Participatory breeding for Securing Organic Cotton and Genetic Diversity

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Why we get engaged in organic cotton breeding in India?
Challenges of organic cotton in India

• India has been the largest organic cotton producer, 10 years ago India supplied 80% but dropped now to 56%, with a decrease of 20% from 2014/15 to 2015/16!!!

• Organic cotton in India is less than 2%, while genetically modified Bt cotton reached 95% in less than 10 years

• Public breeding and seed multiplication were neglected

• Local non-GM seed supply were eroded

• Commercial seed companies have limited interest in non GM cotton (higher production risks, risk of Bt contamination, small demand)

• High dependency on global seed company holding Bt licence resulting in high seed price and concentration on high input agriculture (high level of fertilizer, pesticide, irrigation)

• Breeder’s seed is already contaminated with Bt, causing Bt contamination throughout the cotton value chain
India fastest adopter of Bt cotton

Reference:
www.transgen.de
## Cultivated cotton species in India

<table>
<thead>
<tr>
<th>Species</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gossypium hirsutum</td>
<td>Upland cotton tetraploid</td>
</tr>
<tr>
<td>Gossypium barbadense</td>
<td>Pima / Egyptian cotton tetraploid</td>
</tr>
<tr>
<td>Gossypium arboreum</td>
<td>Desi cotton diploid</td>
</tr>
<tr>
<td>Gossypium herbaceum</td>
<td>Desi cotton diploid</td>
</tr>
</tbody>
</table>

![Images of cotton plants]

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Historic development of cotton species in India

Prof. Dr. R. W. Bharud, Mahatma Phuke Agricultural University
Rahuri, MA, All Indian Cotton Improvement Project

→ 95% F1 hybrids of Bt hirsutum cotton
→ loss of genetic diversity
→ loss of farmers’ choice for GMO-free seed
→ endangered organic cotton production in India
Challenges and Research Gaps of Organic Cotton

- Limited genetic improvement of non-GM cotton after introduction of Bt-cotton
- Missing public breeding programs for organic and low input conditions and nationwide cultivar testing under organic conditions
- Loss of genetic diversity: the more resilient traditional desi cotton (G. arboreum) disappeared from production
Selecting the right cotton varieties

**American Upland cotton (G. hirsutum)**

- **Advantages:**
  - High yields
  - Longer staple (higher price)

- **Disadvantages:**
  - Needs more water
  - Needs more manure
  - More prone to pests

- **Suitable for:**
  - Deep soils
  - Heavy soils
  - Good irrigation

**Indian ‘desi’ varieties (G. arboreum, G. herbaceum)**

- **Advantages:**
  - Better drought resistance
  - More tolerant to succing pests

- **Disadvantages:**
  - Longer vegetation period
  - More difficult to pick
  - Mostly shorter staple (lower price)

- **Suitable for:**
  - Shallow soils
  - Sandy soils
  - Little/no irrigation
## Seeding the Green Future – Participatory organic cotton breeding

### Objectives

- Re-establish non-GM cotton seed chain in India
- Develop new cotton cultivars adapted to organic farming
- Foster varietal lines and traditional cotton species
- Seed sovereignty
- Empowerment of farmers

### Methods

- Participatory cotton cultivar trials
- Initiate decentralized participatory cotton breeding
- Capacity building with focus on female and tribal farmers
- Advocacy on international level
First Steps: The Dharwad Declaration

National Workshop June 21st 2011: «Disappearing non-GM cotton - ways forward to maintain diversity, increase availability and ensure quality of non-GM cotton seed» Dharwar Declaration

Jointly organized by bioRe India Ltd., FiBL Switzerland, University of Agricultural Sciences Dharwad including main stakeholders

To combine forces for immediate action and support of:

- Collaboration & Exchange, e.g. private public partnership
- Desired Policy Changes, e.g. establishing GM-free zones
- Evaluation and multiplication of existing cotton cultivars under organic and low-input conditions
- Establishing and optimizing the non-GM seed chain
- Continuous improvement of non-GM cultivars
Organic cotton research in India and advocacy


- **Participatory Cotton Cultivar Evaluation**
- **Involvement in Seed & Soil Task force of Textile Exchange**
- **Green Cotton**
  - Cotton breeding & genetic diversity
- **Seeding the Green Future**
- **Farming Systems Comparison in the Tropics (SysCom) 2007 –2022**

- Workshop
  - Disappearance of non-GM cotton
- Follow-up workshop
  - Disappearance of non-GM cotton
- Organic
  - Cotton Seed Summit
- 2nd Participatory research Symposium

**1st Participatory research Symposium**

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Breeding Scheme

Time Table

Green Cotton
Phase I 2013-2016/17

2017

Seeding the Green
Phase II 2018-2022

Future Phase III
2022-

Further yield trials

F7

F6 – F12

Multi-location testing, licensing, seed increase and cultivar release

P1 x P2

F1

F2

Phenotypic screening

Plants spaced planted in rows for individual plant selection

F3

F4

Families grown in progeny rows for selection.

F5

F6

Preliminary yield trials. Select single plants.

F7

F8 – F12

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Formal plant breeding and seed supply

Participatory plant breeding and seed multiplication

One Way Information: Scientist

Extension Service

Farmer

Society

Public & Private Breeding

Variety release

Seed Propagation

Seed traders

Farmers

Climatologist

Molecular biologist

Agronomist

Social Scientist

Breeder

Seed producer

Economist

Customer

Trader

Politics

Farmer

Economist

Society

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Seeding the Green Future

Methodologies and Tools for Participatory Research

- Participatory rapid appraisal
- Mother - Baby Trial
- Farmer field schools
- Farmer research committees
- Participatory technology development
- Action research

Mother trial (on-station)

Baby trials (on-farm)

21 cultivars x 2 replication

Best 5 cultivars tested in 10 on-farm trials

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Start of on farm trial and training

Capacity building in

- Varietal Testing
- Seed multiplication
- Seed processing & cleaning
- Germination Testing
- Seed Health
- Storage
- Crossing techniques
- Selection techniques

Regular Workshops with all Stakeholders
Farmers Field Days and Demo Trials

Ceccarelli 2010

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Spreading of on farm trials

Ceccarelli 2010
Breeding material from different breeders or seed companies

Start participatory breeding at two cotton growers organisation: Selection of early and advanced generation

On-station & On-farm baby trials of best lines

MLT in different pedoclimatic regions

Two seed producer provide organic non-GM cotton seed for ALL organic farmers

Seeding the Green Future
Capacity building
Involve farmers in selection criteria, cultivar testing & selection, breeding activity

Cultivar selection

Single plant selection

Priority of Traits for Farmers

<table>
<thead>
<tr>
<th>Trait</th>
<th>Male (%)</th>
<th>Female (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Many Branches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boll size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-5 compartments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep root</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boll opening</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easy picking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Easy cotton release</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous flowering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hairy leaves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Earliness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Wilting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germination</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiber quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disease tolerant</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Male (%)
- Female (%)
Creating new diversity of traditional cotton

- Collection of traditional Indian cotton *G. arboreum*
- Crosses of traditional Indian cotton and modern cotton species
- Multiplication of offspring
- Single plant selection in early generations (F2 - F5)
- Testing advanced generations (F6-F9)
Development and implementation of new cultivars

• Multilocation trials of 20 to 50 lines with replication in organic farms for yield stability, resistance, fiber quality in 3 different States under irrigated fertile soil and rainfed under sandy soil

• **150 on farm baby trials of best candidates** including traditional cotton and open pollinated cotton in 6 States and growing conditions

• **18 pilot trials** in farmers field to compare with hybrid cultivars

• **Seed multiplication** of best candidates in isolated areas

• Registration of cultivars

• Commercialization of truthfully labelled seed
SGF Trial Sites (2018-19)
150 on farm trials

1. Madhya Pradesh
2. Maharashtra
3. Rajasthan
4. Odisha
5. Gujarat
6. Andhra Pradesh

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Seeding the Green Future On-farm Trials

On-Farm Baby Trial with colour code

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Cultivar Type</th>
<th>colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suraj 1</td>
<td>HV</td>
<td>green</td>
</tr>
<tr>
<td>PA-255</td>
<td>AV</td>
<td>orange</td>
</tr>
<tr>
<td>Shankar-178</td>
<td>HV</td>
<td>blue</td>
</tr>
<tr>
<td>Mallika 207</td>
<td>HH</td>
<td>purple</td>
</tr>
<tr>
<td>Suraj 2</td>
<td>HV</td>
<td>green</td>
</tr>
<tr>
<td>Chetna_J1</td>
<td>HV</td>
<td>yellow</td>
</tr>
<tr>
<td>Namaskar 81</td>
<td>HH</td>
<td>pink</td>
</tr>
</tbody>
</table>

- Farmer can choose 5 from a set of 5 to 10 pretested cultivars where sufficient seed is available.
- In addition he needs to use always the same check which is replicated to allow for Bayesian statistics.

FiBL  See DIVERSIFOOD homepage and R-package
https://priviere.github.io/PPBstats_book/family-1.html#model-1
Seeding the Green Future On-farm Trials

On-Farm Pilot trials according to choice of farmer

Farmers field with his commercial cotton cultivar 0.4 acre

harvesting window to assess yield and fibre quality 5 x 5 m

new cotton cultivar 0.1 acre
Results highlight the need for agro-ecological zone specific cultivar development for different soil and water dynamics.
Systems-based breeding concept

Systems-based breeding including civil society, policy, nature, agriculture, and value chains and markets as interrelated components of the entire system.

Example for cross-sector promotion of organic cotton breeding

Poolfunding of organic breeding:
50% Foundation Mercator Switzerland
50% Organic Cotton Accelerator

Project Governance, Activities & Partners

Green Cotton Phase I 2013-2016/17
Seeding the Green Future Phase II 2018-2022
Seeding the Green Future Phase III 2022-2026

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Importance of International Cooperation

**Textile Exchange:**
- annual Organic Cotton Market Report
- established 2012 Organic Cotton Round Table
- with annual meetings the task force Seed & Soils

**Organic Cotton Accelerator:**
Pooling resources of international textile brands to support
- cotton breeding projects in India
- develop business models and sourcing practices that secure the integrity of organic cotton supply chain
First Results on Participatory Breeding and Conclusion

- Engagement of all actors of the value chain allow a targeted selection of cultivars that are best suited for their growing conditions and meet demand of market.

- Traditional desi cotton are more tolerant against sucking pest, more tolerant towards drought and flooding and morphological distinct from GM-cotton, and do not cross with them.

- Empowerment of female farmer and involvement in breeding improves adoption of new cultivar types.

- Training, capacity building, farmers organisations and shared decision power is important as well as a neutral facilitator fostering collaboration between cooperations.

- Linking farmers with textile industry is needed to develop a supply chain partnership with mutual benefit and secure supply of high quality organic cotton fiber.

- Breeding is part of the value chain and needs support from the textile industry.
Outlook
Linking Seed & Breeding Initiatives on global scale

- Capacity building to empower organic farmer organisations
- Sharing of information, knowledge, practices, testing protocols
- common R&D projects
- Status quo analysis of available species and cultivars
- Focus on biodiversity and adaptation to climate change
- Exchange of seeds: among partners, between countries? Open source seeds, farmer owned seeds
- Maintenance breeding with quality system to avoid GMO contamination
- Scholarship, Training, institutional exchange
- Political lobbying for organic cultivar testing
- Linking stakeholders, partner recruitment
- Develop business plan for breeding and seed production
- Common fundraising to approach different brands, Crowd funding
Farmers’ own seed

Commerical F1 Hybrids
Hirsutum varietal lines
Farmers own selections
Desi varietal lines

Farmer needs to buy each year

Chetna Cooperatives & Seed banks
Procure 400 kg of varietal seed cotton & gin

200 kg of locally suitable varieties stocked for 100 certified organic farmers.

Farmers can use their farm saved seed

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Tula
Roadmap of Seeding the Green Future

<table>
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<tbody>
<tr>
<td>Clusters &amp; FOs</td>
<td>Regions</td>
<td></td>
</tr>
<tr>
<td>2 clusters</td>
<td>Central India</td>
<td>Central, Southern</td>
</tr>
<tr>
<td>5 FOs</td>
<td>5 clusters</td>
<td>and Northern India</td>
</tr>
<tr>
<td></td>
<td>20 FOs</td>
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<td>10 clusters</td>
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<td>40 FOs</td>
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<tr>
<td>Regions</td>
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<tr>
<td>New cotton lines</td>
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<td></td>
<td>10</td>
<td>30</td>
</tr>
</tbody>
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Success factors to scale:
- Successful fundraising from donors, foundations, industry

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