

High Density Planting System – Next Revolution in Cotton Farming in India

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Indian Cotton

- Plays significant role in agricultural and industrial economy and social aspects of the country
- Occupies second premier position next to food crops in providing clothing
- Major fibre and cash crop, and Provides 60 per cent of raw material to the textile industry.
- Cultivated in tropical as well as sub-tropical regions
- Accounts for 29 per cent of total exports, 5 per cent value of agriculture output, 4 per cent GDP, 14 per cent industrial production, 11 per cent to the country's export earnings
- Indian textile industry- second largest employer and 40-45 million people engaged in cotton processing, trade and related activities.
- Largest exporter of cotton yarn (26.7%) and textiles (10%) of the manufactured goods.

Species Composition of Cultivated Cotton in India

Species	Area (million ha)											
	1947-48	%	1955-56	%	2000-01	%	2007-08	%	2014-15	%	2021-22	%
<i>G. hirsutum</i>	0.14	3	3.21	41	2.61	32	1.80	19	0.24	02	0.18	1.5
<i>G. arboreum</i>	2.79	65	2.84	36	1.39	17	0.90	10				
<i>G. herbaceum</i>	1.39	32	1.78	23	0.89	11	0.40	5				
Hybrids	-	-	-	-	3.26	40	6.40	66	11.47	98	12.47	98.5
Total	4.32	-	7.83	-	8.15	-	9.50	-	11,71	-	12.60	-

Cotton is Grown in >70 Countries

30 Countries have > 100,000 ha



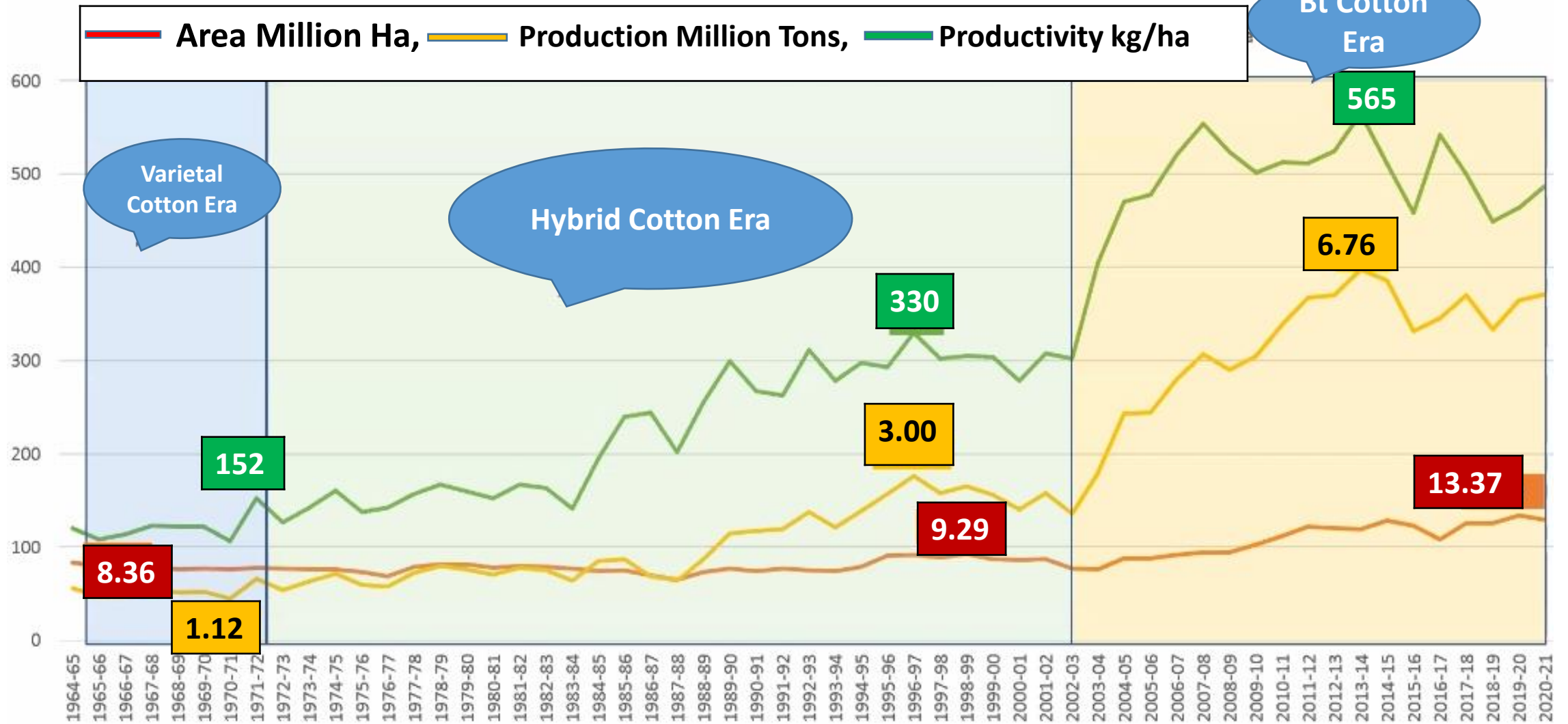
Cotton in India



Cotton Growing States

- India has the World's largest cotton area 13.3 million hectares. 39 % of the global cotton area.
- But contributes only 23% to Global production.
- India has the largest irrigated cotton area in the world 4.3 million hectare.

Indian Cotton Scenario



Long history of cotton which can be conveniently divided into 3 era

Cotton lint Requirement Projection

(million tonnes)

Year	Domestic	Export	Total
2030	4.08	4.87	8.95 (50% more)
2040	5.53	6.59	12.12
2050	6.97	8.32	15.29

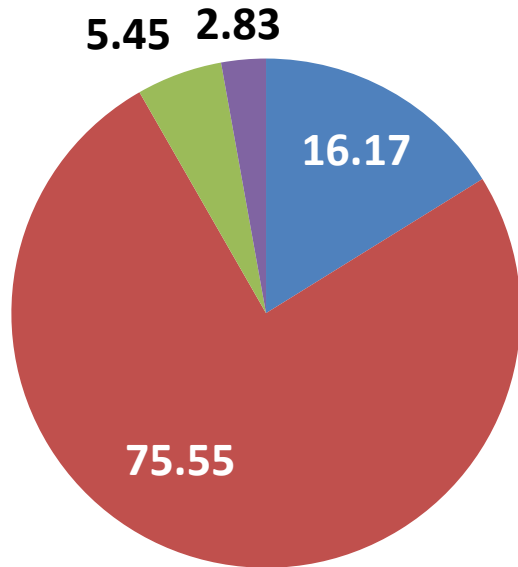
@47 sq m cloth / per capita requirement, The current use at 34 sq m cloth /per capita & current production at 6 M tonnes.

Projected Productivity (kg lint /ha) with current area (12 m ha)

Year	Productivity (kg lint /ha)	% annual Increase required over current productivity (503 kg lint/ha)
2030	746	4.8%
2040	1010	5.0%
2050	1274	5.1%

Classification of Cotton Growing Districts into Efficiency Groups.

% Cotton Area



- Most Efficient
- Less Efficient
- Inefficient
- Efficient

Category	*No. of districts	Area (ha)	% Area	Meanlint Yield (Kg/ha)	Yield Range (kg lint/ha)
Most efficient	26	1,935,338	16.17	624	(501-848)
Efficient	16	417,089	2.83	628	(512-711)
Less efficient	75	9,043,627	75.55	351	(145-497)
Inefficient	40	652,896	5.45	334	(118-496)
Total	157	11,970,029	100.0	402	(118-848)

*Districts > 5000 ha cotton area

(Prasad *et al.*, 2022)

Characters of Hybrids and Varieties Cultivated in India and other Countries.

Characters	India	Australia, Brazil, Turkey, China, USA and Mexico
1. Cultivars	Hybrids	Varieties
2. Spacing (plant to plant)	60/90/120 cm Spaced Planting	10 cm HDPS
3. Seed rate kg/ha	2.0	12.0
4. Plant Population /ha	11,000 (1-2 plants/Square meter)	>1,10,000 (10plants/Square meter)
5. Plant architecture	Bushy	Erect-compact
6. Flowering (days)	80-100	60-70
7. Bolls/plant	20-100	8-10
8. Lint yield (kg/ha)	< 500	>1500
9. Number of pickings	3-5	1
10. Sowing and picking	Manual	Mechanized
11. Harvest index	0.2-0.4	0.4-1.0
12. Ginning Out Turn (%)	32-34	38-44
13.. Crop duration (dys)	160-240	140-160
14. Labour requirement (Nos./ha)	100 to 120	1-10
15. Pink bollworm infestation	High (Long duration)	Low (short duration)
16. Seed production	Cumbersome	Easy
17. Non Bt seeds in bolls	Present (Heterozygous Bt genes)	Absent (Homozygous Bt genes)

Major Challenges of Indian Cotton

- Low yields, Yield stagnation, Low harvest index,
- Degraded soils and high fertilizer usage,
- Bt resistant pink bollworms,
- Increased usage of insecticides,
- Usage of spurious Bt-HT-seeds,
- Long duration Bt-hybrids kept longer for multiple pickings,
- Farmers do not follow the 'refuge strategy',
- High cost of cultivation and reduced profitability.

Meeting Projected Cotton Production by Adoption of HDPS *Bt hirsutum* and *G. arboreum* Varieties

Year	Spacing cm	Aprox. Plant Stand with 90% Germination	Boll Weight (g) hir/arb	No. Bolls/ Plant hir/arb	Seed Cotton Yield Kg/Ha	GOT % hir/arb	Lint Yield Kg/Ha	Meeting Projected Production in M. T. in 12 M. Ha
2030	90x 10	1,00,000	4/2.5	6/9	2400	35/40	840	10.08
2040	90x10	1,00,000	4/3	7/9	2800	38/40	1064	12.77
2050	90x10	1,00,000	4/3	8/10	3200	40/40	1280	15.36

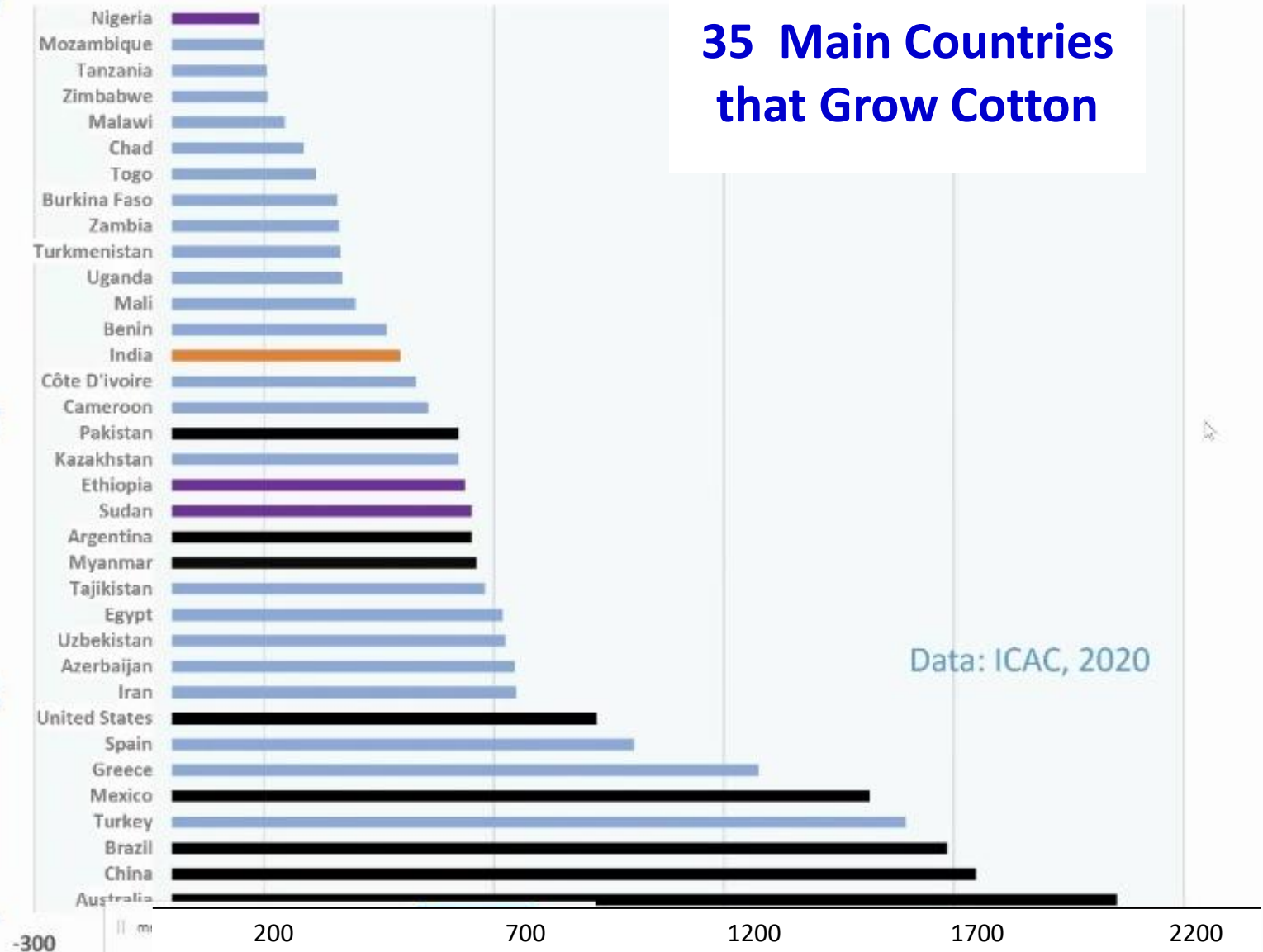
Low Yields in Wide – Spaced Cotton

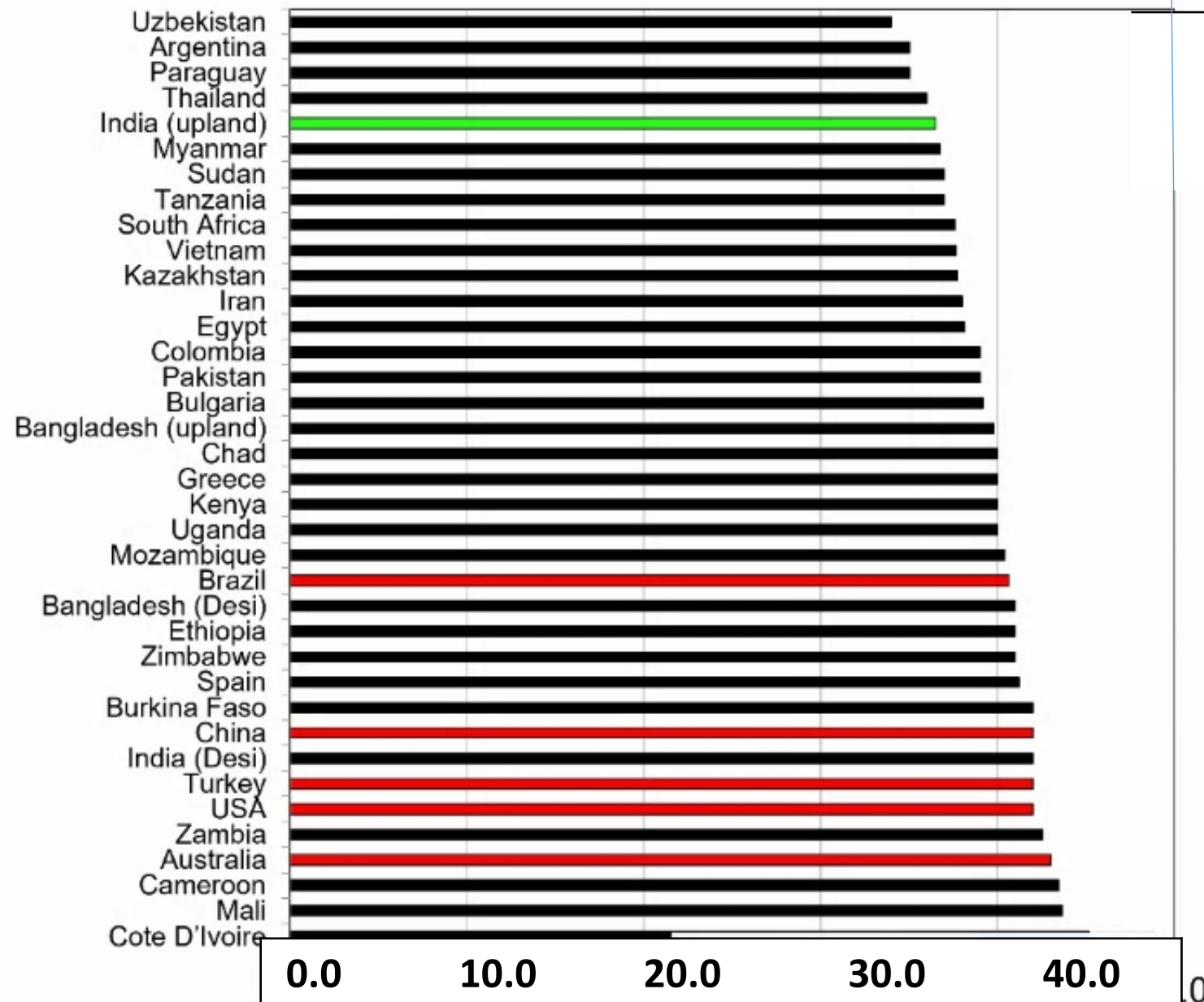
90 x 30 cm
90 x 45 cm
90 x 60 cm
90 x 90 cm

90 x 20 cm
80 x 20 cm

90 x 10 cm

35 Main Countries that Grow Cotton





Ginning Percentage

Australia 43%

Africa 42%

USA 42%

Turkey 42%

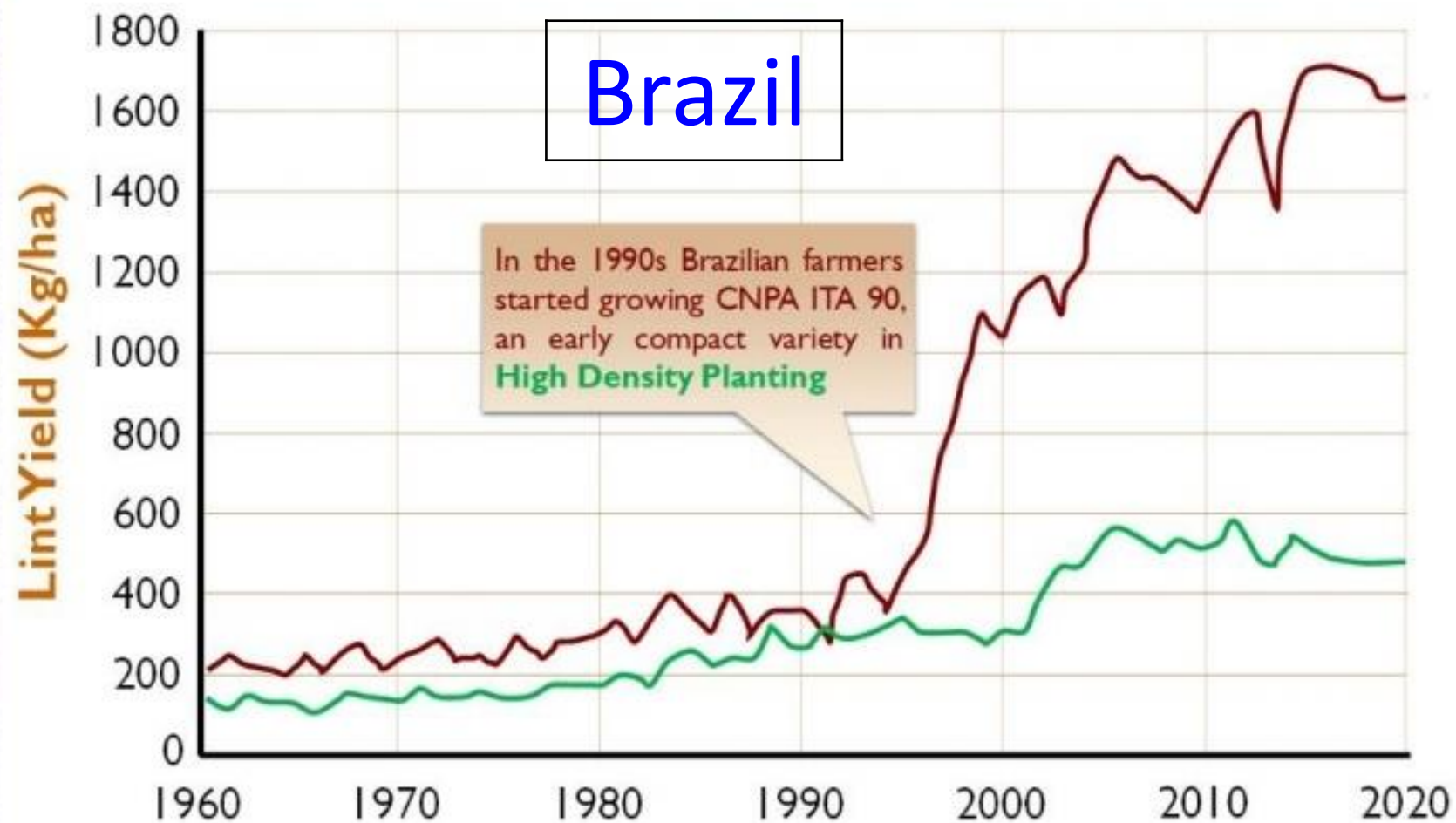
China 42%

Brazil 41%

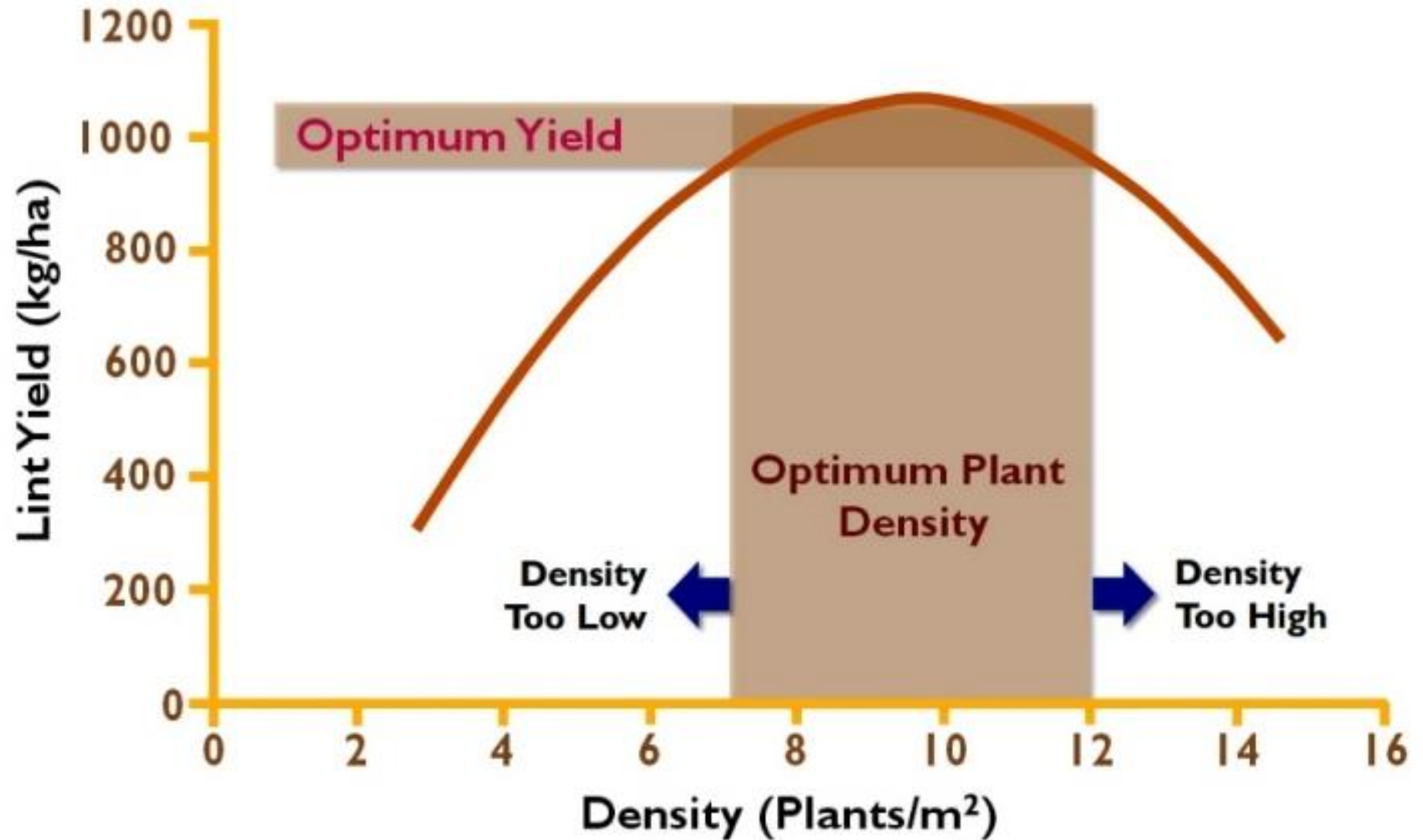
India **35%**

Ref: COTTON PRODUCTION
PRACTICES, ICAC 2017

High Density Planting - A Game-Changer in Cotton Agronomy



Optimum Plant Density in Cotton



Development, Promotion and Cultivation of *G. hirsutum* Bt and *G. arboreum* Cotton Varieties Suitable for High Density Planting System

In India	Australia, Brazil, China, USA and Mexico etc
<ul style="list-style-type: none">• Bt cotton hybrids• Medium to long duration• Bushy plant types• Plant population 11000/ha (90x60 cm to 150x 90 cm)• Harvest index (HI) 0.20-0.40• Productivity <500kg/ha	<p>Bt Cotton Varieties</p> <p>Short to Medium Duration</p> <p>Erect and Compact</p> <p>> 100,000/ha</p> <p>100x10 cm</p> <p>0,40-0.80</p> <p>>1500 kg/ha</p>

Asiatic cotton (*G. arboreum* L.)

- Short to medium coarse fibers
- Tolerance to drought, insect pests, nematodes and diseases (root rot and leaf curl virus)
- Suitable to grow under low input conditions
- Adaptable species for rainfed and irrigated conditions.



G. hirsutum HDPS

Development, Promotion and Cultivation of *G. hirsutum* Bt

and *G. arboreum* Cotton Varieties Suitable for HDPS

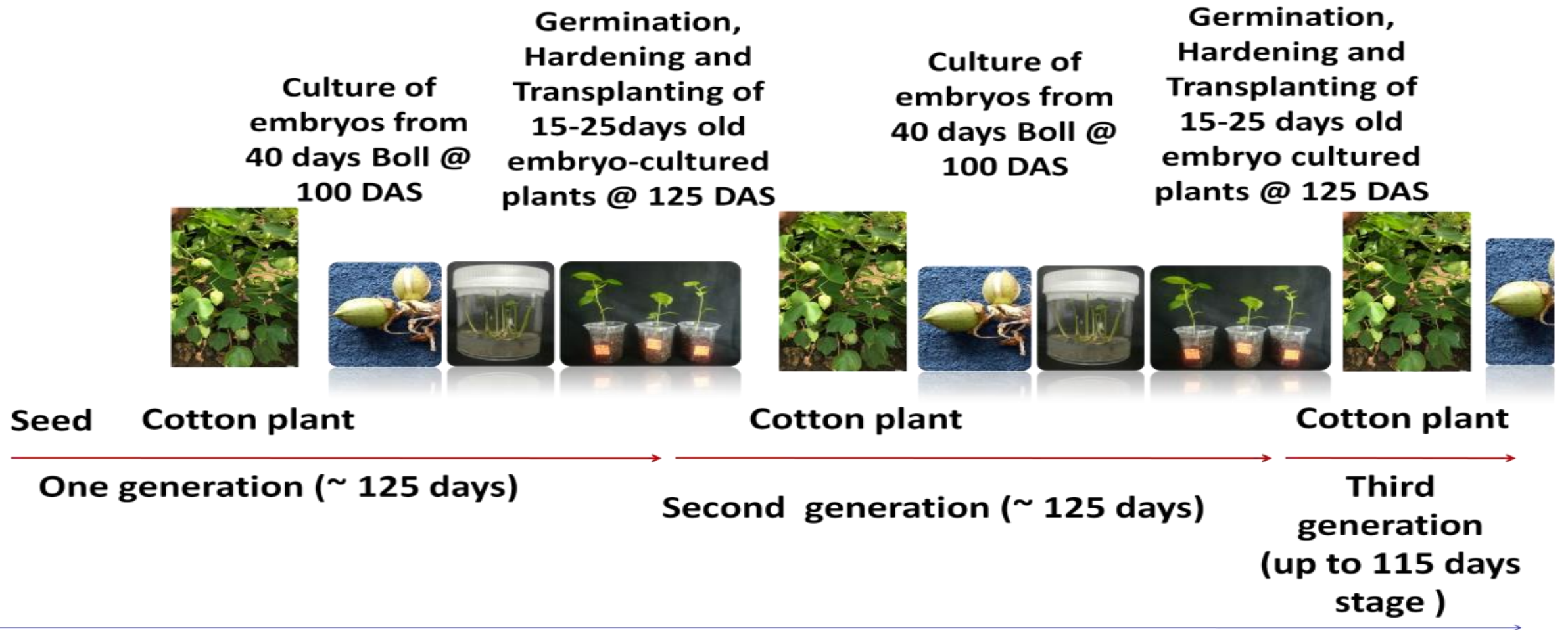


G. arboreum HDPS

The adoption of HDPS with better genotypes and management practices - a viable approach to break the current stagnation of yield.

1. From the experiences of Australia, Brazil, Turkey, China, USA and Mexico countries
 2. Recent Indian experiences of cultivation of *G. arboreum* cottons (2016-18) and non Bt cotton *G. hirsutum* varieties (2000-03) under HDPS
- This necessitates the evaluation of available Bt cotton varieties and *G. arboreum* cottons (140-160 days, big boll size > 4.0 g and > 3.0 g respectively) with higher harvest index (0.4-0.8), ginning out turn (> 35% and > 40% respectively) with population of 1,10,000/ha for their suitability to HDPS and achieve the projected production-productivity by 2030,
 - As it is known that cotton plants are characteristic of elasticity, plasticity and homeostasis, so plants can adjust to the prevailing environment.
 - Simultaneously it is required to breed Bt cotton varieties *G. hirsutum* and *G. arboreum* suitable for HDPS, right from F2 generation screening under HDPS (90x10 cm spacing) and adopting speed breeding and utilizing other technologies to breed suitable genotypes to meet the required production and productivity projected for 2040 and 2050.

Speed breeding (through Embryo Culture)



One year (> Two and half cycle)

Raghavendra *et al.*, 2022

District wise Cotton Growing Situation and Measures in India

Production Groups	Growing conditions , recommended measures to increase production
Most Efficient Districts 16.17% area, 26 districts, yield range 501 to 848 with average 624kg lint/ha	Deep medium to deep fertile soils with irrigation /assured rainfall. Promotion of short to medium duration Bt cotton and high yielding <i>G. arboreum</i> varieties under HDPS to facilitate double cropping, minimising tillage, crop residue management for better soil health, mechanization to reduce cost of cultivation, drip-fertigation cum mulching technique for higher water productivity.
Efficient Districts 16 districts, 2.83% area, yield range: 512 to 711 and average 628kg lint/ha	Better agro climatic conditions suitable for cotton production. Promotion of short to medium duration Bt cotton and high yielding <i>G. arboreum</i> varieties under HDPS to facilitate double cropping. Adverse factors or competing crops limiting the cotton area. Priority for any potential area expansion under cotton.
Less Efficient Districts largest 75.55% area, spread across 75 districts, yield range of 145 to 497 kg with average of 351kg lint/ha	Cultivated on shallow to medium deep soils, predominantly under rainfed conditions. Growing short duration Bt cotton and <i>G. arboreum</i> varieties under high density planting system (HDPS), timely sowing with pneumatic planters, avoiding mono cropping and improving soil health through crop rotation or double cropping (under residual moisture) preferably with legumes, residue management of cotton stalks, drip cum mulching technique for higher cotton productivity in irrigated pockets is the option to increase productivity.
Inefficient Districts 5.45% area, spread in 40 districts. yield range 118 to 496 with average of 334 lint kg/ha.	Cotton production is not sustainable due to lower yield because of both biophysical and socio-economic limitations. Cotton area in each district is also comparatively low; hence there is scope for cultivation of short to medium duration high yielding <i>G. arboreum</i> and Bt cotton varieties under HDPS, crop diversification to remunerative crops and intercropping system are the options.

Cotton Growing Situation and Measures in India

- In India cotton is grown in 157 districts.
- 26 most efficient, 16 efficient, 75 less efficient and 40 inefficient cotton producing districts.

To increase cotton production and productivity in different districts, it is required.

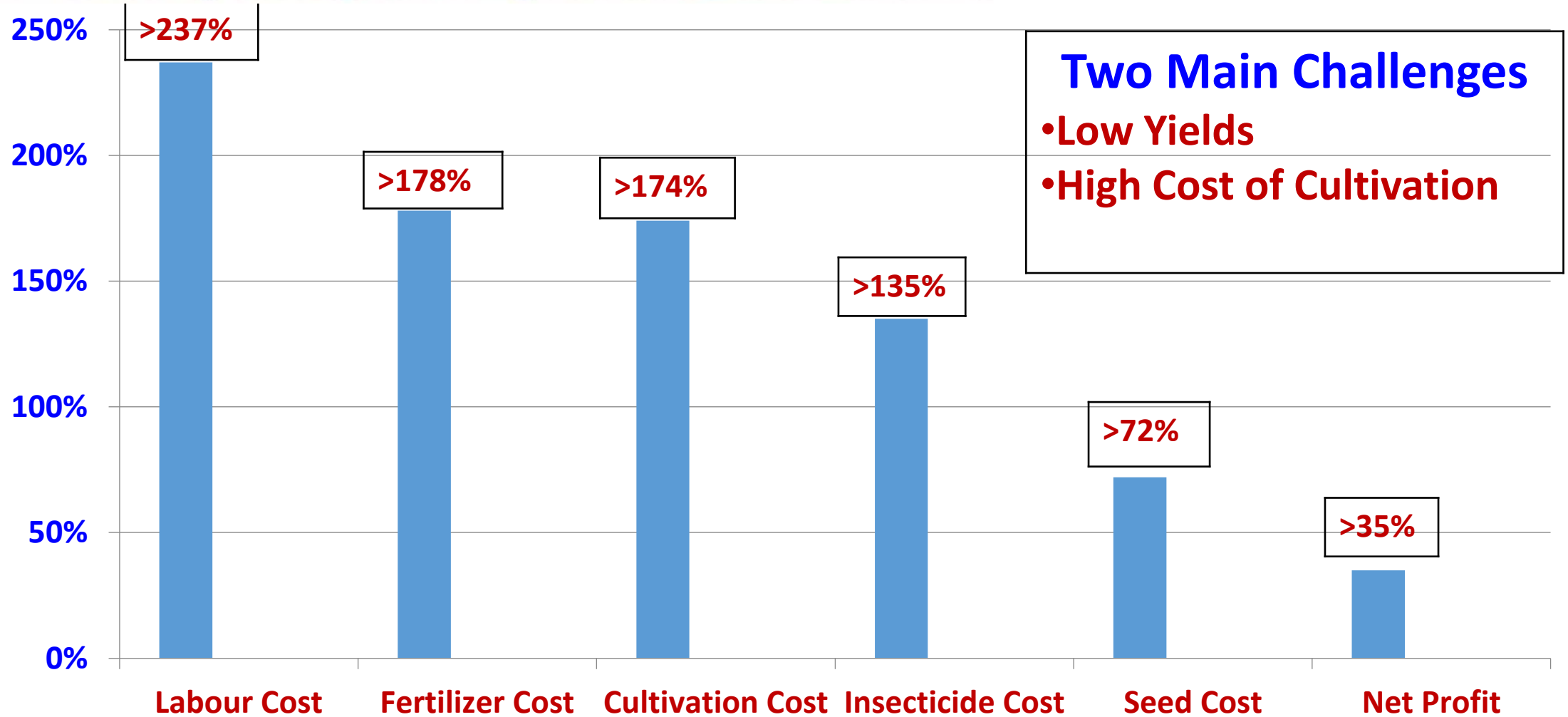
- to promote short to medium duration Bt cotton and high yielding *G. arboreum* varieties under HDPS to facilitate double cropping and minimizing tillage.
- it is also needed to follow crop residue management for better soil health.
- mechanization to reduce cost of cultivation and
- in irrigated area drip- fertigation cum mulching technique for higher productivity and production in cotton.

HDPS

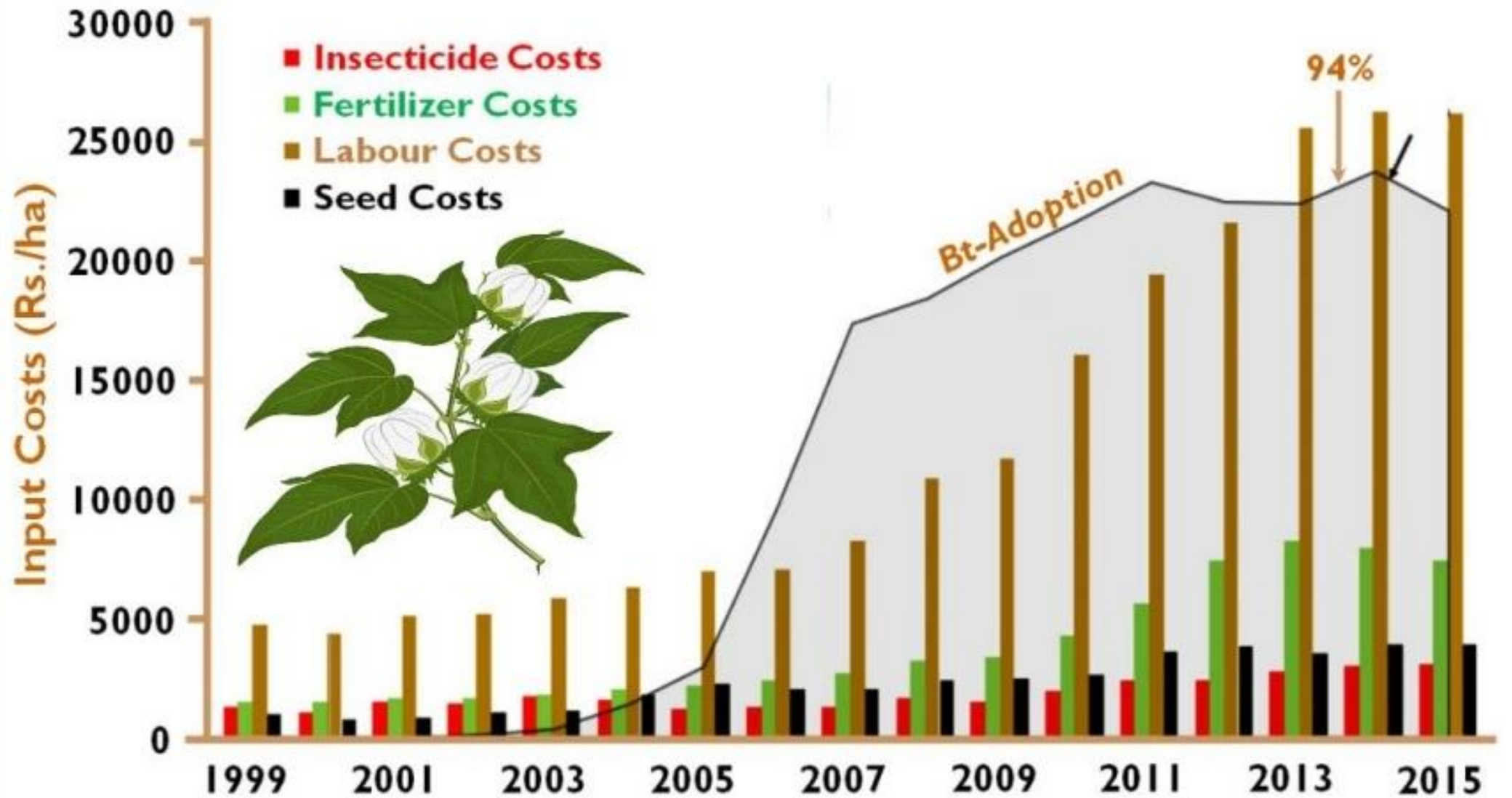
Merits	Demerits
Increase in yield & fibre quality	Reduction in boll size
Reduction in fertilizer use & labour cost	Require canopy management hormones and topping
Reduction in weed population due to smothering	Increased water moisture requirement
More bolls on primary plant axis	Shedding of squares and bolls due to crowding
Early crop maturity	Require defoliants for facilitating machine harvesting
Suitable to rainfed, shallow and medium deep soil as it avoids terminal drought	
Synchronous boll bursting amenable to machine harvesting	
Reduction in insecticide usage due to smaller window	
Facilitates double cropping and increase profitability	
Minimum tillage, reduce run off and increased soil moisture	

Indian Cotton

Despite 35% irrigated area & Adoption of best available technologies, Indian lint yields have been low with a 15-yr average of 511 kg/ha with a global rank of 37.



Rising Input Costs



(Source: Kranthi, 2018)

Breakup of Human Labour Utilization for Cotton Cultivation in India

Operations	Man days/ha	%	Cost Rs (\$)/ha	%
Land Preparation	2	1.56	577(\$7.22)	1.74
Sowing	14	10.94	2672(\$33.4)	8.05
Fertilizer/Manure Application	9	7.03	2562(\$32)	7.72
Irrigation	3	2.34	709(\$8.86)	2.14
Weeding	33	25.78	6121(\$76.5)	18.45
Pesticide Application	18	14.06	4868(\$60.85)	14.68
Picking/Harvesting	44	34.38	14185(\$177.3)	42.76
Stalk Cutting & Removal	5	3.91	1478(\$18.5)	4.46
Total	128	100	33172(\$414.65)	100

Projected figures for 2019-20 based on the cost of cultivation values of 2017-18

Source: https://eands.dacnet.nic.in/Cost_of_Cultivation.html

**Rotavator &
Harrows**



**Cleaners &
Ginners**



**Mobile
Shredder**

**Land
Preparation**

Sowing

Pneumatic Planter

**Crop
Management
& PGR**

Boom Sprayer



Defoliants



Drone Spraying

**Crop Residue
Management**

Picking

**Cotton
Picker**

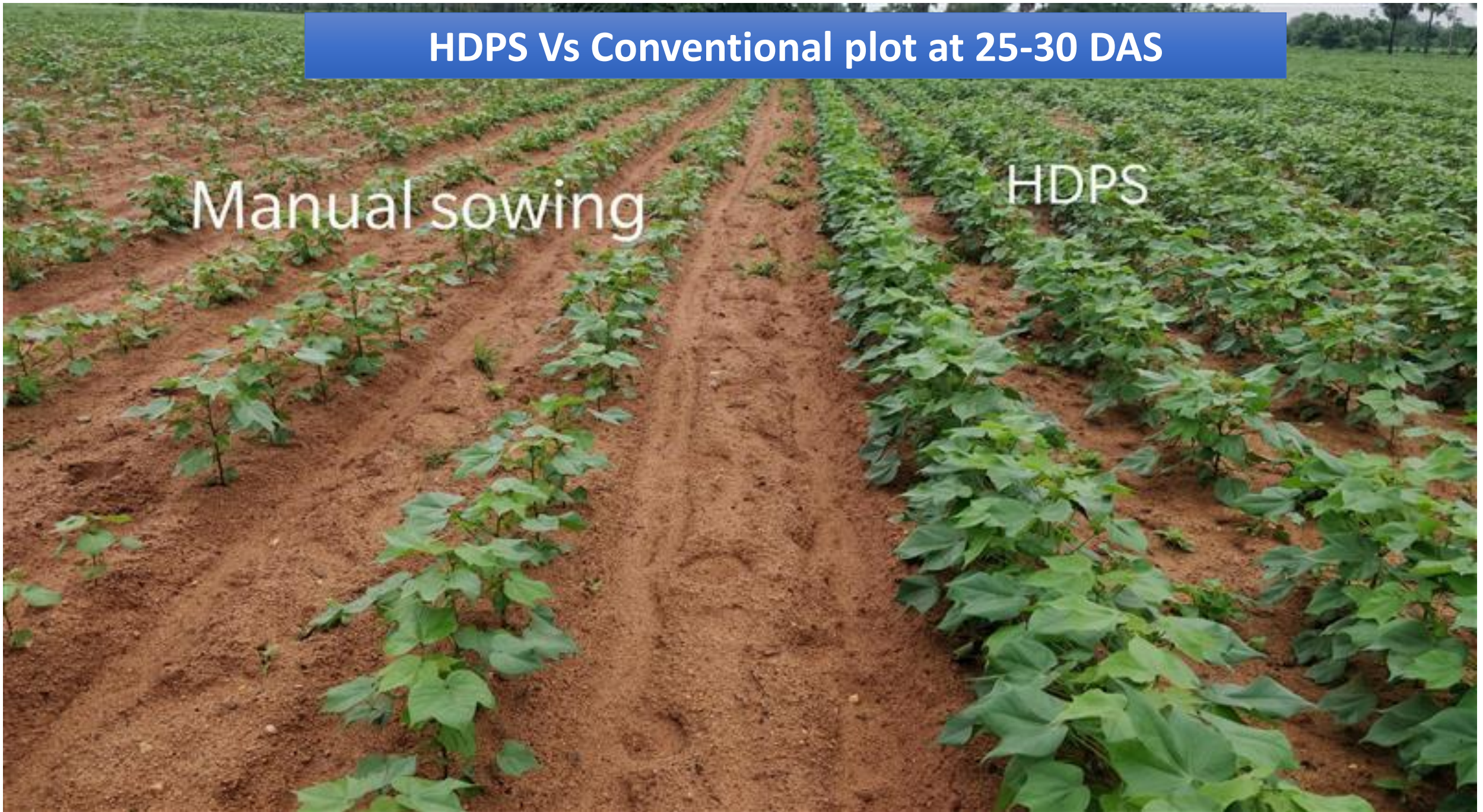


**Mechanization
of Cotton
Cultivation**

HDPS Vs Conventional plot at 25-30 DAS

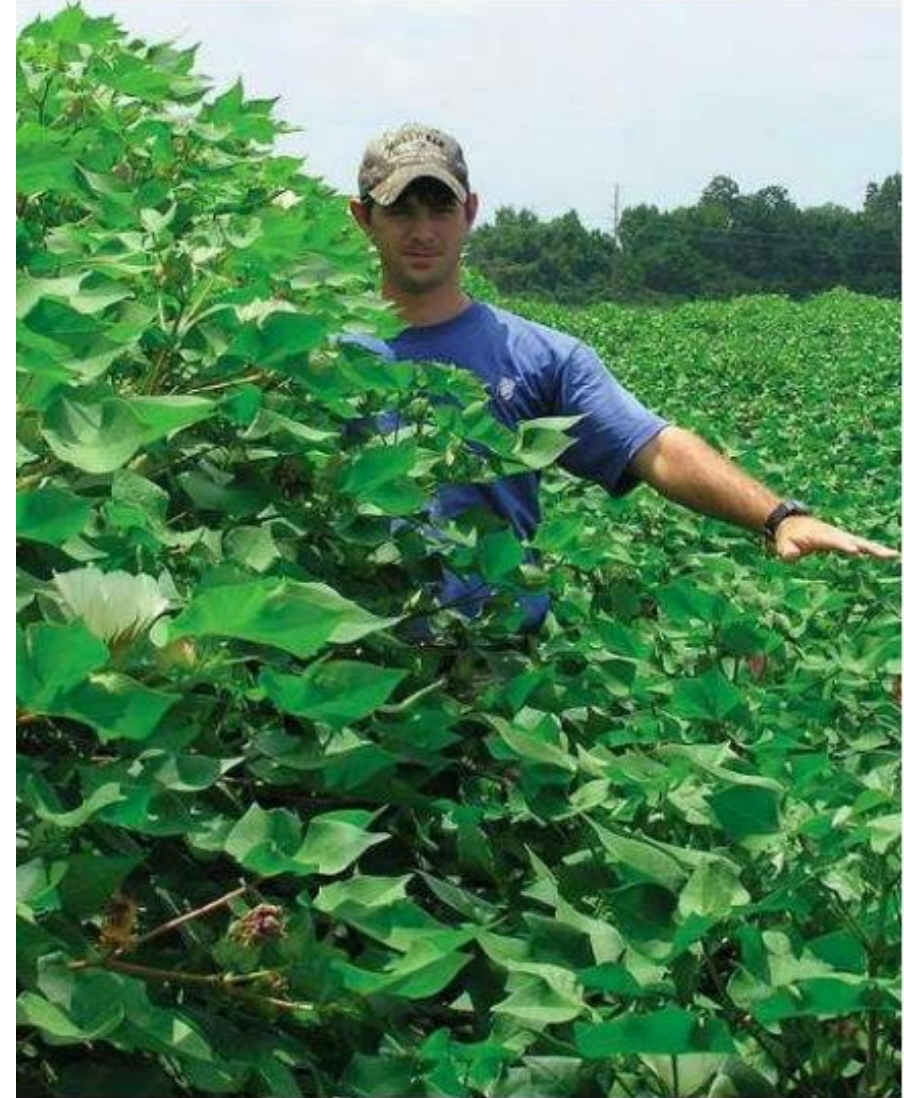
Manual sowing

HDPS



Canopy Management

- Planting suitable genotypes
- Restrict plant height to 65-70 cm with zero or one monopodium and 10-12 sympodia
 - Detopping at 75 DAS
 - Removal of vegetative branches (monopodia)
 - Use of PGRs Mepiquat Chloride to reduce excessive vegetative growth.



Defoliation

Restricting growth followed by defoliation to facilitate in harvesting fully opened bolls through mechanical pickers

The application of MC and Defoliant combination

- MC (Mepiquate Chloride) 50 g ai/ha at 45 and 65 DAS
- Dropp ultra (Thidiazuron and Diuron) @ 200 ml/ha at maturity
- Required to standardise the dosage and the time of application as these dependent on genotype.



Weed Management

- In cotton first 60 days, crop should be free from weeds to get the full potential.
- Application of recommended pre and post emergence weedicides and or 2-3 inter -cultivations are very important.

Common Name	Dose ai/ha	Time of application	Post Emergence	
Fluchlorin	0.75-1.0	Pre sowing	Quizolopos- ethyl + Pyriithibac Sodium	1 ml / litre
Triflurlin	1.0	Pre sowing		
Pendamethalin	1.0-1.50	Pre emergence	Fusiflex(Fluaifop-p- butyl+Fomesafen)	2 ml / litre
Diuron	0.5-1.0	Pre emergence		
Oxadizone	0.5-0.75	Pre emergence	Fluchloralin	5 ml / litre
Alachlore	1.0-1.50	Pre emergence		

- Aadoption of HT- Bt technology (after the approval)

Inter-culturing Machines for Small Farms



Water Smart Hi-Tech Agro-Techniques for Cotton Cultivation

Drip + fertigation + Biodegradable poly ethylene mulching with balanced fertilization **recorded huge saving of irrigation water with enhanced resource use efficiency and seed cotton yield of 7820 kg/ha as compared to conventional irrigation with NPK alone (3290 kg/ha)**

Balanced fertilization (120:60:60 kgs NPK/ha + Zinc Sulphate + Magnesium Sulphate (50 kg/h) for soil application a each) + Boron as Solubor (1 kg/ha) + 0.15% as foliar twice at flowering and boll development stages



(Nalayini et al., 2012)

Drip-Fertigation in Cotton

Irrigate more area in less water, less electricity and less time

- 50% of water saving in drip irrigation, reduced cost on weeding, inter culture and preparatory works in cotton cultivation.
- Uniform Distribution and increased efficiency of water and fertilizers.
- Maintain optimum moisture/field capacity in soil lead to minimize dropping of squares and flowers
- Productivity of 114 %(4.57 t/ha) higher than furrow irrigation 2.13 t/ha.
- 350Kwh/ha electricity consumption saved

Jade, 2022

Pest Management

-Incorporation of resistance/tolerance is essential to enhance the region wise cotton productivity,

- Northern region: tolerance to Leaf Curl Virus, Whitefly, Jassids and pink bollworm;
- Central and South: Pink boll worm, Jassids and drought;
- South: Mirid Bug and Flower Bud Maggot, Tobacco Streak Virus.

-New technologies need to be utilized for breeding biotic, abiotic stresses resistance and better fibre quality cotton genotypes to increase the production, productivity, reduce cost of production and increase farmers' income.

- introgression breeding (53 wild species),
- marker assisted selection,
- RNAi,
- CRISPR- Cas 9 etc,. SDN 1 SDN 2

Major Problems in Cotton in India

- **CLCuV (North)** – Only resistant Bt varieties and *G arboreum* cottons
- **PBW** – **Short term strategies** like short to medium duration genotypes, Early sowing, use of CREMIT - Controlled Release Emission Mating Interruption Technology, 4 applications at 35, 70, 100, 125(optional) DAS @ 312 g/ha. Use of PB ropes/knots of Gossyplure 300 per ha., shredding of stalks, destroying of ginnery waste. -- **Long term Strategies** : Eradication of PBW
- **TSV(South)** -- Removal of Parthenium weed , Stem application of monocrotophos in 1:4 ratio at 30 and 45 DAS and imidacloprid in 1:20 ratio at 60 DAS. Use of blue sticky traps. Vector Management: Spraying of botanicals like 5% NSKE or neem oil 1500 ppm@ 1 litre per acre. Spraying of chemicals like fipronil 5 SC @ 1 lit or acephate 75 SP @ 750 g or imidacloprid 17.8 SL @ 200 ml or acetamiprid 20 SP @ 100 g or thiamethoxam 25 WG @ 100 g per ha in rotation.

Why Nanotechnology in Cotton ?

Themes	Nanotechnologies	Benefits
1. Seed	1.1. e-Nose for quality assessment	On-site detection
	1.2. Bioimaging of seeds	Quality separation
	1.3. Seed Invigoration	nZnO for seed quality
	1.4. Seed nano-fibre encapsulation	Complete delivery of inputs
2. Soil	2.1. Hydrogel for soil amendment	Conserve soil moisture
	2.2. Nutri-capsule for multi-nutrients	Balanced crop nutrition
3. Plant	3.1. Foliar Nano-Urea spray (drones)	Yield increase 8-15%
	3.2. Early detection of Diseases	Losses minimized
	3.3. Smart delivery of biomolecules	Effective pest control
	3.4. AI to detect whitefly	Forewarning of pests
4. Produce	4.1. Stability of colour in cotton	Stable colour in textiles
	4.2. Nano-film for packaging	Biodegradable films

Courtesy: Dr K S Subramanian TNAU , CBE

Maintenance of Soil Fertility, Sustainable Cotton Yields and Higher Economic Returns

- Discouraging mono-cropping of cotton with suitable crop rotations with pulses, cereals, vegetables, oil seeds and green manuring crops to maintain soil fertility and sustainable cotton yields.
- Adoption of double cropping system in irrigated and rainfed (under residual moisture) cotton area with short and medium duration Bt cotton and *G. arboreum* varietal cultivation.
- Adoption of remunerative cotton based inter cropping systems and suitable crop rotations for higher economic returns and enriching the soils.
- Short duration pulses like green gram, peas, beans, coriander; oilseed crops like groundnut, soybean and sunflower crops can be intercropped with cotton crop based on the soil types and climatic conditions instead of cultivating cotton as sole or entire crop.

Identification of efficient legumes for cotton inter-cropping

Under HDPS for rainfed conditions to enhance soil fertility and farm income

Arboreum cotton



Cotton + Cowpea
CEY=1853 ; Additional Gross
Income: **Rs. 14015**



Cotton + Cluster bean
CEY=1956 ; A.G.I :Rs. 19987



Cotton + Green gram
CEY=2211 ; A.G.I : Rs. 32571

Hirsutum cotton



Cotton + Black gram
CEY=1899 ; A.G.I : Rs. 19691
CEY: Cotton equalent yield Kg/ha



Cotton + Groundnut
CEY=2125 ; A.G.I : Rs. 30844
A.G.I : Additional gross income Rs./ha



Cotton + Soybean
CEY=2412 ; A.G.I : **Rs. 45007**



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Thank You all