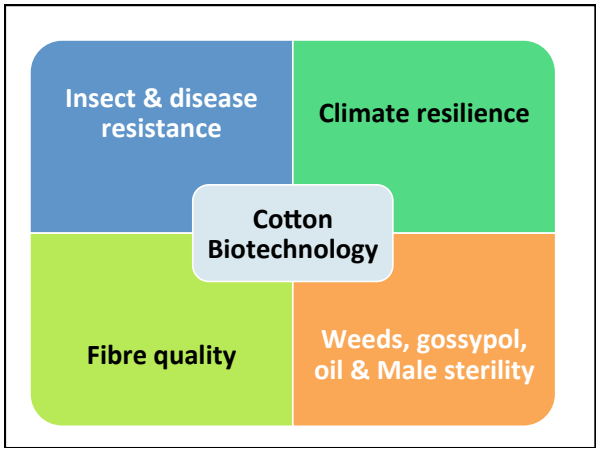
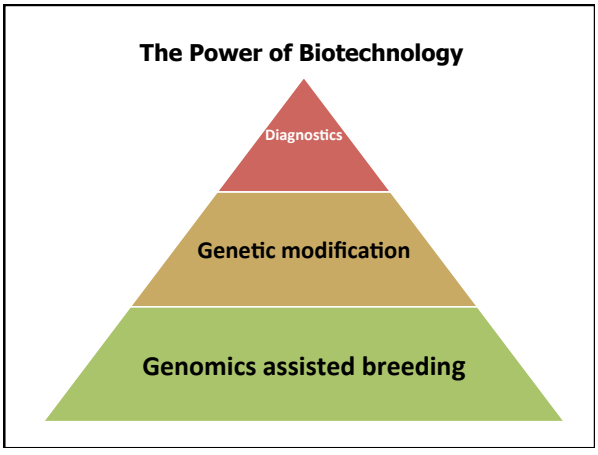
GM cotton seed business
US $ 2.0 billion every year





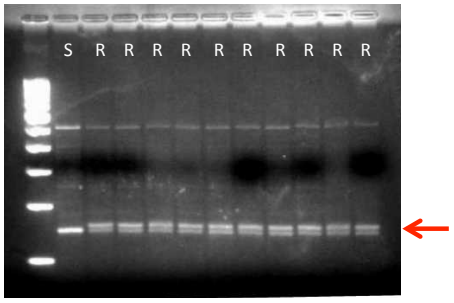
Decoding the Cotton Genome

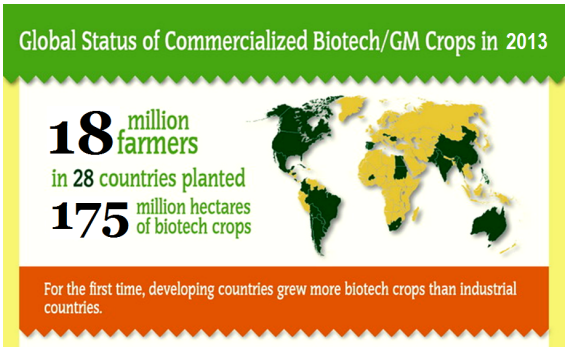
Gossypium raimondi (D_5)
775 Mb *Wang et. al 2012, Patterson et al., 2012*

Gossypium arboreum (A_2)
1694 Mb *Li et al., 2014*

Gossypium hirsutum (A_2)
2400 Mb *Li et al., 2015; Zhang et. al 2015*

Marker Assisted Breeding
for Bacterial Leaf Blight Resistance
CIR 246 Marker



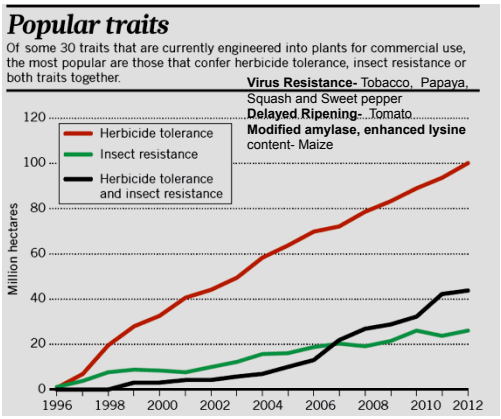


12 Main GM Crops

Soybean, Cotton, Maize, Canola, Alfalfa, Sugarbeet,PapayaSquash, Sweet pepper, Poplar, Tomato and Potato

The 4 Major Biotech Crops in 2012 are Soybean, Cotton, Maize and Canola.

SOYBEAN	COTTON	MAIZE	CANOLA
grown in 11 countries 81% of global planting	grown in 15 countries 81% of global planting	grown in 17 countries 35% of global planting	grown in 4 countries 30% of global planting

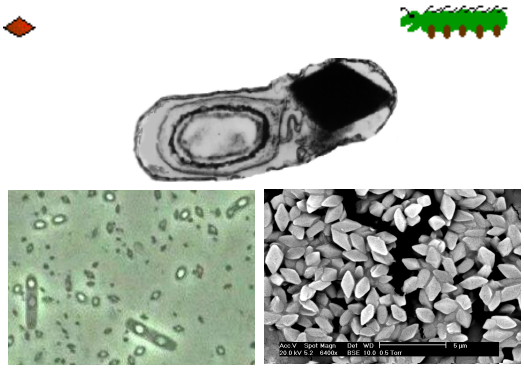


Biotech Cotton

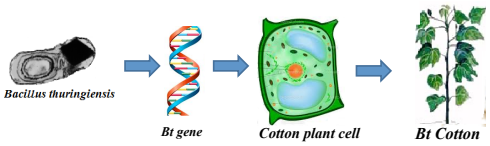
Bollworms

American Pink Spotted

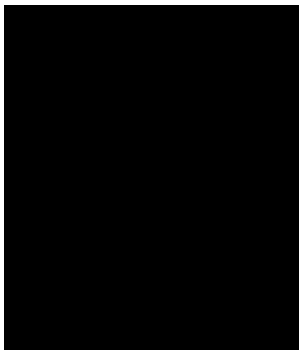
Bacillus thuringiensis



Development of Bt cotton



Bt Cotton was approved in 2002 in India



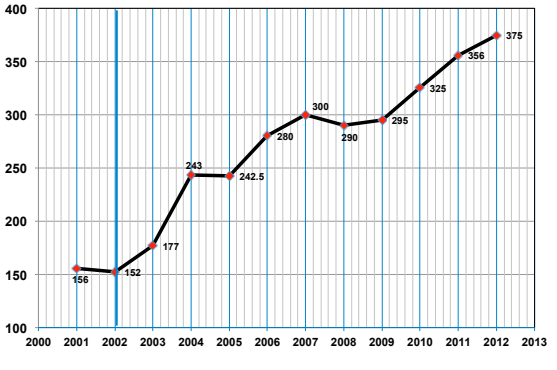
1128 Bt Cotton Hybrids

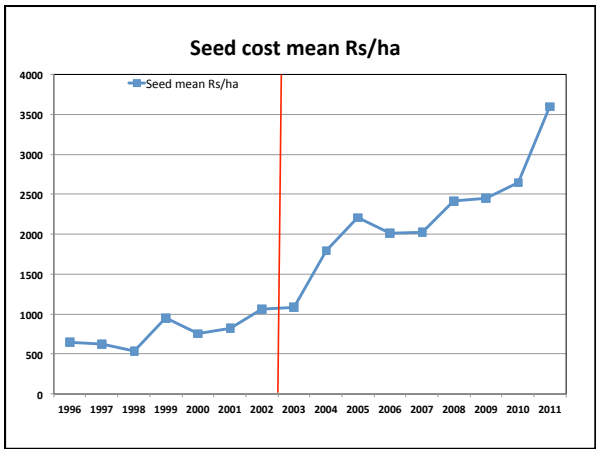
2012

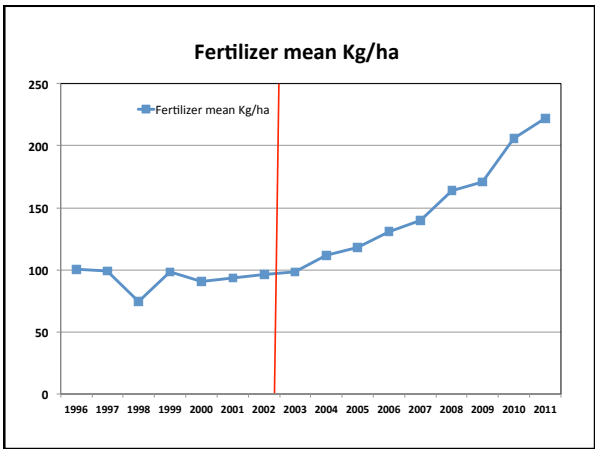
95%

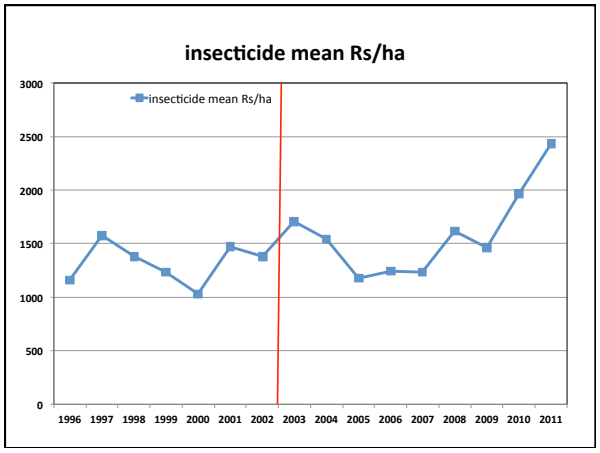
Cotton Area is Bt Cotton

Cotton Production




Seed cost mean Rs/ha
Seed mean Rs/ha
4000
3500
3000
2500
2000
1500
1000
500
0
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


Fertilizer mean Kg/ha
Fertilizer mean Kg/ha
250
200
150
100
50
0
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

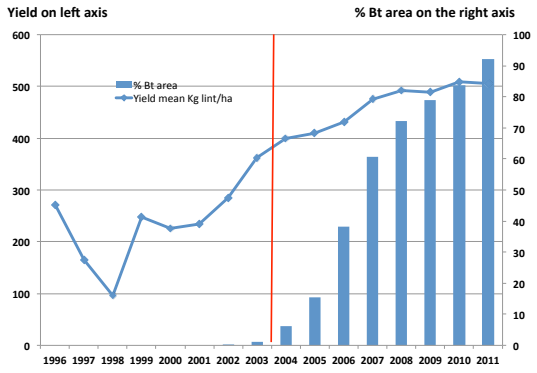

insecticide mean Rs/ha
insecticide mean Rs/ha
3000
2500
2000
1500
1000
500
0
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


Minor Pests Became Major Pests

All India Average inputs, Yield and % Bt Area

	Seed mean Rs/ha	Fertilizer mean Kg/ha	insecticide mean Rs/ha	Yield mean Kg lint/ha	% Bt area
1996	642	101	1165	271	
1997	622	99	1575	166	
1998	534	74	1381	96	
1999	958	99	1238	247	
2000	756	91	1032	225	
2001	826	94	1470	234	
2002	1058	96	1385	284	0.4
2003	1086	98	1708	362	1.1
2004	1793	112	1543	400	6.2
2005	2212	118	1182	410	15.4
2006	2013	131	1241	432	38.2
2007	2023	140	1238	475	60.8
2008	2422	164	1615	493	72.3
2009	2450	171	1463	489	79.1
2010	2652	206	1972	509	83.8
2011	3594	222	2429	506	92.1

Yield and % Bt Cotton Area



Mummy Returns?

Resistance to Bt Crops

Bt transgenic crops			
Fall armyworm, ***Spodoptera frugiperda***	Bt Cry 1F **corn**	Puerto Rico	2010
Pink bollworm, ***Pectinophora gossypiella***	Bt Cry 1Ac **cotton**	India	2011
African stem borer ***Busseola fusca***	Bt Cry 1 Ab **corn**	South Africa	2011
Western corn rootworm, ***Diabrotica virgifera***	Bt Cry 3 Bb 1 **corn**	USA	2011
Cotton Bollworm ***Helicoverpa zea***	Bt Cry 1 Ac **cotton**	USA	2010

Pyramiding genes for resistance management

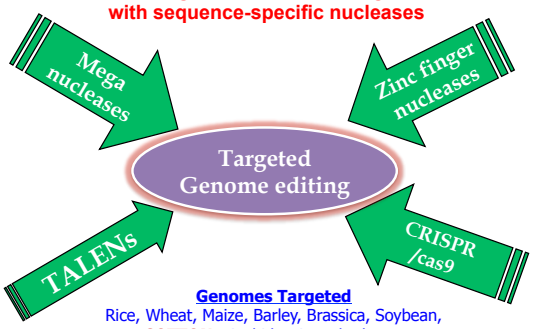
It is a game of chess …

Herbicide Tolerance

On 20th March 2015
World Health Organization (WHO) Declared
Glyphosate (Roundup) as a probable Carcinogen

New Technologies

Targeted Genome editing with sequence-specific nucleases

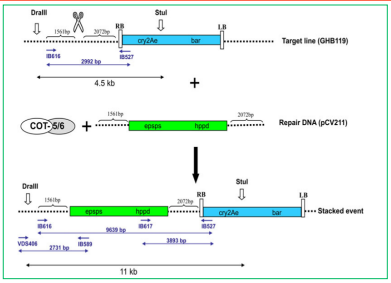


Genomes Targeted
Rice, Wheat, Maize, Barley, Brassica, Soybean,
COTTON, Arabidopsis and tobacco

Plant Biotechnology Journal
Plant Biotechnology Journal (2013) 11, pp. 933–941 doi: 10.1111/pbi.12085

Targeted molecular trait stacking in cotton through targeted double-strand break induction

Kathleen D'Halluin[1,*], Chantal Vanderstraeten[1], Jolien Van Hulle[1], Joanna Rosolowska[1], Ilse Van Den Brande[1], Anouk Pennewaert[1], Kristel D'Hont[1], Martine Bossut[1], Derek Jantz[2], Rene Ruiter[1] and Jean Broadhvest[1]

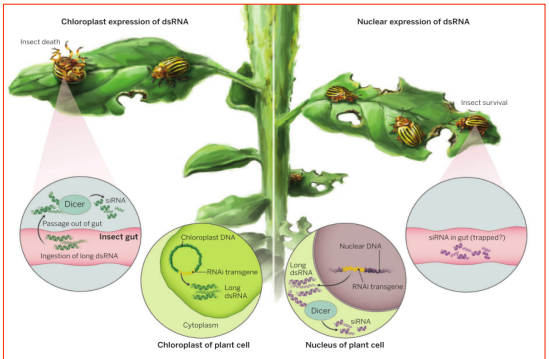


GM Wheat and Cotton that scare aphids

Rothamstead Station UK

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

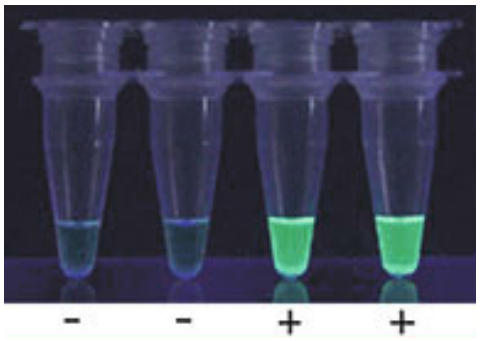
Michael H. Beale, Michael A. Birkett, Toby J. A. Bruce, Keith Chamberlain, Linda M. Field, Alison K. Huttly,

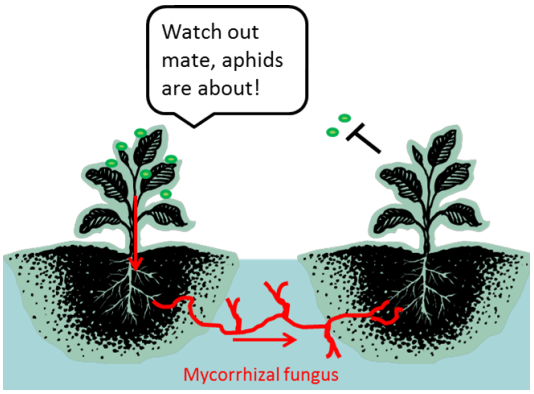


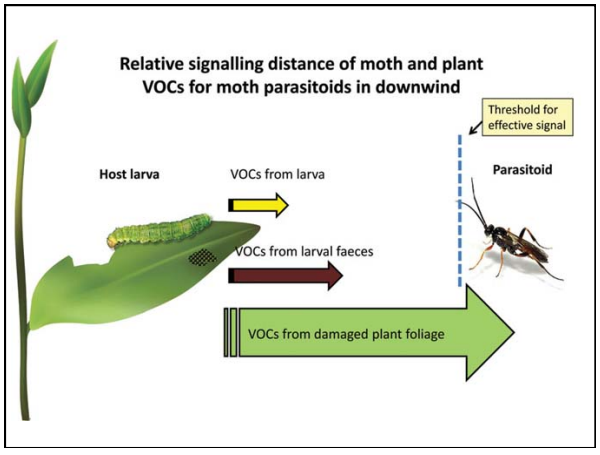
Anti-insect RNA. Transgenic potato plants engineered to express insect-specific long dsRNA in chloroplasts kill potato beetles, whereas those plants expressing dsRNA in the plant cell cytoplasm do not. Chloroplasts do not process dsRNA into siRNA. Therefore, beetles that feed on the chloroplast-transformed plants ingest almost entirely long dsRNA, whereas beetles feeding on nuclear-encoded dsRNAs consume mostly short interfering RNAs (siRNAs). Long dsRNAs are readily absorbed by the beetle's gut cells, and a strong RNAi response is elicited, resulting in high mortalities of the feeding pests. The siRNAs either may not be readily absorbed in the gut or are not in a form suitable to induce RNAi effectively.

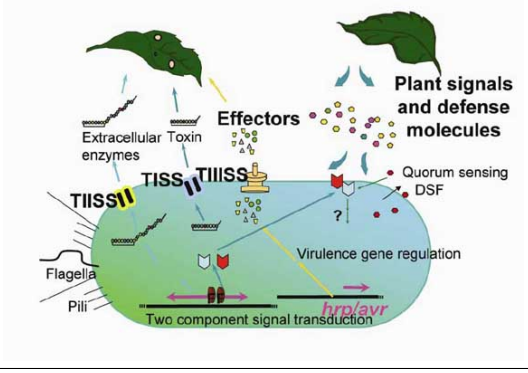
Steve Whyard (2015) Science 347, 950-951

DNA/RNA detection 30 minutes
Loop-Mediated Isothermal Amplification (LAMP)

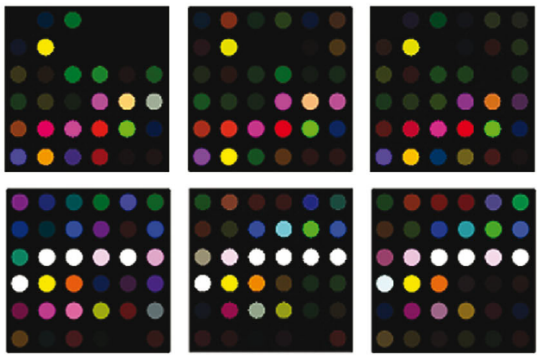






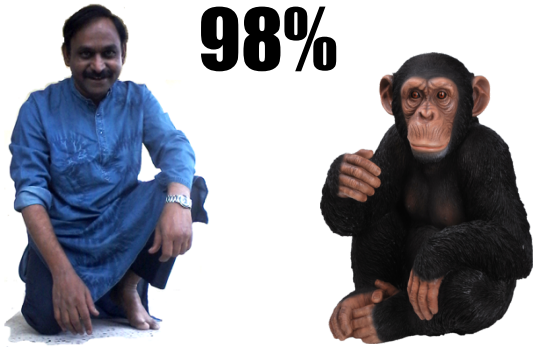


Optical Electronic Nose



DNA Similarity

98%



Exciting Applications

GM technology

provides exclusive solutions for

VIRAL DISEASES
CRYPTIC INSECTS
SALINITY
DROUGHT
CLIMATE CHANGE
QUALITY IMPROVEMENT

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

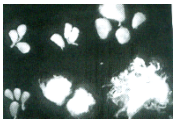


Spider silk: 5 times stronger than steel, twice as elastic as nylon. water proof and stretchable

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.

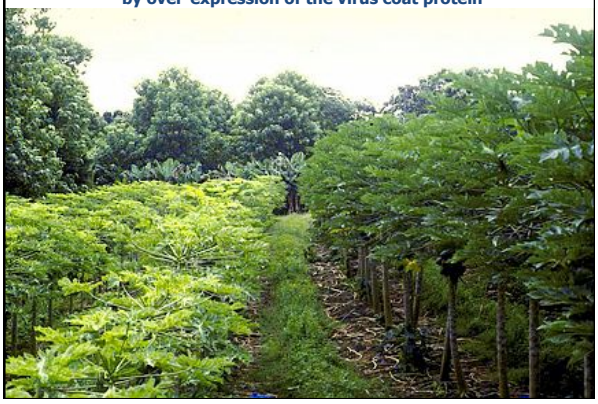
Insect silk proteins in wool producing mammals

Patent no: 2001-218289/22 Karatzaz and Huang (China)

Silk protein gene from *Bombyx mori* was expressed in wool follicles

Ringspot-Virus resistant GM papaya

by over-expression of the virus coat protein

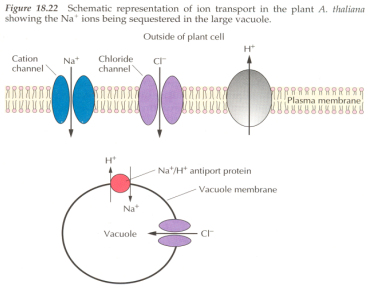


Drought Resistant GM Cotton Maize and Tomato

Salt-Resistant GM Tomato crop

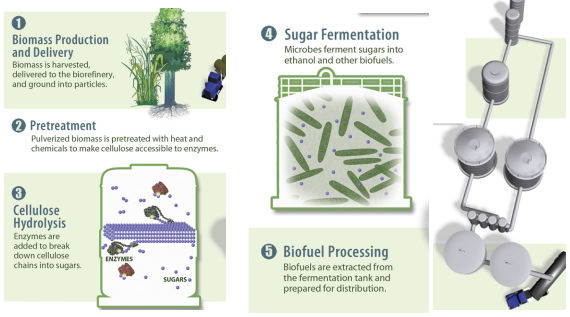
Salt-Resistant GM Cotton crop

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



Bio-Fuel

Alcohol from GM technology



Non-transgenic corn Transgenic corn

nature biotechnology Volume 25 NOVEMBER 2007

Control of coleopteran insect pests through RNA interference

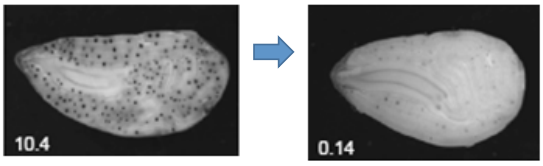
James A Baum[1], Thierry Bogaert[2], William Clinton[1], Gregory R Heck[1], Pascale Feldmann[2], Oliver Ilagan[1], Scott Johnson[1], Geert Plaetinck[2], Tichafa Munyikwa[1], Michael Pleau[1], Ty Vaughn[1] & James Roberts[1,3]

nature biotechnology Volume 25 NOVEMBER 2007

Silencing a cotton bollworm P450 monooxygenase gene by plant-mediated RNAi impairs larval tolerance of gossypol

Gossypol Reduction in seeds

Dr Kirthi Rathore, Texas 2006



Challenges

1. **Sharp decline in fertilizer factor productivity**
2. **Increase in pests and diseases** due to Imbalanced usage of fertilizers
3. **Increase in insecticide** usage by 30% to 56,000 tons over 5 years
4. **Insect Resistance development** to Bt cotton and insecticides

Way Forward

1. **Conservation Agriculture**
2. **Biological** -Soil nutrient and health enhancement
3. **Cropping systems:** Cereals-Legumes/pulses-Fodder
4. **Use Biotech to the best potential**