Technologies for increased Crop yield

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WORLD POPULATION

- World population is 6.9 billion in 2010 and increasing
- It is projected to touch 7.6 billion mark in 2020 (*Source*: United Nations Population Division).
- Eighty per cent of it currently reside in the less developed regions.
- The population distribution is given in the following table

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POPULATION DISTRIBUTION

	Percentage Population	
Region	2010	2020
Africa	15.0	16.6
Asia	60.3	59.9
Europe	10.6	9.6
Latin America	8.5	8.4
North America	5.1	5.0
Oceania	0.5	0.5

Source: United Nations "World Population Prospects" 2008.

World Population: 2010: 6.9 billion, 2020: 7.6 billion)

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FEEDING THE BILLIONS

- In view of increasing population particularly in developing countries, it is imperative to increase crop production.
- Agricultural land is shrinking, part of it is being used to develop infrastructure for increasing population.
- Therefore, the millennium challenge is to produce more food from less land.
- Technological interventions shall increase food production many more folds.

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TECHNOLOGY: DEFINED

- Technology is the application of organized and scientific knowledge to solve practical problems.
- In agriculture, the success of a technology can be measured only when it gets transferred for increased crop production.
- Therefore we have most of the agricultural innovations focusing on seed, the most vital and critical agricultural input.

INCREASING CROP PRODUCTION

- Crop production could be increased (all other factors remaining
- the same) :

a. by use of *quality seeds of high yielding varieties*

b. by judicious use of appropriate

Technologies for value addition

c. using appropriate agronomic innovations

- It is estimated that all other factors remaining the same the use of quality seed of high yielding varieties increases crop yield by 15-20% (P K Agrawal).
- In certain conditions this increase could be 30 to 60%

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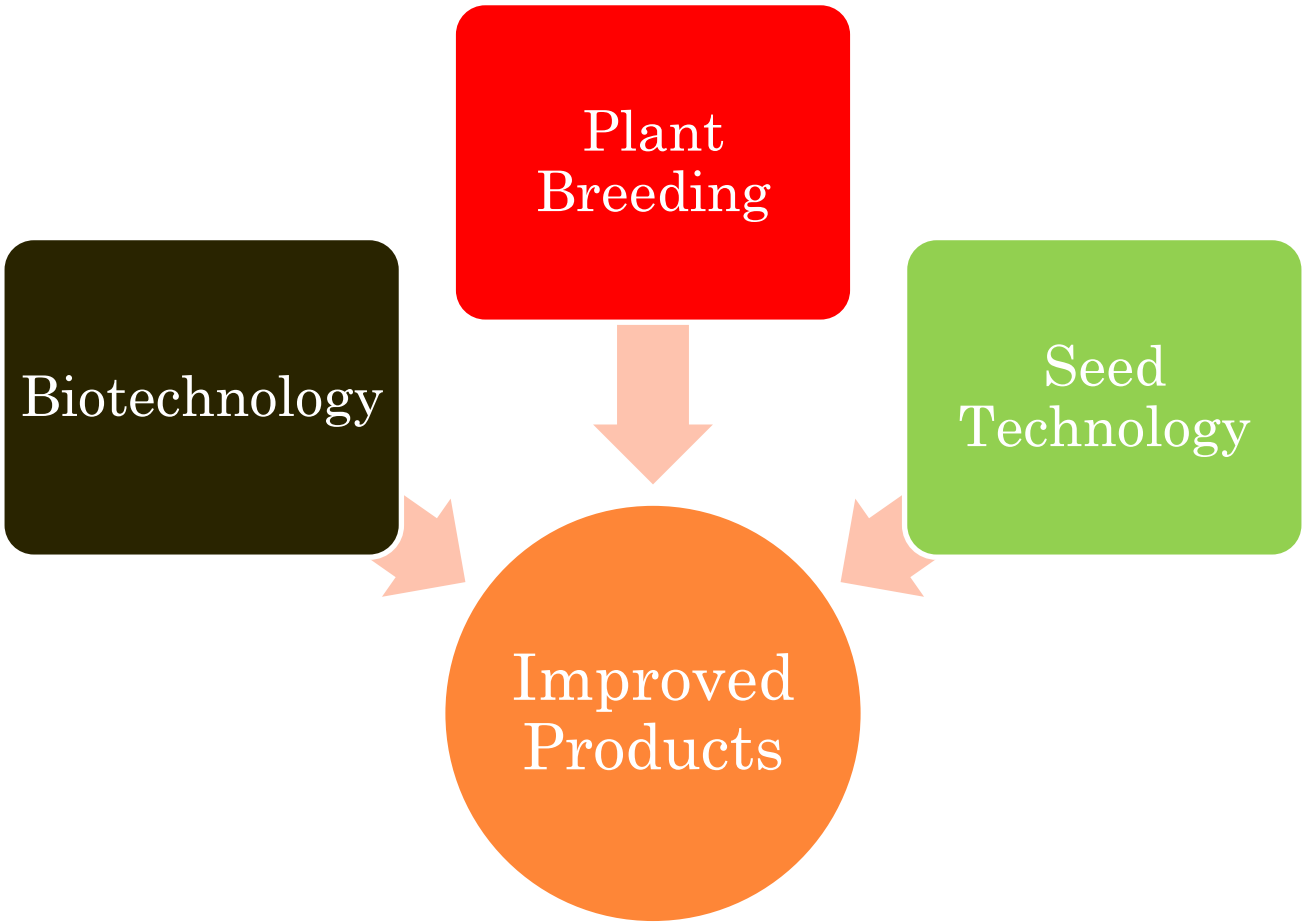
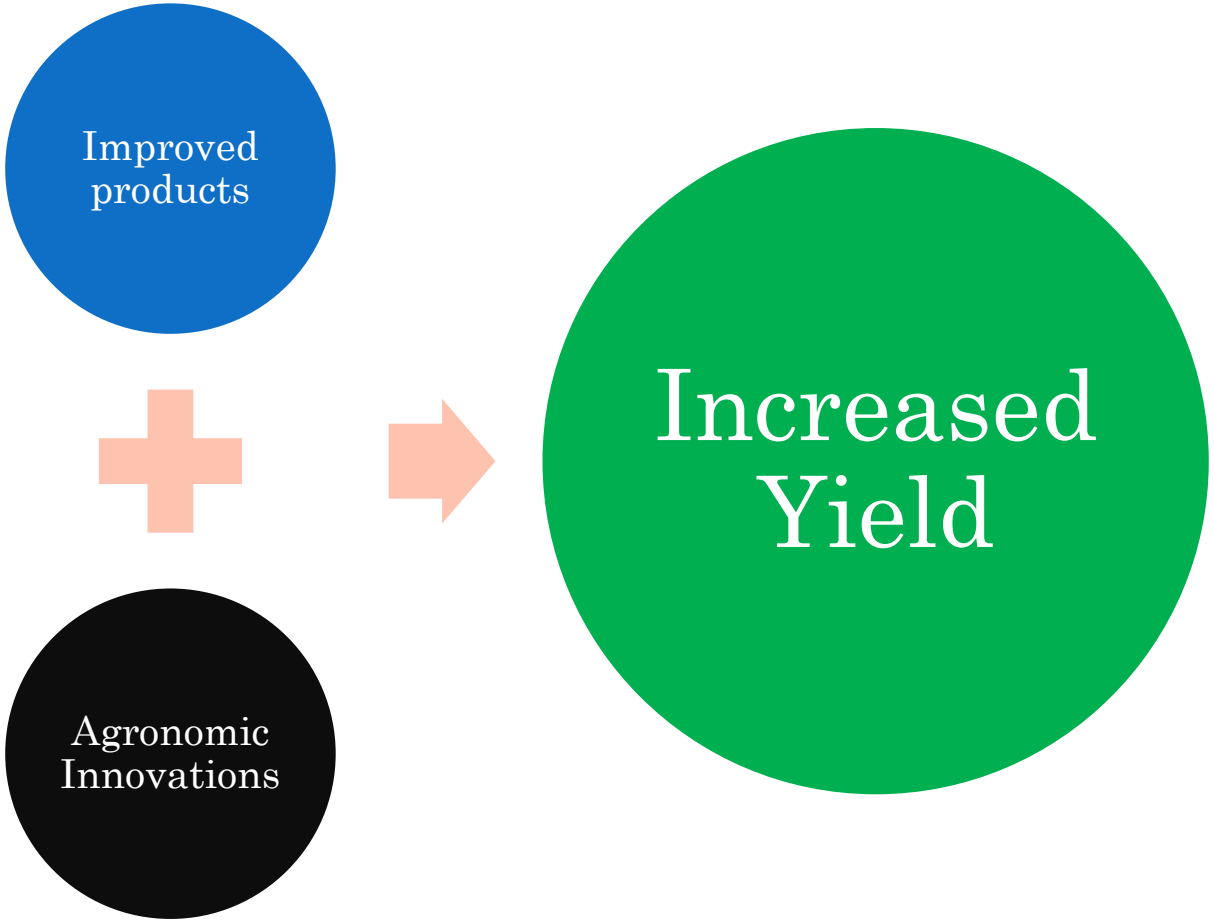
TECHNOLOGIES FOR INCREASED YIELD-1



TECHNOLOGIES FOR INCREASED YIELD-2



PRESENTATION ON VARIOUS TECHNOLOGIES

The following technologies have helped in increasing crop production in the World:

1. Dwarfing gene
2. Hybrid Technology
3. Biotechnology particularly cry genes in cotton
4. Seed Technologies: Seed Vigor, seed coating
5. Agronomic Technologies: Row-Plant Spacing, Minimum tillage etc.

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TECHNOLOGY: DWARFING GENE

- Dwarfing gene: Rht genes were introduced in modern wheat varieties in 1960s by Dr Bourlaugh from Norin 10 cultivars of wheat grown in Japan
- In 1966, India imported 18,000 tons of dwarf wheat from CIMMYT
- Results: Fantastic, it is a history that food deficit country like India became self sufficient and at times export food

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TECHNOLOGY: HYBRID

- 1930s: First hybrid was developed in Maize in USA
- 1970: First hybrid was developed in cotton in India
- 1976: First hybrid was developed in Rice in China

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TECHNOLOGY: BIOTECHNOLOGY

- Flavr Savr Tomato was the first Biotech crop commercialized in USA in 1994 by Calgene
- Its production stopped in 1997
- Calgene was eventually bought by Monsanto, which was primarily interested in Calgene's ventures into cotton and oilseed.

GLOBAL AREA OF BIOTECH CROPS (ISAAA, 2009)

Year	Million Hectares
1996	1.7
2000	44.2
2004	81
2008	125
2009	134

Advantage of using Biotech Crops:

1.Increased Production

2.More friendly to environment

3. Socio-economic benefit to farmers particularly small scale farmers

4. Mitigating some of the challenges associated with climate change

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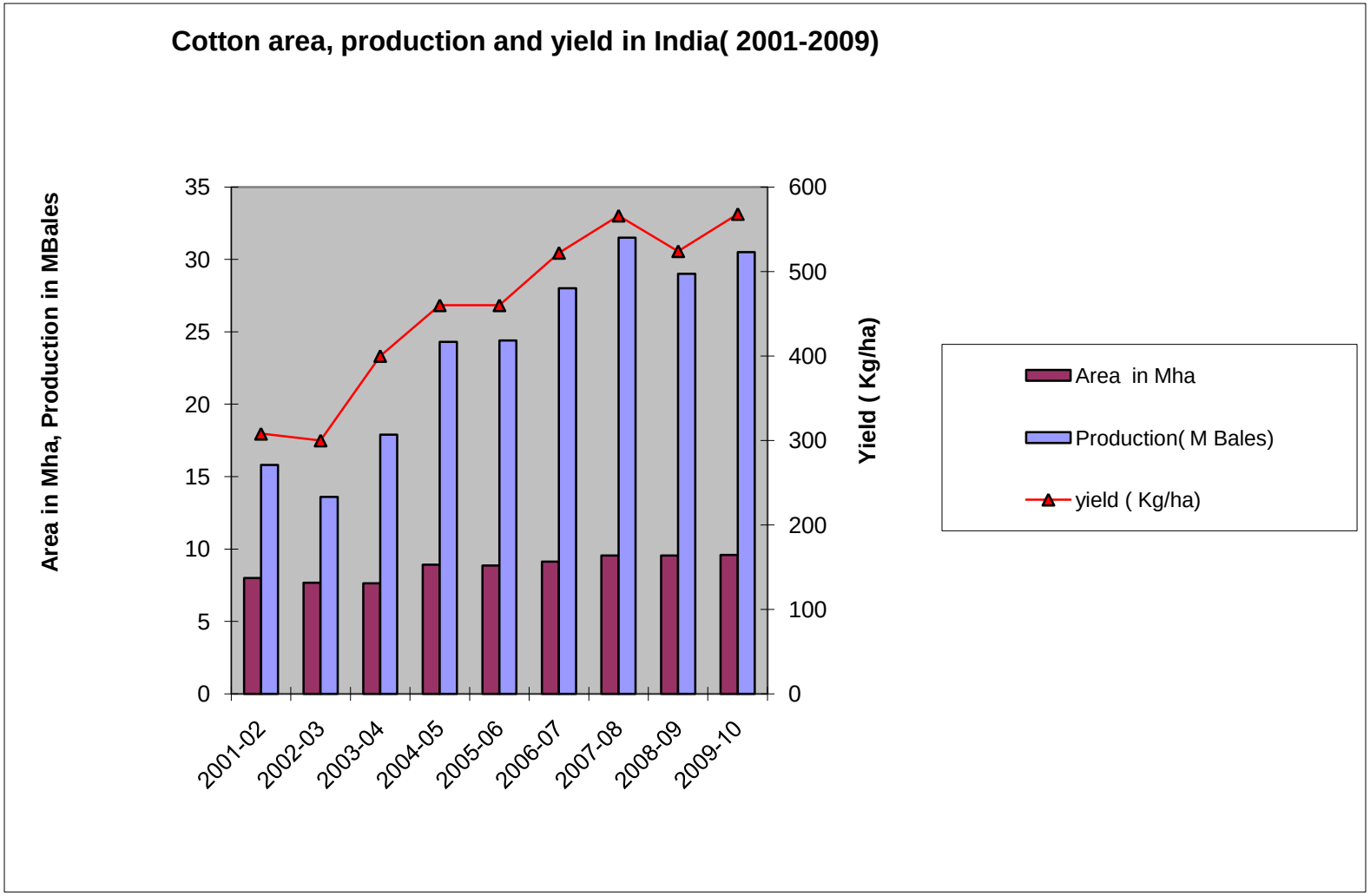
BIOTECH CROPS: COTTON IN INDIA

- 1995:DBT gave permission to Mahyco to import Bollgard cotton
- 1996: a small quantity of seed of Coker 312 containing cry 1Ac (Event: MON 531) was imported from Monsanto, USA
- Regulatory trials related to biosafety and agronomic impact were conducted for 6-7 years
- 2002: Commercialization of cotton on March 26
- Cotton is the only Biotech crop commercialized in India.
- Since 2002, tremendous progress in cotton production has been achieved which is shown in the following slides

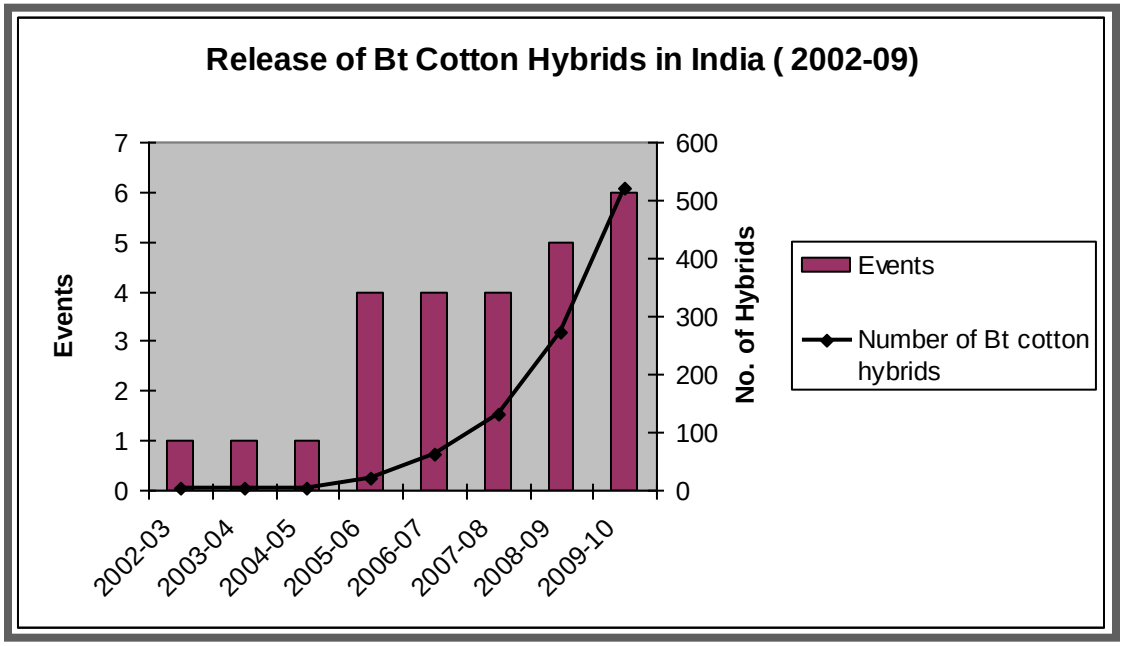
COTTON AREA, PRODUCTION AND YIELD



SIX EVENTS ARE COMMERCIALLY APPROVED

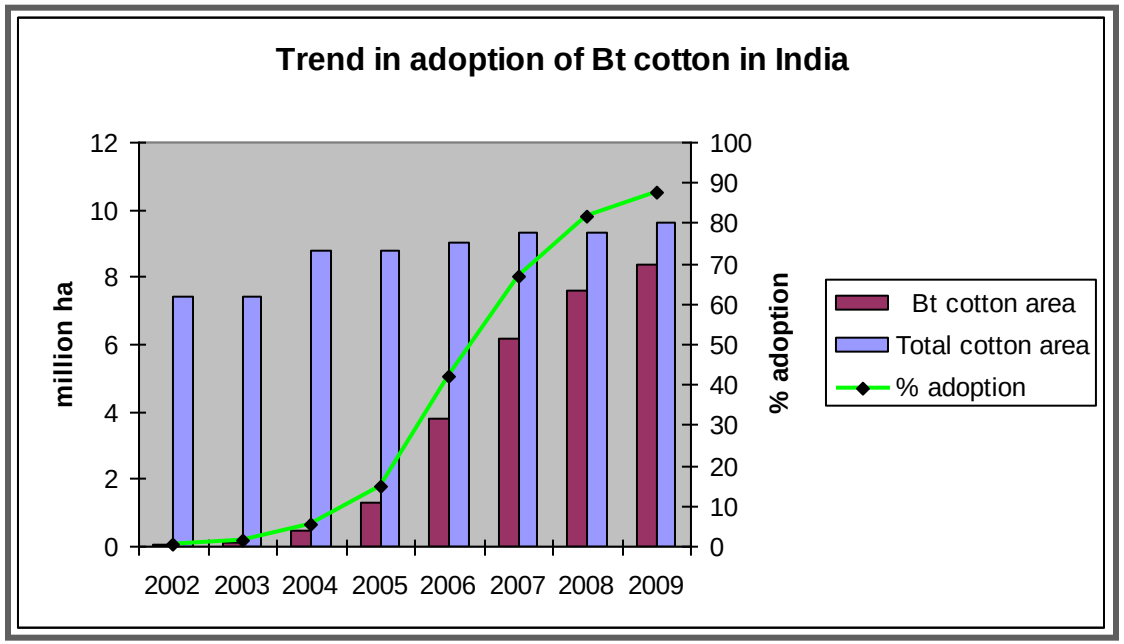
Event	Owned by	Year of release
MON 531	Monsanto	2002
MON 15985	Monsanto	2006
Event 1	JK (IIT Kharagpur), India	2006
GFM (Fusion gene)	Nath (Chinese)	2006
BNLA 601	ICAR and UAS, Dharwad, India	2008
MLS 9124	Metahelix, India	2009

HYBRIDS APPROVED FOR CULTIVATION IN INDIA (GEAC, DBT, GOVT. OF INDIA)



522 hybrids have been approved for cultivation

BT COTTON ADOPTION IN INDIA (ISAAA, 2009)



Total cotton area: 9.4 million hectares (23.5 million acres)

FURTHER GROWTH IN COTTON BUSINESS ?

- From the previous slides it is apparent that , almost 90% of the total cotton area is sown with Bt cotton
- Therefore the question is whether it is almost the dead end for Bt cotton business in India? How the growth in Bt cotton business is going to come
- The answer: It is going to come by manipulating row-plant spacing thus increasing the seed rate, which shall give higher yield
- When Bt cotton was introduced in India the recommended seed rate was 450 gm/acre
- Now seed companies are recommending 700-800 gm/acre seed rate
- The increased seed rate gives higher yield
- The result is given in next few slides

EFFECT OF SPACING ON COMMERCIAL COTTON YIELD

(MAHARASHTRA: YIELD KG/ACRE)

NORMAL SPACING (NS): 3X3 (4840 PLANTS/ACRE)
CLOSE SPACING (CS): 3X2 (7260 PLANTS/ACRE)

Plant type	NS	CS	Additional yd in CS	% increase over NS
Open, erect	1137.53	1440.58	303.05	21.53
Open, semi erect	1249.04	1544.25	295.20	20.41
Open, erect	1222.15	1513.24	291.09	20.53
Semi bushy	991.01	1259.79	268.78	22.51
Open, semi erect	1155.79	1399.31	243.52	18.56
Bushy	1046.02	1226.66	180.65	15.31
Bushy	1061.57	1362.50	300.93	23.41
Total	**1123.30**	**1392.33**	**269.03**	**20.32**

Total cotton area in the State: 3.142 million hectare, maximum area in India

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ECT OF SPACING ON COMMERCIAL COTTON YIELD (MAHARASHTRA: YIELD (KG/ACRE)

NORMAL SPACING (NS): 5X2.5 (3485 PLANTS/ AC)
CLOSE SPACING (CS): 5X1.25 (6969 PLANTS/AC)

Plant Type	NS	CS	Additional yd in CS	% increase over NS
Open, erect	725.46	993.45	267.99	26.98
Open, semi erect	784.01	1093.83	309.82	28.32
Open, erect	829.27	1121.94	292.67	26.09
Semi bushy	628.91	846.38	217.47	25.69
Open, semi erect	647.12	1039.85	392.73	37.77
Bushy	861.95	1232.26	370.31	30.05
Bushy	807.12	1141.87	334.75	29.32
Mean	**754.83**	**1067.08**	**312.25**	**29.17**

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Total Cotton Area in the State: 1.399 million hectare, 3rd largest in the country

ANDHRA PRADESH – (All locations)

Normal Spacing (NS): 3x3 (4840 plants/ ac), 3.5x3 (4148 plants/ ac), 4x3 (3630 plants/ ac)

Close Spacing (CS): 3x2 (7260 plants/ac), 3.5x2 (6222 plants/ac) , 4x2 (5445 plants/ac)

Hybrid	Boll No		Boll wt (g)		Yield (kg/ac)			
	NS	CS	NS	CS	NS	CS	Additional yd in CS	% increase over NS
Open, erect	56.42	50.38	5.94	5.95	1199.65	1504.52	304.88	20.94
Open, semi erect	59.51	56.04	4.74	4.72	1211.08	1519.42	308.34	20.19
Bushy, big boll	68.4	66.24	5.37	5.34	1239.1	1629.86	390.76	23.32
Bushy, med boll	63.16	56.93	5.09	5.1	1154.6	1491.8	337.2	22.85
Total	**61.87**	**57.4**	**5.29**	**5.28**	**1201.1**	**1536.4**	**335.29**	**21.83**

Values are mean of nine locations data

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Cotton: Conclusion of close spacing

1.Marginal difference in boll nos.

2. No difference in the boll weight

3. 20-30% more yield due to more plant

4. Benefits seen irrespective of 'plant type'

5. Therefore the Seed Companies are advocating planting of 700-800 gm seed/acre instead of 450 gm seed

6. It will fuel the sale of more packets of seed and expected that the sale will ultimately double i.e. 3.0 million packets to almost 6 million packets

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COTTON: BIOTECH INTERVENTIONS

In addition to 6 events commercialized, research and field trials have been undertaken/are underway for the following insect resistance and herbicide tolerant genes:

i. *vip3A+cry1 Ab by Syngenta*

ii. *cry1 Ac+ cry 1F by Dow Agrosciences*

iii. *cry1 C by Meta-Helix Life Sciences*

iv. *cry1 Aa3, cry1 F, cry1 Ia5, cry1 Ab by ICAR institutions*

v. *cry1 Ec by J.K. Agri Genetics*

vi. *cp4epsp gene by MAHYCO*

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CP4EPSP GENE BY MAHYCO

- Popularly it is named: Round-Up Ready flex gene
- And shall be known as Event MON 88981
- Expected to be deregulated in June 2011 by MMB
- State intervention in fixing the sale price is a tricky problem

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BT BRINJAL(*SOLANUM MELONGENA*)

- India is the second largest producer of Brinjal in the world (after China), accounting for 25% of global production.
- It faces a serious threat from the Fruit and Shoot Borer (FSB) causing up-to 70% yield loss.
- Therefore, farmers resort to intensive pesticide application till harvest, causing serious health and environmental concerns.
- Bt brinjal,was developed through a public –private partnership in India.
- The Bt brinjal event EE-1 (Cry 1Ac) has been developed by M/s Maharashtra Hybrid Seeds Company Ltd, India in collaboration with two State Agricultural Universities.
- The presence of Cry 1Ac decreases insecticide requirement by as much as 80%.

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BT BRINJAL-II

- Since India is a biodiversity hotspot for this crop, stringent evaluations were carried out to rule out the possibility of natural crossing occurring between cultivated and wild species/ unrelated plant species which can result in gene transfer.
- The product was approved for commercialization by the Genetic Engineering Approval Committee which is the country's highest biotech regulatory authority.
- Though all experimental evidences were supportive, the Government refused to allow its commercialization citing public health concerns.
- Thus politics wins over science.

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Hybrid Rice

- Rice is the main staple food for more than half the World's population.
- It has potential to increase crop production
- First Hybrid Rice was cultivated in China in 1976
- India started concentrated efforts on hybrid Rice development in 1989
- There are several hybrids, from Public and Private sector available for cultivation
- The private sector is the dominant player
- In spite of the availability of several hybrids limited area in cultivation: about 1.5 million hectares out of about 43.77 million hectares (3.4%)

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HYBRID PADDY

- It is cultivated predominantly in lesser developed parts of India e.g. eastern Uttar Pradesh, Bihar, Jharkhand, Chattisgarh, Punjab and Haryana (Punjab and Haryana are developed)
- Many tribal farmers have taken up its cultivation.
- Average yield advantage over varieties is 1.0 to 1.5 tons/ha

REASONS FOR LOW ADOPTION OF HYBRID RICE

- Lack of acceptability in south India due to region specific grain quality requirements
- Nature of rice grain: Stickiness and presence of mild aroma upon cooking.
- Yield advantage is not large enough
- Lack of extension education about hybrid rice
- It is expected that better hybrids will be evolved to give at least 3-4 tons yield/ha advantage over the research varieties with enhanced ability to fight drought and disease
- then hybrid area will increase very fast and by the year 2015 it may touch 20-25% of the rice cultivated area in India.

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BIOTECHNOLOGY INTERVENTIONS

- No transgenic rice has yet been commercialized in Asian countries,
- Biotic-stress tolerance has been the primary focus for private sector as well as public sector research institutions including those in Asia.
- Specific traits being worked in this category include resistance to bacterial blight using Xa21 gene, rice blast, various viral diseases, the brown plant-hopper, and yellow stem borer, the latter-using Bt technology being the closest to commercialization.
- For abiotic-stress tolerance, transgenic rice plants have been developed with tolerance to various conditions viz. drought and salinity.
- Regarding the nutritional traits, one of the most promising application of transgenic technology has been the development of vitamin A enriched varieties, popularly known as **Golden Rice** due to the slightly yellow colour conferred to the endosperm .

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GOLDEN RICE

- First successful product of GM based bio-fortification with pro-vitamin A trait.
- Researchers have found that in Japonica Golden Rice , an intake of only 120 g is required for meeting the Vit A's RDA. (Paine et al, 2005;Tang et al, 2009)
- There are many issues still to be sorted out before it is commercialized for public good, e.g. reduction in beta carotene quantity in presence of light, acceptance of it because of color, bioavailability of pro-vitamin A when transferred to local cultivars etc.
- Bio fortification of rice with iron and zinc are also being carried out by several public and private sector organizations.

GENE MUTATION IN PADDY: (DEBORA MACKENZIE, NEW SCIENTIST, MAY 24, 2010)

- discovery of a gene mutation that can bump up yields by a full 10 per cent is exciting news.
- Miura's team (Japan) used standard plant breeding to introduce the mutation to new varieties, and ended up with as much as 52 per cent more grains per plant.
- Jiao's team (China) put the mutant gene into new rice varieties using genetic engineering and, under field conditions rice yields increased by 10 per cent.

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Seed Technology :**Seed Vigor**

- Seed Vigour: Degree of aliveness, is an important parameter
- I would not like to go in detail on it because Stan is talking about it on Friday, June 18. (from one hypothesis to many predictions and uses).
- Attempts have been made to relate it with stand establishment (good relationship particularly in vegetables) and field performance (particularly yield) with mixed results
- In developing countries vigour has been measured routinely but not much work relating it to field performance.

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Seed Technology -contd

Seed Coating Techniques

Film Coating

- Film coating technique commercialized as an integrated agricultural input delivery system particularly in low volume high value seeds because

1. Achievement of better results even at lesser dosages of pesticides etc.
2. Insect mortality is faster- important in case of virus vectors (White-fly)

- In India the technology is not in much use because it is not economically viable in field crop seeds.

Safer seed storage

- Film coated seeds, when stored in moisture pervious or impervious containers, recorded significantly superior field emergence as compared to non coated seeds in tomato
- However, storage under Low Temp Low Humidity Condition (15± 1°C; 30± 5% R.H) was found to further enhance the storability of film coated seeds
- Moisture sorption studies of coated and non coated seeds revealed lower moisture (in vapour phase) retention by film coat as compared to the natural seed coat, whereas during direct imbibition of free water on blotter the film coated seeds recorded 141% increase in weight within 24 hrs, compared to 103 % in the case of non coated seeds

  (Jacob, S.R, 2007. Unpublished)

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Green Seed Technology-Use of Plant products for enhanced seed storage

Seed coating using botanicals

- Neem based products @15 mg Azadirachtin/kg seed have been found to provide safe storage in cereals and pulses up-to 6 months, on par with chemical pesticides

Seed coating using inert materials

- Inert dust materials like Diatomaceous earth, Rice husk ash and Fly ash (all@ 5g/kg seed) found to be potential seed protectants against storage pests in cereals and millets

(Source- Report of the National Seed Project (Crops), 2010, Indian Council of Agricultural Research, New Delhi, India)

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Technologies in pipeline

Crop	Trait	Developed by	Details of product
Corn	IR+HT	Monsanto and Dow Agro sciences	8 gene stacked product, combining 8 different herbicide tolerance and insect protectant genes (for both above and below ground), with different modes of action
	DR	Monsanto and Mendel Biotechnology Inc.	engineered with Plant nuclear factor Y (NF-Y) B), giving an estimated 10% yield enhancement under drought stressed condition
Rice	DR	Wageningen University & Research Centre and University of Agricultural Sciences, Bangalore	HARDY gene from Arabidopsis successfully validated for enhanced water use efficiency in rice
Soybean	enhanced omega-3 fatty acid content	Monsanto	As a land based alternative to fish oil,

Leaf Albedo bio-geoengineering

- Threat of global warming has triggered research for its technological solutions
- bio-geoengineering-crop varieties having specific leaf glossiness and/or canopy morphological traits are specifically chosen to maximize solar reflectivity.
- genetic modification of plant leaf waxes or canopy structure could achieve greater temperature reductions
- although better characterization of existing intraspecies variability is needed first.(Ridgwell et al, 2009

THANK YOU

Thank you for your kind attention