life

- Stakeholders involved:
  - farmers, biotech companies, the food industry, scientists/researchers, regulatory agencies, environmental groups, the public

The Ethical Issues of GMOs

- **Environmental Impact**
  - potential effects on non-target organisms + overall health of ecosystem
- **Gene Flow**
  - genetic contamination to native plant species
- **Consumer Choice & Informed Consent**
  - transparency in labeling + risks associated with consumption
- **Health & Safety**
  - rigorous testing + long-term evaluation; allergen concerns
- **Economic Equity**
  - Impacts towards traditional farming; affects the livelihood of small-scale farmers
- **Ethical Use of Technology**
  - responsible research practices, considers potential risks, adheres to regulatory guidelines

Thank You!

Any Questions?

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