NOVEL TECHNOLOGIES FOR COTTON, Today and tomorrow

Dr. C.D. Mayee

President, South Asia Biotechnology Centre (SABC)

& Indian Society for Cotton Improvement (ISCI)

WHY COTTON IS IMPORTANT ?

- There are nearly 7 million cotton farmers, mostly small
- Cotton & textile account for 1/3 of total foreign exchange
- Cotton provides employment to 43 m people, 7 million farmers + 36 million employed in textile industry
- There are > 1.8 M registered looms, 1600 spinning units and 290 composite mills
- Cotton, therefore has livelihood security attach to it

Uniqueness of King Cotton

- **India - four species of cotton**
- **Cotton - 9 to12 million hectares**
- **India - inter-specific diploid hybrids & intra-specific tetraploid hybrids**
- **Average cotton holding <1.5 ha; 8-8.5 million cotton farmers**

- **Diverse cropping practices including hand dibbling to drip-based-precision-planting to technology-intensive-inter-cropping system**

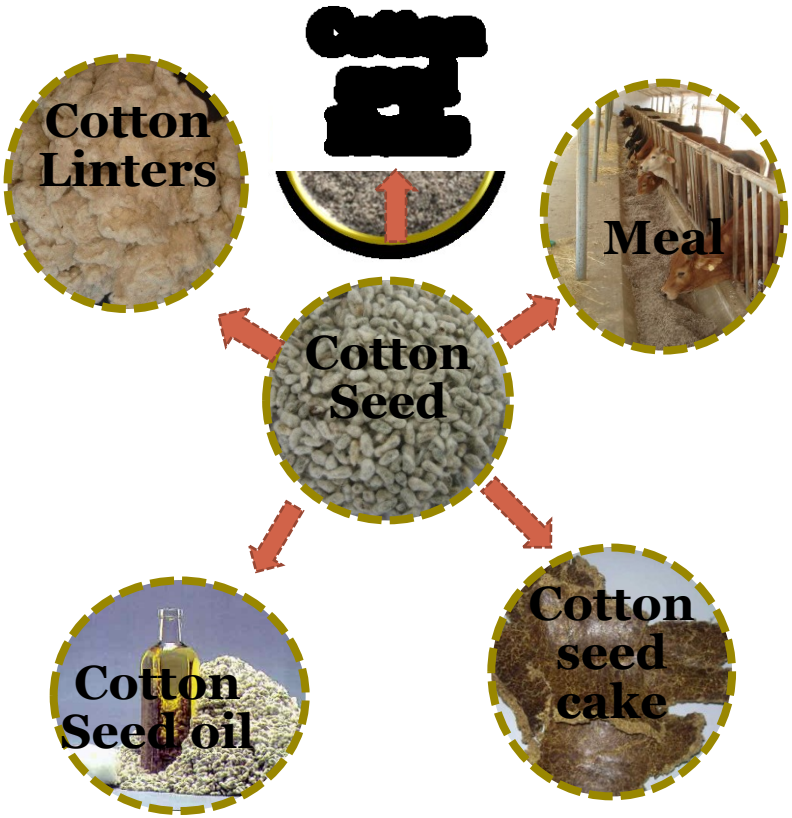
- **A robust cotton value chain providing employment to roughly 50 million people**

Value-addition to Cotton Plant By-produce

By-produce of Cotton

Cotton Seed
125 lakh tonnes per annum

Cotton Plant Stalks
30 million tonnes per annum



By- products of Cotton seed

Cotton Linters
5 lakh tonnes/annum

Cotton seed Hulls
34 lakh tonnes/annum

Cotton Seed oil
15 lakh tonnes/annum

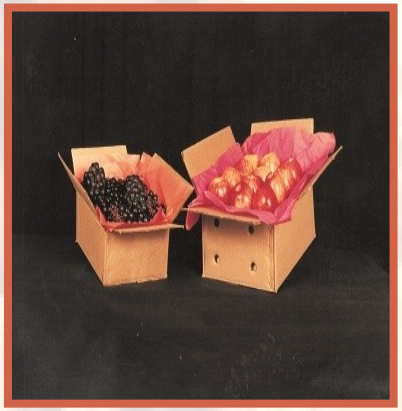
Meal
4.4 million tonnes/annum

Value addition to Cotton Stalk

- Particle Boards
- Pulps & papers
- Corrogated boxes
- Briquettes as fuel
- Bio-enriched compost
- Growing Mushrooms

Particle Boards from Cotton Stalks

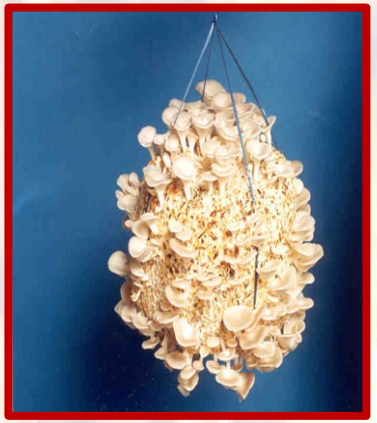
Pulps & papers



Corrogated boxes

Briquettes as fuel

Bio-enriched compost from cotton stalks
A- Cotton stalks
B- Compost



Growing Mushrooms

Advantages

- Additional income to farmers
- Rural Employment
- Avenues for Rural Industry
- New Raw Materials for industry
- Conservation of Natural Resources

COTTON: PAST

- Rich experience of growing cotton
- Productivity then was less that 60 kg lint per ha But processing technology fairly advanced
- Cotton trade to Britain began in 1640 through Calicut and hence the name Calico
- India was the largest exporter of textiles
- Desi cottons, *G.arboreum* and *G.herbaceum* were largely grown by the farmers
- Opportunities to be harnessed industry

COTTON: Post 1947

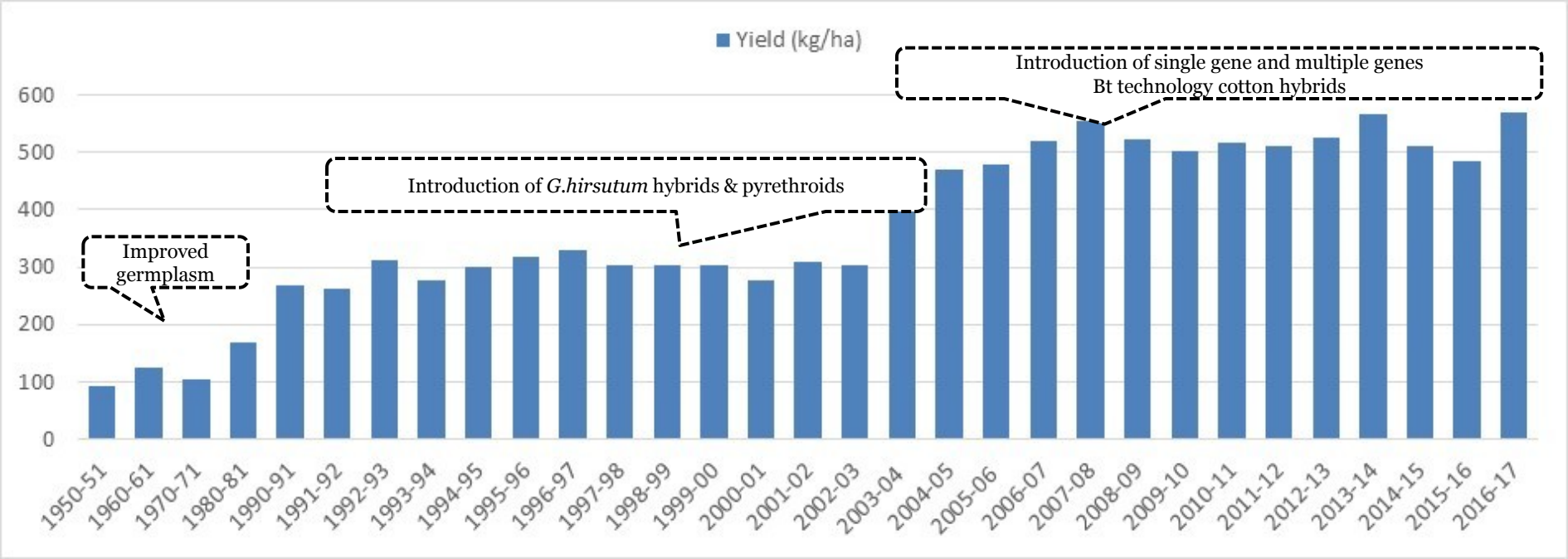
- Desi cottons were slowly but steadly replaced by american cotton, G hirsutum
- Quality improvement was given impetus with yield in new cottons
- Egyptian cotton, G.barbadense was also brought but due to high susceptibilty not spread in to main cotton growing areas
- Research was concentrated on the hirsutum cotton as it brought new problems like bollworms into prominence
- The fight against bollworm ended with plethora of insecticide in to cotton cultivation
- Opportunities to be harnessed industry

Technology Change in Cotton Growth

Period of change	Technology change	Production change (m bales)
1952 – 1962	Arboreums to hirsutams	6.80 (+2.61)
1962 – 1972	Hirsutam quality improvement	7.23 (+0.43)
1972 – 1982	Hybrids adoption (Inter and Infra-species)	9.90 (+2.67)
1982 – 1992	Pyrethroid Protection	14.00 (+4.10)
1992 – 2002	Technology fatigue (Bollworm resistance to Pyrethroid, sucking pest epidemic)	13.60 (-0.40)
2002 – 2012	Bt cotton era, hybrid expansion, Newer insecticides and IRM	32.00 (+18.19)

*In 1952, the production was 4.15 m bales with productivity of 105 kg lint / ha as against the production of 31.5 m bales with productivity of +500 kg lint / ha

PHASES OF YIELD STAGNATION IN INDIAN COTTON



Source: Analyzed by SABC, 2017

PHASES OF YIELD STAGNATION IN INDIAN COTTON

Yield levels (kg lint /ha)	Period of stagnation when range limited
88-110	1951-60
125-140	1961-70
150-180	1971-80
180-220	1981-90
250-320	1991-03
450-570	2011onwards

How to break the stagnation scene

- Yield stagnation broken by many countries form 600 kg /ha to 2600kg (Australia), 1600kg (Brazil), 1500kg(China, Mexico and Turkey)

- This was achieved by using Biotech mode, Water, micro-irrigation use, Mechanization, IPM, INM and use of technologies

- Can India regulate the ever expanding number of hybrids in eco-based cultivation

HOW DID INDIA BROKE THE LAST BARRIER ?

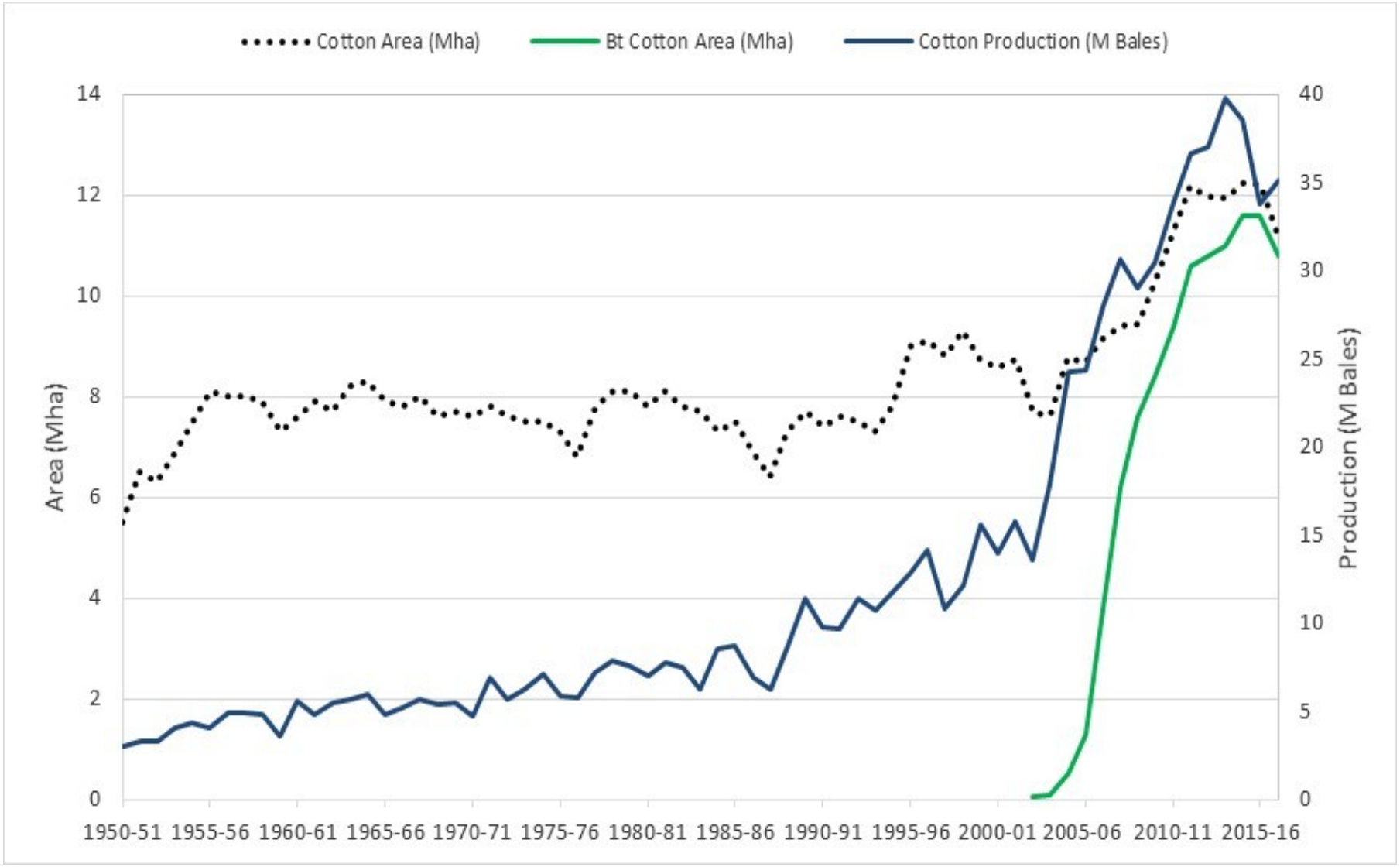
- The yield of cotton was stagnant for 15 years from 1989 till 2003
- BARRIER OF STAGNATION REMOVED BY ADOPTING THE BT COTTON IN 2002, THE FIRST AND ONLY BIOTECH PRODUCT
- And it changed the Indian cotton scenario ---

Why Biotech Cotton?

- Bollworm developed resistance to pyrethroids
- Cotton became highly susceptible to Lepidopteran pests
- *Frequent occurrence of the outbreak of Helicoverpa armigera* resulting in crop losses up to 80%
- Cotton consumed 46% of total insecticides valued at US$504 million in 2001
- Farmers suffered losses- annual yield as low as 300 kg/ha, and often <154 kg/ha in rain-fed areas
- Indiscriminate usages of chemical insecticides
- Increasing import of raw cotton to meet textile need

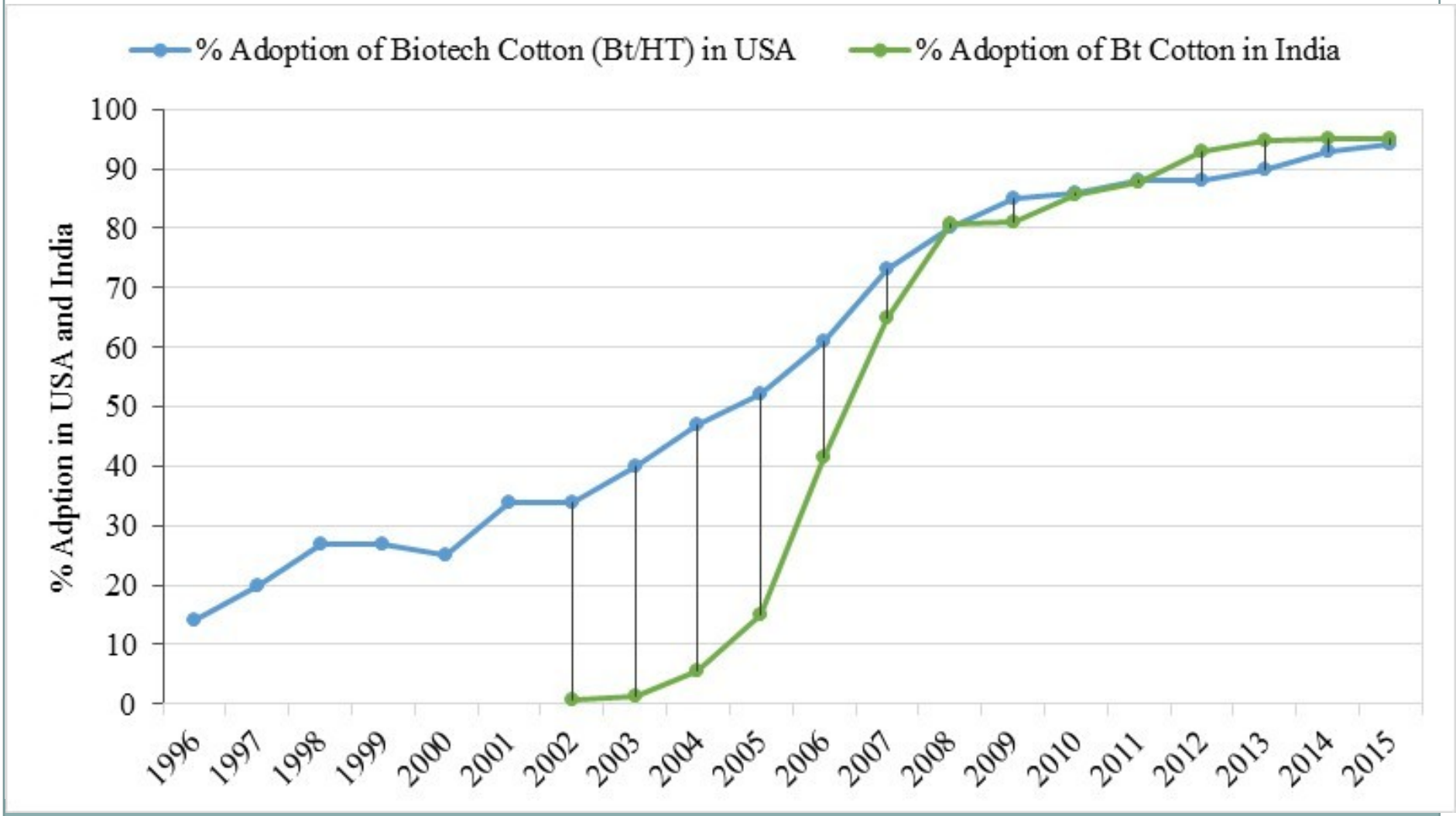
Source: ISAAA, 2016; ISCI 2013; Kranthi, 2012; Manjunath 2011; Mayee, 2013

Adoption of Biotech Cotton, 2002-2016



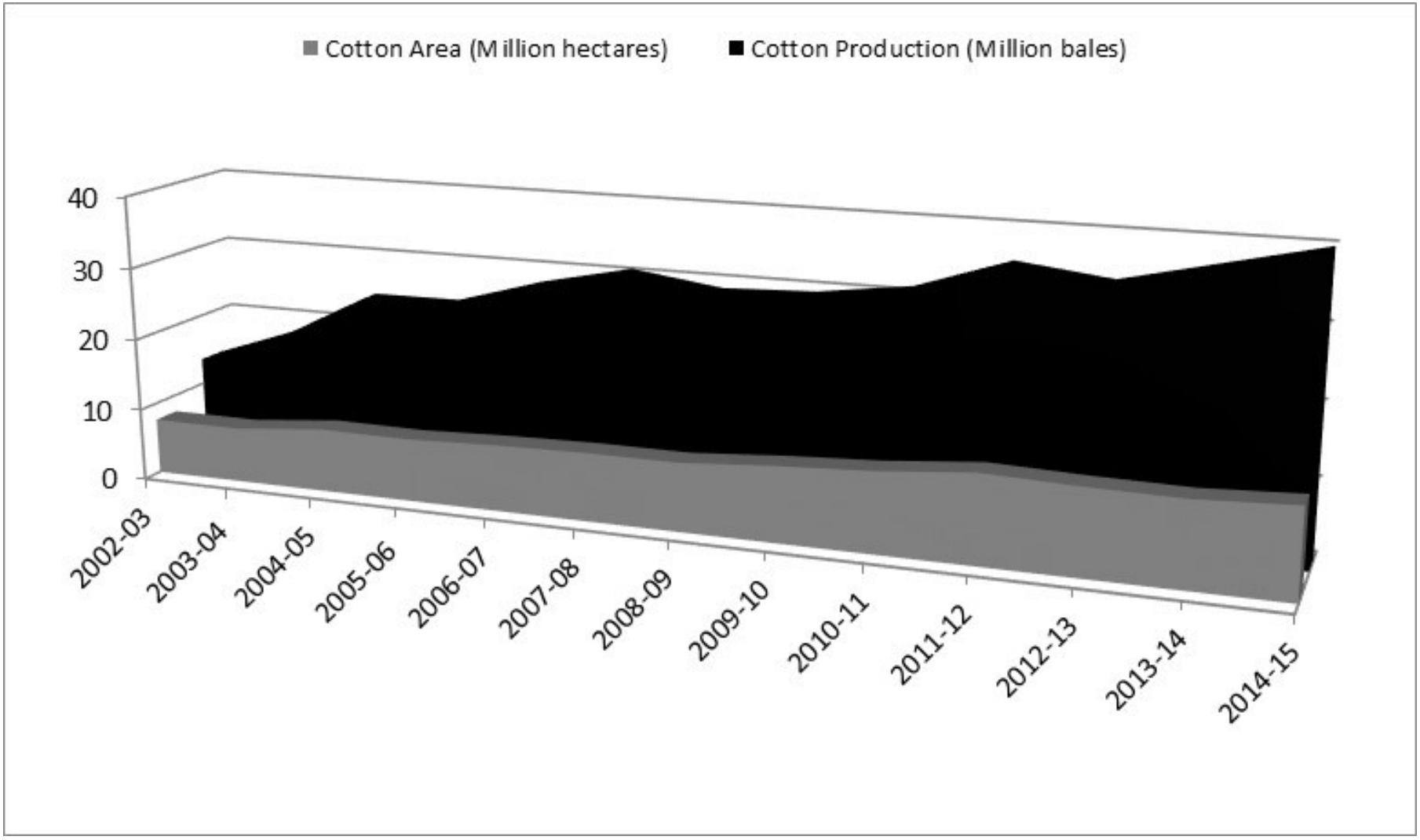
Source: ISAAA, 2016

Adoption of Biotech Cotton by Farmers in India and USA, 1996 to 2015



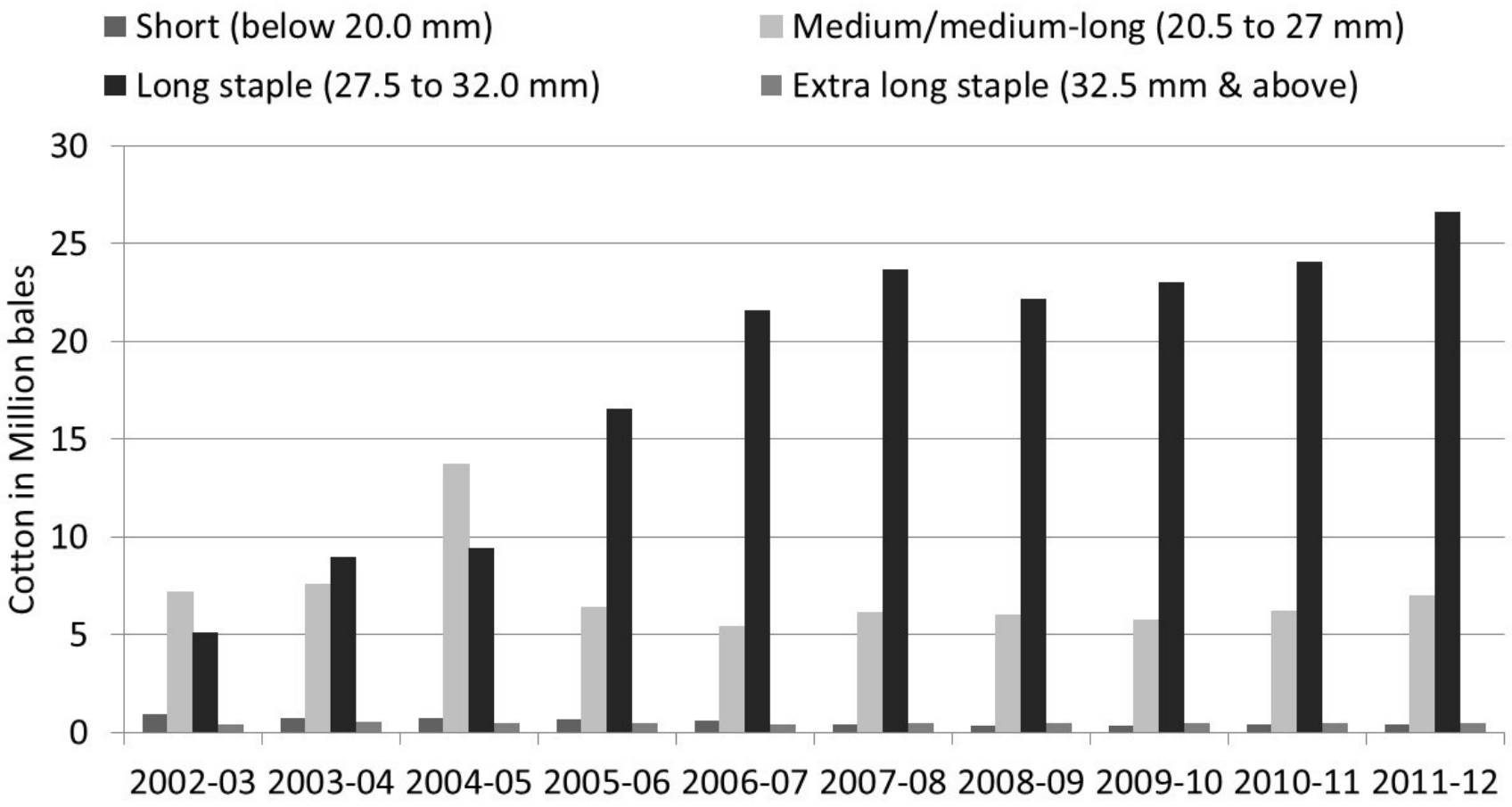
Source: SABC, 2016

Cotton Transformation Cotton Hectarage and Production in India, 2002 to 2015



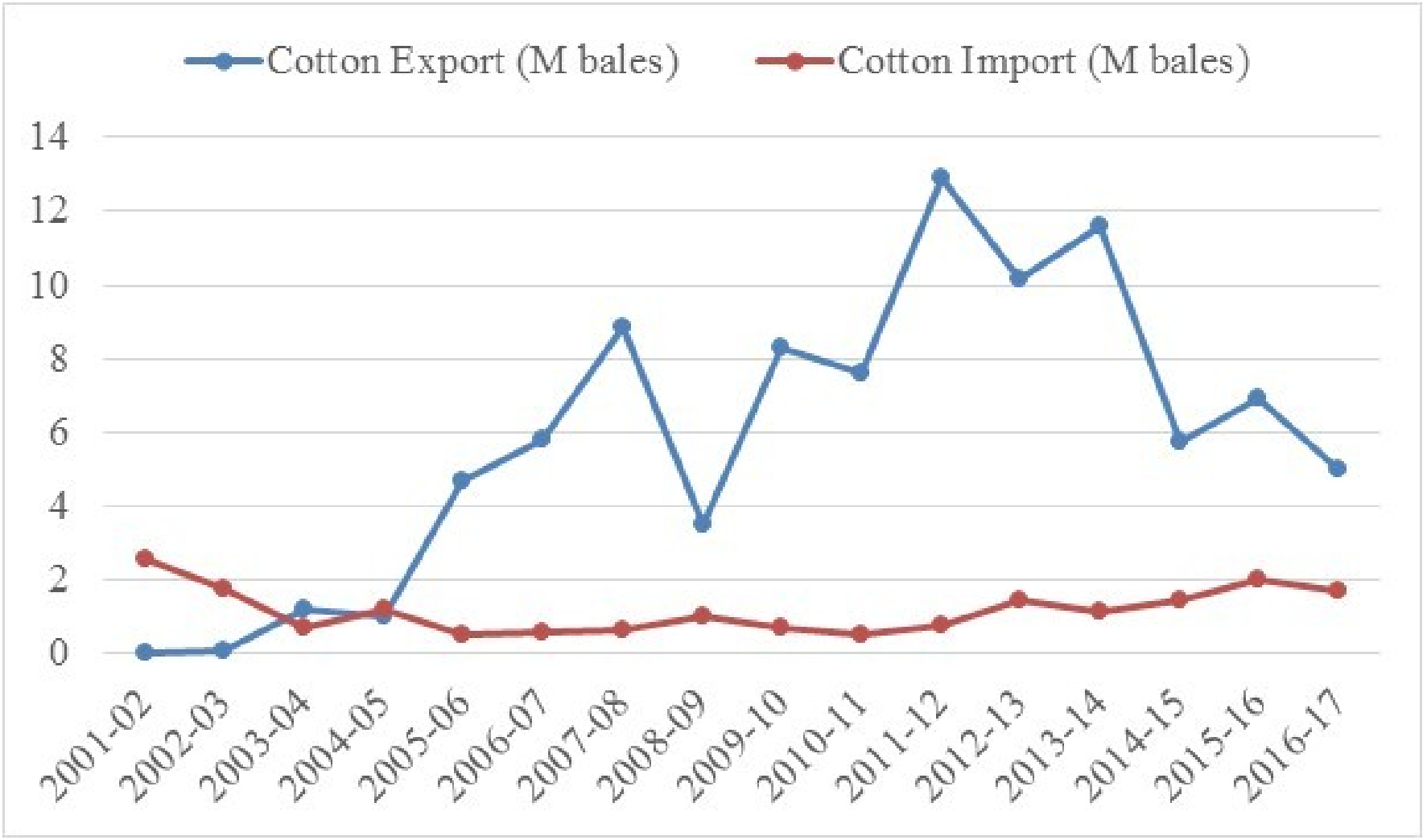
Source: CAB, 2015; ISAAA, 2016

Cotton Transformation Growth of Long Staple Cotton in India, 2002 to 2012



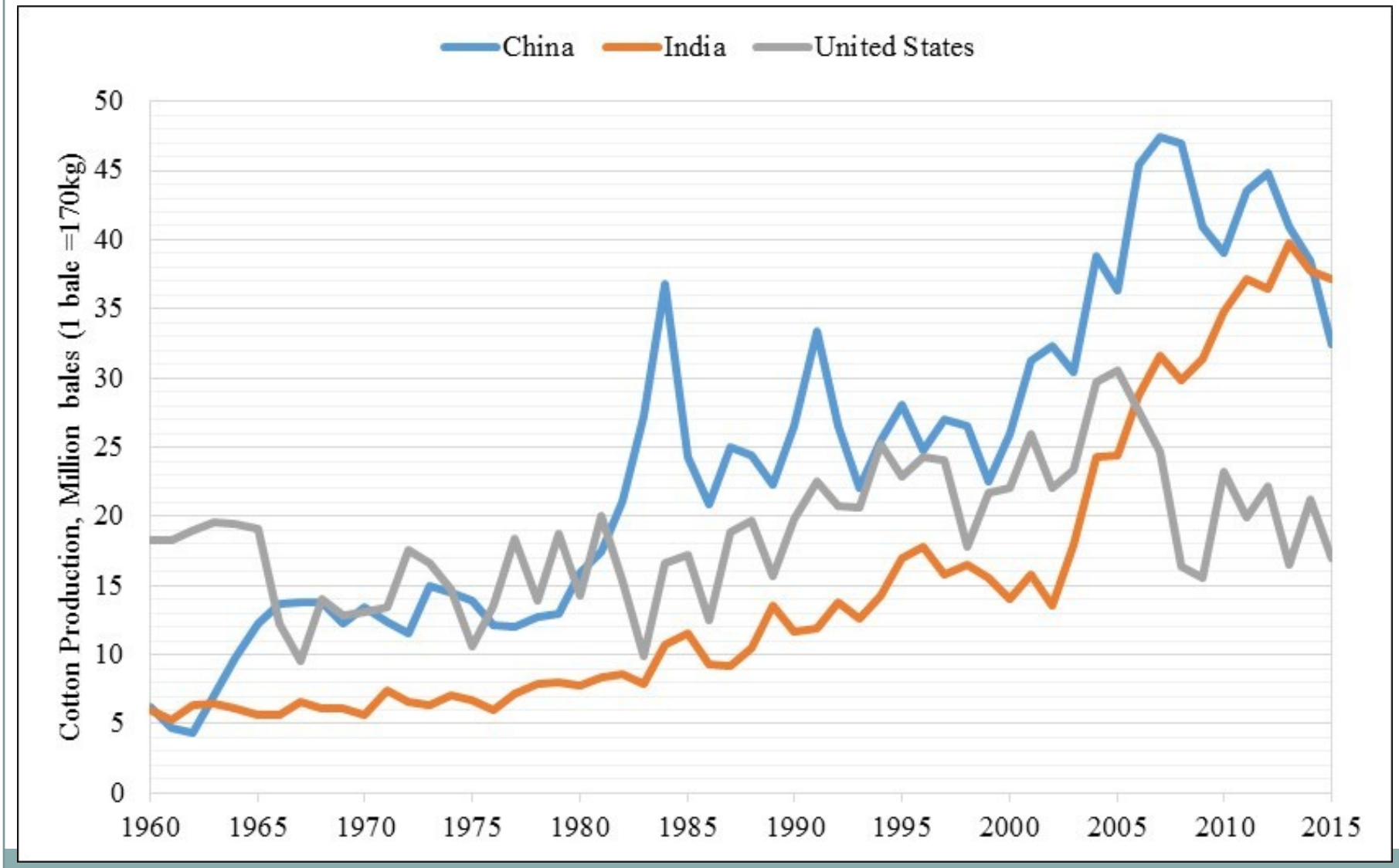
Source: Cotton Advisory Board (CAB), 2013; Cotton Corporation of India, 2013

Cotton Transformation Export and Import of Cotton in India, 2002 to 2016



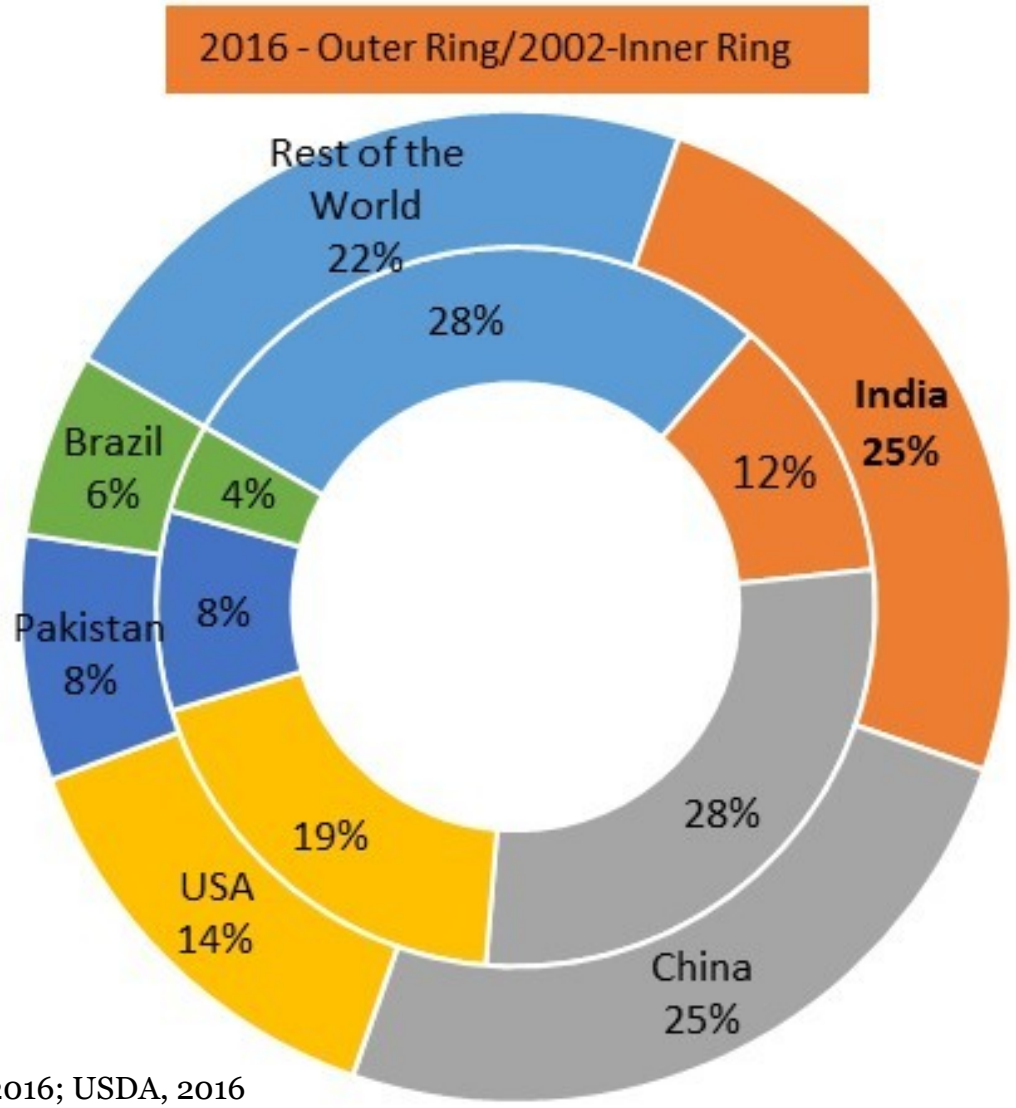
Source: Cotton Advisory Board (CAB), 2017; Cotton Corporation of India, 2017; Analyzed by SABC, 2017

Top Three Cotton Producing Countries



Source: ISAAA, 2016

Cotton Transformation Distribution of World Cotton Market Share by Top Five Countries, 2002 & 2016



Source: ICAC, 2016; USDA, 2016

FUTURE HOPE: Genomics and Biotechnology

- Cultivars suitable for HDPS
- Cultivars suitable for mechanical picking
- Salt and drought resistant varieties /hybrids
- Gene mining for quality fibre specially stength
- Indian cotton can make edge through this

PRECISION FARMING

- WATER MANAGEMENT IS KEY ISSUE BOTH IN RAIN FED AND IRRIGATED SYSTEM
- MICRO-IRRIGATION USE ESSENTIAL IN DRY LAND AREACOVERING 60% AREA
- DRAINAGE IMPROVEMENTS IN IRRIDATED AREA AND CONTROLLED IRRIGATION
- USE OF FERTIGATION TECHNOLOGY WITH INM
- CAREFUL USE OF GROWTH PROMOTING CHEMICALS DURING GROWTH
- IMPROVEMENT OF ORGANIC CARBON CONTENT

PRECISION PLANT PROTECTION

- IPM SYSTEM FOR REDUCIN THE PESTICIDE USE . IT HAS TO BE BASED ON THRESHHOLDS,CONSTANT MONITORING ,USE OF PHROMONE TRAPS,SANITATION FOREWARNINGS AND NON CHEMICAL PESTICIDE USE AS FAR AS POSSIBLE
- SHORT DURATION CULTIVARS IN RAIN FED AREAS
- CRITICAL TIME OF SOWINGS FOR CONTROL OF PESTSAND DISEASES

Implements Designed, Developed & Validated by CICR

Self propelled Check row planter (CICR & DrPDKV)

A 3-row, self propelled check row planter with pneumatic metering. Cost saving over traditional was 75% due to proper placement of seed. Actual field capacity was 0.51 ha/h with 88 % field efficiency. Cost of operation was Rs. 215/ha remarkable less than any other traditional method

Solar Knap Sack Sprayer

Patent F.No 1559/Mum/09

Rs 8000. 15-18° tilt. Light weight and works non-stop

Bullock drawn precision planter with an innovative vertical rotor metering mechanism

Reduced seed damage and uniform seed placement.
Germination percentage: 98% Seed rate: 4.2 kg/ha.

Need For Cotton Machine Picking Technology

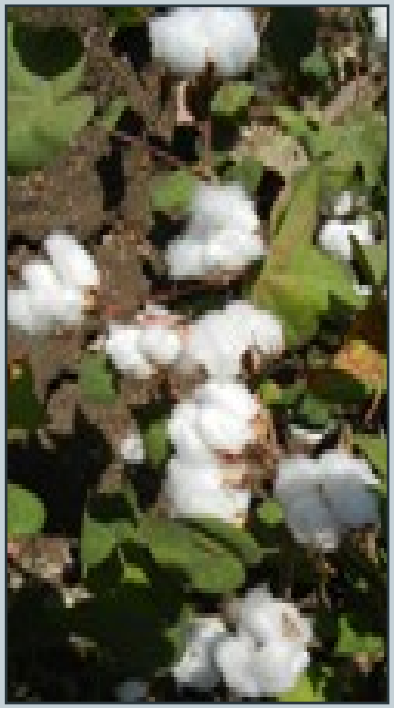
- Cotton Picking is Highly Labour Intensive and expensive
- Scarcity of Labour is making it increasingly difficult for farmers to rely on manual picking of cotton
- With the advent of Cotton high density planting system there will be an increased need for mechanization of cotton picking

Hybrids -More bolls per plant

4 g boll x
100 bolls per plant x
10,000 plants/ha

40Q/ha

Ideal Plant Type for Mechanical Picking



- Ideal Plant type for Mechanical Picking
  - Height: 105-135 cm
  - Monopodia: 0-1
  - Sympodial length : 20-25 cm
  - Plant growth habit: Erect
  - Boll bearing and Bursting: Synchronous

Experience with High Density Planting

Early sowing

The crop escapes bollworms & moisture stress
Overcomes Flooding

Coragen & Fame control bollworms effectively

Less weed infestation –less cost of weeding
Less crop foliage -less nutrients needed
Early & single picking –less labour needed

Less labour cost on sowing, weeding and picking

Low production cost Rs 15,000/ha

GM crops to scare insects

Insects release chemicals called alarm pheromones when they are scared by their enemies. This warns their colonies to escape. New biotech crops express alarm pheromones that scare the specific insect pests

The alarm pheromone for many species of aphids, which causes dispersion in response to attack by predators or parasitoids, consists of the sesquiterpene (*E*)-farnesene (*E*f). High levels of expression in *Arabidopsis thaliana* plants of an *Efsynthase gene* cloned from *Mentha piperita were used* to cause emission of pure *E*f. These plants elicited potent effects on behavior of the aphid *Myzus persicae* (alarm and repellent responses) and its parasitoid *Diaeretiella rapae* (an arrestant response).

PNAS

Aphid alarm pheromone produced by transgenic plants affects aphid and parasitoid behavior

Michael H. Beale, Michael A. Birkett, Toby J. A. Bruce, Keith Chamberlain, Linda M. Field, Alison K. Huttly, Janet L. Martin, Rachel Parker*, Andrew L. Phillips, John A. Pickett†, Ian M. Prosser, Peter R. Shewry, Lesley E. Smart, Lester J. Wadhams, Christine M. Woodcock, and Yuhua Zhang

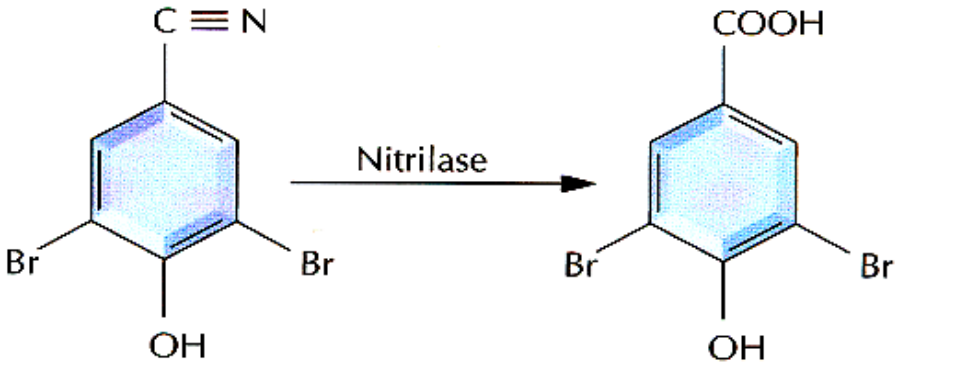
Rothamsted Research, Harpenden AL5 2JQ, United Kingdom

Communicated by James H. Tumlinson, Pennsylvania State University, University Park, PA, May 15, 2006 (received for review March 1, 2006)

Herbicide-resistant plants:
Giving plants the ability to inactivate the herbicide

Herbicides: Bromoxynil, Glyphosate and Glufosinate

- Resistance to bromoxynil (a photosytem II inhibitor) was obtained by expressing a bacterial (*Klebsiella ozaenae*) nitrilase gene that encodes an enzyme that degrades this herbicide
- Resistance to glyphosate was obtained by over-expressing EPSPS gene from bacteria



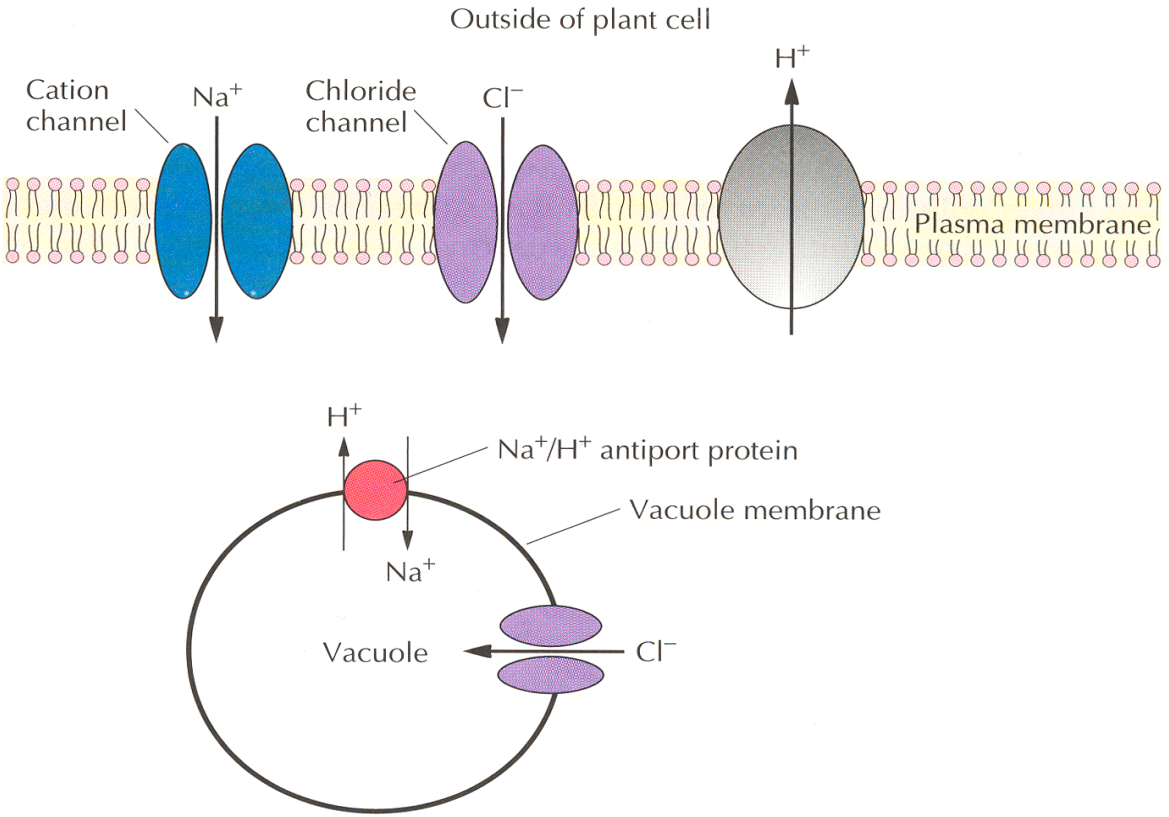
Bromoxynil

3,5-Dibromo-4-hydroxybenzoic acid

Salt-Resistant GM crops

Over expression of the gene encoding a Na+/H+ antiport protein which transports Na+ into the plant cell vacuole has been done in plants allowing them to survive on 200 mM salt (NaCl)

Figure 18.22 Schematic representation of ion transport in the plant *A. thaliana* showing the Na^+ ions being sequestered in the large vacuole.



Future GM Cotton fibers using silk genes from silkworm, *Bombyx mori* and spider *Araneus* sps.

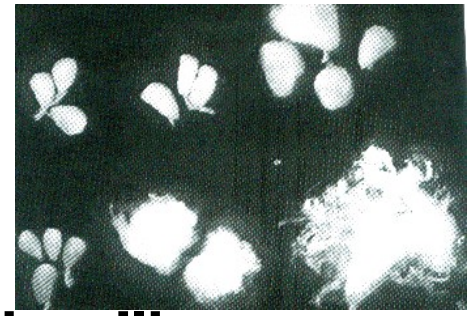


Spider silk: 5 times stronger than steel, twice as elastic as nylon. water proof and stretchable

Silkworm silk: 5-10 times more extensible than cellulose. Better thermal properties

A pencil thick spider silk strand can stop a boeing 747 in flight !!

Genes from Spider, Bacteria & Spinach improve cotton fibre traits



Cotton fibrocyte expression vector plasmid of spider silk gene.
(Wang, Li and Niu (2002) Patent no. CN1380418:2:20.11.2002)

Bacterial genes for improvement of cotton/flax fiber quality.
(Proc. National Academy of Science, USA ,(1996) 93:12768- 12773).

Polyhydroxy butyrate synthesis in transgenic flax.
Journal of Biotechnology (2004) 107: 41-54.
Polyhydroxy butyrate from bacterium *Alcaligenes eutrophus* when introduced in cotton fibres enhanced thermal insulation in the resultant fabric.

Transgenic cotton with improved strength, length, micronaire and fibre weight. *Proc. of the Beltwide Cotton Conference Vol 11: 483-483 (2001).*
Sucrose phosphate synthase gene was isolated from spinach and introduced into cotton. The resultant GM cotton pushed fibre quality to the premium range.

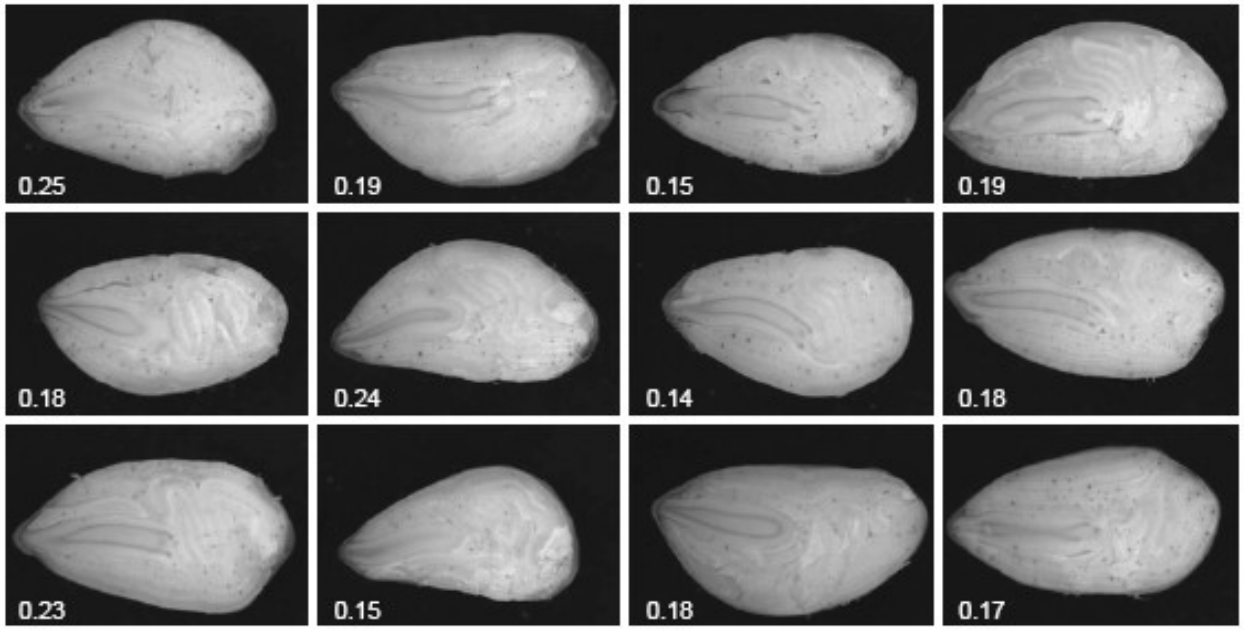
Engineering cottonseed for use in human nutrition by tissue-specific reduction of toxic gossypol

Ganesan Sunilkumar*, LeAnne M. Campbell*, Lorraine Puckhaber†, Robert D. Stipanovic†, and Keerti S. Rathore*‡§

*Institute for Plant Genomics and Biotechnology and §Department of Soil and Crop Sciences, Texas A&M University, College Station, TX 77843; and †U.S. Department of Agriculture–Agricultural Research Station, Southern Plains Agricultural Research Center, College Station, TX 77845

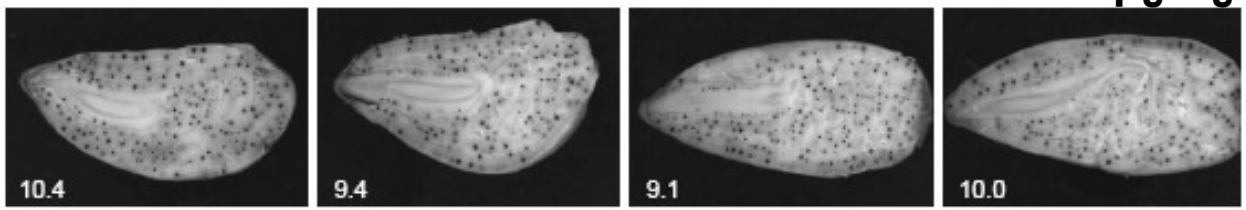
PNAS, Nov 2006

A. T2 seeds from line LCT66-81-5



B. Seeds from wild-type plant

10 µg/mg



Challenges: 2015 onwards(cont)

B. Social and Economical

1. **Public acceptance of new technologies like transgenic products**
2. **Patenting and nationalism**

C. Political and Policy

1. **Exim policy of raw cotton and textiles**
2. **Investments in Processing technology**
3. **Value creation through byproduct Utilization**

A farmer near Jalna in Maharashtra examining his freshly sown Bt cotton field. *Express photo*

ACREAGE SHIFTS

King Cotton's comeback

The fibre crop, along with maize, seems the most attractive planting option for farmers this kharif

HARISH DAMODARAN

BHASKARRAO MORE last year sowed *tur* (pigeon-pea) and *moong* (green gram) on four acres and cotton in the rest of his eight-acre holding. In this kharif season, he has already planted seven acres under cotton, leaving a sole acre for *moong*.

"I grew more pulses last time only because prices were Rs 9,000-10,000 per quintal. But having got a rate of only Rs 3,500-4,500 for my five quintals of *tur* and three quintals of *moong* this February, I have gone back to cotton," notes this farmer from Tupewadi village in Badnapur taluka of Maharashtra's Jalna district.

The same goes for Raosaheb Vittalrao Gavhane from Hiswan Khurd in Jalna *taluka*, who, like many farmers here, cultivates pulses as an inter-crop with cotton or soyabean. "I usually plant *tur* in about five rows and cotton in 150 rows every acre. Last year's prices led me to raise the *tur* planting to 10 rows and reduce the cotton rows to 140. But I realised less from my two quintals this time than from one quintal in 2016," he remarks.

The story of 2017 kharif so far clearly has been about cotton's comeback at the expense of pulses. The Union agriculture ministry's data bear this out: As on June 16, farmers had sown 16.67 lakh hectares (lh) under cotton, as against last year's corresponding all-India area of 12.25 lh. This, even as pulses acreage has dipped from 3.63 lh to 2.22 lh.

"The government declared a minimum support price (MSP) of Rs 5,050 per quintal for *tur*, but the farmers who tried to sell to state agencies had to wait for 7-8 days for their crop to be lifted. They were told that there are no *bardanas* (jute bags) to pack the procured produce. Most farmers couldn't afford the cost of waiting so long and chose to offload to private traders at Rs 4,000 per quintal or below," says Gavhane.

The contrast with cotton couldn't have been more. "I did not even have to go to the *mandi*. The traders themselves came to buy the *kapas* (raw un-ginned cotton) straight from my fields at Rs 5,600 per quintal this February, compared with Rs 4,000 in the previous year," he adds.

Cotton is typically a 175-180 day crop, with the first harvest ("picking") taking place some 120 days after sowing towards the second week of June. Subsequent pickings — there could be five in all — happen thereafter every 15 days or so. In a normal monsoon year, farmers with access to basic irrigation (stored rainwater conveyed to fields through, say, a three-horsepower motor pump) can harvest around 12 quintals per acre. With drip irrigation, which allows an extra picking, this could go to even 15 quintals.

For farmers, the biggest cost is that of picking. At Rs 500 per quintal for 12 quintals, it works out to Rs 6,000 an acre. The second major expense head is pesticides. About six sprays of branded insecticides such as 'Confidor', 'Actara' and 'Polo' – mainly against sucking pests like thrips, jassids, aphids and whitefly – cost roughly Rs 4,000 per acre, excluding Rs 200 on labour for each round of spraying.

This is followed by weeding (four rounds costing Rs 750 each) and inter-culture (five times; a farmer not owning bullocks will have to hire these each time at roughly Rs 600). Then, there is fertiliser. Gavhane applies one 50-kg bag each of 19:19:19 NPK complex fertiliser (currently retailing at Rs 1,120), 10:26:26 (Rs 1,160), di-ammonium phosphate (Rs 1,260), muriate of potash (Rs 580) and urea (Rs 300) on every acre, adding up to Rs 4,420. The least expenditure is on seeds. A packet of 450-gram Bt cotton seeds sells at Rs 750 and at 1.5 packets per acre, that comes to just Rs 1,125.

Farmers sowed 16.67 lh under cotton as on June 16, against last year's corresponding all-India area of 12.25 lh. Pulses acreage, on the other hand, has dipped from 3.63 lh to 2.22 lh

"Inclusive of Rs 1,000 for field preparation, my total cultivation cost will be within Rs 25,000 per acre. Even if I get Rs 5,000 per quintal this time on 12 quintals yield, my net return would be Rs 35,000 per acre," explains Gavhane. For farmers like him in Marathwada — or even those from the neighbouring Vidarbha region — the planting choices during the current kharif season essentially reduce to cotton, pulses, soyabean and maize.

At the current market prices, pulses aren't the most attractive option. Soyabean realisations have also plunged to Rs 2,400-2,500 per quintal from Rs 3,600-3,700 a year ago. But this is a crop with cultivation costs at hardly Rs 10,000 per acre. With average yields of eight quintals per acre, farmers still stand to make money. Moreover, given its short duration of 90-100 days — enabling planting of a succeeding rabi winter crop of wheat, *chana* (chickpea) or Maldandi *jowar* (sorghum) — soyabean cannot be written off yet.

Cotton's real advantage is its relative hardiness. Soyabean can be a washout if it rains heavily during seed setting or harvesting time. Cotton, on the other hand, is picked four-five times. "Even if the rains aren't too good, the farmer is assured of at least two pickings. If the monsoon turns out good, he may give the plant more water and fertilisers for it to yield an extra picking of 2 quintals," points out Usha Barwale Zehr, Joint Director of Research at Maharashtra Hybrid Seeds Company.

Cotton apart, the other 'hot' crop this time could be maize. A poor crop last year, courtesy drought in Peninsular India, has meant that the ruling prices, at Rs 1,550-1,600 per quintal, are above the Centre's MSP of Rs 1,425. They may not fall much — one plausible reason being the clampdown on the cattle/buffalo meat trade. That, it is being said, has increased the demand for poultry meat, which also translates into higher feed grain consumption. Like Bt cotton, maize has benefited from technology, with the advent of single-cross hybrids yielding 30 quintals and more per acre over 110-120 days.

The agriculture ministry data show an increase in maize area from 5.62 lh to 6.01 lh so far, while the same for soyabean is down from 1.01 lh to 0.45 lh.

Cotton Is Cool