GM Crops in the Indian Context: Looking Back, Looking Forward

Imran Siddiqi
CCMB, Hyderabad

Outline of Points:

Background:

- Basics of Transgenics and GM
- Widely deployed GM traits – herbicide tolerance (HT), bacillus thuringiensis toxin (Bt)
- Concerns with HT, Bt

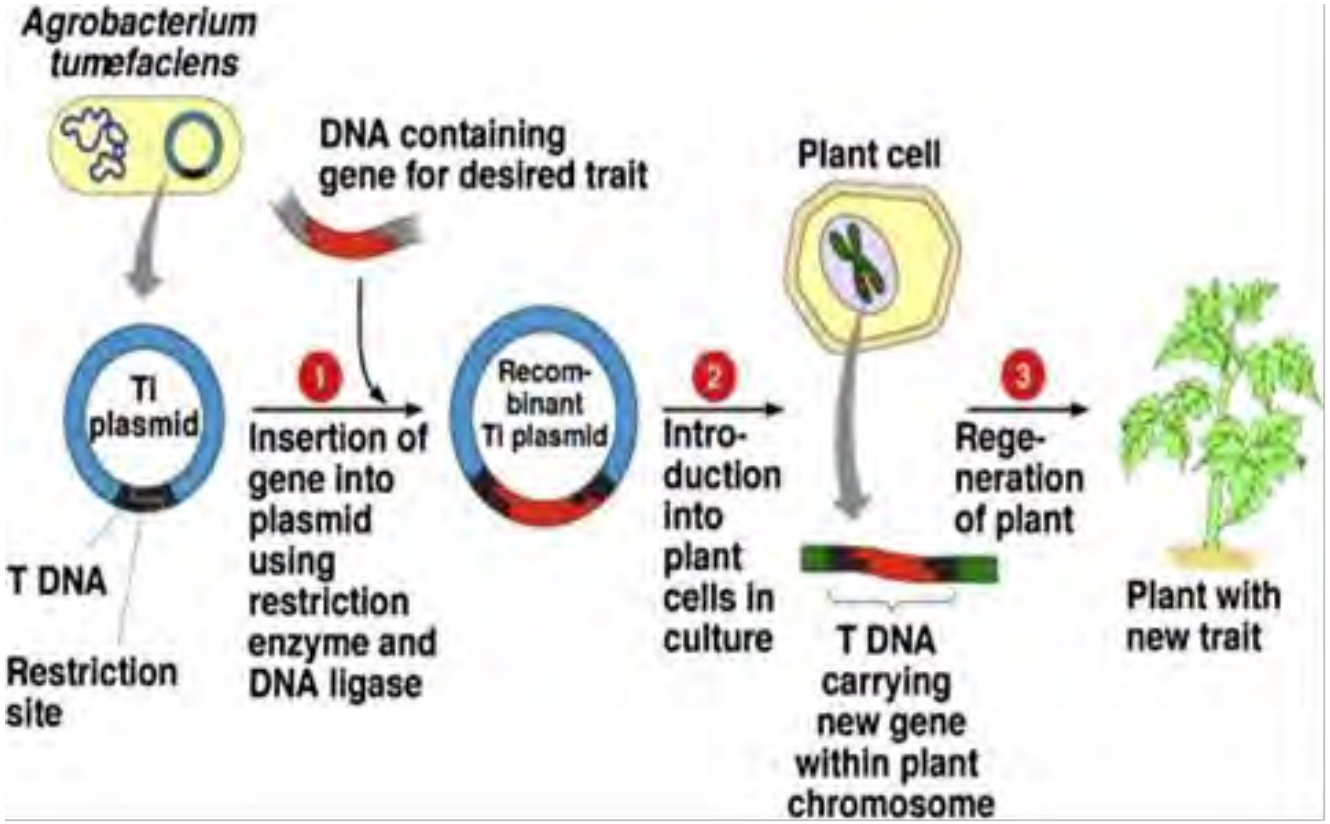
GM in India:

- Cotton in India
- Performance of Bt cotton hybrids
- Emergence of Bt resistant insect pests (PBW)
- Looking back: Analysis of Bt cotton hybrids in India (context, drivers, consequences)

Future considerations:

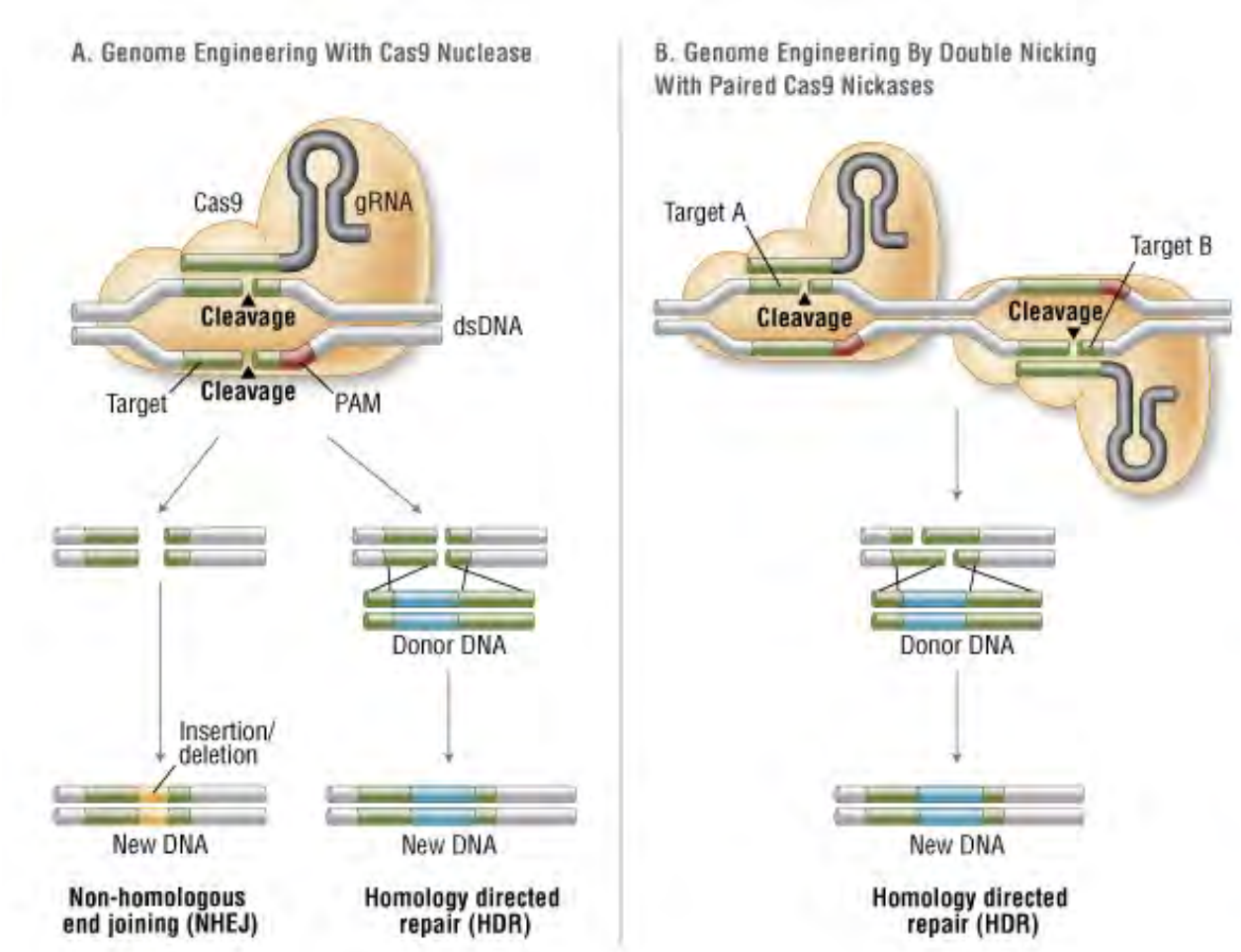
- Technology and policy: productivity, sustainability, farmer incomes
- Assessment of suitability and potential impact of the GM product across the cross section of farmer as part of the regulatory process. Is hybrid cotton really suitable?
- Assessment of short term benefits vs possible long term down side
- Scope of GM Regulation and ensuring compliance

Making a GM Plant



- Insertion of T-DNA is at random locations in the plant genome
- T-DNA insertions are often multi-copy and clustered together
- Insertions are often associated with deletions and rearrangements of plant DNA

Genome Editing: Targeted Changes in DNA



- Targeted gene mutation
- Introduction of new (donor) DNA at precise locations

Usage of GM Crops (2014)

Worldwide:

- 181 million hectares under GM crops
- 4 major GM crops: soybean, corn, canola, and cotton account for 99% of GM crop area
- Soybean: 111 million hectares of which 82% (90 mha) is GM.

India:

- Bt cotton

HT Technology Simplifies Weed Management

- HT is a weed control technology in which the crop is genetically engineered to become resistant to a herbicide. This allows the herbicide to be used in much larger amounts on the field, replacing other weed control measures and resulting in essentially “quantitative killing” of all weeds leaving only the engineered crop to grow.
- Effective in large cropping systems. In India farm size is small (< 3 acres)

How does HT differ from conventional herbicide treatment?

- Conventional herbicide treatment involves treatment with limited amounts of different herbicides in combinations.

- Conventional herbicide treatment is generally used as part of a set of practices (Integrated Weed Management) whereas HT largely replaces all other weed management practices.

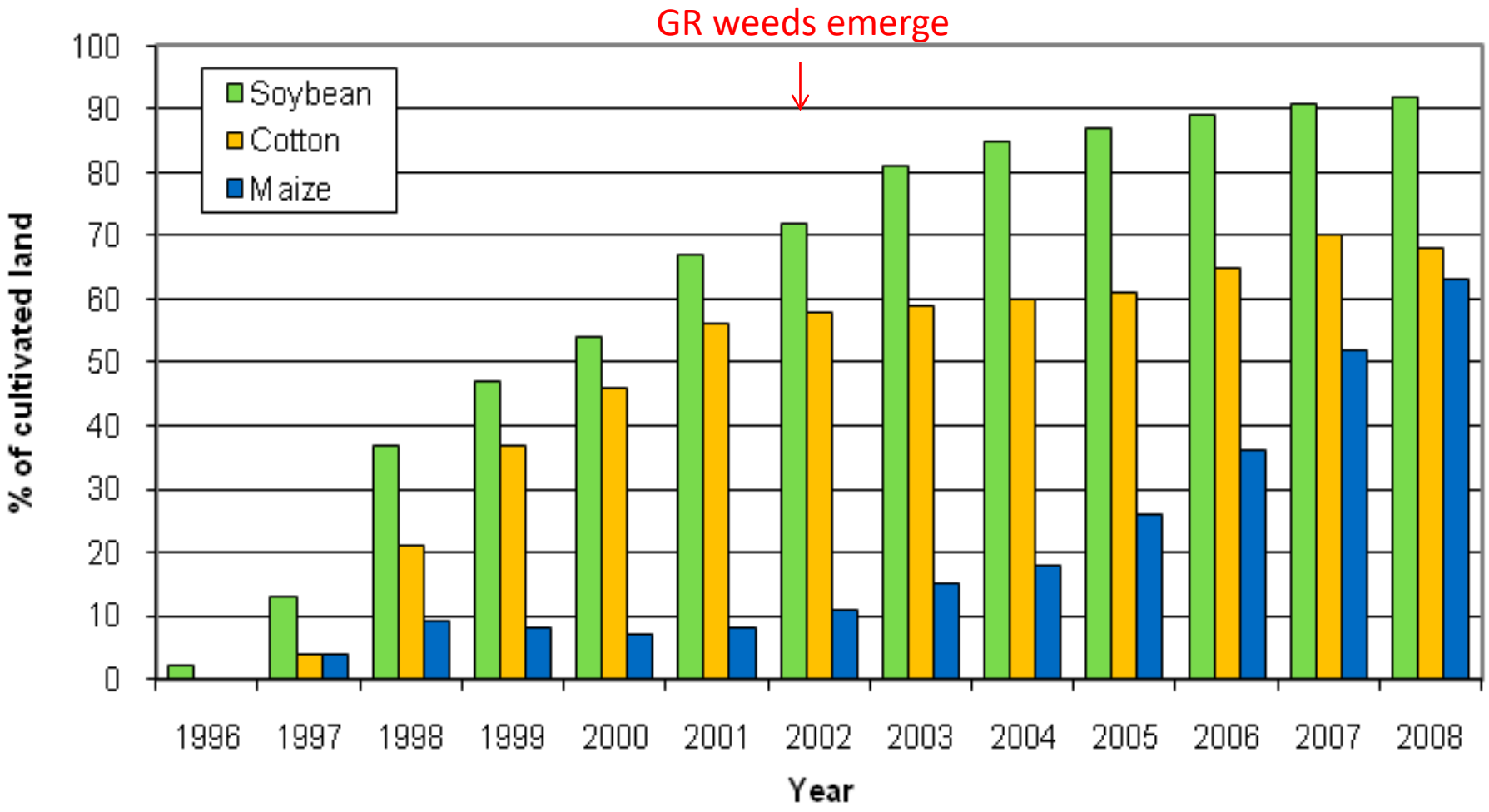
What are the environmental consequences of increased herbicide application in HT?

Overdeployment of a SINGLE chemical method as in HT that kills all weeds imposes very strong selection for emergence and spread of resistant weeds. Once these emerge they can spread very rapidly because of absence of competition from other weeds. This also leads to increased herbicide use. The most extensive HT trait used till now is glyphosate resistance.

" Taking into account applications of all pesticides targeted by the traits embedded in the three major GE crops, pesticide use in the U.S. was reduced in each of the first six years of commercial use (1996– 2001). But in 2002, herbicide use on HR soybeans increased 8.6 million kgs (19 million pounds), driven by a 0.2 kgs/ha (0.18 pounds/acre), increase in the glyphosate rate per crop year, a 21% increase. Incrementally greater annual increases in the kilograms/pounds of herbicides applied to HR hectares have continued nearly every year since."

(Benbrook, 2012. Environmental Sciences Europe 24:24; based on USDA data)

Adoption of Glyphosate-resistant (HT) crops in USA



Duke and Powles, 2009: Agbioforum 12(3&4): 346-357

Overuse of HT Leads to Rapid Emergence and Large Scale Spread of HR Weeds

- Glyphosate resistant (GR) weeds in the USA first emerged 5-7 yrs after start in 1995 of HT adoption. By 15 yrs, 20 different glyphosate resistant weed species had spread to 22 million hectares in the USA.
- Prior to 1995 glyphosate had been used as a conventional herbicide for 20 yrs without GR weeds arising and spreading in the USA.
- Emergence and spread of glyphosate resistant weeds due to indiscriminate overuse of a single herbicide for weed control across successive crop rotations (soybean-corn; soybean-cotton)

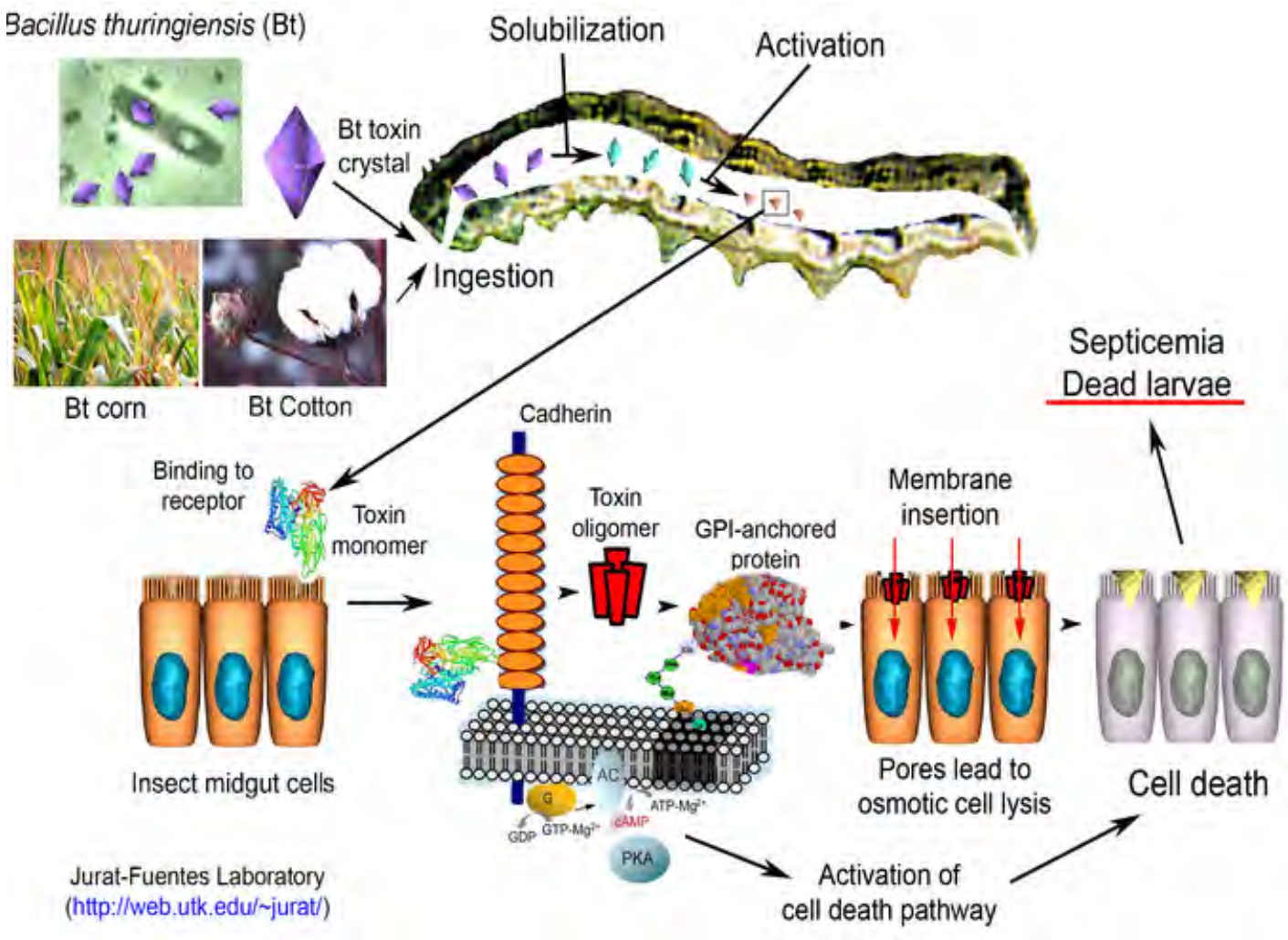
Diversity of Weed Management Methods Preferred over HT:

Broad agreement among weed science experts that a diversity of weed control methods is necessary rather than a single method:

US National Academies of Sciences, Engg., Medicine Report on GM Crops 2016:

- “On the basis of the committee’s review of the theoretical and empirical literature, there is no scientific consensus on the best practices for delaying resistance simply through use of mixtures of herbicides.”
- “There is an obvious need for weed management that includes approaches other than continuous use of herbicides.”

Bt Technology Engineers Plants to Express an Insecticidal Protein from the Soil bacterium Bacillus thuringiensis

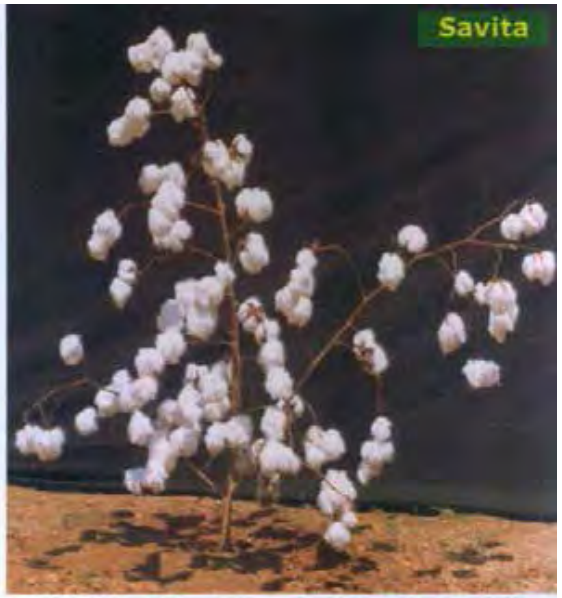


Bt Cotton in India

- India was the first country to use hybrid cotton starting in the 1970's; the only country using Bt cotton as hybrids (2002)
- The need for Bt cotton arose due to the emergence of the American bollworm (ABW) as a major pest of cotton (American cotton) in India (late 1980's)
- Overuse of synthetic pyrethroid pesticides associated with emergence of ABW as a cotton pest
- Use of Bt cotton has been effective in controlling ABW and has been projected as leading to India becoming the second largest producer of cotton in the world
- Pink bollworm (PBW) resistant to Bt has recently emerged as a major pest of cotton in India

Why Hybrid Cotton?

Hybrids



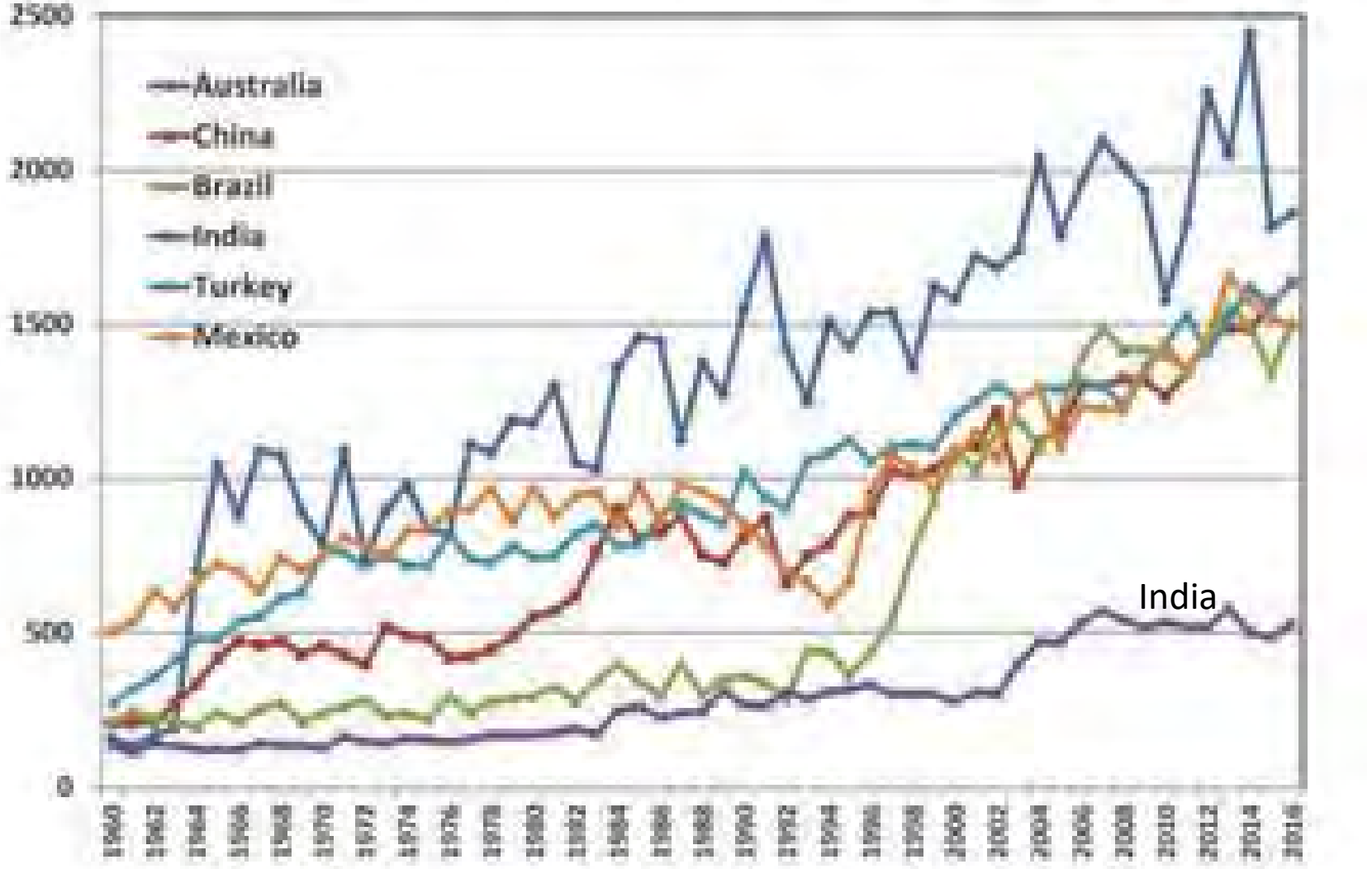
40-100 bolls / plant

Varieties

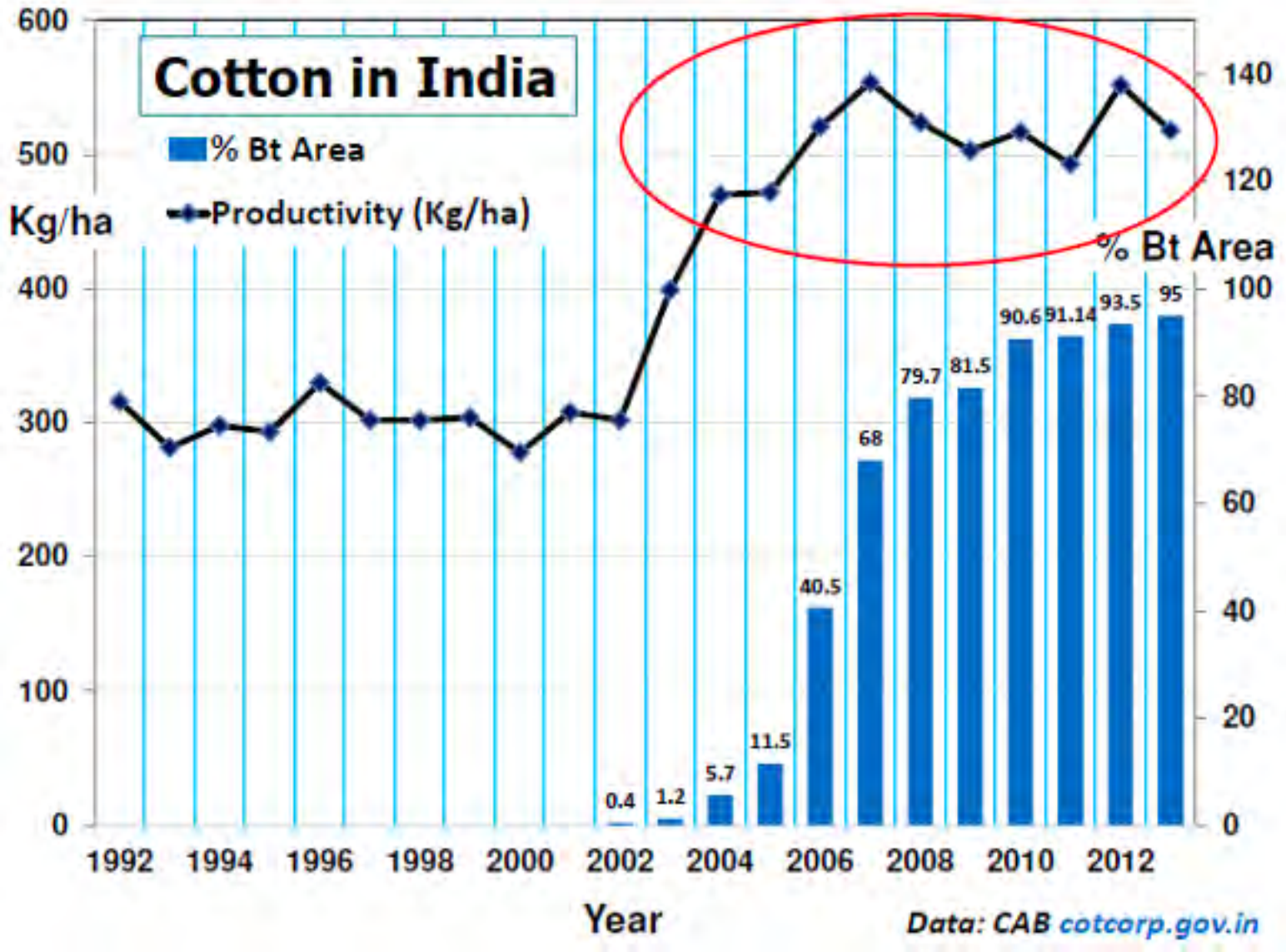
20-30 bolls / plant

Cotton Productivity in India is Low Compared to Other Countries

Cotton lint yields Kg/ha in Au, Chn, Brz, Ind, Trk, Mx



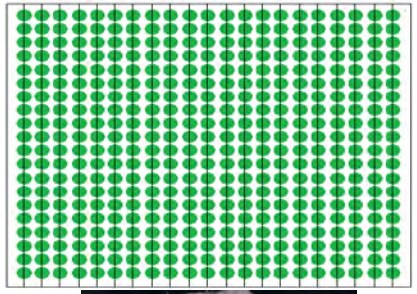
Major Portion of Cotton Yield Increase Slightly Preceded Bt Cotton Hybrids



High Density Planting of Narrow Compact Varieties Gives Higher Yield Than Low Density Planting of Broad Hybrids

Compact Varieties

5-20 bolls/plant

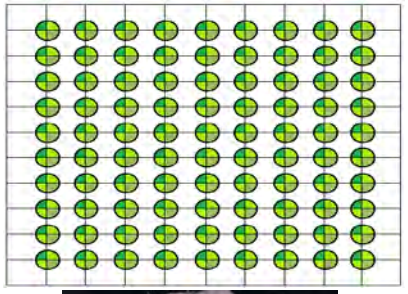


5-8 kg seeds/acre

Yield: 1000-2000 kg/ha

Hybrids

40-100 bolls/plant



0.4-0.8 kg seeds/acre

Yield: 500 kg/ha

Comparison of Bt cotton hybrids and varieties

	Bt Cotton Hybrids (India)	Bt Cotton Varieties (Au, US, Chn, Br, Mx)
Crop duration	160-240 days	150-160 days
Flowering/fruiting duration	80-160 days	60-100
Plant density	11000/ha	110000-160000/ha
Number of pickings	3-5	1
PBW infestation in long dur.	High	Low
N Fertilizer use	224 kg/ha	120 kg/ha (USA)
Water requirement period	Long/Late	Shorter

Overall Experience of HT and Bt Technologies

- Both HT and Bt technologies have been effective for the first 5-10 yrs of usage and led to reduction in use of chemical pesticides
- For both HT and Bt weed/insect resistance has emerged due to overusage accompanied by increase in use of chemical pesticides
- In the case of HT, herbicide resistant weeds continues to spread at a high rate

Bt Cotton in India

- Effective in control of ABW but resistant PBW has emerged as a major pest
- Used in a suboptimal context as hybrids instead of compact varieties; higher input costs; increased risk to farmers particularly in rainfed areas (uncertainty of water over long duration of the crop)
- Possible contribution to distress among low resource farmers
- Use of hybrids enabled retention of control by the seed company and charging of high royalties

Lessons:

- Context of application of a technology determines outcome
- Broad suitability of a GM product across the cross-section of farmers as part of the regulatory process
- High cost and time of development and regulatory clearance favours developers with deep pockets and overuse/monoculture leading to breakdown and unsustainability

Perspectives on Future GM in India

- Excessive reliance on technological solutions including GM to solve agricultural problems ignoring wider underlying issues can distort policy. In India reducing risk to farmers (lowering input costs), infrastructure, and increasing farmer incomes (MSP in theory and practice) needs greater attention (Swaminathan Commission Report, 2006)

- Major problems such as climate change and reduced groundwater availability pose complex challenges

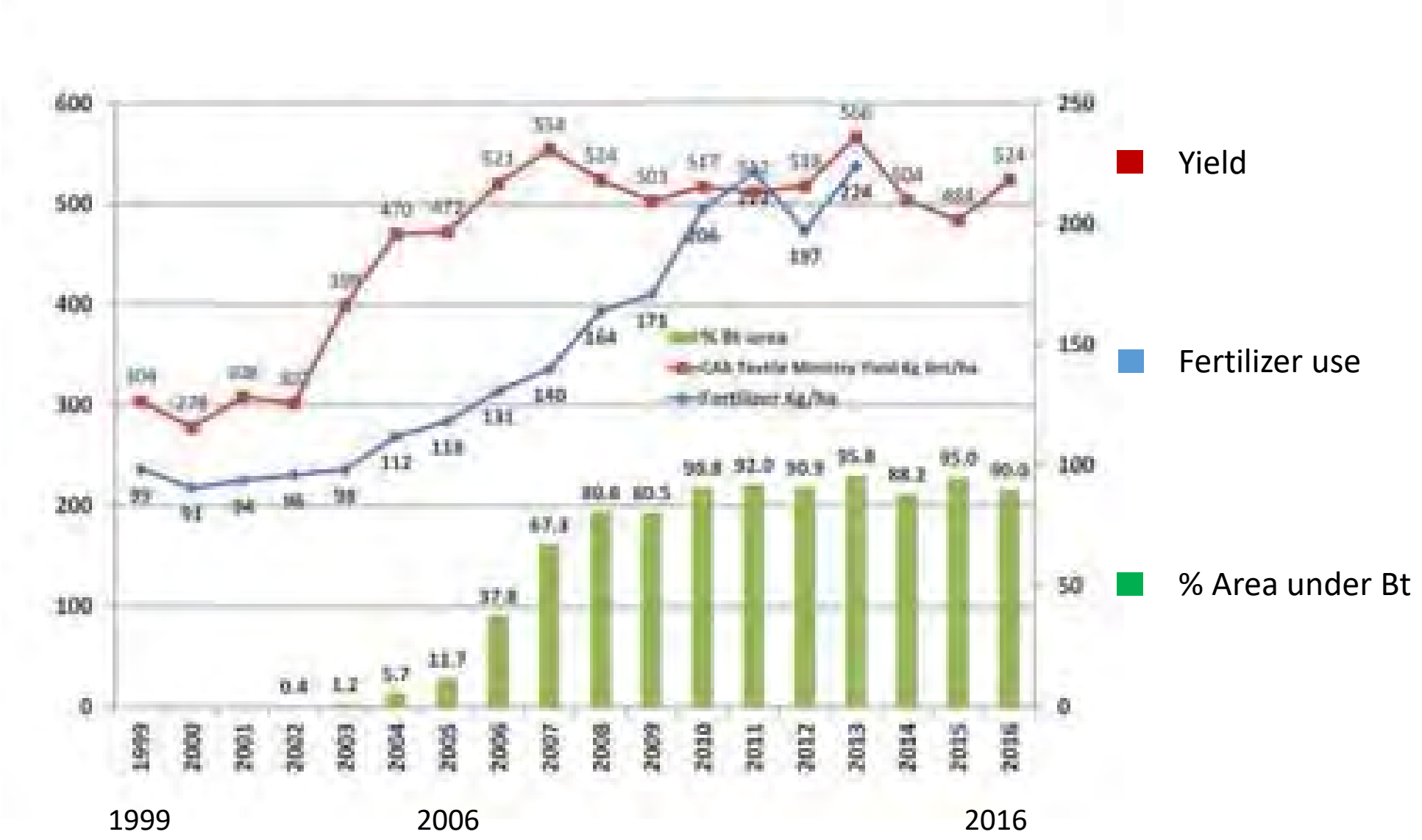
- Alteration of endogenous plant genes by methods such as CRISPR and introduction of modified plant genes into plants (cis-genics) reduce safety concerns than transgenics, however these too will require rigorous testing

- Longterm sustainability vs shortterm gains. Combinatorial practices for pest and weed control are likely to be more sustainable than single point solutions that come with high environmental cost

Perspectives (contd.)

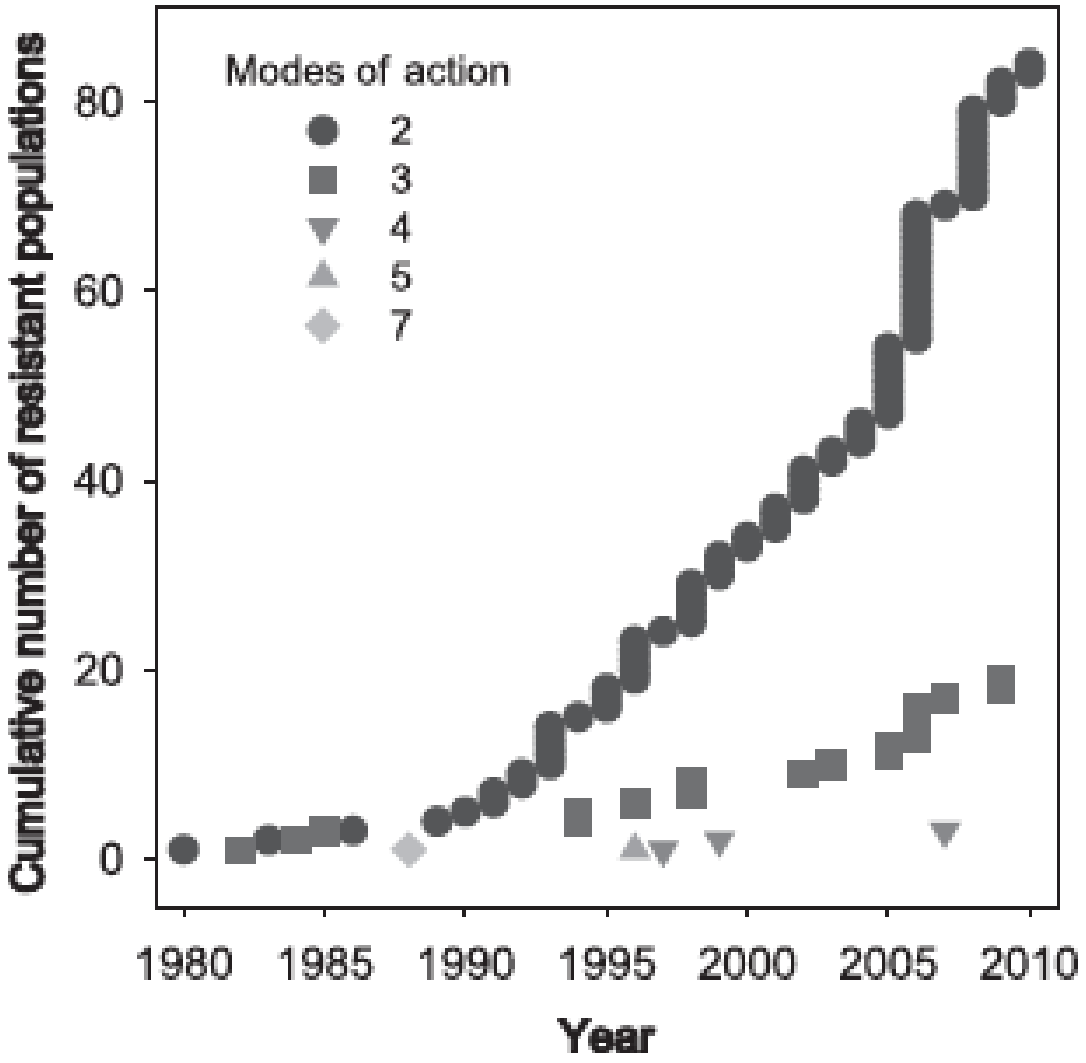
- Labour shortages and HT; Longterm vs shortterm
- High cost of GM development and the right of farmers to save seed (Indian Seed Act, 1966)
- Detection of contamination and illegal GM; deterrence and enforcement

Major Portion of Cotton Yield Increase Slightly Preceded Bt Cotton Hybrids



1999 2006 2016

Weeds resistant to multiple herbicides: 108 biotypes in 38 different species



Mortensen et al., 2012. Bioscience 62:75-84

Photo: James Quinn

60% 30% 10%

Fruiting Branch

Herbicides Proposed by Developers for Stacking

Synthetic auxin herbicides: 2,4-D; Dicamba

28 documented weed species resistant to 2,4-D and/or Dicamba

Therefore resistance to 2,4-D and Dicamba including double resistance already exists and can spread rapidly if/when these are used in the context of HT

Bottom Line: Use of chemical methods alone, singly or stacked as part of HT is almost certain to lead to emergence and spread of HR weeds. Stacking is not fundamentally different from using a single herbicide.

Use of herbicides with stacking predicted to increase total herbicide usage to 3.15 pounds/acre by 2025 (Mortensen et al., 2012)

Herbicides Proposed by Developers for Stacking

Synthetic auxin herbicides: 2,4-D; Dicamba

28 documented weed species resistant to 2,4-D and/or Dicamba

Therefore resistance to 2,4-D and Dicamba including double resistance already exists and can spread rapidly if/when these are used in the context of HT

Bottom Line: Use of chemical methods alone, singly or stacked as part of HT is almost certain to lead to emergence and spread of HR weeds. Stacking is not fundamentally different from using a single herbicide.

Use of herbicides with stacking predicted to increase total herbicide usage to 3.15 pounds/acre by 2025 (Mortensen et al., 2012)