Innovations in seed for sustainable and economic cotton production

10th Open session: Genetics, Diversity to enhance cotton productivity
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Agenda

• Innovations in Seed
• GM cotton technologies
  • Contribution to Agriculture & Environment
  • Commercialized
  • Under development
• Challenges
• Opportunities for consideration
• Summary
Innovation in Seeds can be achieved through...

- **Genome Editing**
  - SDN 1, SDN 2 and SDN 3
    - Disease resistance, weed control
    - Quality traits

- **Genetic Engineering**
  - Insect resistance
  - Disease tolerance
  - Herbicide tolerance
  - WUE
  - NUE
  - Drought tolerance
  - Quality traits

- **Breeding**
  - Genetic variability
  - Genetic diversity
  - Interspecific segments
  - Molecular breeding
  - **Precision Breeding**
  - Quality parameters
  - Native traits
GM IR traits: Reduce the environmental & human health impacts of pesticides

- Less insecticide sprays and conserve beneficial insects
- No or negligible impact on non-target organisms
- Protect biodiversity
- Reduce farm worker exposure to pesticide sprays

Raven PH. 2010.
Marvier et al., 2007
Carpenter, J. E. 2013
GM HT traits: Facilitate the adoption of no-till and conservation tillage systems and the related environmental and ecological benefits

- Less Erosion and Healthier Soil
- Conserve Soil Moisture
- Reduce Soil Compaction
- Low Greenhouse Gas Emissions
- Additional carbon storage

Brookes, G. and R. Barfoot 2014
## GM Cotton traits commercialized across the globe

<table>
<thead>
<tr>
<th>Trait</th>
<th>Singles</th>
<th>Combinations</th>
<th>Stacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insect resistance</td>
<td>LEP’s Sucking pests</td>
<td>LEP’s</td>
<td>With HT</td>
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<td>LEP’s</td>
<td>With HT</td>
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<tr>
<td>Herbicide tolerance</td>
<td>Glyphosate</td>
<td>Gly +Glu</td>
<td>with IR</td>
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<tr>
<td></td>
<td>Glufosinate</td>
<td>Gly + isoxaflutole</td>
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<td></td>
<td>Bromoxinil</td>
<td>Gly + Glu + 2,4-D</td>
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<tr>
<td></td>
<td>Sulfonyl urea</td>
<td>Gly + Glu + Dicamba</td>
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<td>Gly + Glu + Isoxaflutole</td>
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<td>Gly + Glu+ Dicamba + Isoxaflutole</td>
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<td>Glu + 2,4-D</td>
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<td>Output traits</td>
<td>Low gossypol</td>
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Twenty-five Years of Biotech Cotton Success

1996
Bollgard®
(MON531 – Cry1Ac)
- High dose (>99.9%) for tobacco budworms
- 75-90% control for cotton bollworm
- Greatest resistance risk in the South
- 5% refuge

1997
Roundup Ready™ Cotton
(MON1445 – cp4 epsps [aroA:CP4])
- Allowing the use of glyphosate herbicide over the top of the cotton crop, as weed control cotton

2003
Bollgard II®
(MON15985 – Cry1Ac/Cry2Ab2)
- Cry2Ab2: a second high dose for tobacco budworms
- Cry1Ac + Cry2Ab2: An effective high dose for cotton bollworm
- Natural refuge

2006
Roundup Ready® Flex Cotton
(MON88913 – cp4 epsps [aroA:CP4])
- Enabled flexibility of glyphosate application over the top of the cotton crop to include later stages of development

2016/2017
Bollgard 3
(MON15985 x COT102 [Vip3Aa19])
- Vip3A reinforces B proteins in Bollgard II
- Multiple modes of action for cotton bollworm
- Natural refuge

2021
ThryvOn™ Technology
(MON88702 – modified Cry51Aa2)
- First season-long product with effective and consistent control against Lygus and Thrips, which leads to a direct reduction in the need for insecticide sprays

2022
Bollgard 3
(MON88701 [dim-o-har] x MON88913) with BGII or BG3
- Xtend flex technology offers tolerance to these herbicides: dicamba, glyphosate and glufosinate with an efficient and effective weed management system
Best in class innovation for cotton growers

**ThryvOn™ Technology**

*Industry first biotech trait* for piercing and sucking insects.

**Bollgard® 4**

4th generation cotton trait multiple modes of action for key lepidopteran pests

**HT4 cotton**

Biotech trait with five herbicide tolerances

Advancing sustainable agriculture

Industry-first biotechnology trait will dramatically expand grower options and reduce crop protection applications.

Weed control systems enable conservation farming practices, improving carbon sequestration.
## GM Cotton traits : Private sector pipeline*

<table>
<thead>
<tr>
<th>Trait</th>
<th>Players</th>
<th>Genes</th>
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</thead>
<tbody>
<tr>
<td>Insect resistance (leps)</td>
<td>Bioseed</td>
<td>Cry2Ai</td>
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<td></td>
<td>Dow</td>
<td>Cry1F+Cry1EC</td>
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<td>JK Seeds</td>
<td>Cry1Ac + Cry1EC</td>
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<td>Krishidhan</td>
<td>Cry1Ac+Cry1EC</td>
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<td></td>
<td>Metahelix</td>
<td>Cry1Ac, Cry1F, Cry1C+Cry1A</td>
</tr>
<tr>
<td>Insect resistance (sucking pests)</td>
<td>Bioseed</td>
<td>asal</td>
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<tr>
<td>Herbicide tolerance</td>
<td>Mahyco</td>
<td>Glyphosate tolerance</td>
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<tr>
<td></td>
<td>Metahelix</td>
<td></td>
</tr>
<tr>
<td>Virus resistance</td>
<td>Mahyco</td>
<td>Coat protein gene of TSV</td>
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<tr>
<td>Nitrogen use efficiency</td>
<td>Mahyco</td>
<td>AlaAt</td>
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<tr>
<td>Water use efficiency</td>
<td>Mahyco</td>
<td>Ipt</td>
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</table>

*Information as per literature / announcements in public domain.

*Bayer, Corteva, BASF, BioHeuris, PlantArcBio speculated to be working on next gen IR and HT traits*
GM cotton traits: Public Institutes Pipeline*

Virus resistance (CSIR)

Virus Resistance Coat Protein, Drought (CICR)

Sucking pest Control (CICR)

Truncated Cry1F Cry1A3 (CICR)

Cry1EC, Cry1Ac, Cry2Axi, AFAL (NBRI)

Cry1Fa1, cry2Aa, cry1AC-F /Drought (NRCPB)

Sucking pest and Virus Resistance (PAU)

CryIAa1, CryIAbl, CryIAc1 and CryIAl (IARI)

Fungal Resistance Chitinase (CICR)

Cry2a, Cry1Ax1 (TNAU)

Virus Resistance (CCS HAU)

Sucking pest/drought (NBRI)

*Information as per literature / announcements in public domain.

A new approach is needed to deliver greater innovation.
Precision Breeding & Product Design

- Thousands of genomic datapoints on every new line
- Prediction models for all product-defining traits
  - Examples: lint yield, length, strength, bacterial blight resistance
- Algorithms that allow us to start with the end in mind
  - Biotech trait package
  - Disease resistance requirements
  - Target range of environments
- If breeding is finding a needle in a haystack, now we are focusing our technology development on putting more needles in the haystack

+ Improved prediction models and algorithms to guide new starts earlier in the pipeline with full product in mind
+ Improved phenotyping and operational technologies enable larger breeding pipeline and datasets
Cotton Precision Breeding Strategy

- Prescriptive Data Collection
- Genomic prediction
- Genetic Evaluation
- Selection Index
- Faster cycle time
Evolving from selecting the best to designing the best

What we can learn from seed chipping, markers, genetic mapping and predictive analytics

- Proprietary seed chipping technology enables breeder to *know every seed*

- Latest marker-assisted breeding, genetic mapping and predictive analytics fuel an increase in the number of products screened early in the breeding process

- Researchers can make faster decisions to pinpoint which products are best for testing in local fields

- Powered by data analytics, breeders can make more informed selections earlier in the pipeline to enable longer field testing before commercialization

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**Seed Chipper**

A sample of DNA from a seed chip is sequenced and analyzed

**Sequencing Machine**

A 2x2 inch gene sequencing chip holds the equivalent of 14 acres of information

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Millions of data records are analyzed nightly from our breeding database, accelerating our research pipeline. The use of molecular markers identifies key genes in combating diseases.
Transforming Seed Logistics

Delivering more valuable, timely data on each product

Evolving our operations to better represent customer fields...

New, centralized seed distribution process enables seeds to be counted, sorted and then organized to be planter ready - providing new levels of precision and data accuracy.

Adaptable, high throughput seed processing and distribution system capable of managing hundreds of thousands of SKUs for our global field testing program.

Optimally select and manage plot locations, represent a broader diversity of field conditions, and maximize product evaluation.

Video: Transforming Seed Logistics Brings Value to our Customers
Challenges

Purpose of technology

Policy

Regulations / guidelines

Stakeholder Engagement

Resources

Germlasm / Pedigree

sustenance

• Cultivation
• Seed Production
• Quality
• Handling & Distribution

• Suitability
• Amenityability

• Commercial viability
• Stakeholder acceptance
• Management programs

• Time
• Money
• People

• Agriculture road map
• IP / PVP regimes
• Partnerships

• Developing to Developed
• Long, time taking process
• Multiple agencies
• Multitude of guidelines / requirements

• Alignment & commitment
• Knowledge gap
• Process delays
• Voice of the farmer

• Agricultural sustenance
Factors to ensure success of innovation

- Priority: Identify & define key requirements for each geography, focus on it.

- Partnerships: Global / Regional, Public & Private
  - Coalition for breeding / R &D

- Policy & Regulations: In the areas of technology, germplasm exchange, value sharing mechanism, decision making, approval process etc.

- Resource allocation: Monetary support, incentives, Manpower, Technical knowhow

- Sustainability: Awareness and education programs, Monitoring & Stewardship programs
Introduction of GM traits has helped cotton growers to increase productivity, provided social and economic and environmental benefits. Promotion and adoption of new methods like Genome editing, Precision breeding techniques at a faster pace is required to address biotic and abiotic factors.

A well define policy regime supported with predictable regulatory approval process would open doors for investment in developing innovative solutions.

Innovations in seed should be combined with other programs – GAP, CP, biologicals etc – to maximise the benefits.

For sustainability, implement stakeholder awareness programs, monitoring and stewardship programs etc.

Innovations should help to reduce input cost, increase productivity and help to conserve natural resources.
THANK YOU