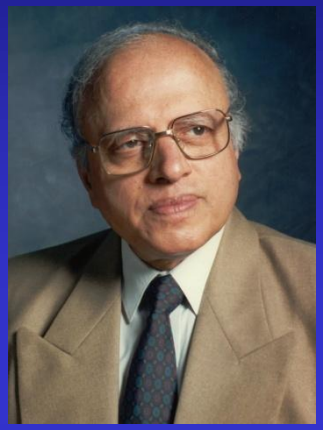
Advances in Agricultural Biotechnology for Sustainable Growth and Food Security

T R Sharma, *PhD*
Project Director
National Research Centre on Plant Biotechnology
Pusa Campus, New Delhi
www. nrcpb.org ; trsharma @nrcpb.org

Indian Agriculture: Post Independence



Prof. MS Swaminathan

Prof. NE Borlaug

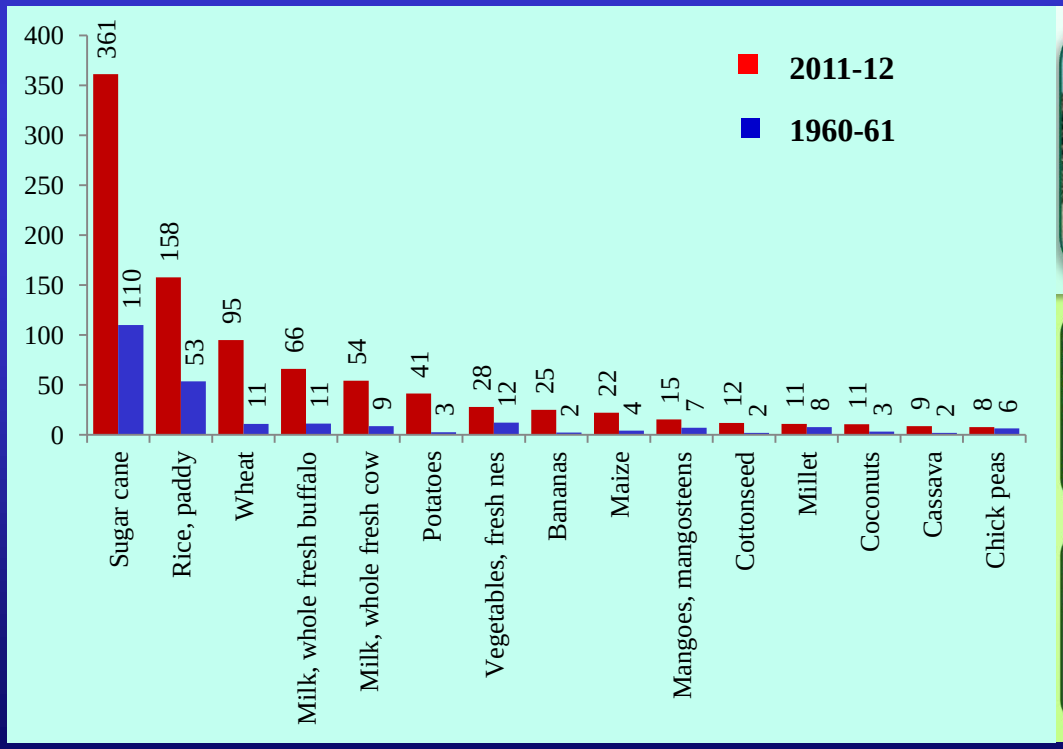
Green Revolution

Growth of Indian Agriculture

Between 1951 to till date

- Food grain production: 5X (51 to 257 MT)
- Milk production: 8X (17 to 127 MT - World No. 1)
- Fish production: 11X (0.75 to 8.4 MT)
- Horticulture : 6X
- Meat : 8X; Egg : 27X
- Poverty and hunger percentages more than halved

India has 2% of world's land, 4% fresh water but 16% of world's population and 10% of cattle.

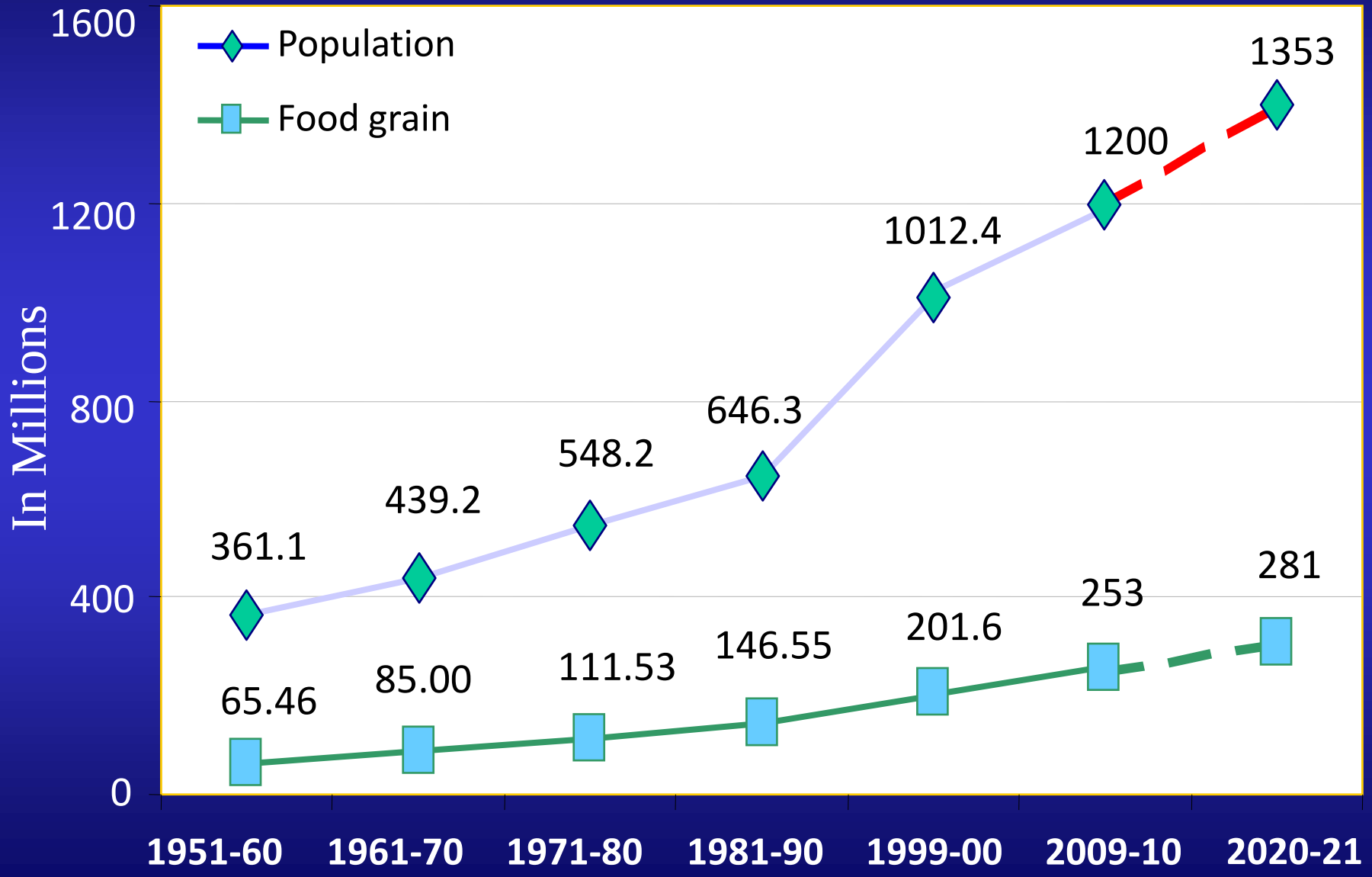


Source: FAOSTAT, 2014; State of Indian Agriculture, 2013-14

Challenges Ahead

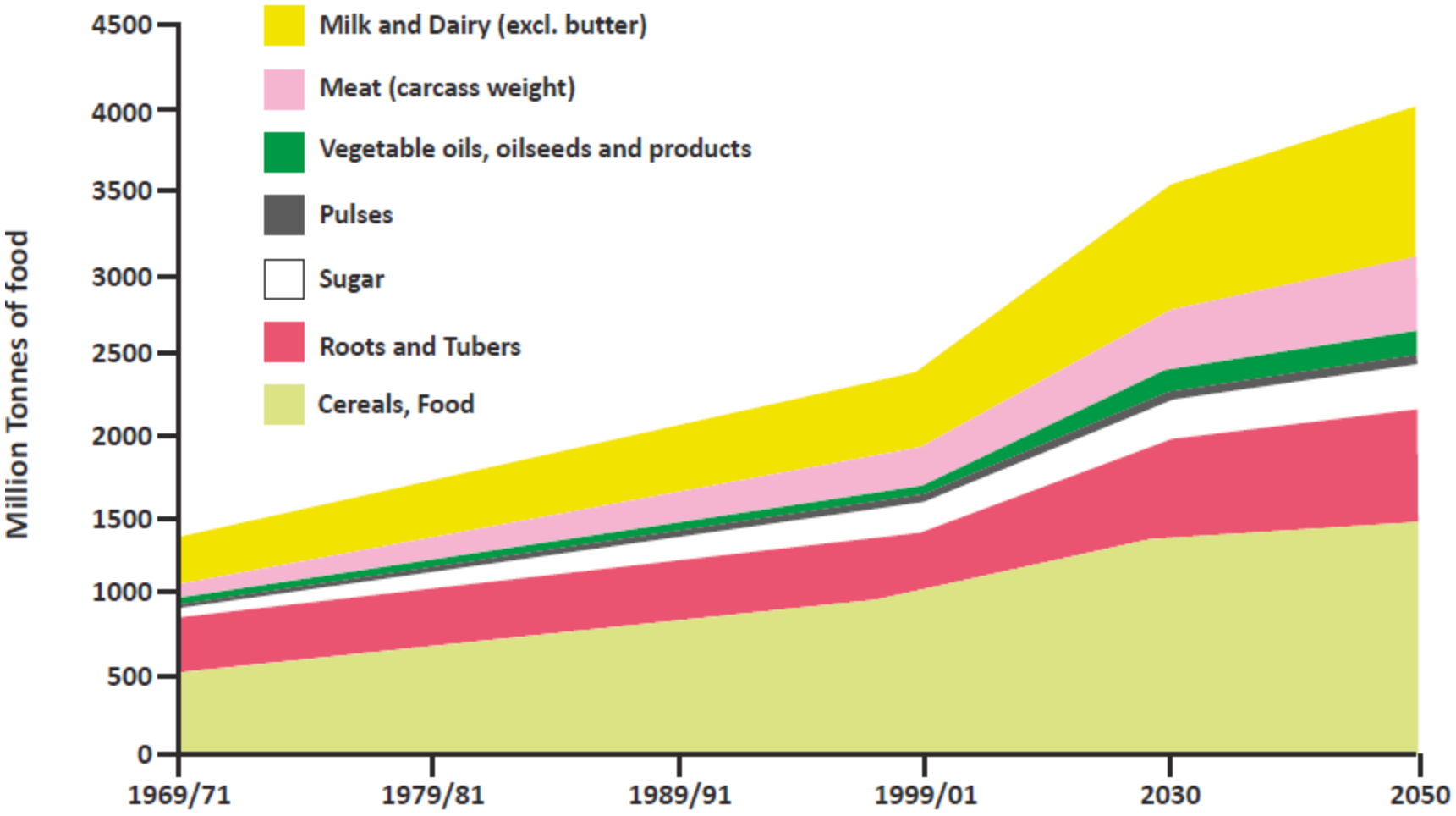
Population and Production of Food Grains

Trends and Projections



Source: http://populationpyramid.net/india/; NCAP, 2009

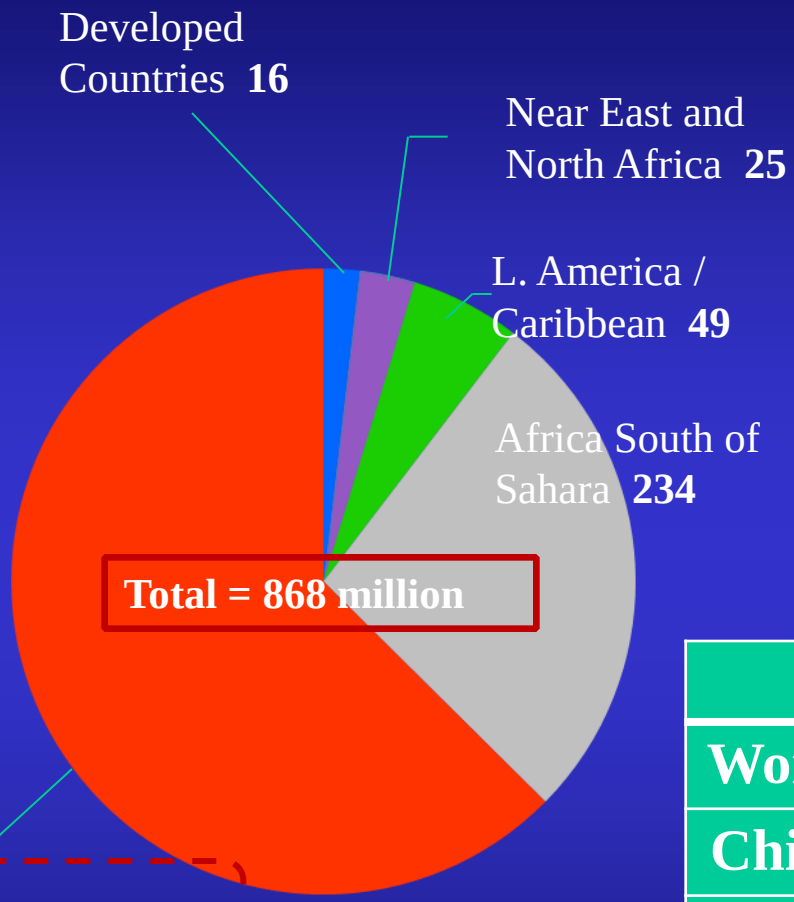
The future demand for food products

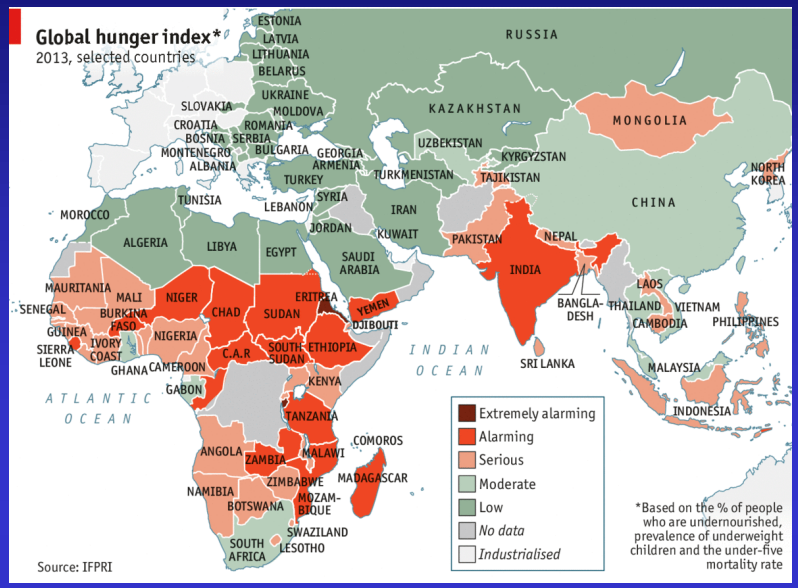


Choudhary *et al*., Plant Biotechnology Journal (2014)

India's Global Hunger Index (GHI) Score

Majority (62%) of world's hungry live in Asia and 25% in India.





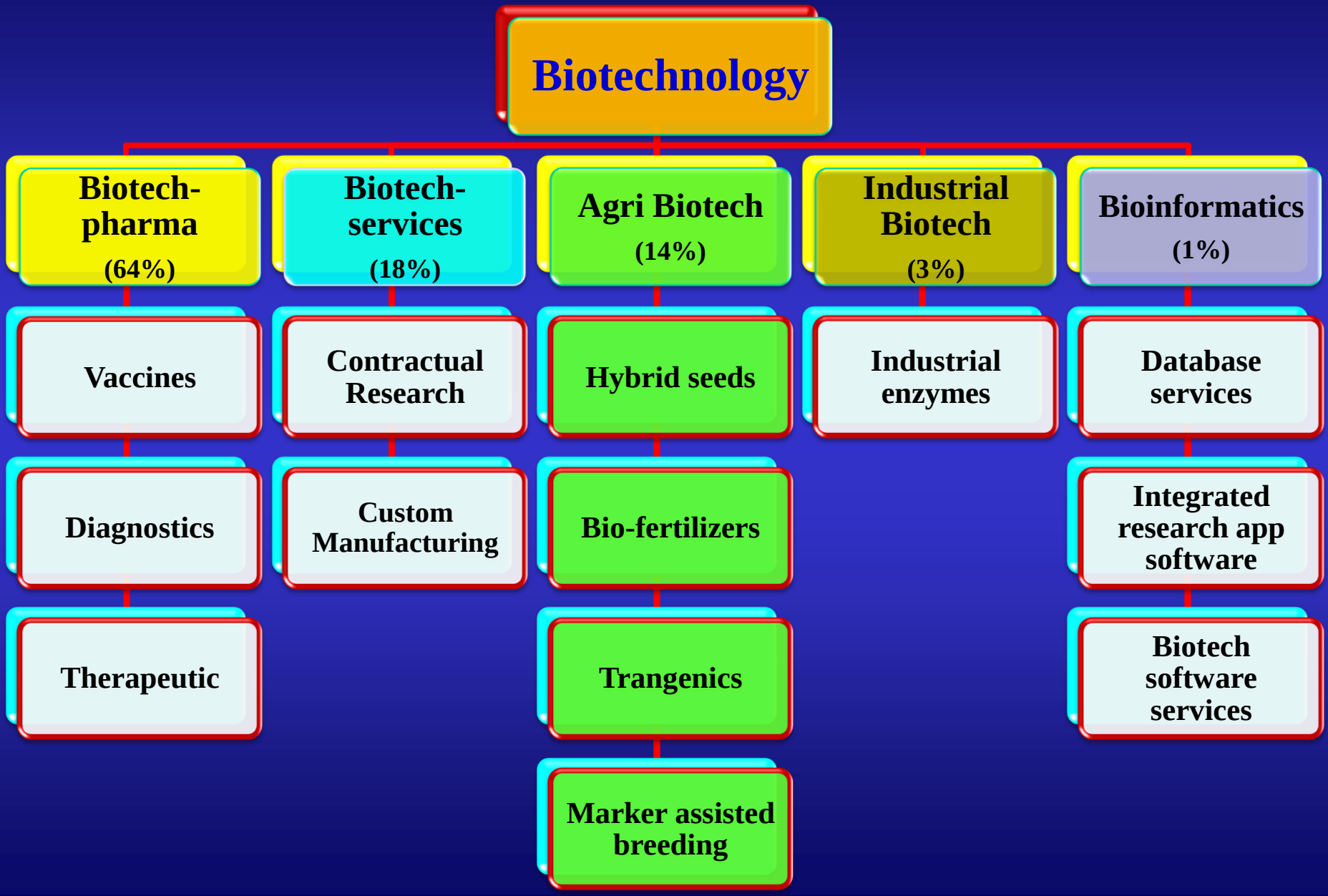
	1990	1996	2001	2011
World	19.7	17.0	16.0	14.6
China	11.7	9.1	6.8	5.5
Brazil	7.6	6.2	5.3	< 5
India	**30.4**	**22.9**	**24.1**	**23.7**

Among BRICS Countries, India has Alarming Level of GHI

Source: IFPRI, 2011; FAO, 2012

Applications of Biotechnology in Indian Agriculture

Biotech Industry in India



Four Agri-Biotech Players Among Top 20 Biotech Companies

Rank 2013	Company	BioScience Revenues in Rs Crore			%Change over 2011-12
		2012-13	2011-12	2010-11	
1	Serum Institute of India	2374.00	1708.00	1041.00	38.99
2	Biocon	1871.00	1676.40	1483.00	11.61
3	Nuziveedu Seeds	778.13	745.00	610.00	4.45
4	NovoNordisk*	712.00	647.28	462.00	10.00
5	Syngene International	557.00	410.00	318.00	35.85
6	Reliance Life Sciences*	535.00	401.00	283.00	33.42
7	Eli Lilly*	391.66	290.16	204.00	34.98
8	Bharat Serums and Vaccines	389.00	298.32	226.00	30.40
9	Biological E	353.00	98.96	246.39	256.71
10	Fortis Clinical Research Ltd (FCRL)	344.40	287.00	86.00	20.00
11	Novozymes South Asia*	343.00	297.66	242.00	15.23
12	Ankur Seeds	341.00	325.00	250.00	4.92
13	Indian Immunologicals	325.65	255.93	269.07	27.24
14	GlaxoSimthKline*	312.00	257.66	177.51	21.09
15	Bharat Biotech	299.83	277.70	265.00	7.97
16	Tulip Group	260.00	225.00	185.63	15.56
17	Haffkine Bio-Pharmaceutical	253.41	160.02	86.00	58.36
18	Mahyco	246.00	314.00	359.00	-21.66
19	Advanced Enzymes	229.36	180.00	154.00	27.42
20	Rasi Seeds	229.00	392.00	371.88	-41.58

Biospectrum, June 2013

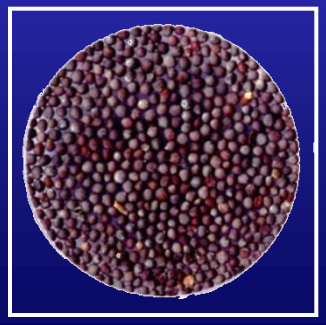
Biotechnology in Agriculture

Key technologies	Brief description	Examples
Functional Genomics and Molecular Breeding	• A technique based on gene injection from the same crop genome • An efficient way of introducing the desired characteristics (available within the crop genome) in the seed • Marker Assisted Selection (MAS) a key application used to develop hybrid crops in India through gene pyramiding and stacking	• Pusa Basmati 1 • Samba Mahsuri • Swarna Sub 1
Transgenic (GM)	• Involves gene injection from a different crop genome • Useful for introducing the desired traits in a seed if the target traits are not available in the same genome • Injection of *Bacillus thuringiensis* (Bt) a key application to make crops resistant to pest attacks	Bt cotton
Targeting Induced Local Lesions in Genomes (TILLING)	• Based on deoxyribo nucleuc acid (DNA) sequencing that enables identification of induced and naturally occurring variation in several species • A reverse genetic, nontransgenic method for improving a quality trait in a crop plant • Not subject to the same regulatory approval requirements as transgenic crops • Arabidopsis TILLING library used extensively to search for mutations in the genes of interest	• Wheat • Maize • Barley

Indian Biotech Agriculture Industry: Vision 2025 (CII)

Developed a High Yielding Mustard Variety Pusa Jai Kisan

Features
High yielding - 17-20%
Avg Yield - 19-25Q/ha
Early Maturity - 115-125 days
Lodging resistant, shattering resistant
Suitable for both timely and late sown conditions
Suitable for irrigated conditions of North West Zone comprising Gujarat, Rajasthan and Maharashtra



- A somaclonal variant (Bio-902) of Varuna
- Released in 1994 as ‘Pusa Jai Kisan’
- One of the top three cultivated varieties till date

Development of Mustard Hybrid

- The *Moricandia* based CMS and fertility restorer lines have been developed and distributed to the public as well as licensed to private companies
- *Moricandia* system contributed to commercial production of mustard hybrids **NRC Sankar Sarson** (DRMR, Bharatpur**)** and **Coral 432** (Advanta India**)**

Development of Improved Pusa Basmati 1

- Pyramiding of two genes namely *xa13* and *Xa21* from IRBB55 for bacterial blight resistance in the background of Basmati rice
- Developed in collaboration with Division of Genetics, IARI
- Released as 'Improved Pusa Basmati1' for commercial cultivation in 2007
- Donor for BLB resistance in Basmati germplasm
- 11.9% higher yield over Pusa Basmati 1 and 33.5% higher yield over Taraori Basmati

Improved Samba Mahsuri Pyramided with 3 Genes for BLB Resistance (2008)

xa5, xa13 and *Xa21*

Euphytica (2008) 160:411 422
DOI 10.1007/s10681 007 9564 6

Marker assisted introgression of bacterial blight resistance in Samba Mahsuri, an elite indica rice variety

Raman M. Sundaram • Manne R. Vishnupriya •
Sunil K. Biradar • Gouri S. Laha • Gajjala Ashok Reddy •
N. Shobha Rani • Nukala P. Sarma •
Ramesh Venkata Sonti

'Improved Samba Mahsuri' has good agro-morphological features (figures a & b) and has excellent grain quality parameters (figures d & f) similar to Samba Mahsuri (figure c & d)

QPM Hybrid in Maize (2008)

Vivek MH 9 Vivek QPM 9

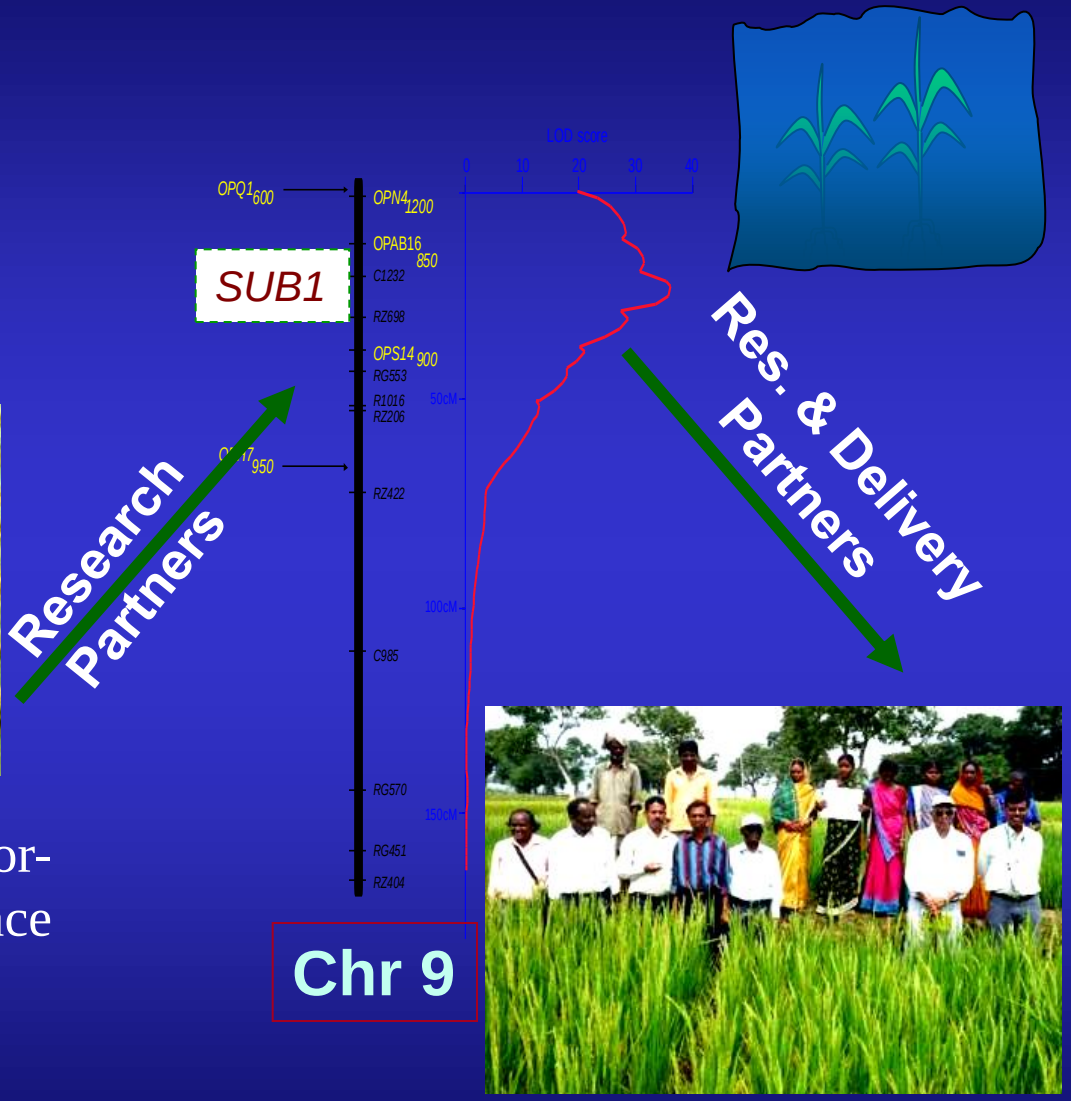
Hybrids/ Yield (Q/ha)	CVRC (Z1, Identified)	SVT (Uttarakhand) Released
Vivek 9	61.18	39.27
FQH 4567 (QPM)	63.60	42.75

Besides, 10 MAS derived QPM inbreds developed and registered

Submergence Tolerant Rice with SUB1 QTL

- 1970s: Donors identified
- 1990: Breeding lines, mapping
- 2006: *SUB1* cloned, MABB
- 2009: Sub1 varieties released

Sub1A, an Ethylene-response-factor-like Gene Confers Submergence Tolerance. Xu et al. (2006) Nature.



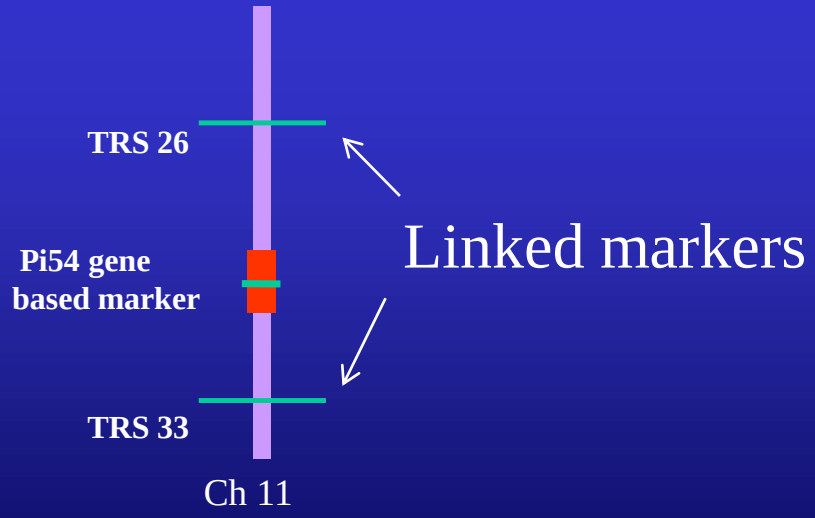
SUB1 on Chr 9 provides protection for 10-18 days of flooding

Developed Blast Resistant Varieties of Rice

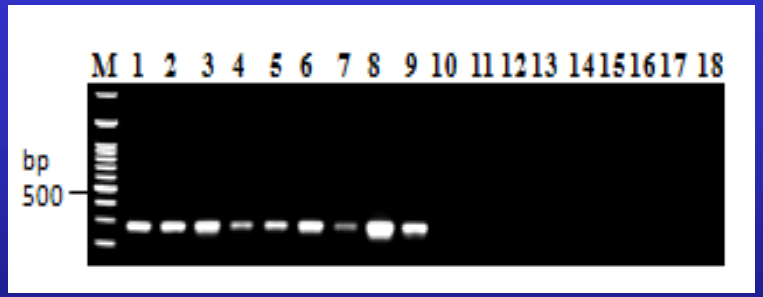
Blast Susceptible line

Resistant Donors

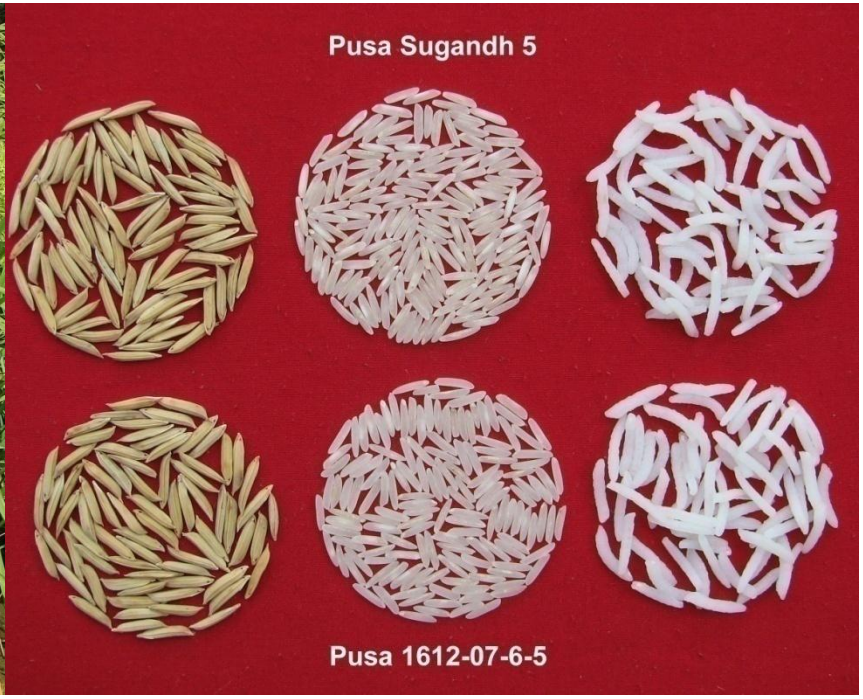
Pi54 gene



Gene based and linked DNA markers



Pusa 1612: A MAS derived blast resistant NIL of Pusa Sugandh 5 released (2013)



- Carries genes *Piz5* and *Pi54* conferring resistance to blast disease
- First MAS derived variety in India to be released through NIL trial
- Released in Region II (Punjab, Haryana, Delhi and Jammu & Kashmir) of the Basmati growing areas of north-western India
- Will save more than Rs 60.0 Crores (~10.0 Million USD)spent on fungicide spray

Source: Dr AK Singh, IARI

Genetically Modified Crops

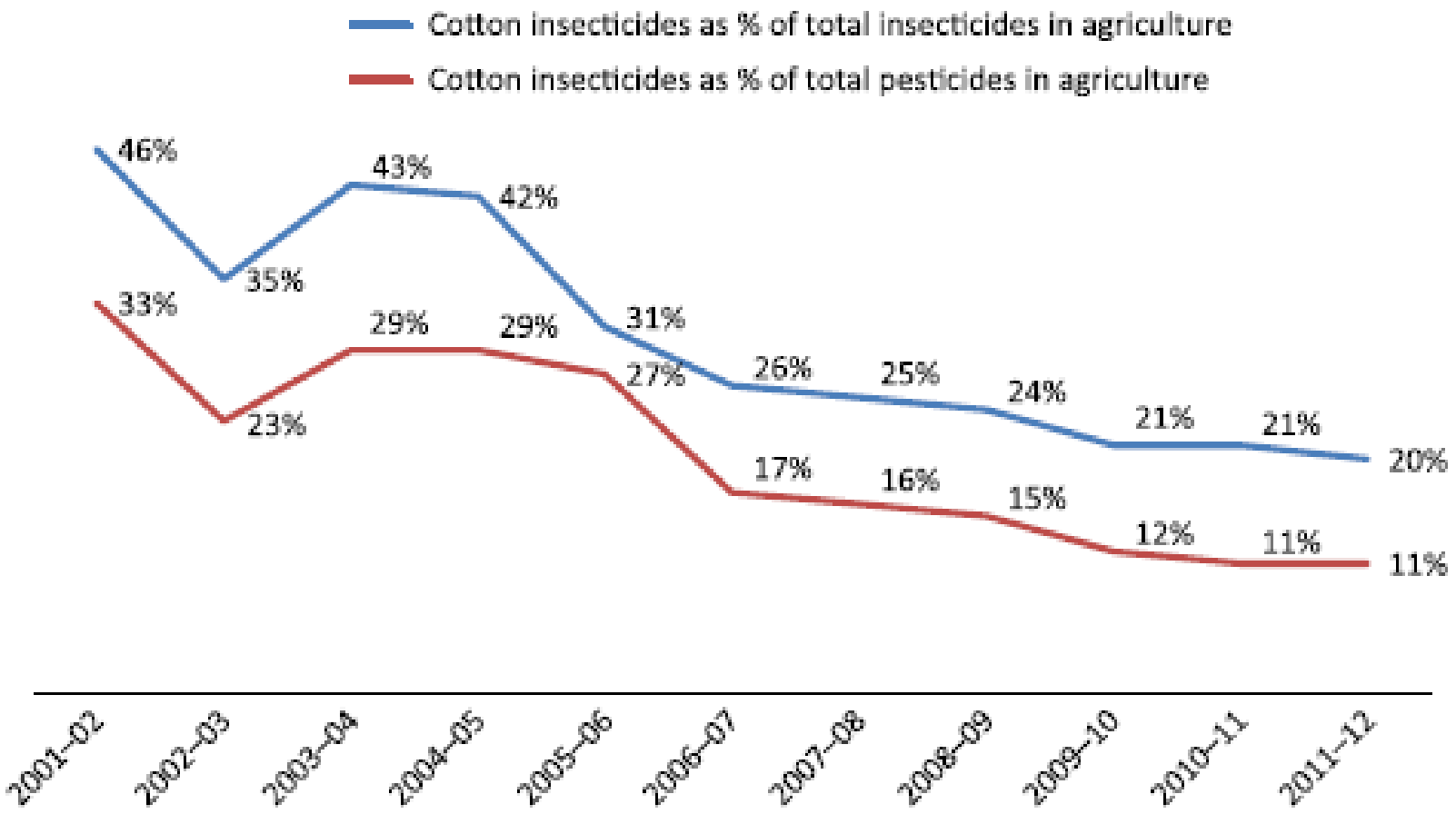
Bt Cotton in India: A Success Story

Indicators	2001-02	2012-13
Events	01	06
Hybrids	03	1095
Yield/ha (Kg)	308	550
Production (M bales)	13.6	37
Area (Mha)	0.5	11
Farm income (Million USD)	14.6	2100
Companies	01	40
Ex-Imp (Million MT)	-4.25	+1.25
Pesticide spray on cotton (MT)	5748	222

Source:
James, 2013;
Mayee and Choudhury, 2013;
Brookes and Barfoot, 2014

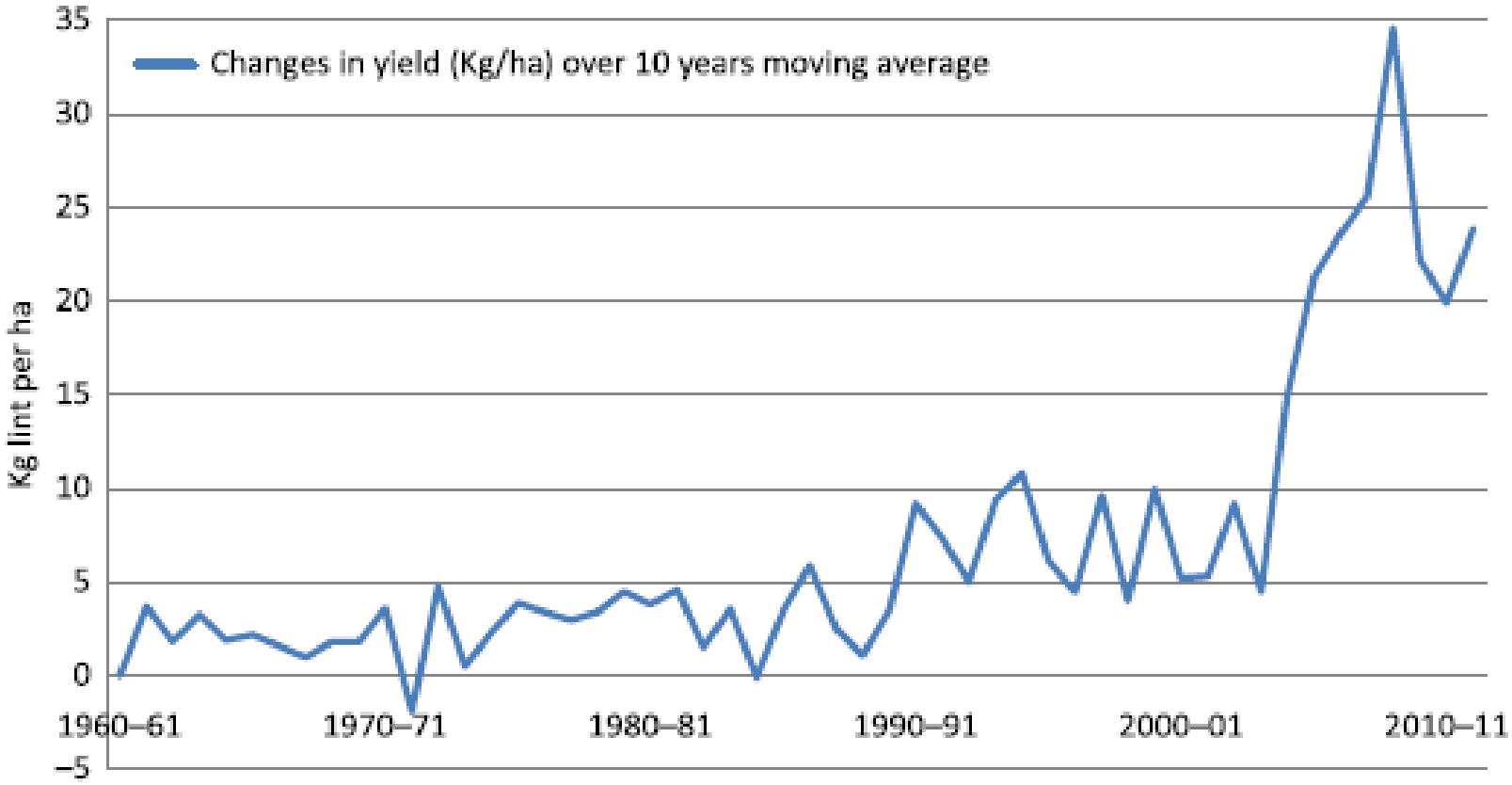
Percent reduction in insecticide use on cotton with respect to total insecticides and pesticides used in agriculture in India after the Introduction of GM cotton

(2001–2011)



(Kranthi, 2012).

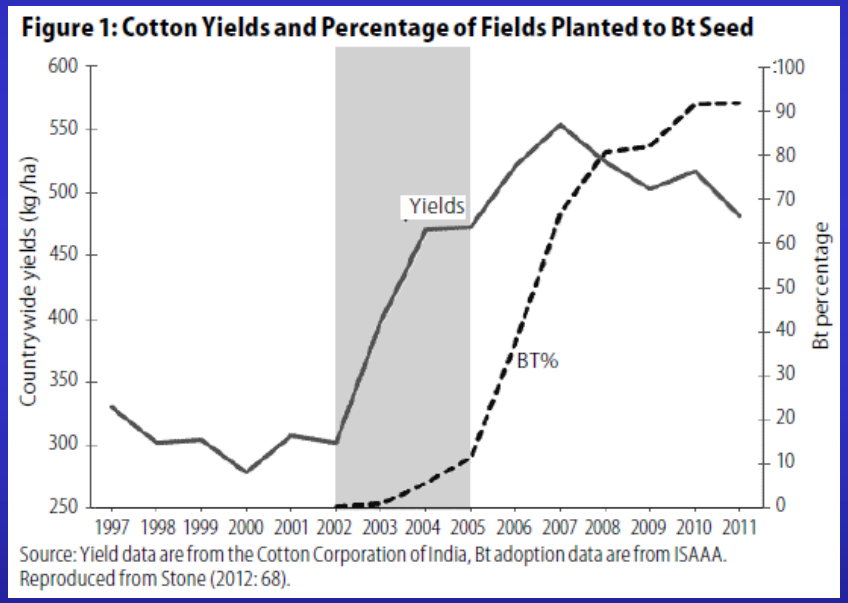
Changes in cotton yield after the introduction of GM cotton

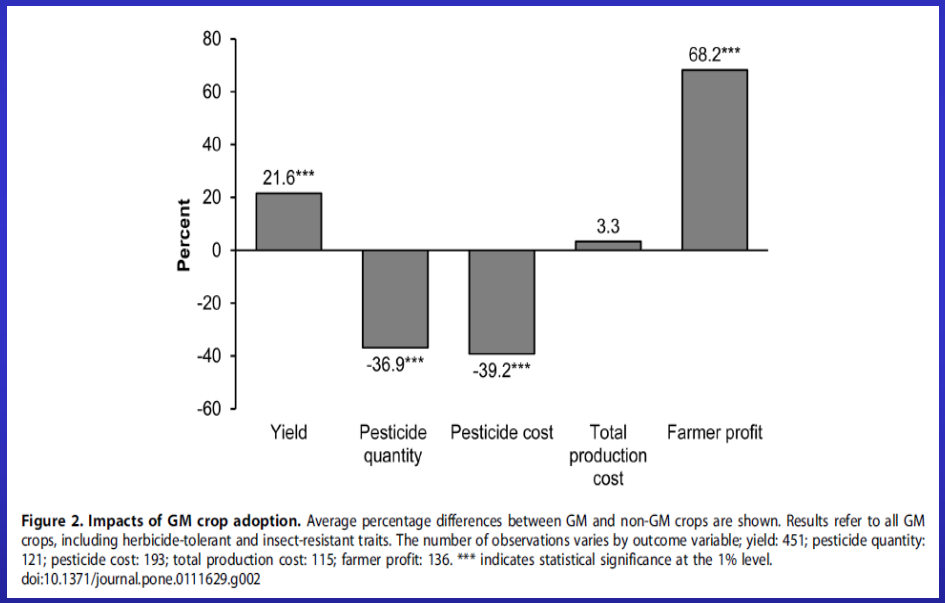


Choudhary *et al*., Plant Biotechnology Journal (2014)

Role of Bt Cotton in Poverty Eradication

On an average, GM technology adoption has reduced chemical pesticide use by 37%, increased crop yields by 22%, and increased farmer profits by 68%.





Ronald J Herring (2013) Reconstructing Facts in Bt Cotton Why Scepticism Fails. Economic & Political Weekly, August 17.

Klumper W and Qaim M (2014) A Meta-Analysis of the Impacts of Genetically Modified Crops. PLoS One 9 (11), e111629

Bt-Brinjal in India

BRL (Biosafety Research Level) II Trial Public-private Partnership With Mahyco

Based on the Indian biosecurity dossier, Bangladesh has processed and released Bt brinjal for commercial cultivation for the 2014 crop season.

Kameswara Rao, C. and Seetharam Annadana, (2014) *Genetically engineered crops in India: A Gordian knot needing an Alexandrian solution.* FBAE, Bangalore.

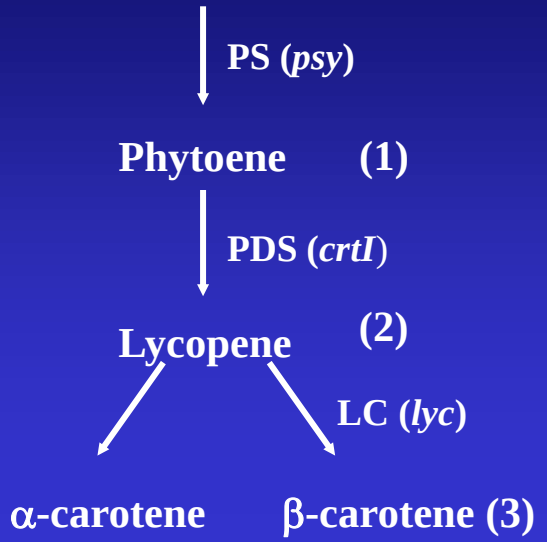
Hybrid Development in Indian Mustard - *Brassica juncea* using GM Technology

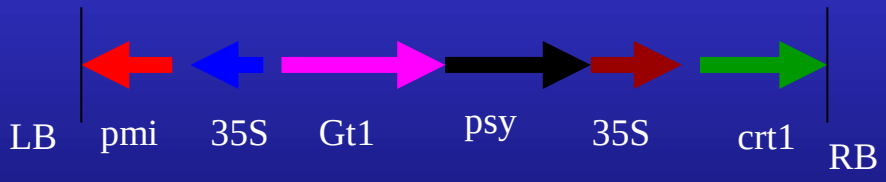
Every Year 250,000 Children Become Blind Because of Vitamin A Deficiency

Media coined the term *Golden Rice* to designate rice seeds that have a yellowish color due to presence of β-carotene. The rice represents *golden* hope for the people who need it most.

Golden Rice

New GR1 and GR2 were developed by Syngenta as part of their commercial pipe-line and have now been donated to the GR Humanitarian Board for use by the GR Network





Various components cloned & assembled
psy: phytoene synthase from maize
crt1: Erwinia
Gt1: rice glutelin promoter

Swarna

Golden Swarna

Transgenic Products in pipeline in India

Field Trials – RCGM/GEAC Approved (up to 2013)

S. No.	Crop	Traits
1.	Cotton	Insect Resistance; Herbicide tolerance
2.	Rice	Insect Resistance; Herbicide tolerance
3	Corn	Insect resistance; Herbicide tolerance
4.	Brinjal	Insect resistance
5.	Mustard	Male sterile female inbred lines; Abiotic stress tolerance
6.	Sorghum	Insect resistance
7.	Cauliflower	Insect resistance

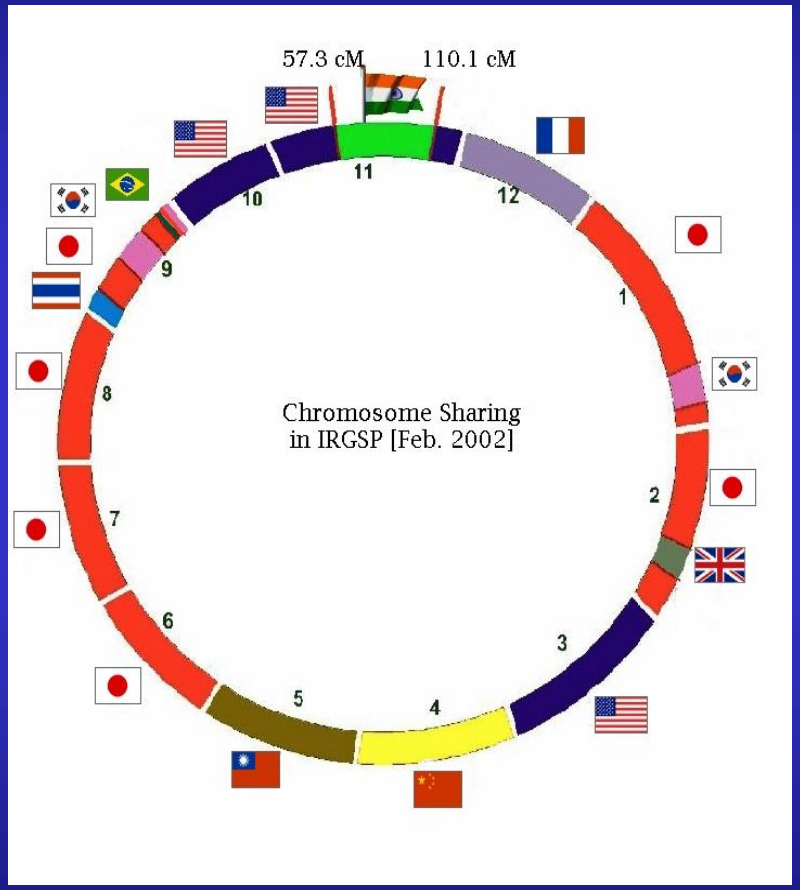
Source: http://igmoris.nic.in/field_trials.asp

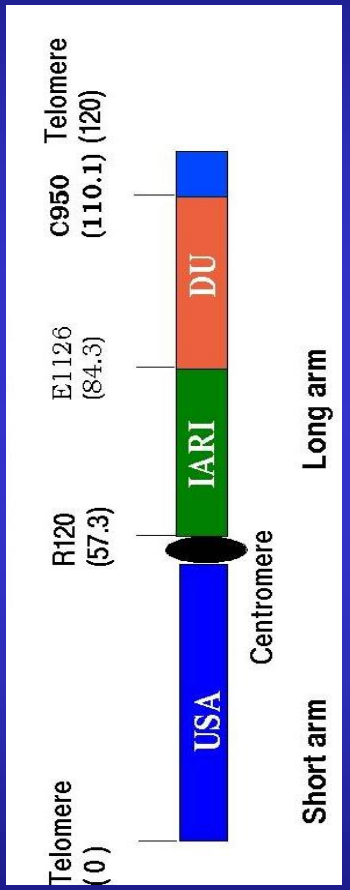
Genomics

Sequencing of Rice Genome

Nature 436, 793-800 (2005)

IRGSP
Japan
United States of America
China
Taiwan
Korea
India
Thailand
Brazil
France
United Kingdom





Variety sequenced: Nipponbare

Genome size: 388 Mbp

Sequencing of Tomato Genome

LETTER

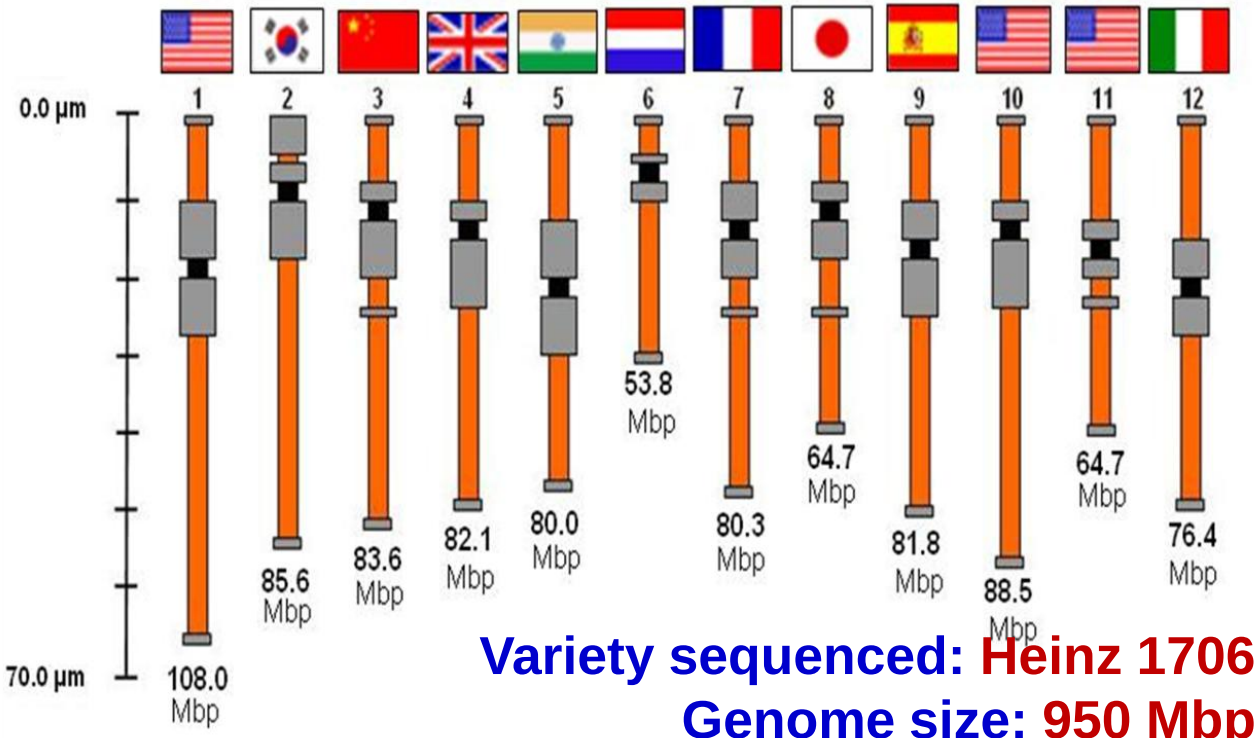
Nature 485, 635–641 (31 May 2012)

doi:10.1038/nature11119

The tomato genome sequence provides insights into fleshy fruit evolution

The Tomato Genome Consortium*

Daniel Buchan[28], Ioannis Filippis[28], James Abbott[28]; Indian Agricultural Research Institute Rekha Dixit[29], Manju Singh[29], Archana Singh[29], Jitendra Kumar Pal[29], Awadhesh Pandit[29], Pradeep Kumar Singh[29], Ajay Kumar Mahato[29], Vivek Dogra[29], Kishor Gaikwad[29], Tilak Raj Sharma[29], Trilochan Mohapatra[29], Nagendra Kumar Singh (Principal Investigator)[29]; INRA Avignon Mathilde Causse[30]; INRA Bordeaux

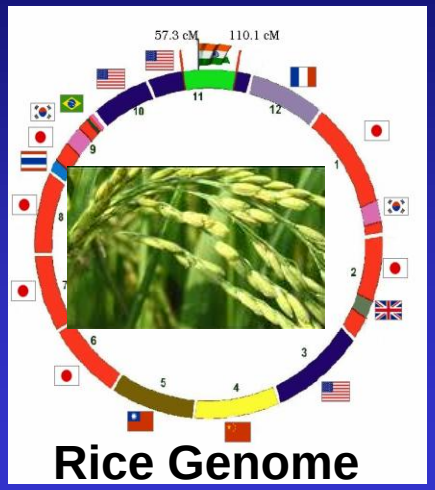


Variety sequenced: Heinz 1706

Genome size: 950 Mbp

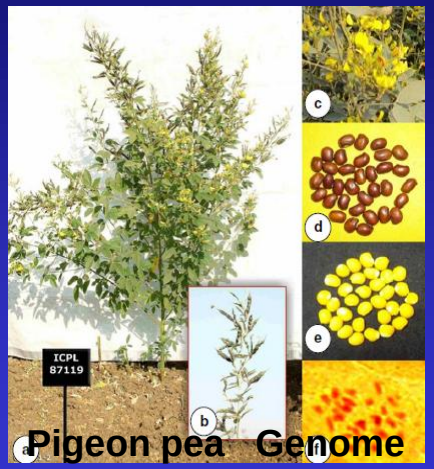
ITGSP
USA
Korea
China
UK
India
Netherland
France
Japan
Spain
Italy

Plant genomics-Indian Contribution



Rice Genome
Nature 2005

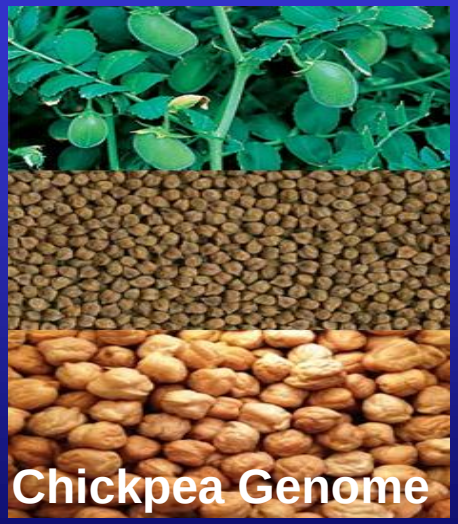
Potato Genome
Nature 2011



Pigeon pea Genome
JPBB 2011

Tomato Genome
Nature 2012

Flax Genome
The Plant J 2012



Chickpea Genome
The Plant J 2013

Wheat Genome
Science 2014

Mango Genome
Decoded

What we need to do????

Average Public Sector Spend in Agriculture Research

Countries	Agriculture Spend*
Pakistan	0.21
Nepal	0.23
India	0.40
China	0.50
Sub-Saharan Africa	0.61
Latin America	1.14
Brazil	1.80

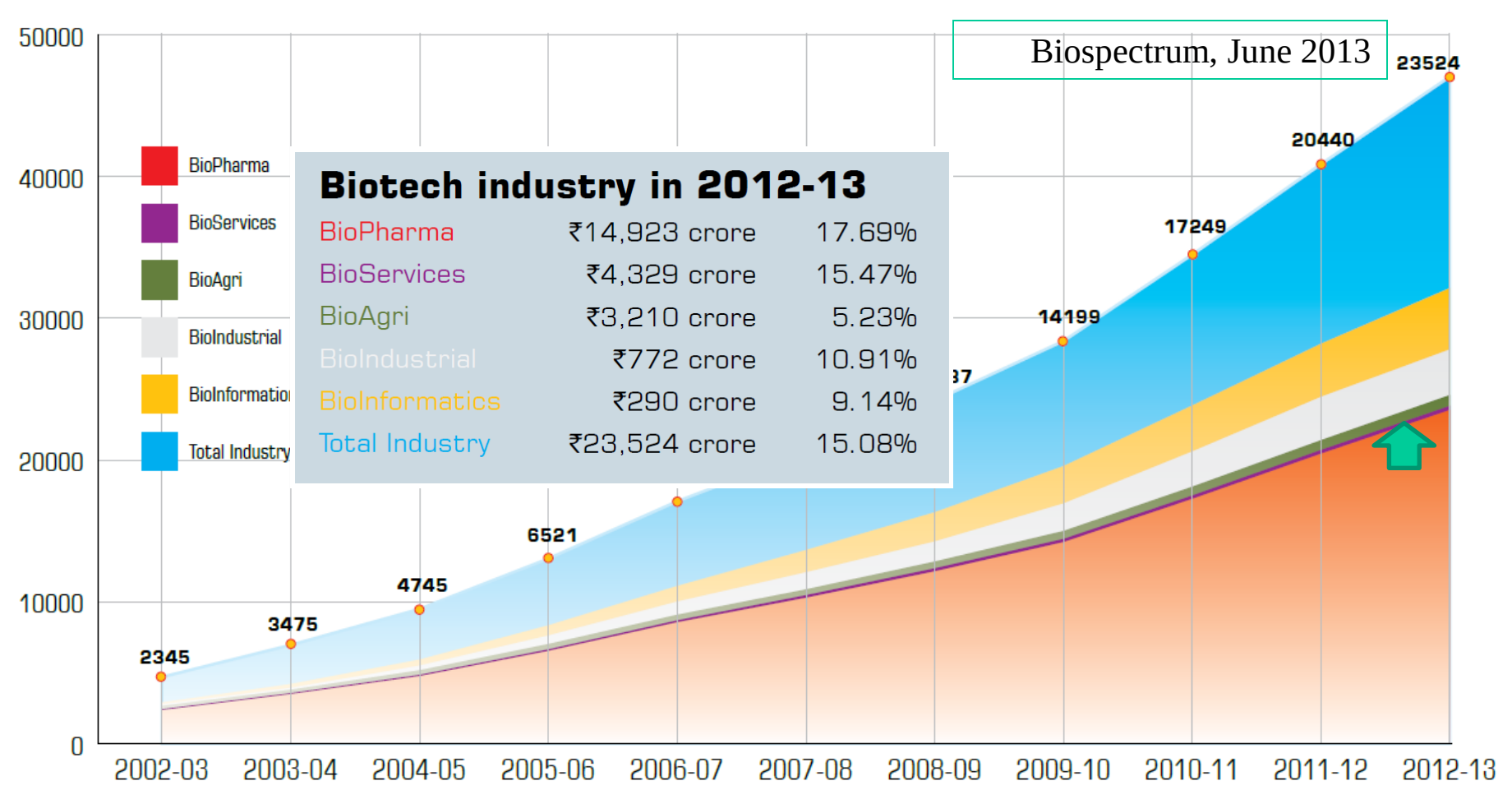
*Dollar invested in agriculture research for every $100 of agriculture output in 2009. In some countries the data relates to 2008 as well.

Source: IFPRI

India's current R&D spend on agriculture is only 0.6 percent of the total agriculture GDP, which is less than the average of 1 percent spent by other developing countries.

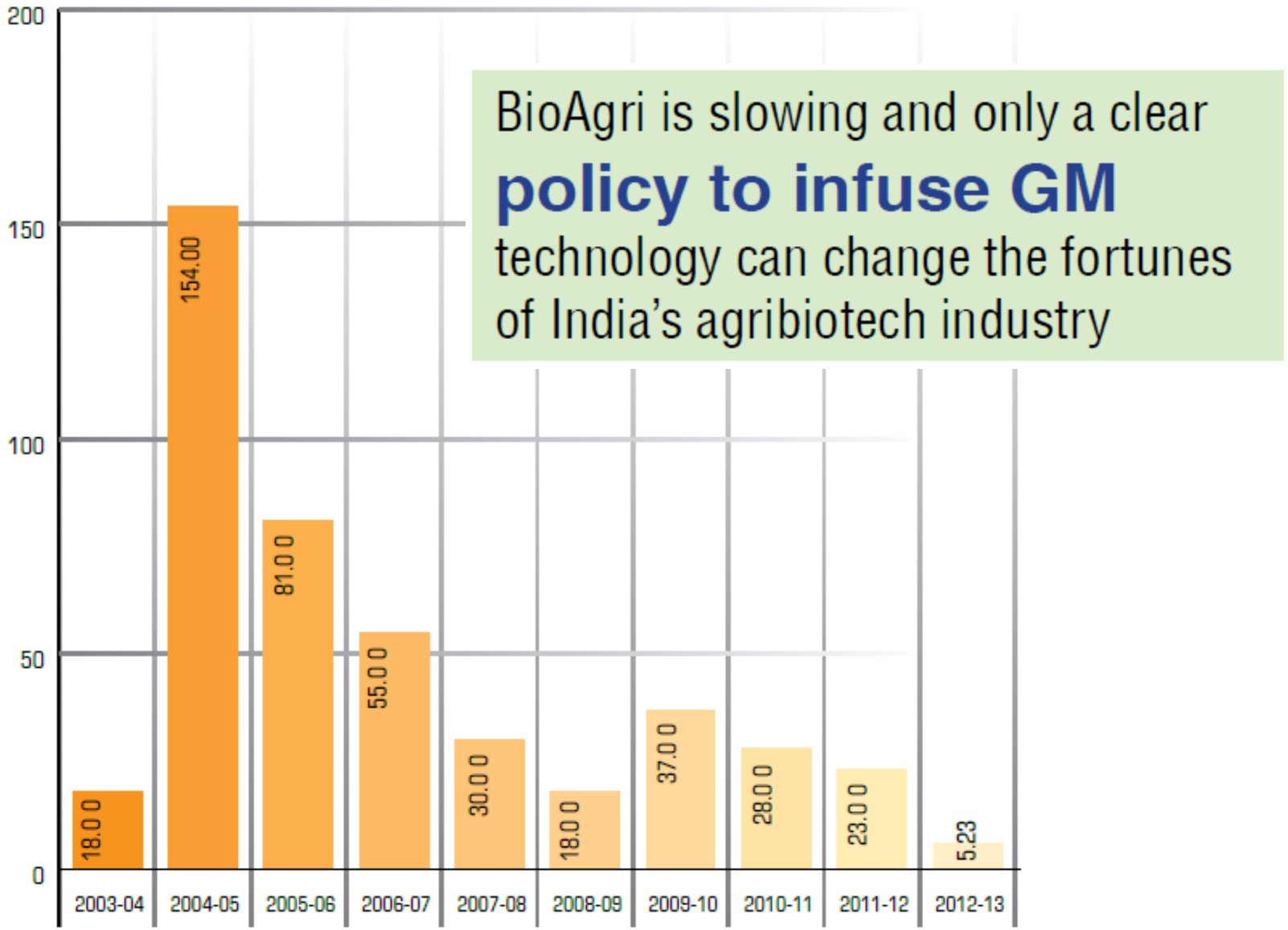
We need to invest more in Agriculture and Biotechnology

Progress of Biotech Industry



Agri-Biotech industry need major technological and financial investments

Agri-Biotech Growth Rate (2003-2013)



BioAgri is slowing and only a clear **policy to infuse GM** technology can change the fortunes of India's agribiotech industry

Biospectrum, June 2013

ASEAN: India Partnership in Agricultural Biotechnology

Areas of mutual interests:

- Develop mission mode projects in the priority areas of agricultural biotechnology for increased crop production

- Collaborative programmes:

i. for the development of "Climate Smart" and "Nutritionally Rich" crop varieties

ii. to manage Post harvest crop losses in horticultural crops

iii. development of multi country-multi commodity projects in Agri.Biotechnology (genomics,matagenomics,MAS & transgenic)

iv. human resource development (HRD) in molecular biology and biotechnology through exchange visits, Post Doctorate programmes, long/short term training programmes etc.

Acknowledgements

Indian Council of Agricultural Research
Govt. of India, New Delhi

Thank you