Next Generation Biotech Cotton

South Asia Biotechnology Centre

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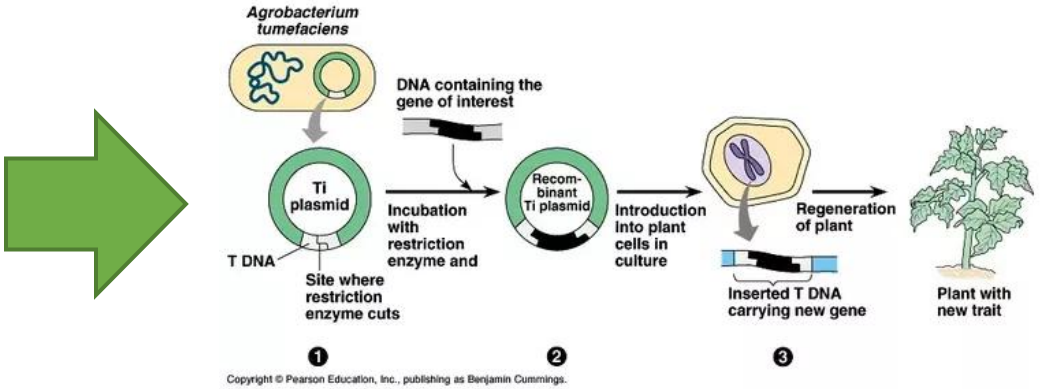
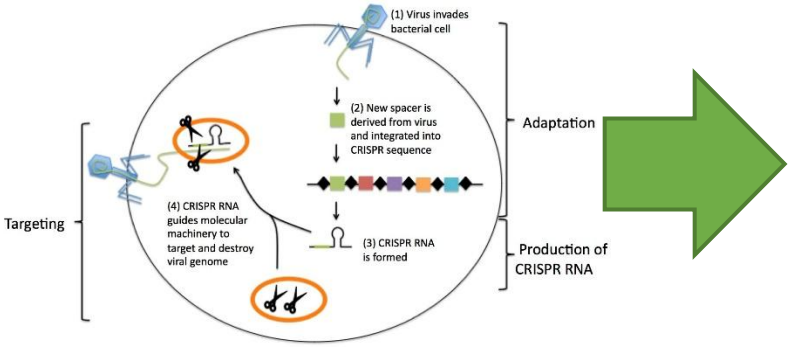
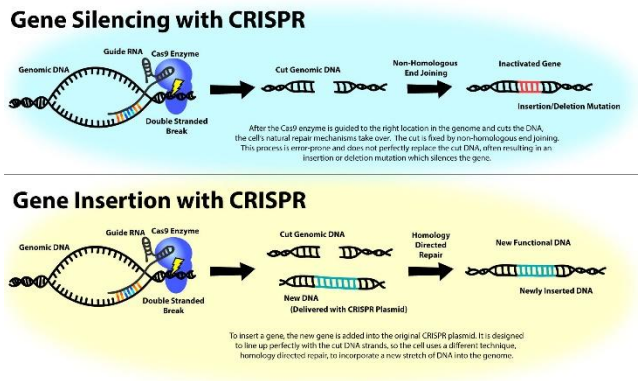
21st Century Crop Innovations

- rDNA Technology
  - Agrobacterium tumefaciens



- Gene Editing Technology
  - Bacterial defense system against virus





Commercial Biotech Cotton Traits

- rDNA Technology
  - Insect Resistant Trait
    - Single gene
    - Multiple Genes
  - Herbicide Tolerant Trait
    - CP4EPSPS/Bar gene (HT)
  - Staked IR/HT Traits
    - Single gene/HT
    - Multiple gene(s)/HT

Global Regulatory Approvals of Biotech cotton, 2002 to 2016

Cotton - Gossypium hirsutum L. : 53 Events	
DD-Ø1951A-7	not available
DAS-24236-5	not available
DAS-24236-5 x DAS-21Ø23-5	WideStrike™ Cotton
DAS-24236-5 x DAS-21Ø23-5 x SYN-IR1Ø2-7 x DAS-81910-7	not available
DAS-21Ø23-5	not available
DAS-21Ø23-5 x DAS-24236-5 x MON-Ø1445-2	WideStrike™ Roundup Ready™ Cotton
DAS-21Ø23-5 x DAS-24236-5 x MON-88913-8	Widestrike™ Roundup Ready Flex™ Cotton
DAS-21Ø23-5 x DAS-24236-5 x MON-88913-8 x SYN-IR1Ø2-7	Widestrike™ x Roundup Ready Flex™ x VIPCOT™ Cotton
not available	BXN™ Plus Bollgard™ Cotton
not available	BXN™ Plus Bollgard™ Cotton
DAS-81910-7	not available
BNLA-601	not available
BXN-1Ø211-9	BXN™ Cotton
BXN-1Ø215-4	BXN™ Cotton
BXN-1Ø222-2	BXN™ Cotton
BXN-1Ø224-4	BXN™ Cotton
SYN-IR1Ø2-7	VIPCOT™ Cotton
SYN-IR1Ø2-7 x SYN-IR67B-1	VIPCOT™ Cotton
SYN-IR1Ø2-7 x SYN-IR67B-1 x MON-88913-8	VIPCOT™ Roundup Ready Flex™ Cotton
SYN-IR1Ø2-7 x MON-15985-7	Bollgard® III
SYN-IR1Ø2-7 x MON-15985-7 x MON-88913-8	Bollgard® III x Roundup Ready™ Flex™
SYN-IR1Ø2-7 x MON-15985-7 x MON-88913-8 x MON 887Ø1-3	n/a
SYN-IR67B-1	not available

Event1	JK 1
GFM Cry1A	not available
BCS-GHØØ5-8	not available
BCS-GHØØ2-5	GlyTol™
BCS-GHØØ2-5 x ACS-GHØØ1-3	GlyTol™ Liberty Link™
BCS-GHØØ2-5 x ACS-GHØØ1-3 x MON-15985-7	not available
BCS-GHØØ2-5 x BCS-GHØØ4-7 x BCS-GHØØ5-8	Glytol™ x Twinlink™
BCS-GHØØ2-5 x BCS-GHØØ4-7 x BCS-GHØØ5-8 x SYN-IR1Ø2-7	Glytol™ x Twinlink™ x VIPCOT™ Cotton
GK12	not available
ACS-GHØØ1-3	Fibermax™ Liberty Link™
ACS-GHØØ1-3 x MON-15985-7	Fibermax™ Liberty Link™ Bollgard II™
MLS 9124	not available
MON-89924-2	Bollgard™ Cotton
MON-Ø1445-2	Roundup Ready™ Cotton
MON-15985-7	Bollgard II™ Cotton
MON-15985-7 x MON-Ø1445-2	Roundup Ready™ Bollgard II™ Cotton
MON-89383-1	Roundup Ready™ Cotton
MON-ØØ531-6	Bollgard™ Cotton, Ingard™
MON-Ø531-6 x MON-Ø1445-2	Roundup Ready™ Bollgard™ Cotton
MON-ØØ757-7	Bollgard™ Cotton
MON 887Ø1-3	not available
MON 887Ø1-3 x MON-88913-8	not available
MON 887Ø1-3 x MON-88913-8 x MON-15985-7	not available
MON-88913-8	Roundup Ready™ Flex™ Cotton
MON-88913-8 x MON-15985-7	Roundup Ready™ Flex™ Bollgard II™ Cotton
Ngwe Chi 6 Bt	Ngwe Chi 6 Bt
SGK321	not available
T303-3	not available
T304-40	not available
T304-40 x GHB119	TwinLink™ Cotton

Regulatory Approvals of Biotech cotton, 2002 to 2016

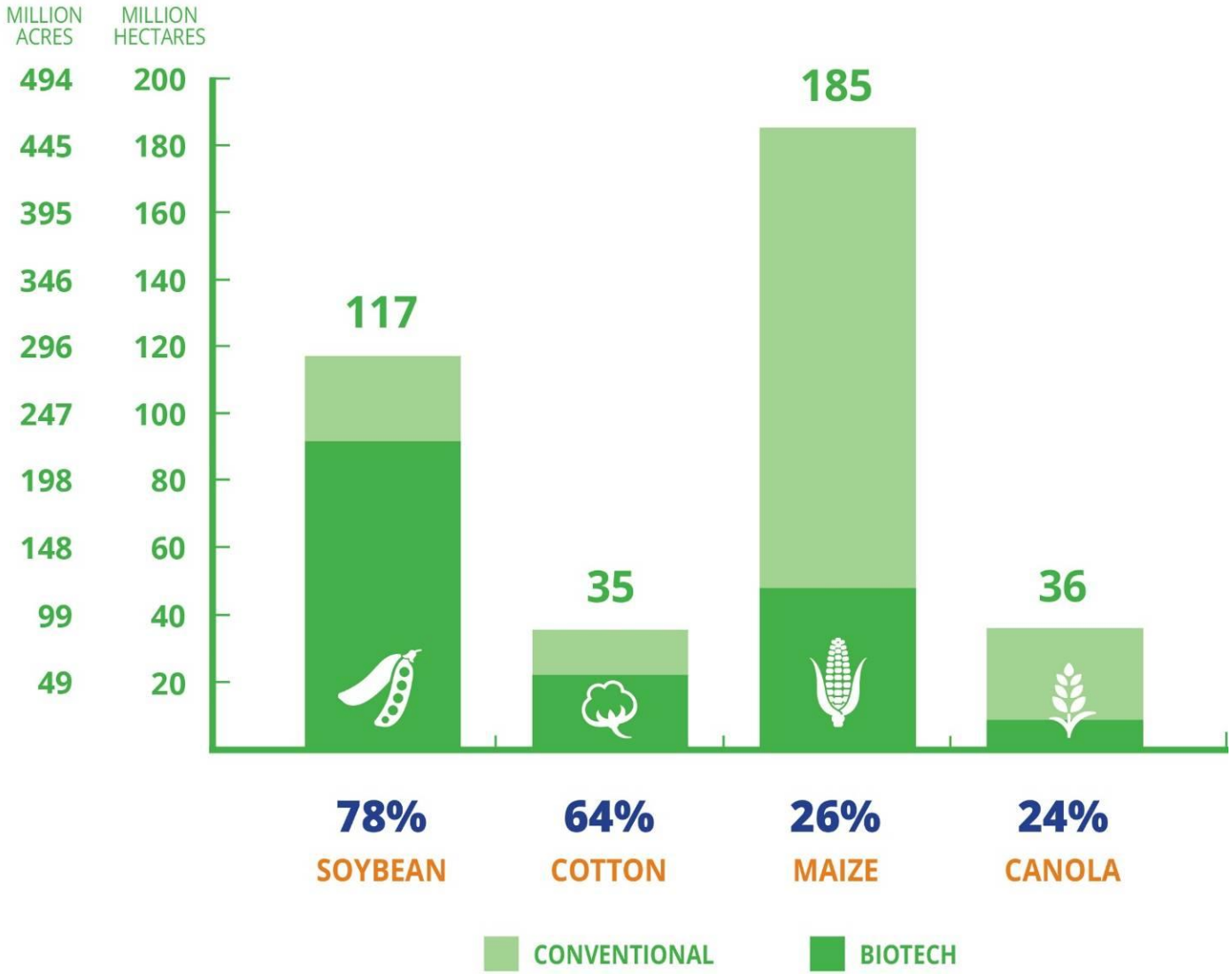
Crop	Gene(s)	Event	Developer	Status	Year of Approval
Cotton	*cry1Ac*	MON-531	Mahyco/Monsanto	Commercialized	2002
Cotton	*cry1Ac* and *cry2Ab2*	MON-15985	Mahyco/Monsanto	Commercialized	2006
Cotton	*cry1Ac*	Event-1	JK Agri-Genetics	Commercialized	2006
Cotton	fused genes *cry1Ab* and *cry1Ac*	GFM Event	Nath Seeds	Commercialized	2006
Cotton	*cry1Ac*	BNLA-601	CICR (ICAR) & UAS, Dharwad	Commercialized	2008*
Cotton	synthetic *cry1C*	MLS-9124	Metahelix Life Sciences	Commercialized	2009**

* BNLA-601 discontinued, **MLS-9124 never commercialized

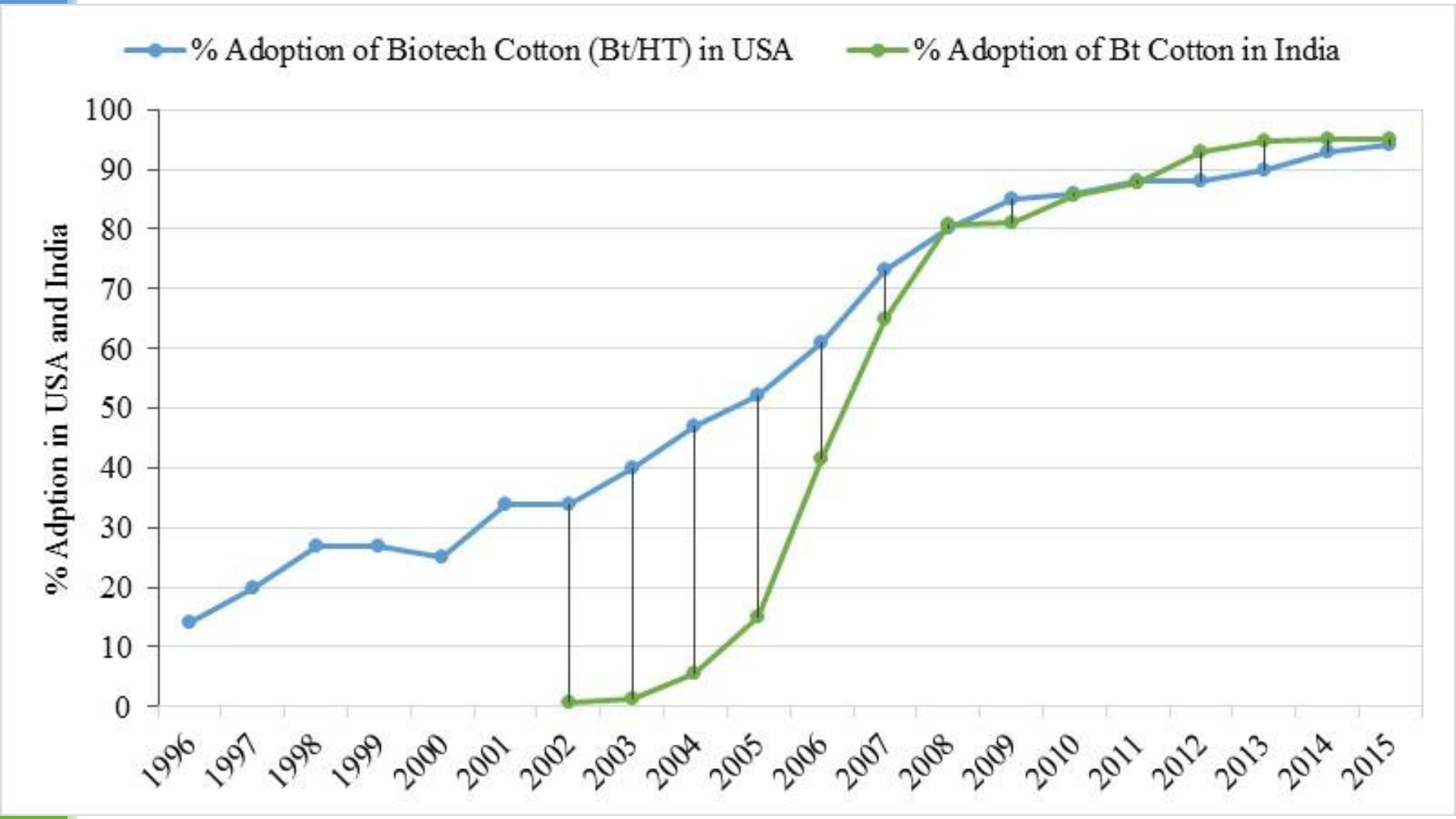
Source: GEAC, 2016; SABC, 2016

Locations of Commercially Grown Biotech Cotton, 2016
-14 mega cotton countries, 22.3 mha

Global Adoption of Biotech Cotton as % of Total Cotton (Million Hectares), 2016

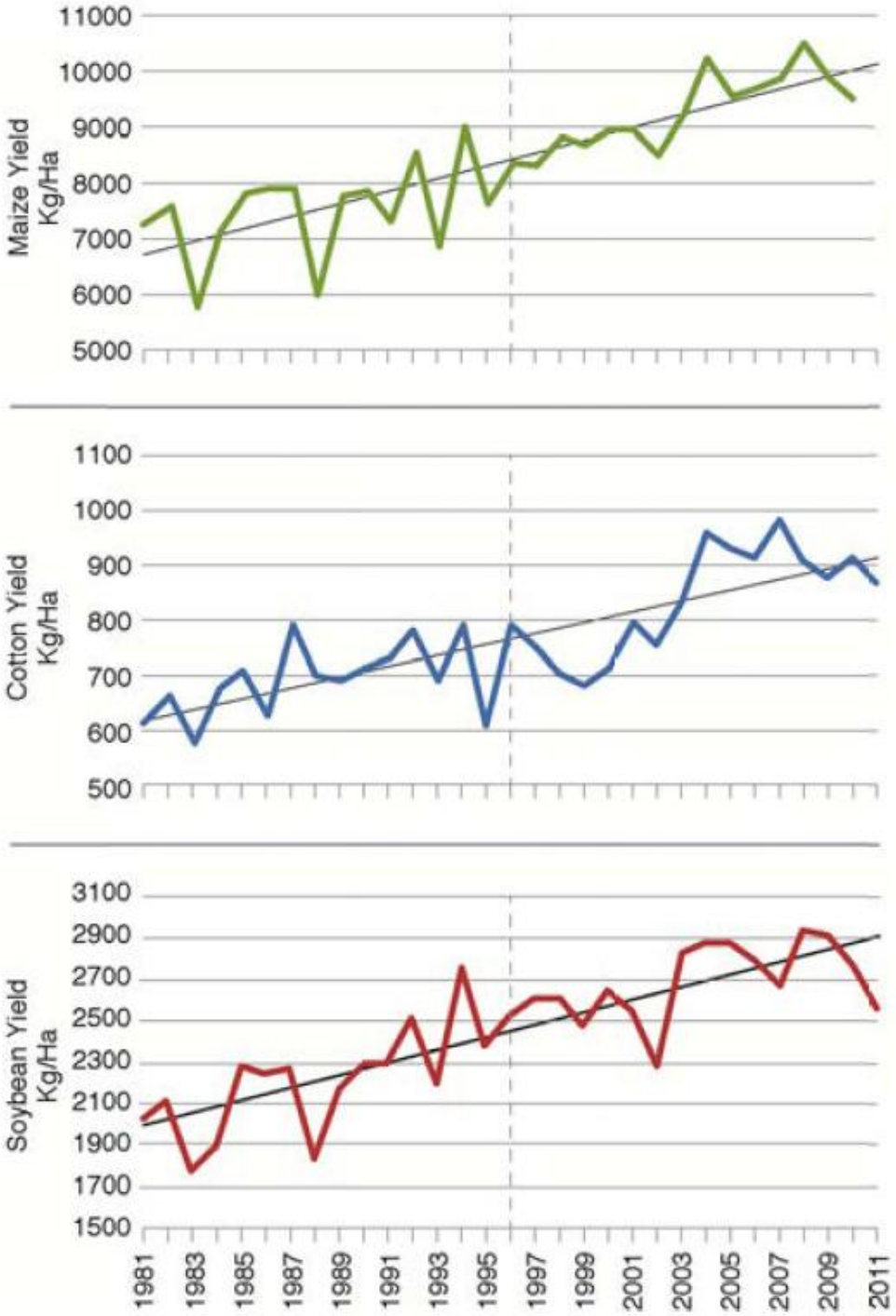


Adoption of Biotech Cotton by farmers in USA & India, 1996 to 2015



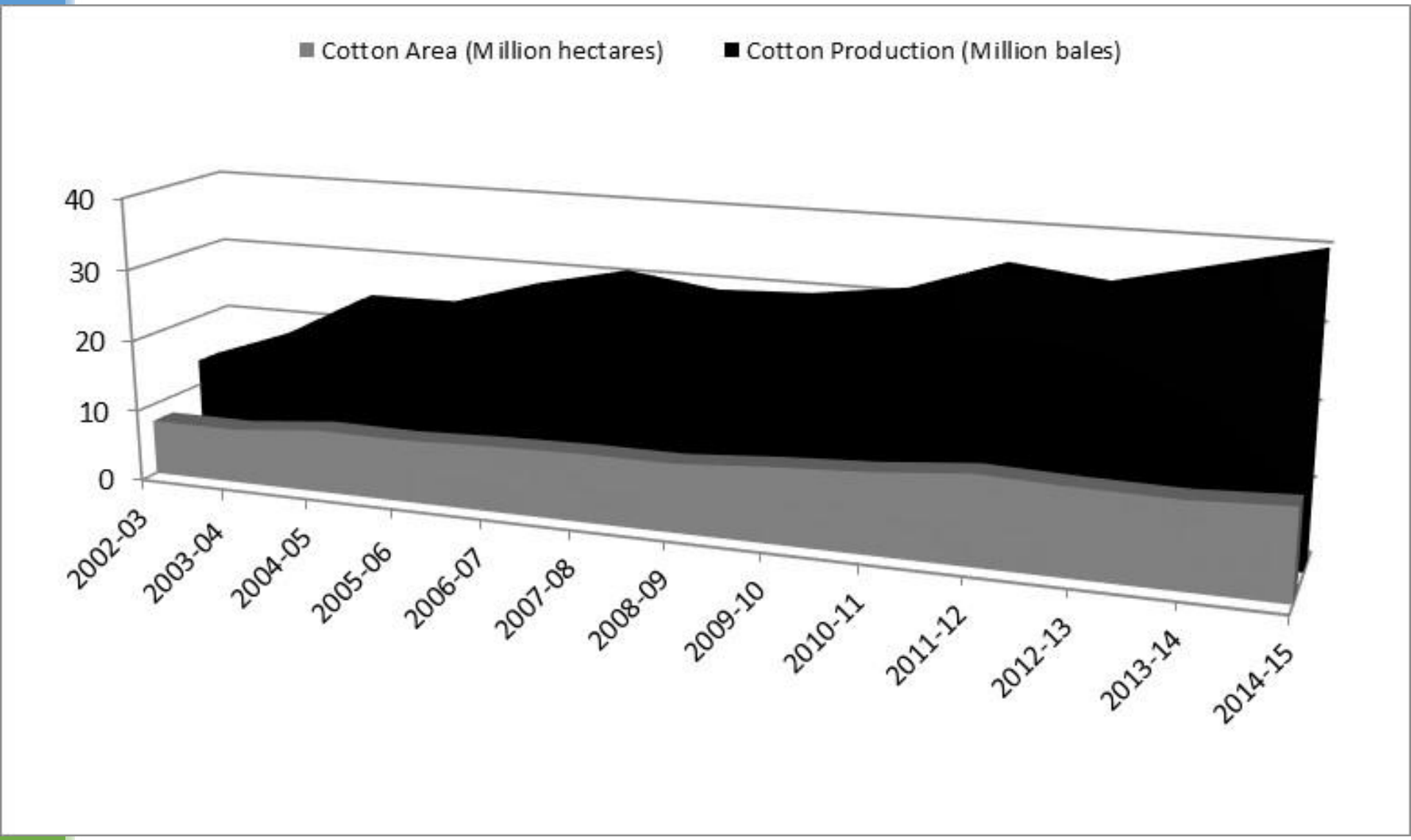
SABC, 2016

Yields of Cotton in USA 1980 to 2011



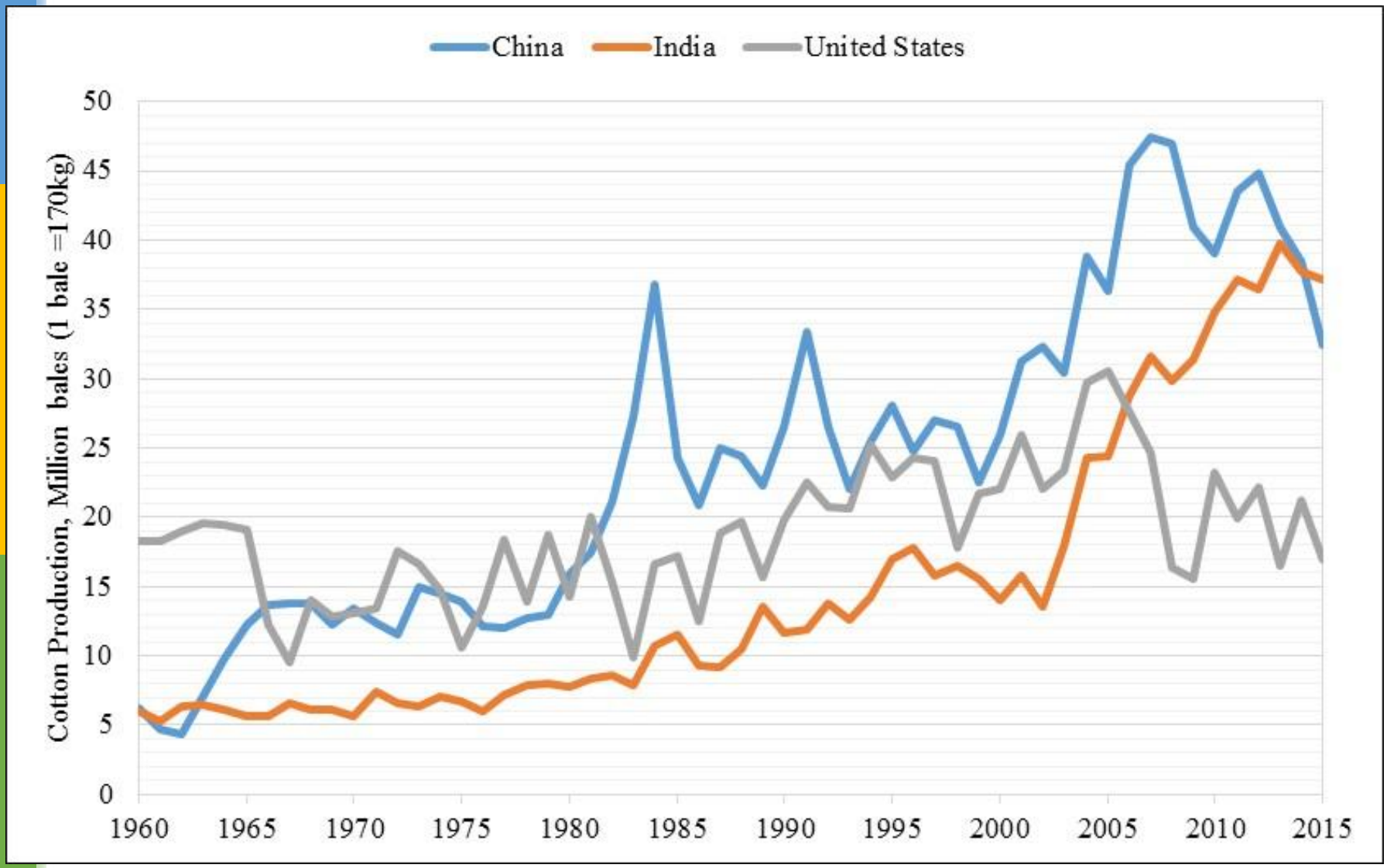
Source: US NAS, 2017

Cotton Production in India, 1996 to 2015



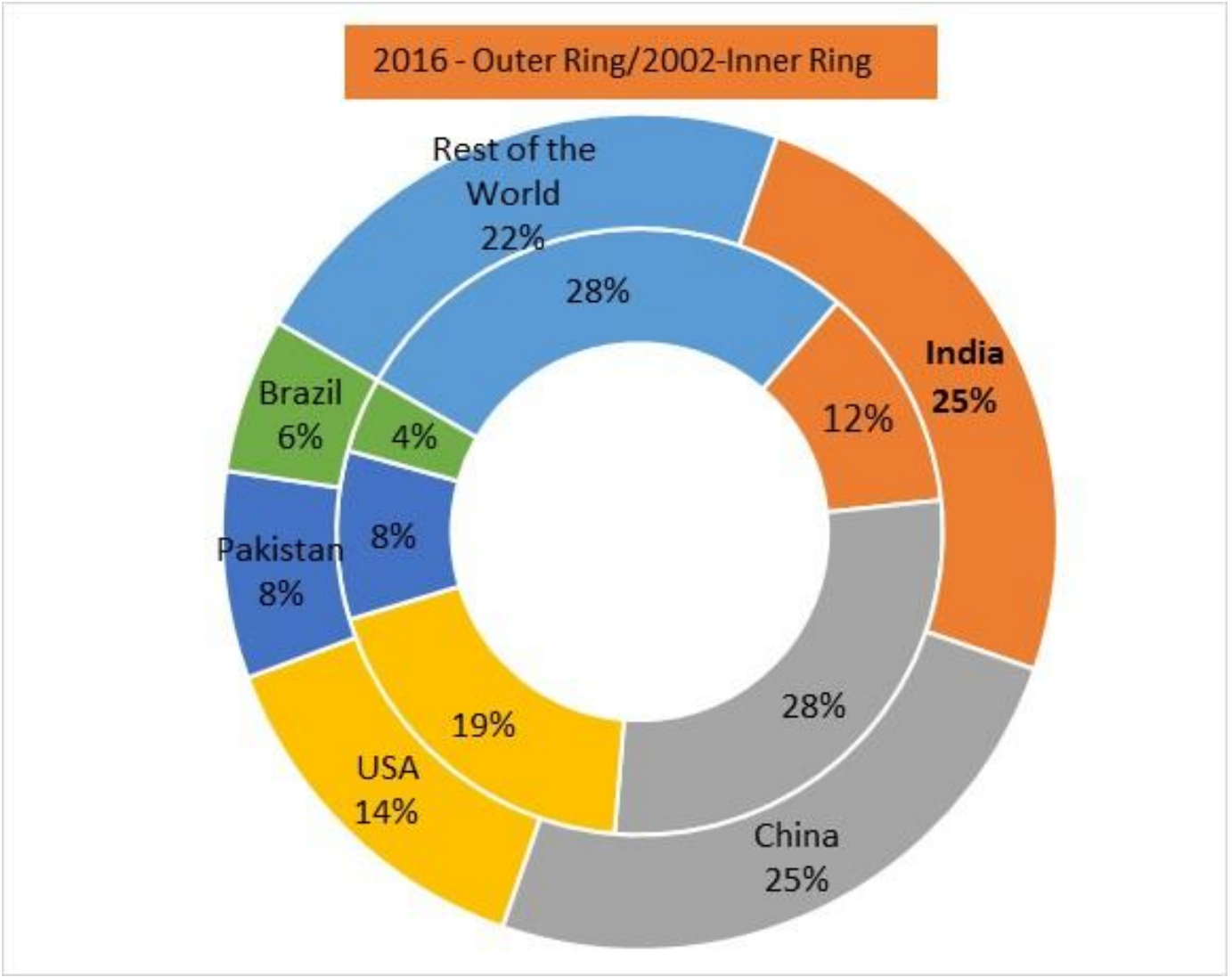
CAB, 2016; SABC, 2016

Top Three Cotton Producing Countries



USDA, 2016; SABC, 2016

Distribution of World Cotton Market Share by Top 5 Countries, 2002 & 2016



Source: ICAC, 2016; USDA, 2016

Nxt Generation Biotech Cotton

- Near-Mid term: Industrial Countries
  - Multiple mode of HT (glyphosate, glufosinate, 2-4 D, Dicamba etc)
  - Gene pyramiding
  - Stacked multiple mode HT/Gene pyramiding
  - Lygus control
  - Water use efficiency
  - Reduced gossypol
- Near-Mid Term: Developing Countries
  - Gene pyramiding
  - Staked IR/HT
  - Diversification of cotton events
  - Virus resistance (CLCV, TSV etc)

India officially imported 35 genes/events of biotech cotton, 1996 to 2016

Year of Import	Gene(s)	Traits	Country	Institution/ Company
1998	cp4epsps	Herbicide tolerance	USA	Mahyco
1999	cry X	Insect resistance	USA	Mahyco
2000	cry X	Insect resistance	USA	Mahyco
2001	vip-3A	Insect resistance	USA	Syngenta India
2002	GFM cry1A	Insect resistance	China	Nath Seeds
2003	cry 1F/cry 1Ac	Insect resistance	USA	De-Nocil
2003	vip-3A	Insect resistance	USA	Syngenta India
2005	cry1Ac (Event MON-531), cryX (cry1Ac & cry2Ab (MON15985)	Insect resistance	USA	Proagro PGS
2005	vip-3A (cot 203 event)	Insect resistance	USA	Syngenta India
2005	Ascorbate peroxidase (APX)	Hydrogen peroxide homeostasis	USA	Ankur Seeds
2005	cry1Ab	Insect resistance	USA	Syngenta India
2006	cp4epsps	Herbicide tolerance	USA	Mahyco
2006	35S-rol A, B & C & Mannosyl transferase	Drought tolerance	China	Nath Seeds
2006	cry1Ac (Mon531) & cry2Ab (Mon 15985)	Insect resistance	USA	Vikki's Agrotech
2006	cp4epsps and cry1Ac & cry2Ab2 (MON 15985 X (MON 88913)	Insect resistance & herbicide tolerance	USA	Emergent Genetics
2006	cp4epsps (MON88913)	Herbicide tolerance	USA	Monsanto India
2008	cry1Ac, cry2Ab	Insect resistance	USA	Monsanto India
2008	cp4epsps	Herbicide tolerance	USA	Monsanto India
2008	2mepsps	Herbicide tolerance	USA	Monsanto India
2008	bar, cry1Ab, cry2Ae	Insect resistance & herbicide tolerance	USA	Bayer Bioscience
2008	cry1Ac, cry2Ab, epsps	Insect resistance & herbicide tolerance	USA	Monsanto Genetics India

2009	cry1Ac, cry2Ab, epsps	Insect resistance & herbicide tolerance	Israel	Monsanto Genetics India
2009	At A-20, At SOS1, At SOS2, At ANP1, At CBF-3	Salinity & drought tolerance	USA	Ankur Seeds
2010	Cry1Ac	Insect resistance	USA	Monsanto India
2010	Cry1Ac	Insect resistance	USA	Monsanto India
2012	flcry1Ab, vip3A, aph4, 2mepsps, cry1Ab, cry2Ae and bar	Insect resistance & herbicide tolerance	USA	Bayer CropScience
2013	DP393-pMON125403	Insect resistance	USA	Monsanto Holdings
2013	Bollgard III RRF(MON15985 x COT102 MON88913)	Insect resistance & herbicide tolerance	USA	Mahyco
2013	Bollgard III (MON15985 x COT102)	Insect resistance	USA	Mahyco
2014	Bt protein	Insect resistance	USA	Monsanto Holdings
2015	GHB614, GHB119, T304-40	Insect resistance	Belgium	Bayer BioScience
2015	MON88913	Herbicide tolerance	USA	Monsanto India
2015	Widestrike events	Insect resistance	USA	Dow AgroScience
2015	BGIII-RRF	Insect resistance & herbicide tolerance	USA	Monsanto Holdings

Source: ICAR NBPGR, 2016; SABC, 2016

Biotech Cotton under R&D in India, 2016

Developer	Trait(s)	Technology	Status
MMB	IR/HT	BG-IIRRF	Pending approval
Dow AgroSciences	IR	WideStrike	Pending approval
Bayer CropSciences	IR/HT	TwinLink/ Glytol	BRL-II trial
MMB	HT	RRF	BRL-II trial
JK AgriGenetics	IR	-	BRL-II trial
Monsanto	IR/HT	BG-IIIRRF	BRL-I trial
Mahyco	NUE	-	BRL-I trial
Mahyco	DST	-	BRL-I trial
Nuziveedu	IR	-	BRL-1 trial
CICR, DU, TNAU, NRCPB, NBRI, UASD, Rasi, Dow, Bayer & Mahyco	IR/HT/DR/VR/NUE/DST etc	-	Laboratory & Greenhouse Stage

Source: DBT-BSU, 2016; GEAC, 2016; Analyzed by SABC, 2016

Novel technologies for commercialization

- **Rainfed cotton- focus on short duration, erect-type, better harvest index and high GOT cultivars**
- **Development, deployment and adoption of high density planting system of biotech cotton hybrids/varieties to maximize yield potential**
- **Mechanization of cotton harvesting**
- **Stewardship in the supply chain of quality Biotech cotton seeds, refuge management, insect resistant management (IRM) & post approval monitoring etc**
- **Management of emerging pests such as white fly and pink bollworms**
- **Diversification of different biotech cotton events**
- **Approval of first stacked trait Bt/HT cotton**
- **Strengthening of PPP to harness crop innovations (rDNA/Gene-editing) for cotton improvement**