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Cotton in India: Past, Present and Future prospects in a novel way

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Cotton plays an important role in economic and social aspects and India ranks first in cotton area (12.6 million ha) globally with a production of 35.5 million bales of cotton (170 kg each bale). About six million farmers are involved in cotton production in the country. Cotton 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 and provides 60 per cent of raw material to the textile industry. Indian textile industry is the second largest employer, and 40-45 million people are engaged in cotton processing, trade, and related activities.

India has long history of cultivation of cotton, and which can be conveniently divided into cotton varietal era (Up to 1970-71), hybrid cotton era (1972-2001) and Bt cotton era (2002 onwards). India is the only country wherein all four cultivated cotton species viz., Gossypium *arboreum*, G. *herbaceum*, G. *hirsutum* and G. *barbadense* are cultivated commercially.

Apart from this, different categories of cotton, unspinnable surgical, very short, short, medium, superior medium, long, Extra Long staple cotton were produced which were suitable for spinning 6s – 120s counts and even up to 200s counts of yarn during cotton varietal and hybrid cotton era. India has uniqueness in the world where Intra and Inter specific cotton hybrids are being cultivated in large scale even today.

Cotton varietal era (Up to 1970-71)

At the time of independence G. *arboreum* and G. *herbaceum* cottons were cultivated in most of the cotton growing areas which was to an extent of 97 per cent. Total cotton cultivated area during 1947-48 was 4.32 m. ha, out of which G. *arboreum* cotton occupied a maximum area 2.79 m. ha (65 %), G. *herbaceum* cotton to an extent of 1.39 m ha (32 %) and remaining 0.14 m. ha was with G. hirsutum which was just 3% of total cotton area (Table 1). Cultivation of G. *hirsutum* cotton gradually increased during cotton varietal era and during 1956, G. hirsutum occupied 3.20 m. ha area (41 %), whereas diploid cottons G. *arboreum* and G. *herbaceum* area reduced to 2.84 m. ha (36 %) and 1.78 m. ha (23 %) respectively. With the increase in area under Hirsutum cotton there was increase in production and productivity in the country during varietal era.

Hybrid cotton Era (1972-2001)

During hybrid cotton era the total cotton cultivated area was 8.15 m.ha, out of which both intra hirsutum and interspecific cotton hybrids occupied about 3.26 m ha (40 %) and varieties of G. *hirsutum*, G. *arboreum* and G. *herbaceum* cotton occupied 2.61 m. ha (32 %), 1.39 m. ha (17 %) and 0.89 m. ha (11 %) area respectively. With the development and cultivation of hybrid cotton on 40 per cent area the production and productivity were almost doubled during the hybrid era.

Bt cotton Era (2002 onwards)

During 2007-08, the area under the varieties of G. *hirsutum*, G. *arboreum* and G. *herbaceum* reduced to 19 per cent (1.80 m ha), 10 per cent (0.90 m ha), 5 per cent (0.40 m ha) respectively and hybrids occupied 66 per cent (6.40 m ha) of total cotton area of 9.50 m ha. Further during 2014-15 varietal cotton area reduced to just 2 per cent (0.24 m ha) and Bt cotton area increased to 98 per cent (11.47 m ha). At present most of the cotton area is under Bt cotton hybrids (> 99%) and varietal area is almost negligible.

Indian Cotton Scenario during Varietal, Hybrid and Bt cotton Era

During the varietal era cotton area was to an extent of 6.58 m. ha with a production of 8.37 m bales and productivity 152 kg lint/ha., whereas during hybrid era the cotton production and productivity were almost doubled (17.65 m bales & 330 kg lint /ha, respectively) due to the introduction of cotton hybrids in India.

During hybrid era there was 70 per cent increase in total cotton area (9.29 m ha) and of which 40 per cent area was under cotton hybrids. Similarly, introduction of Bt cotton hybrids in India reduced the cotton bollworm damage increasing the production and productivity of cotton to an extent of about 40 to 60 per cent. The maximum productivity of 565 kg lint/ha was noticed during Bt cotton hybrid era (Table 2). Despite of increase in area in the country the productivity has dropped even below 500 kg/ha. The productivity reached maximum of 565 kg/ha during 2013-14 and later started reducing. Generally, it is envisaged to breakdown of resistance of BG II to pink bollworm.

Table 1. Species composition of cultivated cotton in India

Species	Area in Million Hectares											
	1947-48	%	1955-56	%	2000-01	%	2007-08	%	2014-15	%	2019-20	%
G. hirsutum	0.14	3	3.21	41	2.61	32	1.8	19				
G. arboreum	2.79	65	2.84	36	1.39	17	0.9	10	0.24	2	0.13	1
G. herbaceum	1.39	32	1.78	23	0.89	11	0.4	5				
G. barbadense					Negligible area							
Hybrids	-	-	-	-	3.26	40	6.4	66	11.47	98	12.47	99
Total	4.32	-	7.83	-	8.15	-	9.5	-	11.71	-	12.60	-

Table 2. Indian Cotton Scenario during Varietal, Hybrid and Bt Era.

Maximum	Varietal Era Up to1971	Hybrid Era 1972-2001	Bt Era 2002 onwards
Area (m. ha.)	6.58	9.29	13.37
Production (m. bales of 170 kg)	8.37	17.65	39.80
Productivity (kg/ha)	152	330	565

During varietal and hybrid era there was diversity of cultivation of all four cotton species and intra and interspecific hybrids but now it is only cultivation of hybrid cottons. All categories of cotton, unspinnable surgical, very short, short, medium, superior medium, long, Extra Long staple cotton was produced and were suitable for spinning 6s – 120s counts and even up to 200s counts of yarn during cotton varietal and hybrid cotton era. But now with cultivation of Bt cotton hybrids, only one category of superior medium - long staple cotton is produced, and it has become difficult to easily utilize this cotton for producing different categories of yarn.

Projected cotton requirement

The present production of cotton is 35.8 m. bales (6 m. t.) produced on an area of 12 m. ha with productivity of 503 kg lint/ha. The projected requirement of cotton is estimated to be almost 50 per cent more by 2030 (8.95 m. t.), nearing to double during 2040 (12.12 m. t.) and during 2050 it will be almost 150 per cent more (15.29 m. t.) as compared to the present production level. In order to achieve these projections, the productivity of cotton in the country should be enhanced to 746 kg lint/ha, 1010 kg lint/ha and 1274 kg lint/ha during 2030, 2040 and 2050 respectively. (Table 3).

Table 3. Projected cotton requirement

Year	Domestic (Million tonnes)	Export (Million tonnes)	Total (Million tonnes)	Productivity (kg lint/ha)
2030	4.08	4.87	8.95	746
2040	5.53	6.59	12.12	1010
2050	6.97	8.32	15.29	1274

Prospects of cotton cultivation in India

Although India is the largest producer of cotton i.e., almost 25 per cent of world production and second largest consumer and exporter, Indian farmers and market are having the problems of low yield and cotton contamination respectively. Though there are several reasons for lower yields and productivity of cotton in India, major reasons are; most of the cotton area is under rainfed condition and the land holdings are very small.

At present in India cotton hybrids are cultivated with spaced planting with a plant population of about 11000/ha as compared to other countries (Australia, Brazil, Turkey, China, USA and Mexico etc.), wherein high density planting system (HDPS) of varieties with a plant population of more than 1,10,000 /ha is practiced (Table 4). In India hybrids grown are of medium to long duration, bushy plant type having low harvest index and lower productivity (500kg lint/ha), whereas, in other countries cotton varieties cultivated are of short to medium duration, erect and compact plant type having higher harvest index and higher productivity (>1500 kg lint/ha). Hence, there is a need to adopt novel production technologies in cotton cultivation to achieve the targeted cotton requirement projections as indicated in Table 4.

Table 4. Characters of hybrids and varieties cultivated in India and other countries.

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	Characters	India	Australia, Brazil, Turkey, China, USA and Mexico
1	Cultivars	Hybrids	Varieties
2	Spacing (plant to plant)	60/90/120 cm	10 cm
3	Seed rate kg/ha	2.0	12.0
4	Plant Population /ha	11,000	>110,000
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 (days)	160-240	140-160
14	Labour requirement (No.s/ha)	100 to 120	1-10
15	Pink bollworm infestation	High (Long duration)	Low (short duration)
16	Seed production	Cumbersome	Easy
16	Bollworm resistance risk	High	Low
17	Non-Bt seeds in bolls	Present (Heterozygous for Bt genes)	Absent (Homozygous for Bt genes)

Strategies for higher and sustainable cotton production in India

- Broadening the species diversity by reviving cultivation of diploid cotton species resistant to sucking pests, leaf curl virus and abiotic stresses as being done earlier (15 % *arboreum*, 10 % *herbaceum*, 34 % *hirsutum*, 1% *barbadense* and 40% hybrids) for sustainable cotton production and meeting industry requirement of different categories of cotton (6s t0 120s count yarn).
- Development and promotion of high yielding Bt cotton varieties having early maturity (140-160 days), big boll size (>4.5 g) with higher harvest index (0.4-0.8) suitable for high density planting system (HDPS) enabling machine picking.
- Development and promotion of high yielding male sterile based Bt cotton hybrids having early maturity (140-160 days), big boll (>6 g) with higher harvest index (0.4-0.8) suitable for both spaced and high-density planting system (HDPS).
- Adoption of strategies to improve the ginning of cotton varieties and hybrids from 32-34 % to 38-40 %.
- Incorporation of resistance / tolerance in the existing potential cotton varieties and hybrids is essential to enhance the region wise cotton productivity, viz; tolerance to

Leaf Curl Virus, Whitefly, Jassids and pink bollworm in northern region; to Pink boll worm, Jassids and drought in Central and South India and to Mirid Bug & Flower Bud Maggot in South India.

- New technologies, introgression breeding, marker assisted selection, RNAi, CRISPR- Cas 9 need to be utilized for breeding biotic, abiotic stresses resistance and better fibre quality traits of cotton genotypes to increase productivity, reduce cost of production and increase farmers income.
- Adoption of remunerative cotton based inter cropping systems and suitable crop rotations for higher economic returns and enriching the cotton soils. Short duration pulses like greengram, peas, beans, coriander; oilseed crops like groundnut , soybean and sunflower crops can be intercropped in cotton crop based on the soil types and climatic conditions instead of cultivating cotton as sole or entire crop.
- Discouraging mono-cropping of cotton year after year with suitable crop rotations with pulses, cereals, vegetables, oil seed crops and green manuring crops to maintain soil fertility and sustainable cotton yields.
- Adoption of drip irrigation and fertigation in spaced Bt cotton hybrids and varieties under HDPS to enhance the cotton productivity.

Technology driven evolution of genetic improvement of cotton, Gossypium *Spp.*

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The evolution of cultivated diploids and teraploid cottons goes dates back to 10 million years ago, and 1-2 million years ago respectively. The utilization of cotton was recorded as early as 5500 BC, the earliest known fabrics was used in the Egyptian mummies. In the Indian subcontinent, the use of textiles was documented during the Harappan civilization (2300-1750 BC). Herodotus, the father of history, in around 445 BC wrote that "The Indians have a wild-growing tree which instead of fruit produces a species of wool similar to that of sheep, but of finer and better quality. The Indians make their clothing from this material". In the Vedangas literature described to have written around 1000 BC, the description about cotton cloths is available. Ramayana, Mahabharata, and the Puranas of the Indian old sacred text also contain references to cotton materials (Ramanatha Iyyar, 1962). The cotton then produced was from diploids, G. herbaceum L. and G. arboreum L. It is also supported by the fact that the cultivated cotton in Asia, Africa was diploid cottons until recently, the

1940s. The oldest cotton fabric has been found in Huaca Prieta in Peru, dated about 6000 BC. It is here that Gossypium barbadense is thought to have been domesticated at its earliest and later G. hirsutum L was domesticated. Local landraces domesticated here were coloured cotton. Cotton (Gossypium herbaceum L.) may have been domesticated around 5000 BC in eastern Sudan near the Middle Nile Basin region, where the cotton cloth was being produced. Egyptians grew and spun cotton from 6–700 CE. In Chinese, the first reported cotton cultivation was from an area now known as Yunnan, sometime around 200 BC. A historian has called the introduction of cotton in the Chinese as "southernization" during which period the cotton species Gossypium herbaceum (an Afro-Asian species), and Gossypium arboreum from India were introduced. The latter species were grown in Guangdong and Fijian provinces during the ninth century AD. The adoption of scientific methods of cultivation came into practice in China only from 1949. It is clear from these facts that in most of the cultivated cottons, the diploids were the first to domesticate in most of the countries.

Technology invention and change in species cultivation:

Innovation in ginning and spinning in the textile Industry made G. hirsutum as king of cultivated species

Especially in India, 100 percent of commercial cultivation of cotton was the Desi diploids. With these diploids only, India was able to produce more than 200 counts of yarn because of the skill of hand weavers for many centuries (Gulati, 1947). Cotton garments and yarns were the very components of attractive business commodities to Europe and Arabian Countries. But Industrial revolution in Europe had led to a change in the breeding strategies to improve fiber qualities to meet the demands of textile industries. In India, initially, the research activities were focused on the adoption of G. hirsutum, tetraploid cottons, to meet the demands of the textile industry, it took nearly 50 years (1850s-1930s) and later breeding suitable G. hirsutum genotypes using less adopted G. hirsutum cottons from the USA were carried. From the 1950s, constantly, desi cotton cultivation started reducing and the G. hirsutum era has begun. In other parts of the world, G. hirsutum was the major cultivating cotton by that time. A lot of breeding work for multiple pest resistance has been carried out in India. Successfully, tolerant varieties are developed viz., G.Cot. 12, G.Cot.10, Khandwa 2, DHY 286, B1007 (G. hirsutum, varieties tolerant to jassids), Kanchana, Supriya, LK 861 (G. hirsutum, varieties tolerant to white fly), MCU 5VT (tolerant to verticillium wilt), Sujay, Digvijay (tolerant to fusarium wilt), Abadhita (tolerant to bollworm) were some of the notable examples (Anon., 1989, Katageri et al., 1990 and Prakash Rao et al., 1991, Khadi et al 1998).

Hybrid technology

Although Meli in 1894 and Cook in 1909 had showed the possibility of exploitation of heterosis in cotton for fiber and yield traits, it has come true in the commercial scale in 1970s. Hybrid technology to exploit intra or interspecific level heterosis for yield and fiber quality was effectively used in India because of the availability of farm workers. The produced hybrids covered nearly 50% of cotton cultivated area in the country meeting the needs of raw cotton suitable for spinning to 30-50s counts (intra hirsutum hybrids) and 60-120s count (intraspecific tetraploid hybrids). Among several intraspecific hybrids, H4 was the first commercial hybrid released in 1970 (Patel, 1971). Among interspecific tetraploid hybrids, Varalaxmi was the first hybrid released in 1972 (Katarki, 1972), and later DCH-32 was released in 1981 (Katarki, 1981) both hybrids were developed by UAS, Dharwad. DCH-32 covered nearly 2.5% of the total Indian cotton area for nearly one and half decades (1980s to 1990s). Because of its spinning suitability of up to 120s yarn counts, this fetched better price to the farmers cultivating them. The G. hirsutum varieties, intra-hirsutum, and interspecific (G. hirsutum x G. barbadense) hybrids together changed the species composition of commercially cultivated cotton. Tetraploids occupied 75 percent of cotton cultivation and diploids occupied 25 percent of the total cotton area in 1990s (Basu, 1999). However, the efforts in improving fiber properties in white cotton diploids making them suitable for 40-50s count (Deshapande et al 1991, Kulkarni et al., 2003) and coloured diploids suitable for 30s -40scount is very significant contributions (Khadi et al., 1996) and tetraploid coloured cottons (Manjula et al., 2013, Saritha and Patil, 2019). In the hybrid breeding, the most important part is development and identification of lines with high GCA coupled with high SCA in combinations. Application of population improvement in cotton has resulted in very successful line development (Patil S S eta al 2013).

GM technology

The intervention of GM technology in bollworms and weed management is the most accepted and widely adopted technology worldwide covering an area of 79 per cent world's cotton cropped area (Anno., 2019). In India also, private companies GM hybrids covered 95% of the cotton cultivating area with the BT technology, i.e., BG I and BG II. Very glorious hybrids of India Viz., Hybrid 4, H6, H8, JKHy 1, NHH44 (intra-hirsutum) and DCH-32 (interspecific) and several varieties in both tetraploids and diploids have been cropped in a very small area just due to the absence of BT technology in them. But, they are now coming back to the cultivation with BG II trait, developed through collaboration between Mahyco Monsanto Biotech Ltd (MMB), State Seed Corporations and State Agricultural Universities. Altogether a new BT event (No.78) from UAS Dharwad with cry1Ac (ICGEB source) is under biosafety trial (personal communication with Dr. Manjula, S. M.).

Molecular Breeding

For molecular marker-assisted breeding (MAB), the basic studies such as developing molecular markers, linkage maps and understanding of marker-trait associations began in 1994, nearly 249 association and linkage mapping studies have been carried, 4285 QTLs have been identified worldwide for major quality traits (Fiber strength- 1123 & fiber length-1147) and yield traits (boll weight- 676, boll number- 186, yield- 275, lint percentage- 878) (Katageri, et al., 2021). The application of molecular markers in molecular breeding has not yet contributed much too deriving lines for commercial cultivation. Availability of whole-genome sequences of as many as nine assemblies of G. hirsutum, four assemblies of G. barbadense, three assemblies of G. arboreum, three assemblies of G. raimondii, and one each assembly of wild species such as G. australe, G. darwinii, G. longicalyx, G. mustelinum, G. tomentosum, and G. turneri (Katageri, et al., 2021), Functional validation of key genes involved in fiber development (Shi et al., 2006, Padmalatha et al., 2012a, Padmalatha et al., 2012b, Hande et al., 2017, Lu et al., 2017), enhances fine-mapping followed by utilization in MAB for improvement. Genome-wide selection through sequencing is becoming very precise in the introgression of targeted traits along with the reduction in the time of breeding (Bernardo and Yu, 2007, Nakaya and Isobe, 2012).

Genome editing technology

Genome editing, a Nobel prize won technology is a great hope since genetically modified food crops are widely discouraged in many countries. The genetic modification through genome editing technology is on par with conventional mutation breeding as the final genotype is free of a foreign gene. Cotton although known as a major commercial crop for fiber purpose; it is also going to a major oilseed crop after reducing gossypol content in oil and increasing oleic acid composition. Efforts made by convention methods of breeding to reduce gossypol deserve appreciation (McMichael, 1960, Zhu et al., 2005, Dong et al., 2007) but the technology developed has not reached the level of commercialization (Benedict et al., 2004). The wonderful effort through RNAi technology successfully reduced the seed oil gossypol without affecting other traits (Rathore et al., 2012, and Palle et al., 2013). This, GMO cotton is expected soon, the commercialization (oral discussion with Dr. Rathore). Efforts are very much in progress to knock down the the over-expressing delta cadenine synthase gene in developing seeds through gene-editing technology at UAS Dharwad. Increase oleic acid in cottonseed oil through genome editing has been published (Chen et al., 2021). In future, these products may go as non-GM for commercialization.

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Threat potential of fall armyworm, *Spodoptera frugiperda* (J. E. Smith) for cotton cultivation in India as new invasive pest and way forward

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In India, adoption of Bt cotton to contain bollworm menace has seen dramatic increase from 0.038 to >115 m.ha in seventeen years. Being largest grower of Bt cottons hybrids expressing *CryIAc* + *CryIIAb* toxins striking benefits of bollworm suppression (>95%), insecticide usage reduction (60-100%) against bollworms and yield advantage (>50%) have been harnessed. But slowly the pest complex jeopardized under various circumstances and cotton suffered with widespread infestation of invasive mealybugs (*Phenococcus solenopsis*). Simultaneously new pests *viz.*,mirid bug *Creontiades biserratense,* flowerbud maggot *Dasineura gossypii* etc have posed much threat potential for cotton cultivation in South India. Along with such problems management pink bollworm has been a challenging issue in Central and South India presently. Thus cotton pest management has new targets now which need revised tools in IPM for sustained profit. In such uncomfortable situation another dreaded polyphagous lepidopteran pest fall armyworm,(FAW) *Spodoptera frugiperda* (J.E.Smith) (Lepidoptera:Noctuidae) invaded India. As a historically associated pest with cotton in other countries it is likely to be another problem to sustainable cotton production in India. The present paper deals with its pestiferous dimensions with respect to cotton and offers a discussion on way forward.

A brief understanding about fall armyworm: The fall armyworm, a native species of tropical and subtropical regions of the America. It is geographically widespread and feeds on a wide range of cultivated plants (Luginbill,1928). Notorious pestiferous nature with high dispersal ability, wide host range, and high fecundity makes the fall armyworm as one of the most severe economic pest. This pest has invaded Africa, with the first detections being reported in Central and Western Africa in early 2016 (Goergen *et al*, 2016), causing significant damages to maize , and in late 2016 and 2017 in parts of Southern, Eastern and Northern Africa . Within a short span of its introduction in Africa, FAW has been confirmed in over 43 African countries.

Being a polyphagous pest FAW is known to cause major damage to economically important cultivated grasses such as rice, sorghum, and sugarcane as well as cabbage, beet, peanut, soybean, alfalfa, onion, cotton, pasture grasses, millet, tomato and potato (Ali *et al*., 1989). A total of 353 *S. frugiperda* larval host plants recorded belonging to 76 plant families, principally Poaceae (106), Asteraceae (31) and Fabaceae (31) as per Ankush *et al,* 2019.

Invasion of fall armyworm in India: Fall Armyworm has been detected for the first time on the Indian subcontinent in mid-May 2018 in maize fields at the College of Agriculture, (UAHS), Shivamogga,

Karnataka as per Sharanabasappa *et al* (2018). In short notice occurrence of this pest has been reported in different states of India *viz.,* Andhra Pradesh, Telangana, Tamil Nadu, Maharashtra and Gujarat infesting maize and sorghum. Fall armyworm feeding on two months old sugarcane crop, variety (Co 86032) was noticed at Ghogaon village of Sangli District, Maharashtra (Ankush *et al,* 2019). Chhattisgarh became the latest state to report the infestation of FAW on maize (Sonali and Nandita , 2018). After its initial dent in corn fields of Karnataka, fall armyworm was found feeding on two months old sugarcane crop, variety Co 86032 at Ghogaon village of Sangli District, Maharashtra on 22nd September 2018 (Chormule *et al.,* 2019). Concurrently, Srikanth *et al*. (2018) reported the occurrence of FAW on 2.5 to 4.0 months old popular sugarcane variety Co 86032 for the first time from the South Indian state of Tamil Nadu in November 2018, with the infestation level ranging from 1.85 to 30.86 per cent. Further, Karnataka itself became the first state to have the fall armyworm infestation on rice crop in India (Kalleshwaraswamy *et al.,* 2019). In July, 2019 occurrence of FAW on ginger foliage at Mudur village of Haveri district, Karnataka was noticed for the first time (Shankar and Adachi, 2019). Now FAW has been confirmed over more than 20 states of India.Preliminary surveys have confured its presence in cotton fields also. The first ever occurrence of fall armyworm on cotton crop was reported from Susare village of Ahmednagar district in Western Maharashtra in 2019. The loss in the FAW infested cotton was assumed 10 per cent according to press coverage of Times of India dated 21st September 2019.In India growing conditions of cotton vary and it shows wide climatic adaptability. Thus, due to favorable climatic conditions FAW could be considered as potential threat to cotton in India as an already relished host in its nativity. Based on its historical association of FAW with cotton, the preparedness has been felt essential to combat its incidence on cotton in India.

Fall armyworm strain: Two strains based on crop adoptability have been recognised in fall armyworm viz., rice and corn strains. However, the corn strain of fall armyworm feeds predominantly on maize, cotton, and sorghum (Prasanna *et al,* 2018). This could have been invaded into India.

Does it pose problem to cotton? or Bt cotton? The fall armyworm has been reported as an economic pest of cotton in Georgia, Alabama, Florida, and Louisiana

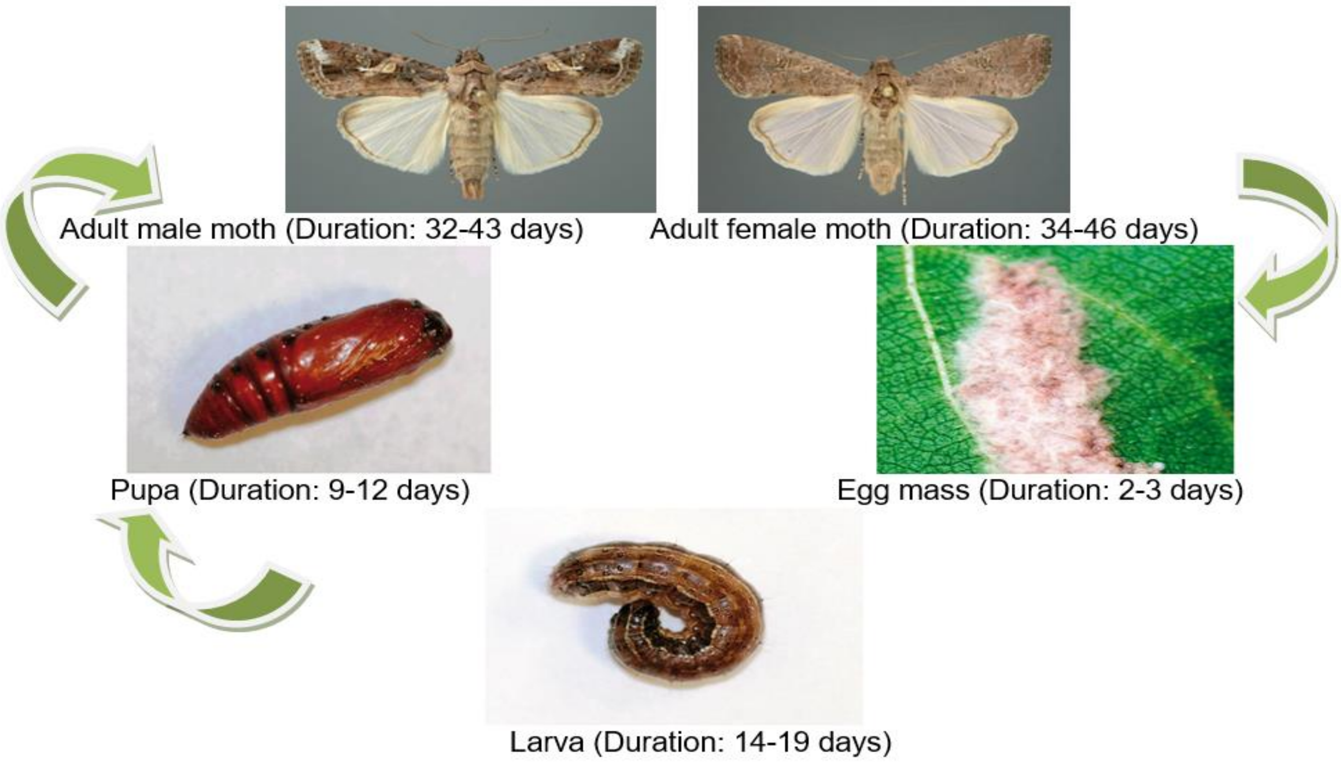
regions of USA (Smith, 1985) In 1977, this pest caused significant damage to cotton throughout the southeastern United States and in 1984, caused economic damage in the Winter Garden area of Texas. In 1985, it was the single most damaging pest of cotton reported in Mississippi (King *et al*., 1986). In southern Alabama and Georgia in 1996, local outbreaks of the fall armyworm were reported on both conventional and transgenic cotton plants expressing a *Bacillus thuringiensis* Berliner (Bt) Cry1A(c) delta-endotoxin (Smith, 1997). Further, Scott (2003) also noticed appearance of fall armyworm found throughout Tennessee and Canada during the late summer and early fall months. Thus fall armyworm larvae have shown the potential to damage cotton fruiting structures at rates comparable to those of the cotton bollworm and tobacco budworm, assuming similar survival rates according to Luttrell and Mink. (1999). Adamczyk and Gore (2004) confirmed better efficacy cotton containing Cry1F against FAW larvae compared to cotton containing only Cry1Ac. According to Armstrong *et al*. (2011) also the single Bt trait was less effective in killing neonates of FAW whereas 100% mortality was caused by WideStrike at 7 and 10 days in third instar larvae. Further Bollgard II® caused 35% mortality at 7 day and 50% mortality by 10 days.

FAW does not undergo diapause, so it migrates annually from warmer climates such as Caribbean Islands, Mexico, Southern Florida, Southern Texas and coastal areas of Southern Georgia, Alabama, Mississippi and Louisiana, northward across the United States (Luginbill, 1928; Adamczyk *et al.,* 1998). Its movement every year generally creates sporadic problems across number of crops, including cotton, *Gossypium* spp. Outbreaks of FAW and subsequent damage can be unpredictable. When outbreaks of fall armyworm occur, the severity of the problem is compounded by its ability to damage a range of vegetative to reproductive structures of plant, creating the opportunity to cause significant crop losses (Hardke *et al.,* 2015).

A laboratory study was conducted to know the food consumption and utilization pattern of fall armyworm (FAW) in different non-Bt and Bt cotton. Highest consumption indices (CI-1.18, GR- 0.23 mg/day, ECI-17.50 %, ECD-42.81 % and AD-51.32 %) were indicated by larvae when fed with leaves of a non-Bt cotton genotype DHH-11. *S. frugiperda* revealed the lowest consumption and utilization indices when fed on leaves of cotton hybrid Bindas BG II (CI-0.21, GR- 0.07mg/day, ECI-7.32 %, ECD-18.44 % and AD-22.44 %).When larvae were fed with squares of non-Bt cotton genotype DHH-11 showed highest indices (CI -0.87, GR- 0.27 mg/day, ECI-38.51 %, ECD-53.37 % and AD-64.55 %) while lowest indices recorded on Bindas BG II Bt (CI -0.30, GR-0.09 mg/day, ECI-17.57 %, ECD-22.53 % and AD-31.52 %). Similar effect was noticed when larvae fed with cotton bolls Non-Bt cotton genotype DHH-11 could lead to highest indices (CI - 0.87, GR-0.46 mg/day, ECI-38.80 %, ECD-59.44 % and AD-74.31 %) whereas Bindas BG II Bt cotton genotype was not well accepted by the larvae and led to the lowest food intake, utilization and assimilation indices (CI-0.16, GR-0.10 mg/day, ECI-22.49 %, ECD-28.41 % and AD-40.22 %). Among non-Bt genotypes Suvin indicated the lowest value for all the parameters. Among leaf, square and boll fed to the larvae the highest CI (1.18) was noticed for leaves and lowest (0.16) for boll. But highest GR (0.46 mg/day) was indicated when larvae were fed on the bolls followed by squares (0.27 mg/day). Hence, bolls and squares found to be more nutritious than leaves to larvae of *S. frugiperda* (Chaithra *et al*., 2020).

Potential loss due fall armyworm in cotton: Thus, fall armyworm larvae have shown the potential to damage cotton fruiting structures at rates comparable to those of the cotton bollworm and tobacco budworm, assuming similar survival rates (Luttrell and Mink, 1999). In 2009, FAW was reported to have infested over 45,000 acres of cotton field, with 124 bales of cotton lost due to infestation in Lousiana. It has been ranked as fifth dreaded pest of cotton. Under protected condition FAW causes 30 % cotton yield loss and under unprotected condition it causes 90% yield loss (Mink *et al,* 1999).

Biology of fall army worm on cotton:



Nature of damage:

a) Leaf skeletonisation by neonates

b) Square feeding

c) Bract and square damage

d) Young boll damage

e) Larva damage to a cotton boll

Early instars (L1–L3 stages) feed on foliage of low /mid canopy. Older instars (L4–L6 stages) are usually present within the lower regions of the plant canopy, feeding on fruiting structures (Cook et al. 2004).
Larvae in the first few instars "skeletonize" (partially feed on) leaves near the egg mass from which they eclosed.
Early in the cotton growing season, later instars have the potential to destroy terminals on cotton seedlings. Heavy infestations have the potential to injure all fruiting forms (Leigh et al. 1996).
Older larvae typically injure bracts, large squares (flower buds), and young bolls in a manner similar to the bollworm. The majority of fall armyworm feeding on cotton occurs during the last three instars and accounts for 98% of the foliage or fruit consumed during their life cycle (Sparks 1979). As much as 80% of food is consumed during the final instar (Luginbill 1928).
Larger larvae feed internally in fruiting structures making successful chemical control more difficult. Cotton bolls at any age are susceptible to fall armyworm damage with significant damage regardless of boll age (Adamczyk *et al.*1998).

Threat potentail to cotton cultivation in India: Cotton is cultivated in varying climatic conditions of tropics as well sub-tropic regions globally. In India also growing conditions of cotton vary and it shows wide adaptability. Due to favorable climatic conditions FAW could be considered as potential threat to cotton in India as it's an already relished host. Other reasons would be:

- Major host crops of FAW *viz.*, maize and sorghum are predominant crops where cotton is also being cultivated, especially in South/Central India.
- FAW has spread to many states in India within a season/year.
- Its biotic potential and adoptability can't be ignored.
- We do not grow widestrike (VIP gene) Bts which have better efficacy for FAW.
- FAW has shown survival on Cry 1 Ac expressing Bts largely and on BG-II cottons to 50-70% extent.
- Poor expression by any means (moisture stress etc) may support FAW survival /encourage.
- Mirid bug could establish as key pest on Bt cotton since it had maize, sorgum, pigeonpea and sunflower as alternate host. Similar would be the case with FAW (Ravi and Patil,2008).

FAW resistance to insecticides and Bt toxin: The high infestation rate of *S. frugiperda* and the major economic losses it causes has led to a reliance on intensive application of chemical insecticides for control. Insecticides registered for FAW management in foreign are Chlorantraniliprole, flubendiamide, spinosad, spinetoram, novaluron, indoxacarb, lambda cyhalothrin etc. And in India are Emamectin benzoate, Chlorantraniliprole, Spinosad, Spinetoram *etc.* Unfortunately the widespread and sometimes indiscriminate use of insecticides has contributed to the development of populations with resistance to several different insecticide classes including organophosphates, carbamates, pyrethroids, diamides and Bt crops. Insecticide resistance in fall armyworm was first reported by Young and McMillian to carbaryl in the corn field in 1979.

The evaluation on the effective dominance of resistance based on the survival of neonates from selected Bt-resistant, heterozygous, and susceptible (Sus) strains of FAW on different Bt varieties revealed that HX-R, VT-R and PW-R strains exhibited high survival on Bollgard II. All resistant strains survived on WideStrike, but only PW-R and Vip-R×Sus survived on TwinLink (Horikoshi *et al.,* 2016).

IRM strategies for management of FAW: Prevent the development of insecticide resistance; use a combination of all available pest management and resistance management tools to decrease FAW exposure to insecticides.

- ✓ Always follow the label directions of each product.
- ✓ Consult product label or IRAC's website (www.irac-online.org) to determine the MOA of each product.
- ✓ Do not treat successive generations with products of the same MOA.
- ✓ The total exposure period of products representing a single MOA applied throughout the crop cycle (from seedling to harvest) should not exceed approximately 50% of the crop cycle.
- ✓ Apply insecticides only when needed based on economic thresholds.
- ✓ Registered pheromones can be used for monitoring purposes.
- ✓ **"Treatment windows" approach:** The period of residual activity provided by single or sequential applications of products with the same mode of action. Window of 60-90 days crop growth needs attention.

Integrated pest management:

➢ **Cultural control:**
- Deep ploughing
- **Selection of varieties resistant to FAW.**
- **Planting dates**: Avoid late planting and avoid staggered planting.
- **Plant diversity:** Intercropping of maize with cowpea, glyrecidia, bean
- Erection of bird perches @ 10/acre

➢ **Mechanical control:**
- **Pheromones traps:** 5/acre – monitoring, 15/acre – mass trapping

➢ **Biological control:**
- **Predators**: Earwigs, Ladybird beetles, *Calosoma sp, Podisus*
- **Parasitoides**: *Telenomus Sp, Cotesia marginiventris, Trichogramma pretiosum*
- Augmentative release of egg parasitoid *Trichogramma pretiosum or Telenomus remus* @ 50,000 per acre
- **Entomopathogens***:* *Metarhizium rileyi*, Bt @ 2g/l, SfMNPV
- Use of bio-pesticides like *M. rileyi* @ or *Metarrhizium anisophliae* @ 5.0 gm/l

➢ **Chemical control:**
- Spinetoram 11.7% SC or Chlorantraniliprole 18.5% SC @ 0.2 ml/ l, Emamectin benzoate 5 SC @ 0.2 ml/l

❖ The resistance management strategies called 'high-dose/refuge' and 'gene pyramiding' have been proposed to prevent or delay the evolution of resistance in FAW to Bt plants.

Way forward: Investigations on adoptability of FAW to cotton and establishment as key pest are essential. Many adhoc recommendations to contain this pest have been issued which could be availed for immediate unforeseen situations.

Monitoring of Cry toxin and insecticide resistance in FAW populations invaded India. Revision of IPM strategies based on field experiments.

Since insecticide usage is already increasing in cotton again in India, FAW management through non-insecticidal approaches would be ideal.

Conclusion: Based on its historical association of FAW with cotton, the preparedness has been felt essential to combat its incidence on cotton in India. As such no information is available about FAW dynamics, damage and management in relation to cotton applicable to Indian contexts. Thus, due to favorable climatic conditions FAW could be considered as potential threat to cotton in India as an already relished host in its nativity. It is necessary to initiate the discussions and experiments as well on possible adaptation of FAW on cotton in India and other Asian countries (Pakistan, China etc) where maize/ sorghum/ sugarcane/ rice and cotton are important crops. If ignored it would be a sustainability issue for cotton cultivation.

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Approaches to finishing cotton fabrics for enhanced functionality and performance

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Cotton is the most widely used textile fibre in the world today. After United States, India is the second largest exporter of cotton fibers (Badanayak*et al.,* 2021). Cotton is a soft, staple fibre native to tropical and subtropical regions worldwide, including the Americas, India and Africa. The fibre is typically spun into yarn or thread and used to create a soft, breathable textile, which is the most commonly used naturalfibre cloth. Currently cotton fibre holds a 56 per cent market share in apparel and home furnishings. Nonwoven textiles and personal care items also make a contribution and are gaining popularity for functionality accorded with comfort.The ban of health hazardous dyes and chemicals way back in 1996-97, gave an impetus for production of eco-friendly fibres, processes and finishes. Cotton is mostly composed of cellulose, protein residue and few minerals, it has convolutions that develops the inter-fibre friction and allows fine cotton yarns of sufficient strength to be spun.

Innovative Technologies:

Enhancing and stabilising colours of naturally coloured cottons

Natural Brown and green Colour Cotton fabric were subjected to the colour stability studies. It was noted that the colour of both the genotypes enhances significantly with alkali treatment/laundering (during scouring/Alkaline detergents), that sustains 10 laundering processes before getting back to the original colour. It was further found that neutral or non-ionic laundering agent used in subsequent washings aids in prolonged retainment of colour of the fabric (Vastrad *etal.,* 2011). Research for improving the sustainability of the colour by preventing photo oxidation involves finishing of the NCC fabric by antioxidants and UV absorbers is being experimented. Natural Colour Cotton (DDCC-1) and Jayadhar white cotton variety lint were hand spun into 2 ply doubled yarn and further hand-woven to produce variegated designers' khadi fabrics, that was used for designing kurtas, shirt and ladies tops with a new concept of detachable garment components that converted the garments from casual wear to occasional wear. Silicon treatment to the NCC handloom fabric made the fabric soft, pliable and comfortable (Namrata, 2012)

Blending and mixing to produce yarn for varied performance

Practically it can be said that the art of textile designing begins at the fibre stage. Technical knowledge of the processes, art of fusion of techniques and design perception with available raw material are the prime factors contributing for scientific product development. Researches on designing yarn include blending and mixing to produce yarn for varied performance. Natural colour cotton was mixed with white cotton of better quality to produce finer yarn suitable for towelling and shirting material. A lot of blending studies are conducted in the Department of Textile and Apparel Designing to produce variegated yarn. Lignocellulosic fibres are non-spinnable and hence were blended with cotton in different proportions (20%, 30% and 50%) to spin in the traditional cotton open end spinning machine to produce yarn of counts 20-40s suitable for outer garments with enhanced thermal insulation properties. The lignocellulosic fibres increase the hairiness of the yarn and hence make the fabric suitable for kitchen wear suitably as cleaning fabric.Instances of blending NCC with mesta fibres using blend proportions of &70: 30 and 80:20, revealed that the 80:20 blend was suitable for furnishing and suiting fabrics (Vastrad *etal.,* 2010).

Mesta/organic cotton blended yarn

Organic cotton DHH-11 was blended with softened mesta fibres in 60:40 and 80:20 proportions. Addition of mesta to cotton yarn enhanced strength but decreased the elongation percentage. The yarn was found suitable for knits, curtains and draperies, kitchen linen and other household textiles. The blending using hemicellulosic fibres is one of the initiatives to minimize the costs of raw material, besides fetch better returns to farmers for the crop residue (Dhanalaxmi*etal.,* 2012)

Advances in fabrication have opened up paths for qualitative and quantitative production systems. Weaving, knitting and non-woven technologies are the popular fabrication technologies that have seen a series of modernization over years. Engineering fabrics for desired performance is an art and this is dependent on the skills of combining yarn and fabrication techniques. With industrializations, high speed machines and automated loom operations have replaced the manual looms and loom operations. Yarn is the primary input and the quality of yarn is very much important as it has to have the required strength to withstand the stress imposed during fabric construction. Waxing during rewinding the yarn during spinning operations enhances the metal-yarn and yarn-yarn abrasion resistance and further improves the Count ngth Product (CSP) too. CSP is an ortant parameter that decides the fabric luction behaviour of yarns (Dhanalaxmi Vastrad, 2015)

igners' creativity and the technical ook is important, as there is a lot of and for textile goods especially the bio- radable ones. The short staple fibres are often rejected owing to the fact that they yield coarser yarn. However, there is a vast scope for varied and creative application of such yarn in the textile industry. NCC yarn of upto 20s in the warp was used to produce a variety of fabrics with variegated end uses by cross weaving with silk, grey cotton yarn, rayon, polyester as weft. Further, such coarser yarn with lesser CSP can definitely be used in the weft to produce blankets, bed linen, furnishings and denims. (Kulloli, 2016).

Natural Colour Cotton Weaves and knits

Functional Finishing

Cotton has no surface characteristics that cause it to be irritating to human skin. Cotton has a soft hand and feels good against the skin.It has a natural affinity for water, so it draws moisture away from the body.It allows moisture to pass freely through it, assisting in evaporation and cooling.It has a high heat conductivity, making it an excellent fibre for maintaining a comfortable sleeping temperature, hence suitably used in infant clothing.It is durable and abrasion-resistant, and this is dependent on the way the fabric is engineered (Paul, 2015).It has a moisture regain of 8%.When wet, it gains 10% of its strength. The cellulose of cotton is arranged in such a way that it has unique properties such as strength, durability and absorbency.It is fresh, crisp, comfortable, absorbent and flexible, with no pilling issues and good alkali resistance (Ibrahim *et al.,* 2019).However, few drawbacks of the fibre are poor wrinkle resistance, shrinkage, poor acid resistance, less abrasion resistance, vulnerability to moth and mildew, requires extensive maintenance and stains are difficult to remove and lack of resiliency. We conducted several studies

Our research on solving some of these drawbacks are very successful.

a. **Antimicrobial finishing**: Natural Colour Cotton (DMB-225) was converted to yarn of 20s and further used for producing singly and double jersey knits. Waxing of the yarn proved to make the yarn suitable for knitting. The fabric was finished with neem, asan, jamun and cinnamon leaf extracts to produce antimicrobial performance. Neem followed by asan leaf extracted have shown higher antimicrobial activity. Further use of micro-encapsulation technology enhanced the sustainability of the finish on the fabric (Dhanalaxmi and Vastrad, 2017)

b. **Microencapsulation finishing** has been patterned in order to introduce such properties as thermoregulation, aromatherapy and fragrance release, de-odorising finishing, biocides, anti-soiling agents, insect resisting finishing like the insecticide-impregnated mosquito nets, UV protection, anti-static properties, soft feel and chemical protection. The micro-encapsulation technology makes the finish available on time and has an extended performance advantage (Dhanalaxmi and Vastrad, 2017)

c. **Nanotechnology** is another advantage for the cotton fabrics that is helpful in functional finishing of cotton fabrics without altering the comfort and desirable properties of cotton. Green nano particles *viz.,* silver, zinc and copper are used to impart antimicrobial properties to cotton fabrics. Silver nano particles synthesized through the green process using plant extracts, have been used for applying on cotton fabrics for antimicrobial performance (Vastrad and Goudar,2016). Silicon and tin nano particles produced by sol gel techniques have been used to coat cotton fabrics to produce self-cleaning cotton fabrics with the principles of photo oxidation and super hydrophobicity. Research on synthesis of Zinc nano and application for multi-functional properties to cotton textiles is in progress.

d. **Enzymatic surface modification** is one of the surface etching processes done to alterthe chemical and physical surface properties to enable the adsorption, covalent bonding of functionalities, entrapment / immobilization, and encapsulation of moieties on textile material substrates. This process is aided by biological catalysts called enzymes. Some of the enzymes used in surface modification of textiles during finishing include; xyloglucan endo-transglycosylase, pectinases, cellulases, cutinases and tyrosinases. In contrast to the conventional chemical finishing treatments given to natural fibres, the use of enzymatic processes offer a non-polluting and effective alternative because enzymes do not generate any harmful by-products, are non-toxic, are substrate-specific, operate under mild conditions, and are biodegradable. As a result, enzymes have an age long tradition of being used in textile wet processing. Enzymatic de-sizing, bio-scouring, bleaching, bio washing and bio-polishing of cotton are well established commercial technologies.

Eco-friendly finishing (Dyeing and Printing): Research is gaining momentum in the current day scenario that demands functional performance with the basic properties. Natural Dyes and pigments are back as heritage and vintage colours and prints due to the added advantages of being antimicrobial and UV protective. The natural dyes are hence very much in demand as infant clothing and are popularly used as *Ayurvastra*- the healing textiles. The department of Textile and Apparel Designing has trained and women SHG members with the art of Natural Dying and infant clothing production skills. The SHGs are linked to maternity hospitals, setting an example of eco-friendly finishing as a sustainable enterprise, as a success story.

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Relevance of semigamy for *in vivo* haploid induction in Cotton

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First haploid flowering plant was discovered in cotton by Miss O.S. Attech in Cotton Research Station, Trinidad in 1920 from *Gossypium barbadense*L. variant known as “Man cotton”, which showed twin seedling phenomena as a resultant of semigamy that lead to identification of first haploid flowering plant in angiosperms(Harland, 1920).Semigamy the term first coined by Battaglia(1945) also known as hemigamy. It is an incomplete fusion of male and female gametes during fertilization, in which sperm nucleus enters into the egg cell but they do not fuse with its nucleus, preserving its viability like the egg cell nucleus and dividing, later on both independently. Semigamy is a kind of apomixes reproduction strategy found in few plant species *viz*., *Coix aquatic*, *Zephyranthes spp*., *Rudbeckia spp*., *Cooperia pedunculata*, *Theobroma cacao* including *Gossypium barbadense*.

In semigamy, once the male nucleus enters into the egg cell, eventually it is sequestered, and becomes ruminant part of the embryo tissue. However, in *G. barbadense*, male nucleus is not sequestered and it contributes to the embryo development as genetic inheritance by independently present in the embryo. Hence, maternal and paternal nuclei proceed to divide independently resulting in combination of progenies arise such as normal tetraploid, diploids, haploids and chimeric embryos. Embryo sectors, which has different ploidy in chimeric forms either diploid or haploid.

This kind of semigamitic lines would be of great help in producing haploid plants that leads to production of homozygous lines. Turcotte and Feaster (1963, 1969, 1982) identified a mutant line 57-4 from a sea island cotton popular cultivated variety Pima S1; which showed the frequency of haploid from 25 to 61%. Further genetic inheritance studies revealed that an incomplete dominant gene (Se) governs the trait semigamy.

Turcottee and Feaster used the morphological marker for study the chimeric pattern in semigamy. Dark green leaves with glanded semigamitic line was crossed with light green leaves with glandless lines resulted in chimeric pattern of and glandless as well as light green with glanded tissues as sectoral chimera tissues(Chaudhari, 1979 and Hodnett, 2006). However, the cytology and molecular mechanism of semigamy induction in cotton were not clear. Differential gene expression studies revealed the up regulation of biosynthetic pathway linked to jasmonatesand gibberellin response proteins DELLA-GAI and down regulation of ethylene responsive transcription factor and allene oxide synthase (Curtiss *et al.,* 2018). In semigatic lines, level of expression of genes responsible for + delta cadinene synthase and tublin proteins were higher. Pathway of delta cadinene synthase is the primary step in the synthesis of gossypol. In *G.barbadense*, (-) entatiomer delta cadinene found to be higher compared with other Gossypium species; it shows the role of gossypol in blocking of tublin fibre, which is necessary for centromere spindle formation for chromosome segregation in meiosis.

Relevance of semigamy in haploid production

Semigamy is a unique system that promotes induction of haploids *invivo*, in conversely *invitro* haploid induction is a complex one and needs efficient tissue culture protocol in orthodox crop like cotton. Once the haploid produced which doubled resulting the plant will be having the doubled chromosomes as of their normal plants and would be completely homozygous. Hence, doubled haploids serve as easiest way to fix the traits. Transfer of semigamy (Se) gene to other non semigamtic lines will be a viable option to harness the haploid induction which would pave the cotton improvement especially to fix the heterosis in inbred lines, that could be used to produce the hybrids. Molecular studies of semigamyis not widely undertaken, in future such studies would lead to unravel the molecular mechanism behind semigamy and apomixis reproduction.

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Development of Cost-Effective Local GM Cotton Technology

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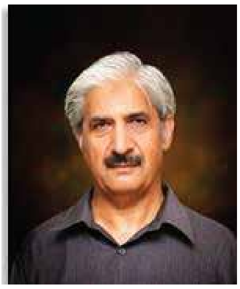

A group of scientists at Center of Excellence in Molecular Biology, University of the Punjab, Lahore, Pakistan have been working to solve cotton problems to make it modern, cost-effective and prosperous field crop for millions of farmers worldwide including Pakistan. This influenced to pursue biotech product development with significant economic silver lining. For that silver lining nothing would have been more suitable than white gold, the cotton. Cotton is crucial for economy and effects more than 70 million farmers directly. Any change, positive or negative, in cotton production has direct and strong effects on rural and national economies. For molecular solution of cotton improvement, we have studied and learned how to apply this model for positive changes in the crop improvement with safer environment in accordance with the domestic and international policies.

Genetically modified CEMB-Klean cotton (CKC) line expressing CEMB-*cry1Ac+cry2A* and CEMB-GTGene showed highest tolerance against bollworms and glyphosate weedicide. CKC was generated by *Agrobacterium tumfaciens*-mediated CEMB-Patented direct gene transfer procedure. About 1200 transgenic lines were screened via molecular, insect feeding and glyphosate application assays, followed by field evaluations to identify agronomically acceptable and genetically stable line with a commercial level of tolerance to glyphosate and desired expression level of Bt genes to effectively control all lepidopteran insects of cotton. The expression level of the best performing CKC lines was quantitated by ELISA in leaf and seed samples at different time intervals and generations under contained testing.

For the very first time in Pakistan, CEMB has developed insect resistant genetically modified advanced cotton varieties containing CEMB-double Bt genes. These cotton varieties got first position in different sets of trial across Pakistan conducted by the Pakistan Central Cotton Committee (PCCC). Afterward, first ever double Bt genes cotton varieties namely CEMB-33, CEMB-66, CEMB-100 and CA-12 were approved and granted Commercialization by National Biosafety Committee (NBC) for general cultivation. It is further pointed out that another four first ever triple genes cotton varieties namely CEMB-Klean Cotton-01, CEMB-Klean Cotton-03, CEMB-Klean Cotton-05 and CEMB-Klean Cotton-06 have also been approved/recommended and granted Commercialization/field trails permission by National Biosafety Committee (NBC) for general cultivation. It has been estimated by the cotton experts that these new triple gene cotton technology will save about 150 billion Rupees in the cost on cotton production in Pakistan. The CEMB transgenic cotton technology has been patented in Pakistan. Twelve national and multinational seed companies have signed agreement with CEMB for the seed production of double and triple genes cotton varieties in Pakistan and one Sudanese Seed Company M/s Aleenah Agriculture Service Company has also signed agreement for the seed production and marketing of CEMB Klean cotton Technology in 12 African Countries.

CEMB-Klean Cotton has won three awards in the invention to Innovation Summit held at different Universities. CEMB will be pleased for any joint ventures with more national and international companies/departments dealing with cotton to disseminate the technology or to develop new technologies.

PERFORMANCE OF CEMB TRIPLE GENES, ALLBOLLWORMS AND GLYPHOSATE RESISTANT (CEMB KLEAN COTTON)-2020, AFTER THREE APPLICATIONS OF GLYPHOSATE @ 4.70 L/Ha, A-COMPLETE WEEDS CONTROL AFTER GLYPHOSATE SPRAY, B-EXCELLENT FRUITING AFTER THIRED SPRAY OF GLYPHOSATE