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TRAINING MANUAL

Relevance and Techniques of Organic Cotton Production

TAP for Cotton

Cotton Technical Assistance Programme for Africa

TRAINING MANUAL

Training Programme on "Relevance and Techniques of Organic Cotton Production"

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CENTRAL INSTITUTE FOR COTTON RESEARCH NAGPUR

Cotton Technical Assistance Programme for Africa

Training Manual on

"Relevance and Techniques of Organic Cotton Production"

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Introduction

Cotton is an immensely important crop for the sustainable economy of India and livelihood of the Indian farming community. It is cultivated in about 33.0 M hectares across the world. India accounts for about 33% of the global cotton area and contributes to 21% of the global cotton produce, currently ranking second after China. India's contribution to global cotton production increased from 14% in 2002 to 20.5% in 2007. The production increased from a meager 2.3 M bales (170 kg lint/bale) in 1947-48 to a previous record production of 17.6 M bales in 1996-97 and an all time highest record of 31.5 M bales during 2007-08 and 2010-11.

Cotton contributes about 65% of the total raw material needs of textile industry in India. Cotton and Textile exports account for nearly one-third of total foreign exchange earnings of India, each year at a recent estimate of Rs.750 billion in 2007. India has achieved significant breakthrough in cotton yarn exports besides increasing its global market share in cotton textiles and apparels. Cotton provides employment and sustenance to a population of nearly 42 M people, who are involved directly or indirectly in cotton production, processing, textiles and related activities. It is estimated that more than 6.0 M farmers cultivate cotton in India and about 36 M persons are employed directly by the textile industry. There are more than 1.7 M registered looms, 1500 spinning units, and an estimated 280 composite mills. Therefore cotton production in India is considered to have a wide reaching impact not only on the livelihood of farmers and economy of the country, but also on international trade.

Cotton in India is grown in varied soils, climates, and agricultural practices under irrigated and rainfed situations. Approximately 65% of India's cotton is produced under rainfed conditions and 35% on irrigated lands. Cotton is cultivated in three distinct agro-ecological regions (north, central and south) of the country. The northern zone is almost totally irrigated, while the percentage of irrigated area is much lower in the central (23%) and southern zones (40%). Under the rainfed growing conditions rainfall ranges from <400 to > 900 mm coupled with aberrant precipitation patterns over the years leading to large-scale fluctuations in production.

Cotton in North India is grown in about 1.5 M hectares in the three states, Punjab, Haryana and Rajasthan. Cotton area in Gujarat increased from 1.54 M hectares in 2000 to 2.6 M hectares in 2010. About 36% of the area (3.9 M hectares) under cotton is in Maharashtra, primarily under rainfed conditions, with the lowest area (3-4%) under irrigation. In 2010, Madhya Pradesh had 0.65 M hectares under cotton. Karnataka grew cotton in 0.52 M hectares, Tamilnadu in 0.13 M hectares and Andhra Pradesh in 1.74 M hectares.

Global Cotton Scenario

During 2010, a total of 25,185,000 metric tons (148 M bales, 170 kg/bale) were produced (Table 1). Among the six major cotton growing countries, Brazil (1600 kg/ha) holds highest productivity level (Table 1) followed by China (1311 kg/ha), USA (945 kg/ha), Uzbekistan (859 kg/ha), Pakistan (684 kg/ha) and India (478 kg/ha). India ranks first in terms of cultivated area occupying 33% of the world cotton area followed by China, USA and Pakistan. Before five years global cotton production had reached a plateau of 19 to 20 million metric tons (111.7 to 117.6 M bales) during 1990 to 2002.

Brazil, China and India rank the best amongst countries which made significant progress during 1999 to 2009. China made spectacular progress with an impressive increase to 47.5 M bales in 2007 from 22.9 M bales in 1999. Brazil, which produced 3.0 M bales in 1998, increased its production to 9.4 M bales in 2007. Similarly, India doubled its production from a stagnating 15.8 M bales in 2001 to 31.5 M bales in 2007.

India's growing cotton is having a perceptible impact on the global import-export scenario. The country has been producing at least 6 to 9 M bales in excess of domestic consumption over the past few years. India became a leading global exporter of raw cotton with exports ranging from 0.6 to 1.5 M tons raw cotton each year from 2005 onwards, while concomitantly, imports declined from 0.43 M tons to 0.09 tons. Domestic consumption also increased from 15.8 M bales in 2002, to an estimated 25.8 M bales in 2010.

Table 1. Global cotton production during 2008-2010

Country	Area (M ha)			Production ('000 Tons)			Yield (Kg/ha)		
	2008	2009	2010	2008	2009	2010	2008	2009	2010
China	6.4	6.4	5.4	8025	6850	7079	1263	1070	1311
India	9.3	10.3	11.1	4930	5015	5304	533	487	478
USA	3.2	3.1	4.2	2790	2654	3970	880	856	945
Pakistan	2.9	3.1	3.2	1910	2019	2188	659	651	684
Brazil	1.0	0.9	1.3	1400	1261	2027	1443	1401	1600
Uzbekistan	1.4	1.3	1.2	1140	850	1031	800	654	859
others	7.5	5.1	6.9	3900	3317	4133	519	650	599
World	**31.6**	**30.2**	**33.0**	**24660**	**21966**	**25185**	**781**	**727**	**763**

Source: ICAC Cotton: World Statistics, September, 2010

Bt-Cotton

Bt-cotton was first approved for commercial cultivation from 1996 in the US. It was released for cultivation in China, Mexico and Australia in 1997, and later in Argentina (1998), South Africa (1998), Indonesia (2001), India (2002), Colombia (2003), Philippines (2003), South Korea (2003), Brazil (2005), Myanmar (2006), Burkina-Faso (2008) and Egypt (2009). Currently an estimated 14.5 m hectare area is under Bt cotton in the world. This accounts for 45% of the total global cotton area (32 m ha). Recently, Cry2Ab and Cry1F have been released in the US for commercial cultivation. Cotton transgenic plants resistant to *H. armigera* have been developed using the cowpea trypsin inhibitor gene in China. Both genes, 'Bt toxins' and 'protease inhibitors' used thus far, are extremely specific in their target range and have been conclusively demonstrated to be safe to the environment.

Bt-cotton technology was first approved in 2002 by the GEAC for commercial cultivation in central and south Indian cotton–growing zones in India in the form of three hybrids (MECH-12, MECH-162, and MECH-184). Subsequently, the GEAC approved RCH-2 (Rasi seeds) in 2004, for cultivation in the central and southern zones. In 2005, another 16 hybrids were approved. Thus, the total reached to 20 *Bt* hybrids, with 6 for north, 12 for central and 9 for south India, thus making available the technology for entire country. Realizing the immense potential of the technology, several Indian Seed companies rushed forward as sub-licensees of the technology to acquire the rights to incorporate the *cry1Ac* gene into their own hybrids. By 2006, the total number of hybrids reached 62, with an additional approval of 38 more hybrids from 15 companies, which also included the commercial release of two new Cry1Ac based events, GFM-Cry1A of China and Event-1 of JK seeds. By 2007, an estimated total of 162 Bt-hybrids (135 Bt-hybrids, excluding brand overlap) were released for commercial cultivation. By the end of July 2008, the total number of Bt-hybrids increased to 280 and by August 2009 the number increased to 619 Bt-hybrids and one Bt-variety. Currently an estimated 1340 Bt cotton hybrids were available in the market during 2011. The area under *Bt* cotton increased from 29 307 hectares in 2002 to an estimated 62 lakh hectares by 2007. In 2011, the area under Bt-cotton is estimated to have reached 91.0% of the total cotton area (121.91 lakh ha) in India (Table 2).

Six Bt cotton events have been approved thus far in India for commercial cultivation. There are four Bt Cotton events expressing Cry1Ac, one event with Cry1C, and one event with Cry2Ab2. The various Genetically modified events are 1. MON531 (Cry1Ac) event of Monsanto; 2. JK Event-1 (Cry1Ac) event of JK seeds; 3. GFM Cry1A (Cry1Ac) event of China, introduced by Nath seeds India; 4. BNLA106 (Cry1Ac) event developed by NRCPB and UAS Dharwad; 5. Event 9124 (Cry1C) event developed by Metahelix, India and 6. Mon15985 (Cry2Ab2) event in Bollgard-II Monsanto.

All the Cry1Ac genes present in the four events released in India are chimeric fusion genes. The *Cry*1Ac gene in the Bollgard event 531 is a chimeric gene of 3534 bp size, with the first 1398 nucleotides (corresponding to the first 466 amino acids) of *Cry*1Ab gene and rest of the 1399-3534 nucleotides (corresponding to the 467-1178 amino acids) from the *Cry*1Ac gene. Except for one amino acid at 766 position, the *Cry*1Ac amino acid sequences are identical to that of the wild type *Cry*1Ac gene. The chimeric gene produces a protein that is 99.4% identical to that of the wild type *Cry*1Ac. The Cry1Ac genes in JK and BNLA106 are chimeric fusion genes of 1842 bp with the first 1398 nucleotides (corresponding to the first 466 amino acids) of *Cry*1Ab gene and rest of the 453 nucleotides (corresponding to 151 amino acids at 467-671 position) from the *Cry*1Ac gene. The Cry1Ac in Nath seeds is >99% identical to the Cry1Ac used in JK and BNLA106 events except that the size is smaller at 1824 bp with the first 1377 nucleotides (corresponding to the first 459 amino acids) of *Cry*1Ab gene and rest of the 453 nucleotides (corresponding to 151 amino acids at 460-664 position) from the *Cry*1Ac gene.

Release and rapid spread of the technology in India

In 2002, The GEAC approved three Bt cotton hybrids i.e. MECH 12, MECH 162 and MECH 184 for commercial cultivation in Central & Southern cotton growing zones in India. The three hybrids were developed by Maharashtra Hybrids Seeds Company Ltd (Mahyco). Two years later the GEAC approved RCH-2 (Rasi seeds), for cultivation in Central and Southern zones. In 2005, the GEAC approved another 16 hybrids. Thus the total reached 20 Bt hybrids, with 6 for north, 12 for central and 9 for south India. By 2006, the total number of hybrids reached 58, with an additional approval of 38 more hybrids from 15 companies, (Mahyco, Rasi, Ankur, Nuziveedu, JK, Nath, Ganga Kaveri, Tulasi, Ajeet, Emergent Genetics, Vikki Agrotech, Vikram, Pravardhan, Krishidhan and Prabhat). Interestingly the recently released Bt-cotton hybrids include three different Cry1Ac events (Monsanto, China and JK seeds, India) that are the only ones commercially available in the world.

Table 2. Impact of Bt cotton on yields

Year	Total area (lakh ha)	BG Area (lakh ha)	BG-II Area (lakh ha)	Total Bt area (lakh ha)	Bt area %	Total Production (Lakh bales)	Productivity (Kg/ha)
2002	78.00	0.294		0.294	0.38	152	331
2003	77.85	0.931		0.931	1.2	177	386
2004	89.20	4.985		4.985	5.59	243	463
2005	88.17	10.148		10.148	11.51	242	467
2006	91.73	36.5	1.5	38	41.42	280	519
2007	94.39	58.74	4.6	63.34	67.1	315	567
2008	94.06	55.6	20.4	76	80.8	290	524
2009	103.12	36.8	48.2	85	82.43	295	486
2010	111.61	37.4	63.8	101.2	90.67	325	495
2011	121.91	26.5	85.4	111.9	91.79	345	481

The introduction of Bt Cotton appears to have resulted in reduction of market share of insecticides used on cotton. Bt Cotton was introduced in 2002 and the area increased to 5% in 2004, 12% and 90% in 2010. Clearly the share of insecticides used on cotton declined from 43% in 2003 to 21% in 2010.

Table 3. Insecticide usage on cotton 1999-2010 (Rs crores)

Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
% Bt Cotton				0.38	1.2	5.59	11.51	41.42	67.1	80.8	82.43	90.67
Cotton Insecticide	879	839	1052	597	925	1032	649	579	733	791	834	880
Cotton fungicide	11	10	6	3	8	6	8	11	25	31	52	67
Cotton herbicide	2	1	1	1	3	4	8	12	22	26	45	87
Total Insecticides in Agrl.	2128	2052	2268	1683	2146	2455	2086	2223	2880	3282	3909	4283
% share of cotton	41	41	46	35	43	42	31	26	25	25	21	21
Total Pesticides in Agrl.	3004	2972	3207	2622	3147	3581	2439	3396	4697	5293	6999	7684

Landmark achievements in cotton breeding

Prior to Independence, undivided Indian subcontinent produced 5.0-5.3 M bales from 8.5 to 9.0 M hectares. When the country gained independence, 2.3 M bales comprising of 67% medium staple and 33% short staple cotton was obtained from *desi* varieties cultivated in 97% of the area (65% *G. arboreum* and 32% *G. herbaceum*) were produced from 4.3 M hectares. During partition, the cotton mills remained in India and the regions that were suitable for long staple cotton went to Pakistan. Therefore efforts were intensified in India to produce long staple cotton that suited the mills. By 1965, 40% of the area was under *G. hirsutum*, 36% under *G. arboreum* and 24% under *G. herbaceum*. Despite intense and concerted efforts to acclimatize and promote American cotton in India, the two Desi species continued to occupy at least 25% of the area (18% of *G. arboreum* and 7% of *G. herbaceum*) until 2000-2001, until recently before the introduction of Bt cotton in India. The American cotton varieties *G. hirsutum* and sea island cotton, *G. barbadense* are more susceptible to insect pests such as jassids, whiteflies, American bollworm (*Helicoverpa armigera*) and diseases such as bacterial blight, *Verticillium* wilt, parawilt and leaf curl virus. The American bollworm derived its name from the fact that it was first noticed only on American cotton *G. hirsutum*, and still continues to cause menacing damage to the species. By virtue of having been cultivated for ages, the two desi species *G. arboreum* and *G. herbaceum*, are known to tide over biotic and abiotic stresses with ease under the native conditions. Therefore these were preferred by farmers over the introduced cotton species. The estimated area under *G. hirsutum* in India was about 93% in the year 2011.

Though continuous efforts were underway to acclimatize American cotton to Indian conditions, systematic efforts on cotton breeding in India started with the establishment of the 'Department of Agriculture' in 1904 and Indian Central Cotton Committee in 1923. However research on improvement of *G. hirsutum* varieties and hybrids intensified after the establishment of the All India Coordinated Cotton Improvement Project in 1967. Until 2001, about 100 improved varieties and 50 hybrids of cotton in all the four species were released for commercial cultivation in all the cotton growing states of the country. Indian breeders have been credited for their achievements particularly in the development of highly adaptable varieties such as Bikaneri Narma, LRA 5166, Narasimha, SRT 1 and MCU 5; early maturing varieties, sucking pest tolerant varieties, disease resistant Desi cotton varieties, high yielding and superior fibre quality varieties of *G. arboreum and G. herbaceum,* development of inter-specific and intra-specific Hybrid cotton, development of high yielding *G. hirsutum* varieties and the development of finest quality *G. barbadense* variety Suvin. One of the most spectacular achievements that stands out as a technology that had the greatest influence on cotton in India is the hybrid cotton. In a landmark development, the world's first cotton hybrid 'H 4' (intra *hirsutum*) was developed by Dr C. T. Patel in India during the year 1970. The hybrid became popular and laid the foundation for research on 'hybrid cotton'. Until 2001, hybrids occupied 45% of the total cotton area and reached about 95% in 2011. There have been several landmark achievements made by cotton breeders in India after independence.

Some of the significant ones which represent pioneering efforts are listed below:

1950: *Gossypium herbaceum* variety 'Jayadhar' released (cultivated even today)

1968: *Gossypium hirsutum* variety 'MCU 5' suitable for 60's counts released (finest quality *G. hirsutum* variety)

1970: World's first Hybrid 'H-4' released (highest yield with superior fibre traits)

1972: World's first Inter specific tetraploid hybrid 'Varalakshmi' suitable for 80's counts released

1974: *Gossypium barbadense* variety 'Suvin' suitable for 120's counts released (finest Indian variety ever)

1976: Bikaneri Narma and its selections ‘F414’ and ‘H 777’ identified for adaptability and high yields in North India.

1978: World’s first GMS based hybrid ‘Suguna’ released from CICR

1980: Hybrid ‘H-6’ with superior fibre quality suitable for 60’s counts released.

1981: Inter specific tetraploid hybrid ‘DCH 32' suitable for 80’s counts released (cultivated even today)

1982: Highly adaptable *Gossypium hirsutum* variety 'LRA 5166' released (high adaptability)

1983: World’s first Inter-specific diploid hybrid 'DH 7' released

1983: Highly adaptable hybrid ‘NHH 44’ released for rain-fed conditions

1992: Early maturing compact variety 'LRK 516' released

1989: *Gossypium arboreum* variety ‘AKA 8401' suitable for 40’s counts released

2000: 40% area under hybrid cotton

2002: Bt-cotton approved for commercial cultivation. Subsequently, several superior Bt hybrids *viz*., Mallika, Bunny, MRC 6301, MRC 7351, Dr Brent, Bramha, RCH 2, RCH 134, Ankur 651, Jay Bt, MRC 6301, Ajeet 11, Tulasi 9, Vikram 5, Krishidhan 441, Bioseed 6488, Kaveri 707 etc., were released for commercial cultivation from the private seed sector.

2008: Highly adaptable superior fibre variety 'Suraj' released

2010: 90% area under 809 Bt cotton hybrids.

Challenges with yield and quality enhancement in India

It should be a priority area of research in countries of Asia and Africa to develop varieties through ‘ideotype breeding’ of compact genotypes suited for narrow and ultra narrow spacing, with specific fibre traits for specific locations. Additionally the compact genotypes with specific fibre traits can be converted to insect resistant biotech cotton. Such location specific high yielding varieties ensure sustainable production in major cotton growing countries of Asia and Africa in the future. it is also important to develop varieties suitable for dense planting that are more efficient in utilizing water and nutrients and can resist pests and diseases. Such measures can not only enhance yields but can also provide sustainable options for optimal and efficient use of inputs.

Hybrids occupied more than 90% area out of 11.1 m ha in 2010. Hybrids have contributed to wider adaptation, higher quality cotton production, higher seed output and enhanced seed oil output. There is need for strong complementary research and development programmes for both hybrids and varieties so that the full potentials and practical advantages of both can be harmonized. Hybrids perform better under higher input technology conditions and superior management. Hybrid seed production is labour intensive and expensive. Research efforts should focus on the development of useful male sterile systems.

There is a continuous demand for improved cotton fibre quality. This demand has been met in the past to some extent by classical breeding. Currently CICR is trying to unravel the process of cotton fibre development step by step and identify the genes involved in determining the specific properties of the cotton fibre. The first strategic plan to improve fibre quality traits is to characterize genes exclusively associated with fibre length and strength expressed during fibre initiation, elongation and the secondary wall formation by utilizing the high fibre length and strength germplasm. Genes available in public domain and specifically implicated in secondary wall formation of cotton fibre *viz*., *cesA-4*, *cesA*-7 and *cesA*-8 genes will be utilized. In collaboration with other partner institute few other candidate genes such as *Myb*, *aquaporin*, *Fibre protein, E6 protein, expansin, annexin* would be validated with fibre specific promoter (*expansin, annexin*) using low fibre length and strength genotypes to improve from 28-30mm with 25g/tex to 32-34mm length with 28-30g/text in HVI mode. Beside, attempt would be made for improvement of fibre quality by transferring heterologous sources genes available in public domain such as SPS gene from spinach, acsA and acsB genes of *Acetobacter xylinum* and Fibroin gene from silkworm. Thus the novel ESTs identified from the high fibre strength cotton and the genes from heterologus sources are expected to be potential candidate for improving fibre strength. Attempt will also be made to identify and characterize Ramie fibre gene for length and strength using microarray analysis.

High yielding elite germplasm lines, which are inferior in only one or two of the desirable traits such as fibre quality or resistance to biotic or abiotic stresses, should be chosen as recurrent parents for marker assisted accelerated back-cross breeding method. Another set of high yielding germplasm lines should be identified, which possess the trait of interest, and can be used as donor parents. Recently, 2,937 SSR primer pairs have been identified as highly informative which target unique genomic sequences and amplify about 4,000 unique marker loci in a tetraploid cotton genome. Chromosome-marker bins, each 20 cM in size, were constructed on the genetic linkage map containing the markers. Thus 207 marker bins were assigned for a total of about 4,140cM which is approximately the size of the tetraploid cotton genetic map. The markers can be used effectively to tag quantitative traits of interest in the already characterized germplasm pools and thereafter utilize in marker assisted breeding programmes for genetic enhancement of elite lines and genotypes to develop high yielding cultivars. Genes conferring strength and fineness can be identified from Ramie and utilized to enhance fibre traits in cotton through genetic transformation. Sucrose phosphate synthase and extensin genes have been shown to enhance fibre length and strength and can be further explored

The demand for short staple cotton (less than 10 counts) and also coarse cotton for non-woven purposes such as surgical cotton, absorbent cotton, technical textiles etc., has been increasing of late. With demand for denim cotton on the rise, short staple cotton of 7-14s count is now in higher demand especially for denim export and local use. Production of fine and superfine counts (40s and above) has increased. 11 - 40s count group represents 71% and hence greater efforts are required in this category. The use of cotton and synthetic fibre blends will increase as it rose to 13% in recent years. MCU5, MCU 5 VT, Surabhi, Suvin, DCH 32 are useful for blending. But fibre maturity requires attention. Good fibre strength and extensibility are important for blending to get good yarn properties. Trash content in Indian cotton has declined significantly in recent times.

Textile industry has been demanding for quality cotton suitable for the recent spinning systems which were developed to achieve higher production rates, productivity and automation for cost reduction of yarn production. Open end (OE) spinning systems - Rotor spinning, Friction or DREF spinning and airjet spinning which ensure high rate of production and large size of yarn and package are coming into existence. Ring spinning for all counts with wide adaptability, rotor (upto 24s), DREF (upto 30-45s coarse counts) and airjet for finer counts (50s and above) and also for man-made fibres and blends including combed cotton, have increased. For the new systems, high fibre strength and fineness are now more important. Often raw material economy in mill is achieved by mixing few varieties to spin the required count. Sometimes mills also underspin. There is a need to improveme fibre strength to 25-30 g/tex for 3 mm gauge, 75-80% mature fibres, reduce stickiness and motes (neps and naps) in interspecific hybrids, low short fibre content/lowered trash content seed coat fragments etc. and improvement in ginning aspects etc., and optimum micronaire value without affecting maturity.

Emerging challenges

Though, India ranks second in the world in cotton production after China, even its best productivity of 566 kg/ha, places it at 24th rank in the list of 80 cotton producing countries. Despite the good progress made by public and private sector research and development, it is a matter of concern that productivity started to decline from 566 kg/ha in 2007 to 522 kg/ha in 2008, 486 kg/ha in 2009 and 475 kg/ha in 2010. Several factors including erratic rainfall and emerging biotic and abiotic stress were found to have influenced the decline in yields. The quality profile of Indian cotton has also changed. Long staple cotton which constituted 38% prior to 2002, increased to an estimated 85% of the total cotton produced in 2010, primarily because of the Bt cotton hybrids, most of which are of the long staple category. However, the Confederation of Indian Textile Industries (CITI) estimates that in the 25.8 M bales utilization capacity, the current requirement of the Indian textile Industry is 37% long and extra-long staple cotton, 53% medium staple and 10% short staple. The area under public research bred varieties and hybrids reduced significantly to less than 8% of the total cultivable area. The area under hybrid cotton increased from 40% in 2002 to 92% in 2010. The area under *G. hirsutum* varieties was 33% in 2000 which reduced to less than 3% in 2009. The area under *G. barbadense*, *G. arboreum* and *G. herbaceum* which was 6.6%, 25% and 13% during 1995, declined to less than 7% in 2010 for the three species together. With intensive selection pressure of Bt toxins used in more than 90% area of Bt crops, and less adoption of refugia and declining area of inter crops in cotton cropping systems, development of bollworm resistance to the Bt toxins is an emerging concern. Resistance has the potential to diminish the benefits of Bt cotton.

In the current scenario, with Indian exports gaining importance, there is a need to reorient research efforts to ensure that the advances made thus far in enhancing productivity levels should be sustained. Export potential for raw cotton as well as value added products will be enhanced thereby increasing our foreign exchange earnings. There will be modernization for ginning, pressing, spinning and textile industry. Breeding for improved fibre qualities as per emerging needs will receive due attention. There will be competitive pricing, grading and better marketing for cotton at national and International level. Appropriate initiatives must be taken up to face the new situation. However, with the cotton production challenged by vagaries of monsoon, onslaught of insect pests and increasing cost of production there is need for reorientation and reinvention of resources. The arena of pest management adds the dimensions of ecological and economic sustainability besides social stability. Cotton cultivation in India has changed immensely over the past five years. There has been a significant change in technologies related to production, crop protection, crop improvement, extension methods, approaches and socio-economic aspects. While, the introduction of genetically modified cotton, in the form of insect resistant Bt cotton, has been credited with the changes, it is prudent at this stage to critically examine factors other than Bt cotton that may have also contributed to the positive change and develop strategic plans for discovery and deployment of indigenous genes through genetic engineering technologies to enhance yields with low input costs.

Intensive plant breeding programs of many crop plants have capitalized on genetic resources and germplasm collections to develop improved genotypes with significant gains in yield. These intensive hybridization and selection plant breeding programs have also unintentionally narrowed the genetic base and increased genetic vulnerability of many of the world's most important crops. The fact that it took about 60-70 years for *G. hirsutum* and 150 years for *G. barbadense* to adapt to the Indian climatic conditions indicates that probably Indian researchers were struggling to identify genotypes for wider adaptability. It is clear that each of the individual cotton genotypes has a specific photoperiod and thermal requirement for optimal performance. Therefore it would be most appropriate to identify individual highest yielding genotypes for extremely specific geographical zones that have a common photo and thermal profile across the season. In the process of attempts to identify common genotypes for the entire zone or the country, it is clear that every year a number of varieties that were submitted for varietal identification were discarded, since their performance would have been inferior in a few locations. Currently private seed companies have taken the lead in hybrid cotton sector. Hybrid seed production is expensive and highly labour intensive. It is praise worthy that the seed industry has been meeting the challenge effectively and profitably. At this juncture, it would be most appropriate for the public funded institutions to develop high yielding varieties for specific local geographical spots and convert them to Bt using the approved events that have been developed by the Government institutes. With the strength of the current germplasm pool and new molecular technologies, it would be possible to develop location specific genotypes that have the potential to yield 3-4 times more than the current productivity, almost comparable to the normal yields that are obtained by varieties elsewhere in the world.

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Organic Cotton Cultivation - A Pragmatic Approach for Resource Poor and Market Challenged Farmers

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Introduction:

Cotton is a major Cash Crop and is the main source of economic development. Over the year, continuous efforts have been made to increase cotton production mainly through use of chemical inputs, irrigation and high yielding varieties. Increased yields are considered beneficial by those involved, including farmers. However, they involved several hidden costs both environmental and social, which have not been reflected in pricing. Hence, despite its 'natural' image, cotton production has become increasingly associated with severe negative environmental impacts which include reduced soil fertility, loss of bio-diversity, water pollution, adverse changes in water balance, social problems related to heavy use of pesticides. Cotton processing is a very resource consuming, polluting and unhealthy industry where large amount of water, energy and chemicals are used at different stages. To create finished goods, fabrics are often coloured with toxic dyes and finished with formaldehyde.

Of the total Pesticides used in agriculture in India, 54 per cent was used in Cotton before the introduction of Bt cotton, which accounted for only 5 per cent of the total land under cultivation. In addition, large amount of herbicides, fungicides and synthetic fertilizers are also used in cotton production. The over use of pesticides has led to pest resistance and farmers have given up cotton cultivation altogether. Pesticides used on cotton can also enter the human chain through cotton seed oil and other non target species and result in contamination of meat, milk, etc.

Cotton cultivation is the second source of pollution from agriculture in the World, it covers the 5% of the cultivated areas, and pollutes 25% (because of pesticides introduced into the atmosphere). Concerns about cost and the detrimental effects on health and environment of the high use of synthetic pesticide and fertilizers have persuaded many small scale farmers to seek alternatives wherever possible.

Agriculture now being market driven we have to adaptation of Organic cotton cultivation should be on the following six criteria's

a. Different Concept
b. Conventional & Organic cotton
c. Labels & Standards
d. Technology Development & Market Diffusion
e. Market today
f. Influencing factors

a. Differential Concept:

Sustainable textiles are manufactured from three main sources as given below.

SUSTAINABLE TEXTILES

- Manufactured
  - from natural materials: Lyocell, Polylactic acid or PLA
- Recycled fibers
  - made from leftover from production
  - second-hand
- Organic textiles
  - Protein / Animal fibre (wool, silk, angora, etc.)
  - Cellulose/ Plant fibre (cotton, jute, hemp, bamboo, etc.)

b. Conventional and Organic cotton:

Since, cotton is obtained from a plant source, the next step is to analyse its cultivation aspects - which can be either Conventional or Organic cultivation techniques.

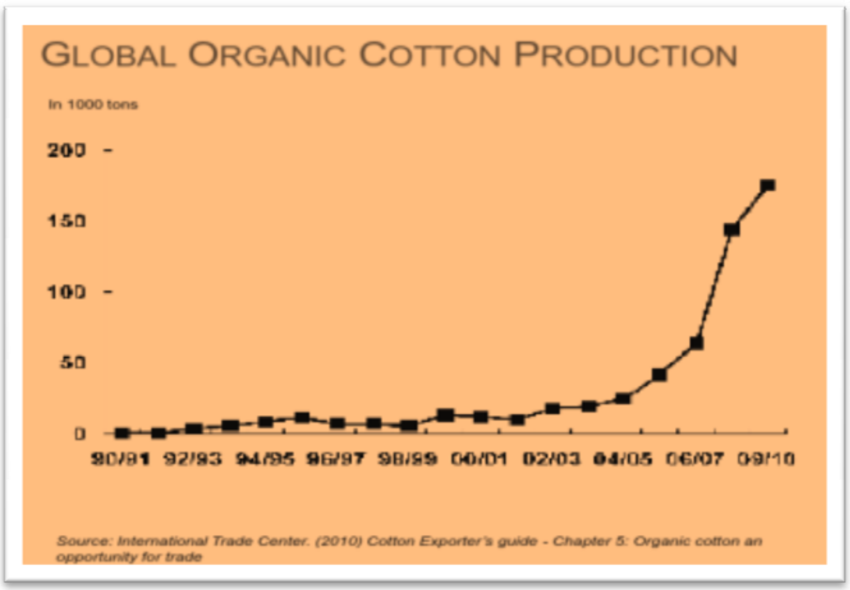
In conventional farming, transgenic seeds, large amount of herbicides, insecticides, fungicides and synthetic fertilizers are used in cotton production. While in organic farming, growing, cotton organically entails using cultural practices, natural fertilizers and biological controls rather than synthetic fertilizers and pesticides.

The difference between Conventional & Organic cultivation is presented below.

Organic vs. Conventional Cotton Farming Methods

Organic cotton production started in Turkey and USA in the late 1980. Other projects followed throughout the last decade in South Asia, Africa and Latin America. Most of the organic cotton projects involved small scale farmers. There has been a significant involvement of outsiders. The number of organic farmers is steadily increasing every year. According to the fourth annual Organic Exchange Farm and Fiber Report 2009, organic cotton production grew an impressive 20 percent over 2007/08 to 175,113 metric tons (802,599 bales) grown on 625,000 acres (253,000 hectares) (Fig 1). Organic cotton now represents 0.76 percent of global cotton production.

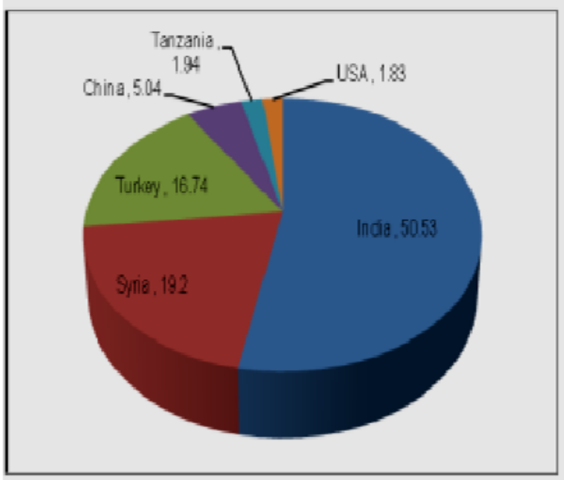
Fig 1: Global Organic cotton production from 1990 to 2010



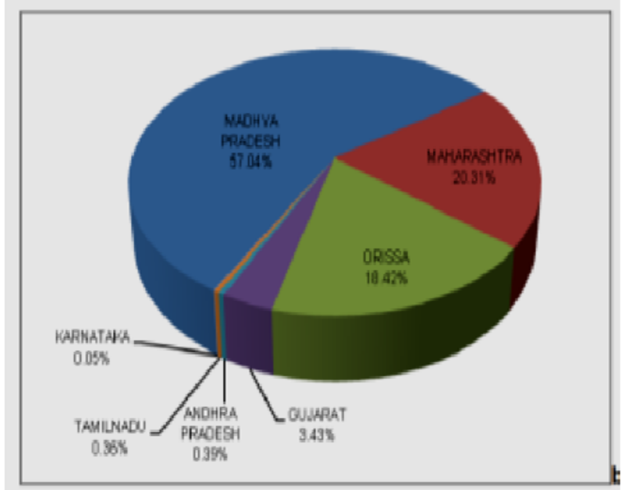
Organic cotton was grown in 22 countries worldwide with the Top Ten producer countries led by India and including (in order of rank) Turkey, Syria, Tanzania, China, United States, Uganda, Peru, Egypt and Burkina Faso. Approximately 220,000 farmers grew the fiber. However, it still remains a small fraction of global production.

The global organic cotton supply has expanded significantly over the past two years. It now represents slightly more than .5% of global production, up from .1% in 2001. According to the *Organic Exchange 2008 Farm and Fiber Report*, organic fiber production was 57,931 MT in 2006/07 and grew by 152% in 2007/08 to 145, 872 MT. In 2008, the top five organic cotton producing countries were India (51%), Syria (19%), Turkey (17%), China (5%), and Tanzania (2%). Altogether, these five countries represent 94% of the world's organic cotton production (Fig 2a). Similarly in India the resource poor region of the country encompassing areas of Madhya Pradesh, Maharashtra and Orissa go for cultivation of organic cotton (Fig 2b).

Fig 2: Country-wise and Indian states share of Production of Organic cotton



Source: Organic cotton Exchange, Farm & Fibre Report, 2008, D&B India



Source: APEDA, D&B India

c. Labels and Brands

The demand for organic produce is increasing at a very rapid rate in the international market. Under conditions of excess demand for organic products, there should be good market for production. The term ‘Organic’ in organic agriculture is a process claim and not a product claim. In other words the products are defined in terms of technology and input used rather than the product itself. Hence, the label ‘Organic’ denotes products that have been produced in accordance with organic production standards and certified by a duly constituted certification body or authority.

Certification of Organic cotton production adds credibility to the final product, assures the buyer of Organic status, encouraging premium price to the farmers. Certification is a system which sets standards and ensures that set standards are met.

Certification programmes and standards vary from country to country in response to regional differences. The International Federation of Organic Agriculture Movement (IFOAM) has produced basic standards covering organic products and also textile processing. In the European Union and certain other countries the term Organic is defined by Legislation. In such regulations, the rules of production, labeling and inspection of all products are clearly defined. The four major labeling are Fairtrade cotton, Cotton made in Africa, Better Cotton Initiative and Organic cotton. The agencies associated in certification is presented in Table 3.

Table 3: Characteristics of four alternatives to conventional cotton

	Organic Cotton	Fairtrade Cotton	Cotton made in Africa	Better Cotton Initiative
Start Year	Early 1990s	2004	2005	2005
Program specific to cotton	No	No	Yes	Yes
Regulating Organization	National organizations	Fair Trade Labeling Organization (FLO)	Aid by Trade Foundation	Better Cotton Initiative (BCI)
Geographical focus	Global	Developing countries	Africa	Global
Countries	22	9	4 (6 by end 2010)	4
Cotton area (2008/09)	253,000 ha	75,000 ha *	117,750 ha	241,200 ha in 2010/11
Cotton production (2008/09)	175,000 tons	28,300 tons**	28,900 tons	First crop expected in 2010/11
Top producing countries	India and Turkey	West Africa and India	Zambia	Expected to be Pakistan
Number of farmers	220,000 (2008/09)	93,000 (2008/09)	140,000 (2008/09)	85,000 (2010/11)
Certification/verification	Third-party verifiers	FLO-Cert (separate certification body owned by FLO)	Third-party verifiers	Third-party verifiers
Price paid to cotton producers	No minimum price	Minimum price + premium	No minimum price	No minimum price
Guarantee for farmers to sell their cotton	No	No	No	No

d. Technology Development & Market Diffusion

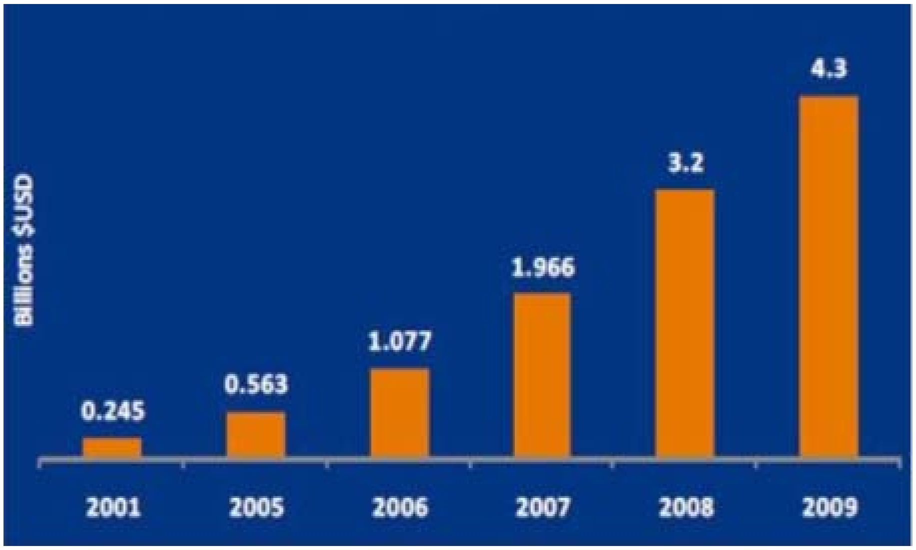
With the onset of industrialization during 1850's the world has seen a tremendous changes in the preferences and demands of people. The historic developments are depicted below

- Until 1900: All production was organic
- Early 1900: Started to use chemical fertilizers and pesticides
- In 1960: Organic food introduced
- Early 1990: Certified organic cotton introduced 100% organic cotton items sold only in special "natural product shops" not consider the look or quality Mainly focusing at environmental aspects
- 1992: Big retailers started to offer organic cotton(H&M, Esprit etc) Eco-fashion look (natural colours)
- Middle 1990: New (synthetic) trends Eco-shops meet a great downturn
- Later 1990: Mainly German and Swiss post order Range of products expanded Nike starts it's blending programme
- Early 2000: Big firms reintroduced organic cotton products Celebrities started to wear organic fashion
- From then: More and more integrated among the ordinary clothes lines

e. Market today:

Rapid expansion of the global organic cotton market was driven in large measure by consumer interest in green products, significant expansion of existing organic cotton programs by brands and retailers, and the launch of organic cotton programs by new entrants to the market. Growing public sector interest in organic farming, along with significant media coverage of organic and sustainable textiles also helped spur growth in the wholesale and retail segments of the market (Fig 3).

Fig-3: Global retail sales f organic cotton products



f. Influencing factors: The three main factor that influence the expansion of organic cotton cultivation are

Demand side

- Greater environmental awareness among consumers
- Big retailers want to improve their brands

Supply side

- Less toxic pesticides for farmers
- Overall - sellers market

Political side

- Fairly slow development
- Ex. Switzerland

Future thrust:

Organic farming systems have attracted increasing attention over the last one decade because they are perceived to offer some solutions to the problems currently besetting the agricultural sector. Organic farming has the potential to provide benefits in terms of environmental protection, conservation of nonrenewable resources and improved food quality. Countries like Europe have recognized and responded to these potential benefits by encouraging farmers to adopt organic farming practices, either directly through financial incentives or indirectly through support for research, extension and marketing initiatives. As a consequence, the organic sector throughout Europe is expanded rapidly (24% of world's organic land). But, in the developing countries like India, the share is around 2 per cent only (included certified and wildlife). However, there is considerable latent interest among farmers in conversion to organic farming in India. But, some farmers are reluctant to convert because of the perceived high costs and risks involved. Those who have converted earning equal incomes to their conventional counterparts, if premium markets are exist for organic produce. Despite the attention which has been paid to organic farming over the last few years, very little accessible information actually exists on the costs and returns of organic farming in India. Similarly, there are only a few attempts of comparing efficiency between organic and conventional production systems in India

The role of the Government is critical in motivating the farmers towards organic farming in the country. Some of the major suggestions for expansion of organic farming are: creation of separate 'green channels' for marketing of organic foods; announcement of premium prices for organic staple food crops; creation of demand by more awareness programs; input/conversion subsidies for encouraging organic growers; more R & D investments on organic farming and finally cheap and quick certification process etc.

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Yield Potentials and Characteristic Features of Cotton Genotypes

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Cotton is the most important commercial crop of India cultivated mainly for its textile fibre till date, due to its inherent eco-friendly and comfort characteristics. With the establishment of All India Coordinated Cotton Improvement Project during the year 1967, more emphasis was given to the improvement of yield as well as quality in cotton, which led to the quantum increase in the production of cotton in India.

The launching of the All India Coordinated Cotton Improvement Project by the Indian Council of Agricultural Research in 1967, knitting together the State Agricultural University Centres of Cotton research and the establishment of the Central Institute for Cotton Research at Nagpur in 1976 are significant milestones in the research setup. This ensured the free exchange of breeding material and multi-location testing of cotton strains even in the early stages of the breeding programmes. The field research programme has always had a happy marriage with the Central Institute for Research on Cotton Technology in Mumbai which contributed significantly to the qualitative improvement of cotton cultivars closely linked to the end-use requirements of the textile industry. New elite varieties and hybrid cottons have been evolved under this project and have contributed significantly to increased production of cotton with desired fibre quality parameters, over the years.

India has the largest area under cotton cultivation with relatively low productivity primarily due to the large area under rainfed cultivation with inadequate supply of inputs. Only in India, all the four spinnable fibre yielding species of *Gossypium viz*., *Gossypium hirsutum*, *G. barbadense*, *G. arboreum* and *G. herbaceum* are cultivated commercially across different cotton growing zones (Table 1).

Table 1. Cotton growing zones in India

Zone	Species grown	% of cotton area	% of cotton production
Northern zone	*G. hirsutum*, *G. arboreum* & Inra-*hirsutum* hybrid	15.60	14.92
Central zone	*G. hirsutum, G. arboreum,* G. *herbaceum*, Inra-*hirsutum* and Inter-specific diploid hybrids	66.66	61.90
Southern zone	*G. hirsutum, G. herbaceum, G. arboreum, G .baradense,* Intra-*hirsutum* and Inter-specific hybrids	16.89	18.73

At the time of independence in India during 1947, 97% of the area was under *desi* cotton and only 3% was occupied by *G. hirsutum*. Presently, 95% of the cotton area is being occupied by *G. hirsutum* varieties and hybrids. The productivity which was 88 kg/ha (1947-48) has risen up to 567 kg/ha. (2007-08). This is the result of adoption of *G. hirsutum* to Indian conditions and research and development work carried out by SAUs, AICCIP and CICR (ICAR).

In India, a variety of cotton of different quality ranges are produced from non-spinnable short staple coarse types to 120s count superfine cotton, though vast majority belong to medium and long staple group. More than 70% of our textile are cotton blended with polyester yarn and pure cotton yarn are exported which accounts for nearly 25% of total yarn production.

Newly developed varieties resulted in yield increase from 15 q/ha to 40 q/ha under irrigated condition and from 2-3 q/ha to 10-12 q/ha under rainfed condition. The crop duration which ranged from 250-270 days was reduced to 140-190 days particularly in North Zone States is indeed a hallmark in the field of cotton breeding. This has resulted in crop rotation with cotton followed by wheat, simultaneously increasing per day productivity. The yield potential of *arboreum* cottons has been improved from 18 q/ha to 38 q/ha in North Zone States and 3-4 q/ha to 10-15 q/ha under rainfed condition in other parts of the country. The characteristic features of some of the recently released varieties and hybrids are furnished in Table 2.

Table 2. Characteristics of recently released cotton varieties / hybrids for cultivation

Name	Species	Average yield (q/ha)	Ginning percent	Fibre length (mm)	Bundle Strength	Mic value
AKA-8	A	12.0	38.0	24.0	20.8	4.6
PAU 626H (FMDH 3)	A	30.0	40.0	20.0	16.0	7.3
CICR-1 (CISA 310)	A	27.0	40.1	20.2	15.7	6.2
CICR-3 (CISA 614)	A	22.0	37.0	20.9	17.5	7.0
HD432	A	21.0	39.3	21.2	17.0	7.0
FDK 124	A	22.0	36.3	20.3	16.6	6.8
DLSa 17 (Gunavanti)	A	20.0	38.0	27.5	22.0	4.5
CNA 1003	A	14.0	35.7	24.4	20.2	5.8
AKDH 5 (PKV SUVARNA)	A X A	15.0	37.2	25.5	21.8	5.5
FMDH 9	A X A	28.0	36.6	22.8	17.6	7.0
FMDH 8	A X A	16.0	39.1	19.8	17.2	6.8
Moti (LMDH 8)	A X A	25.0	38.6	20.0	16.3	7.3
H 1300	H	23.0	36.3	25.0	20.5	4.9
LH 2108	H	24.0	35.2	27.9	21.8	4.6
F 2164	H	24.0	33.2	27.7	21.3	4.4
RAH-IOO (Yugaank)	H	20.0	40.0	28.0	20.3	3.4
ARBH 813	H	21.0	36.3	27.8	21.5	4.5
JK 35	H	20.0	40.0	24.0	20.0	3.9
AKH-8828	H	12.0	40.0	27.0	19.1	3.9
G.Cot. 20	H	18.0	34.9	26.0	21.7	4.7
Suraj (CCH 510-4)	H	30.0	40.1	30.1	22.8	3.6
NH 615	H	15.0	39.0	28.0	20.6	4.1
CNHO 12	H	15.0	35.0	24.6	20.9	4.8
Phule 688	H	18.0	37.3	27.0	22.1	4.0
H 1226	H	23.0	35.0	25.0	21.5	4.2
LH 2076	H	19.0	33.4	27.1	21.9	5.2
H1236	H	20.0	37.8	27.2	22.1	4.5
H1098-i	H	21.0	39.6	24.8	20.1	4.8

SVPR4	H	16.0	36.2	27.9	22.5	4.2
ARCHH 3028	H X H	17.0	34.5	28.7	22.1	3.8
CSHH 243	H X H	34.0	33.7	27.5	23.5	4.6
CSHG 1862	H X H	21.0	34.5	27.8	21.9	4.2
FHH 141	H X H	24.0	34.7	26.3	20.5	4.0
RAHH-98	H X H	25.0	36.0	28.5	21.9	3.5
RAHH-95 (Virajita)	H X H	18.0	39.3	26.4	23.6	3.4
RAHH 259	H X H	23.0	33.7	30.3	22.7	4.0
NHH 206	H X H	19.0	38.1	26.8	20.7	3.5
Kalyan (CSHH 238)	H X H	21.0	33.5	27.6	22.5	4.5
NDLHH-1755	H X H	18.0	38.0	28.0	19.1	3.6
RAHB 189	H X B	21.0	31.8	33.6	25.7	3.0
RAHB-87	H X B	17.0	35.2	35.6	28.7	3.5
DHB 915	H X B	17.0	34.0	34.5	28.2	3.4
DHB 871	H X B	19.0	33.2	35.3	24.2	3.0
RAHB 301	H X B	19.0	33.4	33.3	23.9	3.6

A = *Gossypium arboreum*; H = *G. hirsutum*; B = *G. barbadense*

Egyptian cotton varieties are being cultivated in almost 1% of the total cotton area and have nearly taken 124 years for acclimatization. In India at the instance of British East India Company, *G. barbadense* was introduced during 1831. The initial attempts failed, mainly because of harsh climate under which it was tested. Later, reselection in the Egyptian variety Karnak resulted in the development and release of the first *G. barbadense* variety Sujata (1969). Sujata was crossed with a West Indies variety St. Vincent and Suvin was evolved (1975).

Exploitation of heterosis in cotton was initiated and pursued vigourously in India to increase the cotton production and to improve fibre quality and the efforts paid rich dividends through the development of hybrids and their large-scale cultivation. In fact, India was the first country to commercially cultivate the intra-hirsutum hybrid cotton in 1970. Dr. C. T. Patel was mainly responsible for the hybrid cotton revolution in India by evolving and releasing the hybrid H 4 using G 67 as the female parent and American Nectariless being the male parent under AICCIP.

Currently, several extra-long staple *G. hirsutum* and *G. barbadense* varieties as well as hybrids (both intra hirsutum and inter-specific hybrids) having more than 32.5 mm of 2.5% span length, which were released under AICCIP, are under cultivation in India (Table 3).

Table 3.Characteristics of Extra Long Staple Cottons under cultivation

Variety/Hybrid	2.5% SL (mm)	Mic	BS 3.2mm	Count	Year	Species
MCU 5	33.0	3.2	26.0	60s	1968	H
MCU 5VT	33.0	3.3	25.0	60s	1984	H
Varalaxmi	34.0	3.2	28.0	80s	1972	HB
Suvin	38.0	3.2	38.0	120s	1974	B
DCH 32	36.0	3.0	30.0	80s	1981	HB
MCU 5 VT	32.5	3.3	25.0	60s	1982	H
Savita	33.0	3.8	26.0	60s	1987	HH
TCHB 213	35.0	3.6	25.0	80s	1989	HB

TM 1312 (Surya)	32.5	3.4	26.0	50s	1994	HH
DHB 105	32.0	3.2	25.0	60s	1994	HB
NBHB 11	35.0	3.7	25.0	60s	1996	HB
VRS 7 (Surabhi)	32.5	3.2	24.0	60s	1996	H
CDHB 1 (Sruthi)	35.0	3.5	28.0	80s	1996	HB
Kashinath	34.0	3.0	25.0	80s	1997	HB
Phule 388	35.0	3.4	23.8	80s	2002	HB
Suraj	33.0	3.6	24.0	60s	2008	H
RAHB 87	35.6	3.5	28.7	80s	2009	HB
DHB 915	34.5	3.4	28.2	80s	2009	HB
RAHB 189	33.6	3.4	25.7	80s	2012	HB
DHB 871	35.3	3.5	24.2	80s	2012	HB
RAHB 301	33.3	3.5	23.9	80s	2012	HB

H = *G. hirsutum*; B = *G. barbadense*

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Organic Seed Production in Cotton

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Cotton (*Gossypium* spp.) is the most important natural source of fibre used in textile manufacture. Cotton seed is a rich source of edible oil. The cultivated species of cotton contains 20-27% of non-drying oil. The seed meal contains high per cent of protein, which is rich in essential amino acids like lysine, metheonine, tryptophan and is used as fertilizer and animal feed concentrate. India has the unique distinction of growing all the four spinnable fibre yielding species of *Gossypium* spp viz. *Gossypium hirsutum*, *G. barbadense*, *G. arboreum* and *G. herbaceum* commercially under diverse ecosystems.

The growing concerns over the environmental problems in cotton growing areas and increased awareness regarding use of organic cotton, geared up the need to look for alternative to intensive chemical based cotton production system which was resulted in buildup of pesticide resistance in insects, toxicity of pesticides to natural predators and parasites affecting the natural balance. Indiscriminate and heavy use of harmful pesticides for cotton pests, the resistance of insects against these toxic chemicals boosted and thereby compelled a further increase in use of insecticidal sprays, creating a vicious cycle and escalating cost of cultivation. Organic farming is senses of thoughtful act and will definitely help in reversing this trend and preventing further damage to the environment.

Organic cotton is one production system, which aims to bring back the cotton cultivation on sustainable basis and also protects the environment. The basic idea of organic farming in cotton production is also aimed at conservation and optimum utilization of all natural resources for decent profitability maintaining sustainability of the farm. Cotton is grown organically using methods and materials that have a low impact on the environment. Organic production systems replenish and maintain soil fertility, reduce the use of toxic and persistent pesticides and fertilizers, and build biologically diverse agriculture. Third-party certification organizations verify that organic producers use only methods and materials allowed in organic production.

Pre-sowing seed treatment

Pre-sowing seed treatments with botanicals have been developed as a potential agro-technique to induce drought tolerance without impairing the germination potential of seeds. Seed hardening is one such technique when done with organic substances imparts resistance.

Seed Hardening

The principle is to hydrate seed to initiate early germination events (normally Moisture Content up to 30%) but not sufficient enough to permit protrusion. The germinating seedlings could emerge and produce deep root systems before the upper layers of the soil dried out, hardened or became dangerously hot. Since, for a large proportion of the time that seeds spend in soil for simply imbibing water, often very slowly. To avert this situation seed hydration is proposed. In hardening, seed is allowed to take up water for a period that is less than the 'safe limit'. Once removed from the water and surface-dried, the seed will not continue to germinate unless extra water is supplied, e.g. by sowing into moist soil. If sown into dry soil (to await the rains, for e.g.) the seed will not germinate. It will dry out slowly but will germinate once the soil is moistened by rain.

Seed hardening confers high degree of drought resistance; the excessive water loss of seed could be prevented by seed hardening. The physiological induction is a cause of seed conditioning towards increased drought resistance in crop**.** A number of physico chemical changes *viz*., greater hydration of colloids, higher viscosity and elasticity of protoplasm, higher bound water content, increase in temperature, lower water deficit and more efficient root system occurring in plants from seeds given pre-sowing seed hardening treatment had been enumerated (May *et al*.,1962).

Germination and seedling growth of cotton were found inhibited by the extracts from ripe fruits of *Rubia tintorum* (Agakishiev *et al*., 1978). Whereas, soaking in *Nostoc muscorum* suspension increased the seed yield by 400 kg ha^{-1} (Umarova and Urmanov 1978).

In the process of seed hardening when the dry seeds are soaked in solution the quiescent cells get hydrated activating enzyme reactions leading to early germination process. Activation of cells results in the enhancement of mitochondrial activity leading to the synthesis of more high-energy compounds and vital bio-molecules. These initial metabolic changes culminate in enlargement of the latent embryo. When the imbibed seeds are dried back to original moisture, the triggered germination events are halted. When the seeds are sown in the field and get enough moisture, they undergo reimbibition. On further activation, they recapitulate and the germination events begin from where it had stopped previously. Consequently early emergence and establishment of seedlings are achieved before the available soil moisture is depleted. This physiological preconditioning at the cellular level helps the resulting plants to resist the adverse climatic conditions than untreated seed (Dharmalingam *et al*., 1988). Seed hardening can bring about a number of physico chemical changes in the seed such as greater hydration of colloids, high viscosity and elasticity of protoplasm, increase in bound water content, lower water deficit and more efficient root system (May *et al*., 1962).

To derive the full benefits of seed hardening the process has to be done very precautiously. The efficacy of seed hardening depends on seed to solution ratio. The solution used should be just enough for imbibition of seeds within the stipulated period and not in excess. The study (Rathinavel, 1997) brought out 1:1.5 (W/V) for LRA 5166 and 1:1.65 (W/V) for Uppam cotton as optimum.

The imbibition period is another important factor that determines the efficacy of seed hardening. For cotton, soaking period of 6 h, 18 h, 24 h, and 48 h were reported. However, in a study (Rathinavel, 1997) an imbibition period of 8 h was found sufficient for both cv. LRA 5166 and Uppam cotton. This confirms the results reported earlier (Nirmala *et al*., 1994).

Yet another factor is the concentration of botanical solutions used for seed hardening. Cotton seeds hardened with Pungam leaf extract (1.0%) and Prosopis leaf extract (0.5%) registered higher germination of 74, 72, 72 %, respectively with enhanced seedling growth over control.

Use of plant products as manures and pesticides are very much in vogue as they avoid health hazards and environmental pollution. The present approach of using easily accessible plant material at negligible cost is very recent. The fresh leaf extracts of some of the uncared plants, for example, Prosopis (*Prosopis julifera*) and Pungam (*Pungamea pinnata*) have been found to be useful to harden the seeds with greater benefits than a number of chemicals. Cotton seeds hardened with these aqueous leaf extracts excelled chemical hardening in respect to germination and seedling vigour (Rathinavel, 1997). The factor responsible to impart hardening effect with promotion of germination and growth is not known and it needs further elucidation and critical appraisal. However, it is presumed that some saponins present in these bring about effects similar to that of gibberellins.

The option for seed hardened either with Pungam leaf extract (1.0%) or Prosopis leaf extract (0.5%) was also reported. The germination of seeds was enhanced by 10 %. In addition, speed of germination, root length, shoot length, dry matter production and vigour index were high by 16.5, 10.0, 14.6, 11.5, 24.8 % in the case of Pungam leaf extract and 9.6, 14.9, 6.5, 20.3, 15.2 %, respectively for Prosopis leaf extract. Concentrations lower or higher than these did not confer better effects.

Seed Pelleting

One of the earliest methods of seed "Singulation" was seed pelleting, done to increase the size of the individual seed by coating it with a layer of bentonite clay. Pelleting regulates the size of the seed for precision planting. Pelleting is done for singling of seed, increased flowability in mechanized farming, improved handling in small and irregular seed, accurate distribution, wastage of chemical is prevented, better seed to soil contact, improved seedling nutrition and to overcome stress conditions.

Adhesives

Simple coating with starch gave good flow characteristics to cotton seed, an easier process to handle than acid delinting treatment. Seed coated with polymer film containing micronutrients registered good germination energy and germination.

Coating materials

Coating cotton seed with indigenous material such as mud, ash, cow-dung or their combination did not result in better seed germination (Patil and Dighe, 1983). Pelleting with mud + cow-dung reduced seed vigour to the maximum. It has been reported that cotton seeds pelleted with Arappu leaf powder recorded more viability and vigour (Muruganantham, 1996).

Inoculants

Seeds inoculated with Azotobacter by coating had no significant effect on dry matter yield and vigour of plant irrespective of soil fertility level. Increased plant height, number of branches, bolls plant^{-1} and seed cotton yield were observed when inoculated with *Azotobacter chroococcum*. Seed cotton yield increased by application of Azotobacter as seed treatment alone or with FYM. Cotton seed inoculated with Azotobacter replaced 2/3rd recommended dose of nitrogen (53 kg N ha^{-1}) and resulted in yield attributes and seed cotton yield at par with recommended dose of nitrogen (80 kg N ha^{-1}).

Recent approach

Cotton productivity depends to a large extent on the sowing quality of seeds that are planted. The role of high quality seeds needs no further emphasis and the seed management techniques become all the more important to upgrade the planting value of seeds. The seeds used for sowing should have maximum viability and vigour so that it will emerge rapidly and uniformly in the field even if the conditions are unfavourable. Coating of seeds with different nutrients, biofertilizers, chemicals, biocides, hydrophilic substances and botanicals have been attempted by several workers to solve several problems like soil pH, nutrient deficiency, and protection against soil microbes, seed soil relationship and so on. Uses of botanicals either alone or in combination with nutrients have yielded promising results.

The adhesives used for coating the materials play an important role in seed pelleting. Selection of proper adhesive to bind the materials on seed surface is very essential. Primarily the adhesive should be nontoxic and posses appropriate affinity for the seed coat and selected substrate. The required degree of water solubility strength and plasticity to prevent breakage and dusting are also important. The viscosity must be optimum for easy application. Simple coating with starch gave good flow characteristics to cotton seed. The best effects of rice gruel (40 ml kg^{-1}) for pelleting cotton seeds were reported. However, another investigation revealed 5.0 % maida solution was found to be the best to coat the pelleting material uniformly on the seed.

In the process of pelleting, another important factor to be considered is the property of the coating material. It should posses good stability, hydrophillic nature as it regulates moisture flow into the seed, nontoxic, nonreactive with nutrients and biological agents incorporated into it. A number of coating material has been reported in various crops (lime, Cellulose, Kaolinite, Vermicompost, Arappu leaf powder and Pungam leaf powder).

Cotton seeds pelleted with arappu leaf powder in general improved the germination and seedling vigour. It is reported that *Albizza amara* (Arappu) leaf powder contain Saponins, GA_3 in traces and micronutrients especially zinc. These biocontents might synergistically interact with aminoacids, especially tryphtophan, to form the Indole Acetic Acid (IAA) in the germinating seed to bring about enhancement of seedling growth. The beneficial effects of pelleting cotton seeds (MCU 7) with Arappu leaf powder is well documented.

Effect of eco – friendly seed treatments for maintenance of viability and vigour of seed

LRA 5166 cotton seeds were pelleted with Calotrophis leaf powder, Datura leaf powder, Neem leaf powder, Vitex leaf powder, Turmeric rhizome powder, Acorus rhizome powder using the Gum Arabic (25 %) as the adhesive. The adhesive used was 50ml/ kg of seed along with 100 g of leaf powder. Another set of seeds were dry dressed with botanicals @ 50g of powder/ kg of seed. Seeds were stored in gada cloth bag for 24 months. It was observed that all these botanicals had preserved the seed viability and vigour up to eight months for a level higher than minimum seed certification standards.

Harvest

The time of picking is an important aspect for maintaining seed quality. The picking should commence when the cotton is fully mature i.e., when the bolls begin to open. Several pickings may be necessary since bolls ripen over a period of two to three months. The early pickings give a slightly better germination, but planting seed is best gathered at the peak of harvest. The cotton picked from later formed bolls (last picking) should not be used for seeds.

Precautions to be taken in picking

1. Picking must be done when bolls are fully mature.
2. Picking should not be done while the bolls are wet from decay or rain
3. Bolls spoiled due to rains or damaged by insects or otherwise damaged, should be picked separately and discarded for seed purposes. Such bolls can be picked 10 to 15 days ahead of the first picking. The damaged bolls should not be picked during normal pickings for seed purposes.
4. The cotton picking should be done with a minimum amount of inert matter like leaves and plant parts. This reduces the possibility of mechanical damage from excessive machining of the fibre during ginning.
5. Cotton moist in any way should not be picked or stored. At moisture content of twelve per cent or more, heating may occur and cause damage to seed and fibre. Further, clamp cotton while processing in the gin exposes the seed more to mechanical damage.
6. The picked cotton, when it is completely dry should be stored in a dry place and should be covered if ginning is delayed.

Effect of pickings on seed quality

Numbers of studies carried out have shown differences in the quality of cotton seeds from different pickings. The viability of seeds is higher until about 4^{th} or 5^{th} picking. Seeds collected at the end of the picking season are low in seed weight with low viability than collected earlier. Decrease in seed weight is attributed to reduction in net assimilation rate and it contained higher oil. The seeds obtained from bolls picked from different positions of the plant also differed significantly in respect to germination, field emergence and other seed quality parameters.

The seeds from first picking and in the lower zone of the plant were poorer in quality and those seeds from 4^{th} and 5^{th} pickings from upper zone were better. The poor quality of seeds from the lower zone is due the higher relative humidity and temperature prevailed around the crop canopy during seed development and maturation. Seed quality differed significantly between varieties and sympodia and nodes.

On the other hand, studies carried out on seed physiological traits as influenced by stratified harvests, reported that seed from the first two pickings was found to be ideal in terms of germinability, vigour and seed reserves as compared to later two pickings wherein there was marked reduction for most of the seed attributes, even though the quantum of reduction varied amongst different species. Seed picked from the lower and middle position was found to be of better quality as compared to the top position in the vertical profile. While in the horizontal profile differences were not clearly discernible.

Seed Processing

Following steps are suggested for efficient seed processing

- Raw cotton
- pre-cleaning
- Ginning
- Fuzzy seed cleaning

- Delinting
- Fuzzy seed, Delinted seed cleaning and upgrading
- Gravity separation
- Seed treatment
- Seed packaging & labelling

Ginning Seed Cotton

The saw gin is found effective for ginning seed cotton (Kapas) as compared to roller gins. The results revealed that about 1 to 1.5% seed gets damaged on saw gin and 7 to 8% lint remain with seed compared to 3 to 4.5% seed damage obtained from roller gin and 12 to 14% lint remaining with seed.

Fuzzy seed cleaning

Majority of the fuzzy cotton seed is manually screened and hand picked. The hand picking efficiency of a person is below 12 kg per day for hybrid cotton and 15 kg per day for improved cotton. Attempt was made to modernize seed cleaning operation by introducing machine cleaning which were used to scalp out large size seed with lint for re-ginning, removal of light material and undersized seed. The rate of cleaning was 500 to 700 kg day^{-1}.

Seed certification

The land to be used for production of cotton seed must be free of volunteer plants of cotton. Cotton is mainly a self-pollinated crop but natural cross-pollination has been recorded in all the species. The actual isolation requirements for cotton vary according to the extent of natural cross-pollination. In India, a minimum isolation distance of 50 meters for foundation seed class and 30 meters for certified seed class production from fields of other varieties of the same species, other species and fields of the same variety not confirming to varietal purity requirements for certification is necessary.

Breeder seeds for raising foundation seed crop, foundation seed for raising certified seed crop, parental line seeds for producing hybrid seeds should be obtained from an approved source.

Sowing of cotton seeds for seed production should be informed to the Seed certification agency within 35 days from the date of sowing. Seed field inspections are carried out by the Seed certification agency in two stages one at 75 days after sowing i.e. during flowering and the second in 105 days i.e. at crop maturity stage. In both the stages of inspection, the seed certification authority verifies the seed crop isolation and assesses the presence of off-type plants. Off-type plants are assessed by entering and observing the seed field at a randomly selected site from any side and start moving in the direction of the rows or start at random from any point in any row and count ten consecutive plants in that row. Count the number of off-types, inseparable other crop plants, objectionable weeds, and plants affected by designated diseases within these ten plants.

In general, wherever the plant population is lesser than the actual number to be counted take entire population, study and arrive the purity of the field. Wherever the counting procedure could not be adopted as per the above said procedure, take entire populations study and arrive for the purity of the field

Seed standard

The seed standards prescribed for certification is as follows

Factor	Varieties	
	Foundation	Certified
Physical purity		
Pure seed (Minimum)	98%	98.0%
Inert matter (Maximum)	2.0%	2.0%
Other crop seeds (Maximum)	5 kg	10 kg
Weed seed (Maximum)	5 kg	10 kg
Germination (Minimum)	65.0%	65.0%
Moisture (Maximum)	10.0%	10.0%
For vapour proof containers (Maximum)	6.0%	6.0%
Pure seed	99%	98%
Off-type	1.0%	2.0%

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http://www.ota.com/organic/mt/organic_cotton.html

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Certification Procedures Involved in Organic Cotton Production

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More intensive and economic agriculture production led to wide use of high doses of concentrated chemical fertilizers and chemical pesticides but insufficient use of organics, leading to negative results, decrease in fertility and soil structure. Instead of recycling the plant and animal wastes back into the land as fertilizer, we pollute the air and water by using chemical fertilizers and pesticides including hormones and antibiotics leaving residues in food that may cause cancer and other dreadful diseases. Thus, Organic farming not only restores soil fertility but also reestablishes natural balance and thereby conserves bio diversity. Organic farming is also a solution to global warming.

According to Dr. Christine Jones, one of Australian leading experts of carbon sequestration " by increasing 1 % Organic carbon in one hectare of the soil shall remove 88 tonnes of carbon dioxide from the atmosphere by sequestration thus preventing global warming". The agricultural produce from Organic farms are not only highly nutritive but also contains more antioxidants and has no residual toxins of fertilizers, pesticides, antibiotics and hormones.

Organic Certification intends to assure quality of Organic products and aims at regulating and facilitating the sale of Organic products to consumers. It addresses growing worldwide demand for Organic food. The rising demand for Organic products has fueled the spurt in the demand for certification. The cotton value chain comprises a significant chunk of the total organic trade in India. Certification is a very complete exercise and presence of a much higher number of players in the cotton value chain makes it even more challenging. Certification bodies play a critical role in ensuring the integrity of Organic cotton. The nature of the relationship between the certification bodies and the accreditation body is governed by common global guidelines specified under the ISO guide 65 procedures.

Organic agricultural methods are internationally regulated and legally enforced by many nations, based in large part of the standards set by the International Federation of Organic Agriculture Movements (IFOAM) an international umbrella organization for organic farming organizations established in 1972 (2) IFOAM defines the overarching goal of organic farming as:

"Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved."

Tamil Nadu Organic Certification Department (TNOCD) was established in 2007-2008 to carryout Inspection and Certification of Organic production system in accordance with NPOP (National Programme for Organic Production) launched by Government of India in the year 2000 and notified in October 2001 under the Foreign Trade and Development Act (FTDR Act). Tamil Nadu Organic Certification Department has been Accredited by APEDA (Agricultural and Processed Food Products Exports Development Authority), New Delhi, Ministry of

Commerce and Industry, Government of India. The accreditation number allotted to TNOCD is NPOP/NAB/0019. Organic Certification carried out by this Department is on par with standards of European Union and Switzerland.

Crop Prodution Standards for Cotton Under NSOP

Land Requirement

Land shall be organically managed. If the land is situated in a low lying area to avoid run-off water contamination from conventional farming system, it is essential to dig trenches wherever required. To avoid contamination through wind the Organic farm shall be separated from conventional farm by live fence or man made constructions or a portion of organically managed crop maintained as a buffer zone. A buffer zone of at least 3 meters shall be maintained between conventional and organic management. Simultaneous production of organic, in conversion, conventional production or animal production which is not clearly distinguishable shall not be allowed for certification.

Equipments or implements used for organic management shall be cleaned before use (if it is used already in conventional farming system)

1. **Conversion Requirement**

The conversion period is the time between the start of organic management and certification of crops and/or animal husbandry etc., A minimum of 3 years conversion period shall be required for converting organic farming system from conventional farming system. From the start of the conversion period all the prohibited inputs listed in NPOP shall not be used. The conversion period is calculated from the date of registration or from the date of last application of prohibited input. Product can be certified organic when the National Organic Standards are met during a conversion period of at least 2 years before sowing or in the case of perennial crops, other khan grassland at least 3 years (36 months) before the first harvest of the certified organic crop. The conversion period is reduced or shall be extended based on the past use of land.

2. **Conditions For Reduction In Conversion Period**

If the operator maintains documentation of organic growing methods for at least 3 years. If the land is kept fallow for at least 3 years. If the land is situated away from contaminant sources such as industrial pollution, transport pollution etc.

3. **Maintenance Of Organic Management**

The organic production shall be maintained continuously. Switch back from organic to conventional and again back to organic is not allowed. In cases of switch back the operator shall once again undergo full conversion period.

4. **Landscape**

At least 1% of the area shall be allowed to facilitate biodiversity. The border areas wherever possible shall be grown with trees or other perennial or flowering plants which facilitate in conservation of nature. Landscaping shall contribute beneficially to the eco system.

5. **Choice Of Varieties**

Any variety/hybrids except GMO which suits to the location shall be grown. Varieties resistant to pest and diseases shall be preferred. GMO's are not allowed in organic farming. In the choice of varieties, genetic diversity shall be taken into consideration.

6. **Seeds And Planting Mat**

Seeds/planting materials used shall be from certified organic source. In case of non availability of organic seeds, untreated seeds from conventional farming shall be used for the first year and for subsequent years organic seeds shall be used. In case of growing other varieties which were not grown in the first year, chemically untreated conventional material shall be used. The use of genetically engineered seeds, pollen, transgenic plants or plant materials shall not be allowed.

7. **Fertilizing and Soil Conditioning**

Fertilization policy shall be to increase or at least to maintain soil fertility and the biological activity. Any biodegradable material of microbial, plant or animal origin produced on organic farms shall form the basis of the fertilization programme. The fertility and biological activity of the soil shall be maintained or increased, in the first instance, by cultivation of legumes, green manures, or deep rooting plants in an appropriate multi annual crop rotation programme. Total quantity of manures applied to agricultural production shall not exceed 170 kg nitrogen per hectare per year. Wherever necessary the total stocking density shall be reduced to avoid exceeding the limit of 170 kgs nitrogen per hectare. The operator shall manage plant and animal materials to maintain or improve soil organic matter content in a manner that does not contribute to contamination of crops, soil or water by plant nutrients, pathogenic organisms, heavy metals or residues of prohibited substances. Animal and plant materials include, raw animal manures which shall be composted unless it is applied to land used for a crop not indented for human consumption. Incorporated into the soil not less than 120 days prior to the harvest of a product whose edible portion has direct contact with the soil surface or soil particles. Or incorporated into the soil not less than 90 days prior to the harvest of a product whose edible portion does not have direct contact with the soil surface or soil particles. As nitrogen content in farm yard manure (FYM) vary from 0.4% to 1.5%. It is advisable to test FYM for nitrogen content before use for the purpose of calculation of allowed maximum quantity of manure (170 kg nitrogen per hectare).

8. **Materials Produced on an Organic Farm Unit**
    1. Farmyard & poultry manure, slurry and urine
    2. Vermi compost and coir compost
    3. Crop residues and green manure
    4. Straw and other mulches
9. **Microbiologial Preparations**
    1. Bacterial preparations (bio fertilizers)
    2. Biodynamic preparations
    3. Plant preparations and botanical extracts
    4. Vermiculate
    5. Peat

Products which are not permitted under Certification

1. Tobacco tea
2. Mineral powders (Stone meal, Silicates)
3. Ethyl alcohol
4. Synthetic fertilizers, herbicides, fungicides, insecticides, synthetic growth regulators and dyes.
5. GMO crops or products are prohibited.

Certification body shall ensure to prevent transmission of pest, parasites and infectious agents through the following means: Allowing operator to use seed purchased from off farm after necessary permission by certification body to avoid transmission of pest, parasites and infectious agents from endemic areas.

10. **Weed Management**

Organic weed management promotes weed suppression rather than weed elimination by enhancing crop competition and phototoxic effects on weeds Organic farmers integrate cultural, biological , mechanical and physical tactics to manage weeds without synthetic herbicides.

11. **Critical Issues And Challenges Of Certification**

- **a.** Seeds and other inputs .
- **b.** GMO and Contamination
- **c.** Adequacy and efficacy of internal control system (ICS)
- **d.** Non –conformities and punitive action chain
- **e.** Accountability and transparency
- **f.** Selective Certification on perceived risk
- **g.** Conversion and transition period
- **h.** Dual Certification
- **i.** Scientific estimation of yield
- **j.** Parallel Production

Above issues pose a big challenge for Certification

In India the export of Organic Products have grown at an average pace of 30 percent over the past 5 years. Currently more than thousand branded Organic products are exported from India.During the year 2011-2012 India has supplied certified organic products to the tune of Rs.1866 Crores to Europe, Asia and U.S.A. The export value has risen to 167 percent and 111 percent in terms of volume of food, cotton and textile products.

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Cotton Fibre Quality Evaluation: Principles and Theory

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Cotton Fibre Quality Evaluation helps:

Cotton Breeder
Cotton Grower
Ginner cum Trader
Textile Mills

Fibre parameters crucial to hassle-free processing are:

- Fibre length
- Length uniformity
- Fibre strength
- Fineness/ Micronaire value

In addition:

- Fibre Elongation
- SFC (Short FibreContent)
- Trash & its distribution
- Colour
- Fibre neps
- SCN(Seed Coat Neps)

Instruments have been developed from time to time for evaluating grade and fibre properties of cotton lint. These include simple to very sophisticated instruments, which can measure either a single or a group of parameters. HVI is one such instrument, which measures all the above fiber parameters.

Length and Length Distribution

It has been fairly well established that 'length' is the single most important parameter determining yarn quality for ring spinning. Fibre length is also critical for optimization of machinery settings in each department. However, 'length' in a cotton sample is a variable parameter and it needs to be defined which length is most important -the length of the longest fibre or the length of the shortest fibre or the length of a majority of fibres and so on? Considerable work has been done on this aspect and the definition of length has been narrowed down to two criteria - one based on its 'full' length (i.e. end to end lengths) and the other based on what is called the 'span length' (Fig. 2). These two basic methods are explained in details with their relative merits and demerits.

Staple Length

The most popular parameter based on the full length of the fibre is the 'Staple Length', which was originally defined as 'the length of a typical portion of a sample of fibres. Conventionally, and even today in most of the places where cotton is evaluated, the staple length is estimated by the 'hand stapling' process performed by an experienced person called the classer. Later, some instruments were developed for the objective determination of the staple length. These instruments provided a 'Staple Diagram' – an arrangement of fibres from the shortest to the longest 'full' length

Methods of expressing fibre length

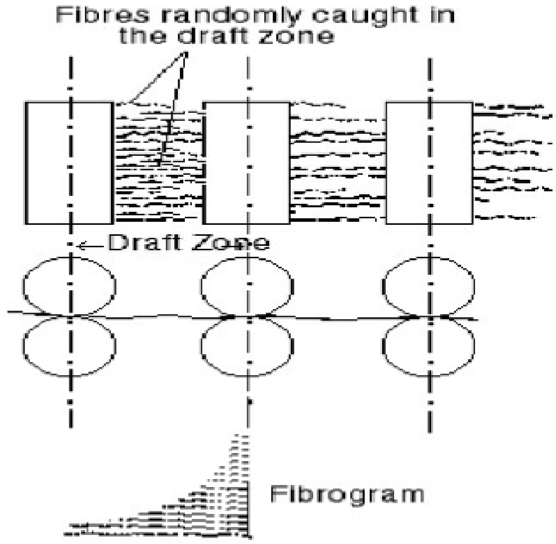
From the staple diagram, the following length parameters can be obtained:

- Mean Length
- Effective Length
- Upper Half Mean Length

Of these parameters, the effective lengths correlates well with the classer's staple length and hence provide an objective measurement of the staple length eliminating the subjective assessment prevalent with the hand stapling arrangement. The staple diagram has for long been regarded as the ultimate way to determine the range of fibre lengths. To make this method as useful as possible, much experimental work has been done on its correlation with yarn spinning, but the method has certain inherent limitations. The Fibrogram method, a relatively recent innovation sought to overcome these limitations.

The Fibrogram

The fibrogram is an arrangement of fibres from the shortest to the longest in terms of span lengths (the distance by which fibres extend from a random catching point). The Fibrogram simulates the way fibres will occur in yarn making processes. The practicality of fibrogram method is revealed when it is recognized that, in processing fibres to yarn, at any instant of time, those fibres caught by rollers or aprons, being transferred from one place to another, follows a fibrogram configuration.

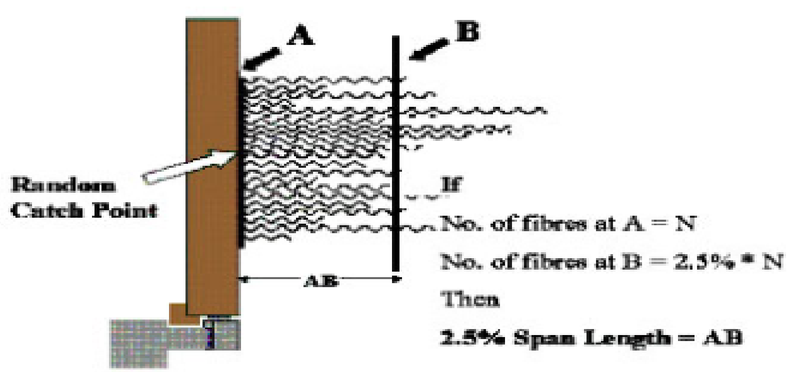


Fibres in the drafting zone

Extending from random catch points, exposed fibre segments will have different lengths even if all fibres have the same full or end to end length. Consequently expressions of fibre length and length distribution extracted from the Fibrogram, rather than the Baer Sorter array, are most useful in explaining fibre behavior in yarn spinning.

Span Length

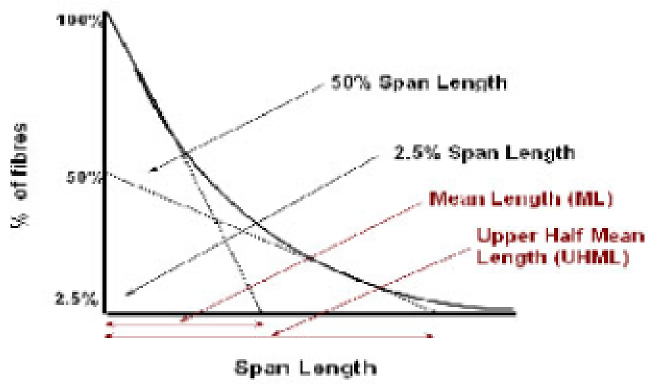
Span Length is defined as the distance exceeded by a specific percentage of fibres extending from a random catch point.



Definition of Span Length

Elaborate studies conducted at the US Dept. of Agriculture have shown that 2.5% Span Length - i.e. the distance exceeded by 2.5% of fibres in the fibrogram – best matches the 'Staple Length' as assessed by a classer and consequently 2.5% Span Length is used as the universal standard for evaluating cottons with regard to its suitability for the spinning process.

Estimating Span Lengths from full lengths and vice versa despite the advantages of the Fibrogram, it has not been established that the Fibrogram can fully replace the staple diagram and hence it often becomes necessary to have a means of conversion from one form of length estimation to the other. In the High volume Fibre Tester, an estimate of the full, end-to-end fibre length distribution is obtained from the span length distribution by constructing tangents on the Fibrogram. For example, placing a tangent to the curve that intercepts the Y axis at the 50% level will establish the X-axis intercept and thereby identify the Upper Half Mean Length. Similarly drawing a tangent at the 100% level will indicate the Mean Length on the X axis and so on.



Method of conversion from Span lengths to Full lengths

Staple length categories of Indian cotton

Category	Range of 2.5 S.L. (mm)	Mean Length (mm)
Short	20 mm and below	18.0 mm and below
Medium	20.5-24.5	18.5-22.0
Medium Long	25.0-27.0	22.5-24.5
Long	27.5-32.0	25.0-29.0
Extra Long	32.5 mm and above	29.5 mm and above

Length Uniformity

It is a well known fact that cotton is a highly variable material and the length is not uniform throughout the sample. The extent of variability of length plays an important role in the performance of cotton fibres. This is because, for a given roller setting (decided based on the 2.5% Span Length or the Effective Length), cottons with a higher length variability results in a number of 'floating' fibres in the drafting zone which ultimately deteriorates the yarn quality.

There are two popular measures of length uniformity in a cotton sample - the Uniformity Ratio (UR) and the Uniformity Index (UI).

There is little ambiguity with regard to the use of these measures since mills adopting the span length concept use the Uniformity Ratio and those adopting the full length concept use the 'Uniformity Index'. The terms are defined as follows:

$$\text{Uniformity Ratio (UR)} = \frac{50\%\text{SpanLength}}{2.5\%\text{SpanLength}} \times 100\%$$

$$\text{Uniformity Index (UI)} = \frac{\text{Mean Length}}{\text{Upper Half Mean Length}} \times 100\%$$

Classification of cotton based on length uniformity

Category	Range of Uniformity Ratio
Poor	Below 42
Fair	42 to 43
Average	44 to 45
Good	46 to 47
Excellent	Above 47

Fibre Strength and Elongation

Fibre strength and Elongation determine the toughness of a fibre which has a direct effect on the yarn and fabric strength. Very weak cottons tend to rupture during processing both in blow room and carding, creating short fibres and consequently deteriorate yarn strength and uniformity. It is usual to test the strength of fibre 'bundles' rather than single fibres since this is more representative and also has an arrangement similar to that in yarn.

It is also common to test the specimens by placing them in clamps with an initial distance of 1/8" between them. This is because, at this distance, the test value is most likely to represent the actual fibre strength. In all the common methods of testing fibre strength (Pressley, Stelometer, High volume Fibre Testing instruments, etc.), the force at break is measured. Unlike fibre length, there is little debate on what property is to be used to compare fibre strength between samples.

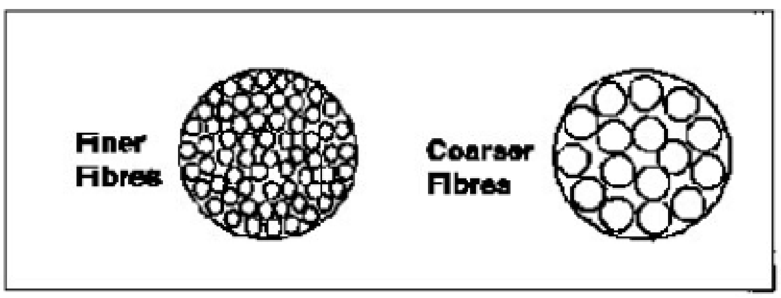
Universally, either the breaking tenacity in grams per tex or breaking length is used. This is because, it is these parameters which determine the strength of the yarn, and not the absolute breaking force in grams.

Ratings of Cotton based on bundle tenacity at 3.2 mm gauge length

Category	Range of Bundle tenacity values in g/tex
Poor	Below 16.0
Low	16.1 to 20.0
Average	20.1 to 23.0
Good	23.1 to 26.0
Very good	Above 26.0

Fibre Fineness

After the fibre length, fineness can be considered to be the most important parameter determining the yarn quality characteristics. This is because fineness influences the number of fibres in the cross-section of yarn. For a given yarn count, the finer the fibre, the higher the number of fibres in the cross-section.



As the number of fibres in the cross-section increases the yarn irregularity comes down. this means that, for a given yarn count, finer fibres produce a better yarn when compared o coarse fibres. Besides, it can be shown that a fine fibre can be spun to finer counts than a coarse fibre. In other words, fineness determines the spinning limit of fibres. Further, in the yarn structure, the finer the fibre, the greater the total surface area available for inter fibre contact and consequently less twist is needed to provide the necessary cohesion. Therefore the yarn twist is dependent upon the fibre fineness. While the importance of fineness has generally been realized by one and all, accurate determination of this parameter has always been a problem. This is because of the fact that, fibres exhibit a variety of shapes and they also vary in cross section along their length and vary from fibre to fibre. Traditionally fineness has been expressed as the mass of a given length of fibres since mass is directly proportional to the area of cross-section for a given length.

The most popular among these expressions is the micronaire value which is defined as the weight of one inch of fibres in micrograms (10-6 grams). Airflow instruments are widely used for the estimation of fibre fineness. These instruments are based on the principle that, for equal weights of fibre samples, the rate of airflow across the sample would be less for finer fibres than the coarser fibres due to the relatively more surface area in the case of finer fibres which offer a drag on the flow of air.

The issue of fineness measurement is complicated by the fact that the rate of airflow through a specimen is dependent not only on the fineness value but also on its maturity.

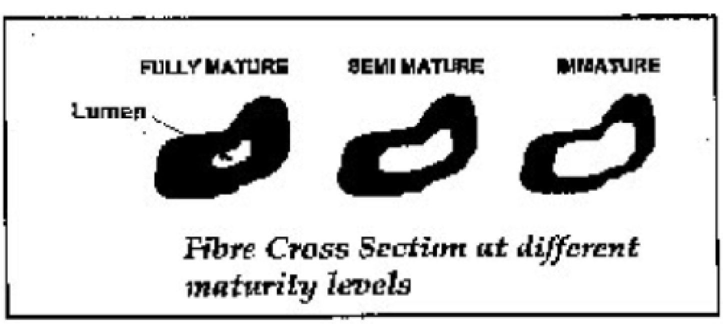
Therefore differences in micronaire values between two tests may indicate either varying fineness or varying maturity. Within a variety of cotton however, the change in the fibre perimeter is not significant and hence micronaire differences could be considered to be due to differences in the maturity of the samples tested. Though micronaire value does not truly represent the "intrinsic fibre fineness", it is nevertheless regarded as an important parameter in determining the yarn quality and spinning performance, and hence is continued to be used by instruments including the latest high volume instruments. The number of fibres in a given weight of cotton will be more in the case of finer fibres than in the case of coarser fibres. If air is blown through both these samples, the plug containing finer fibres will be found to offer a greater resistance than the plug with coarser fibres. This is due to the fact that the total surface area in the case of the former will be greater than the latter and hence the drag on the air flowing past will be more. This differentiating factor is made use of to indirectly measure the fineness of cotton.

Classification of cotton based on Micronaire value

Category	Range of Micronaire value
Very fine	Below 3.0
Fine	3.0 to 3.9
Average	4.0 to 4.9
Coarse	5.0 to 5.9
Very coarse	6.0 and above

Maturity

Maturity of cotton is another important parameter which mainly influences the processing performance of the cotton and yarn quality. The maturity of cotton is defined in terms of the development of the cell wall. A fully mature fibre has a well developed thick cell wall. On the other hand, an immature fibre has a very thin cell wall. One of the main troubles caused by these thin walled immature fibres is nepping, particularly in the case of fine cottons. Immaturity also affects the shade after dyeing. This is because, mature fibres absorb more quantities of dye than immature fibres and consequently any mixing with cottons of varying maturity levels, would result in dark and light patches in the yarn and fabric.



Fibre cross section at different maturity levels

Direct measurement of the cell wall development is not practicable. A method which is still regarded as the standard for measuring maturity of cotton fibres is the 'Sodium Hydroxide Swelling Test'. This method makes use of the fact that, when cotton fibres are swollen in 18% NaOH solution, three categories of fibres could be recognised when observed under a microscope. - Normal fibres, which appear as continuous rods and show no continuous lumen, Dead fibres, which have continuous lumen and appear like a ribbon and Thin Walled Fibres, which are those lying between the two classes. A relation was established between the percentage of these different classes of fibres and the Maturity Ratio (M) and is expressed as,

$$M = \frac{(N - D)}{200} + 0.7$$

Where N and D are the percentage of normal and dead fibres respectively.

Another parameter frequently referred to is the maturity coefficient Mc which is defined by the following expression:

$$Mc = \frac{M + 0.6H + 0.41}{100}$$

Where M, H and I are the percentage of Mature (normal), Half mature (thin walled) and Immature (dead) fibres respectively.

The above methods have proved to be fairly accurate in most instances and either can be regarded as a standard method of measuring maturity. However, it is quite tedious to observe 100 to 200 fibres under the microscope and look for their appearance to categorize them into N and D or M, H and I given in the above formulae.

Colour Measurement

Colour has been one of the primary factors of cotton quality for quite a long time. Apart from its influence over the aesthetic appeal of the product whether yarn or fabric many other fibre properties are also associated with colour. Moreover the natural colour of cotton highly influences the chemical processing behavior and dyeablity of the finished product.

Normally human eye defines colour in a relative measure (i.e) distinguishing different colours is easier than defining the actual / absolute colour. Colour perception highly varies from person to person and distinguishing colours by human eye with slightly varying intensity is highly unreliable as it depends on the amount of light reflected from the sample, the amount of redness or greenness of the sample and the amount of yellowness or blueness of the sample and several other multiple correlated factors. Emergence of electronic colorimeters has totally solved this problem.

Cotton colour falls in a range of white and yellowness with nil or insignificant amount of other colours. This simplifies the colour measurement process to just two parameters - the amount of reflected light called the reflectance, measured as Rd and the yellowness, measured in terms of +b value.

The Rd value expresses the whiteness of the light that is reflected by the cotton fibres. The +b value expresses the yellowness of the light that is reflected by the cotton fibres. The Rd and +b values are used in conjunction with each one to determine the instrument measured colour grade of the cotton sample.

The colour grade of the sample is determined in a two filter colorimeter. This objective method was developed by Nickerson and Hunter in the early 1940s to check the USDA cotton grade standards. Today this objective method is widely used and has replaced the subjective visual grade determined by the cotton classers.

Trash measurement

The amount of non-lint content in a cotton bale is a significant parameter considering the troubles involved in extracting them from the pure cotton fibres to get good quality yarn. The problem is more severe when the different cottons used for a mixing have varying degrees of trash. This is because, trashy cotton requires severe beating in blow room and cards, which may damage the fibres in the cleaner cotton mixed with it. Consequently, optimisation of the process sequence and selection of process parameters becomes extremely difficult.

A popular trash measuring device is the Shirley Analyser, which separated trash and foreign matter from lint by mechanical methods. The result is an expression of trash as a percentage of the combined weight of trash and lint of a sample. Stricter sliver quality requirements led to the gradual evolution of opening and cleaning to remove exclusively certain specific types of trash particles. This necessitated the segregation of the trash in the cotton sample by their size. Video analysis method projects the trash particles as it appears in the finished product. This method will be a better way of trash estimation rather than estimation by means of trash weight.

Moisture Measurement

Moisture measurement has become indispensable since the moisture content in the sample has got significant influence on other fibre properties like fibre length and strength. Moisture value measured by the instrument is the amount of water present in the sample. Moisture in the cotton varies with time, temperature and humidity to which the sample is exposed. Consistent moisture in the sample is necessary to obtain high volume test results with same level of accuracy and precision. The results are accurate and precise when the sample moisture is maintained in the range of 6.75% to 8.25%.

Moisture	Description
Below 4.5	Very low
4.5 to 6.75	Low
6.75 to 8.25	Normal/Std
8.25 to 10.00	High
10.00 and above	Very high

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Nutrient management in organic cotton

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Introduction

Organic farming has been aimed at conservation and optimized utilization of all natural resources for a reasonable profitability under the guiding factors of sustainability of the farm. In order to keep a certain doorstep of profit from the farms, all the farming practices have to be redesigned to undo the ill-effects that have crept in the current agricultural scenario while attempting to increase cotton production in the prevalent cropping systems. India has taken a quantum leap in organic cotton production in the recent past. India is the world leader in production of organic cotton contributing 61% of the global production of 175 thousand metric tonnes.

Organic nutrient management

For economical harvest, fertility of the soil has to be maintained. It can be managed primarily through applications of compost and decomposed livestock manure form sources like cattle-feeding operations, animal husbandry or production facilities including horses, poultry and dairy manures. Suitable crop rotations will have to be found which cause the least depleting effect on the soil. The cropping intensity might be also affected. Legume cover crops (grown without inorganic fertilizers) may be necessary to increase organic matter and soil nitrification. In this regard, inoculation may be necessary to achieve maximum nitrogen fixation. Fertilizers such as granular fish emulsion, humate or other blended organic fertilizers have to be added to the seed row and used for starter fertilization. Supplemental nutritional needs are supplied through foliar applications of seaweed, fish emulsion, humate, cytokinin or other approved organic fertilizers. Micronutrients have to be supplied through organic formulations so that the fiber quality is not affected. Biological enhancers are also permitted to be used for improving nutrient availability and their uptake. Green manuring can improve the fertility status of the soil in addition to its texture.

Application of organic fertilizers will have several advantages. Artificial fertilizers give rise to vigorous growth thus attracting insect pests. It is anticipated that the use of organic fertilizers on suitable hard varieties will result in lower pest infestation and abrupt availability of nitrogen from synthetic fertilizers causes rapid cell elongation, but weakens the cell structure causing more stress and less tolerance to penetration by pests. Thus, cotton grown using organic fertilizers will be less vulnerable to sucking insects. The following organic sources are commonly used for nutrient management in organic cotton production

Manures

Farmyard Manure

Farmyard manure refers to the decomposed mixture of dung and urine of the farm animals along with litter and left over material from roughages or fodder fed to the cattle. On an average well decomposed farmyard manure contains 0.5 % N, 0.2 % P_2O_5 and 0.5 % K_2O.

Compost

A mass of rotted organic matter made from waste is called compost. The compost made from farm waste like sugarcane trash, paddy straw, weeds and other plants and other waste is called farm compost. The average nutrient contents of farm compost is 0.5 % N, 0.15 % P_2O_5 and 0.5 % K_2O. The compost made from town refuses like night soil, street sweepings and dustbin refuse is called town compost. It contains 1.4 % N, 1.00 % P_2O_5 and 1.4 % K_2O.

Sheep and Goat Manure

The dropping of sheep and goats contain higher nutrients than farmyard manure and compost. On an average, the manure contains 3 % N, 1 % P_2O_5 and 2 % K_2O. It is applied to the field in two ways. The sweeping of sheep or goat sheds are placed in pits for decomposition and it is applied later to the field. The nutrients present in the urine are wasted in the method. The second method is sheep penning, wherein sheep and goats are allowed to stay overnight in the field and urine and fecal matter is added to the soil which is incorporated to a shallow depth by running blade harrow or cultivar.

Poultry Manure

The excreta of birds ferment very quickly. If left exposed, 50 per cent of its nitrogen is lost within 30 days. Poultry manure contains higher nitrogen and phosphorus compared to other bulky organic manures. The average nutrient content is 3.03 % N, 2.63 % P_2O_5 and 1.4 % K_2O.

Concentrated Organic Manures

Concentrated organic manures have higher nutrient content than bulky organic manure.

Oilcakes

After oil is extracted from oilseeds, the remaining solid portion is dried as cake which can be used as a manure. Both edible and non-edible oil-cakes can be used as manures. Nutrients present in oil-cakes, after mineralization, are made available to crops 7 to 10 days after application. Oil-cakes need to be well powdered before application for even distribution and quicker decomposition.

Other Concentrated Organic Manures

Blood-meal when dried and powdered can be used as a manure. The meat of dead animals is dried and converted into meat-meal which is a good source of nitrogen.

Table 1 Nutrient potential of different organic sources

	% of dry weight basis		
Source	**N**	**P_2O_5**	**P_2O_5**
FYM	0.5	0.2	0.5
Sheep & goat manures	3.0	1.0	2.0
Poultry manure	3.03	2.63	1.4
Sunnhemp	2.3	0.5	1.8
Daincha	3.5	0.6	1.2
Sesbania	2.21	0.53	2.21
Green weeds	0.8	0.3	0.2
Cotton seed cake (decoticated)	6.4	2.9	2.2
Ground cake	7.3	1.5	1.3

Crop residues

Substantial quantities of crop residues are produced in India every year. Major crops like Rice, Wheat Sorghum, Peal millet and Maize alone yield approximately 236 m.t straw per year. The nutrient potential of cereal straw/residue from five crops comes to 1.13 m.t N. 1.41 t + P_2O_5 and 3.54 m.t. K_2O. Crop residues can be recycled either by compositing or by way of mulch or direct incorporation in the soil.

Biofertilizers

Biofertilizer is one of natural and sustainable nutritional input. Mainly there are two types of biofertilizers which are used on mass scale. These are nitrogenous and phosphatic biofertilizers. The nitrogenous biofertilizer for cotton are *Azotobacter (A. chroococcum)* and *Azospirillum* (*A. braazilense*). These organisms with the help of nitrogenase enzyme fix atmospheric nitrogen known as biological nitrogen fixation. The phosphorus biofertilizers consist of several bacteria (*Bacillus megatherium*, *Pseudomonas striata*) and fungi (*Aspergillus awamori* and *Penicillium digitatum*). It has been estimated that 1 ton *Azotobacter/ Azospirillum* is equivalent to 40 ton Nitrogen @ 20 kg N fixed/year/ crop at 500/g dose and 1 tom PSM is equivalent to 24 ton Phosphorus (P_2O_5). The use of *Azotobacter* enhances the yield of cotton depending on variety and strain efficiency. Pandey and Kumar (1989) reported 7 to 28% increased yield in cotton with *Azotobacter* inoculation. It is reported that *Azospirillum* has positive response in increasing seed cotton yield and better dry matter production (Marappan and Narayanan, 1993). The application *Azospirillum* recorded 430 kg/ha has increased yield over the control. Further, the residual effect of *Azospirillum* was also found positive in terms of yield and population.

Legumes

A distinctive feature of most members of the fabaceae family is the capability to fix atmospheric N_2 biologically. The quantity of N_2 fixed by legumes ranges from 15 to 390 Kg per hectare per year depending on the species and prevailing biotic and abiotic conditions. In a trial with fast growing leguminous green manures *viz*., sunnhemp (Praharaj *et al*. 2004), lucerne, cowpea and clitoria in cotton under irrigated conditions, it revealed that growing and incorporation of all the green manures on 40 days after sowing increased the seed cotton yield (Subramanian *et al.* 1995 , Janardhanan 1989). Incorporation of sunnhemp as green manure increased 9.85 per cent seed cotton yield and resulted in maximum nutrient uptake than without green manuring (Baskar 2004). Several workers were also opined that growing of legumes, as an intercrop was beneficial to soil health and soil fertility (Basu 1992).

There was an increase in percentage of N fixation by cowpea intercrops. Both sole cowpea and the intercrops showed positive N balances of 92 kg/ha for sole cowpea and 1:1 intercrop, and 48 kg/ha for 2:1 intercrop. Yet, cowpea fixed N transferred to the companion cotton crop was very low with 1:1 intercrop (3.5 kg N/ha) and 2:1 intercrop (0.5 kg N/ha) (Rusinamhodzi *et al*. 2006).

The practice of green manuring through cover cropping is widely adopted in the subtropical regions where winter fallow is common. At Sirsa, Haryana, *Melilotus indica* was observed to be promising. Intercropping of legumes helped to reduce the 'N' requirements of cotton to the extent of 25 per cent. At Siruguppa, Karnataka, *in situ* green manuring of green gram (Praharaj *et al.* 2004) and cowpea was found to substitute 25 per cent of recommended dose of nitrogen.

Studies carried out under rainfed conditions with multicut legumes used as long year covers in chilli – *desi* cotton and hybrid cotton at Dharwad (Karnataka) revealed that chilli – *desi* cotton and *Stylosanthes hamata* as cover crop at 1:2 row proportion with a cutting interval of 45 days saved the recommended NPK nutrients (100:50:50 Kg N, P_2O_5 and K_2O per hectare) by about 25-50% in the subsequent year under continuous cropping (Anonymous, 2003). Cover cropping accounted to organic N addition to the extent of 144 Kg/ha and increased soil organic carbon from 0.58 to 0.73% (average of two years) leading to overall improvement in soil fertility.

In case of hybrid cotton *cv* DHH – 11, of the four legume covers (*viz*., lucerne, *Stylosanthes hamata*, *S. scabra* and C*entrocema sp*) screened, Lucerne was found most suitable at 1:2 row proportions in cotton (120cm x 60 cm) at 30 days cutting frequency. Cotton yield was increased by 13.62 per cent and the system reduced weed intensity to the extent of 91.0 and 59.8 % with Lucerne and *Stylosanthes hamata* respectively over sole cotton. Besides soil moisture conservation, cover cropping promised a fertilizer reduction to the extent of 25–50% in subsequent seasons (Kamble, 2003). Thus these studies reveal the possibility of sustained production and maintaining of soil fertility through intercropping of legumes in cotton.

Nutrient management in organic farming is solely depends on manures and legumes. Since availability and economical feasibility of using manure is less practicable, *in situ* green manuring with fodder cowpea and its burying at 40 days after sowing will ensure a steady N supply during the grand growth and flowering periods, when the N demand peaks up in the crop. It hastens microbial activity of soil, reduce the weed growth and enhance the natural enemy build up. This provides around 400-500 kg dry matter per hectare with 2.5 per cent N and contribute 10-12 Kg N/ha during squaring. Other benefits include smothering of weeds, controlling soil erosion and nurturing natural enemies of cotton pest (Rajendran *et al.* 2000). *In situ* incorporation of legumes in biomass production, cotton yield & nutrient status of soil is given in

Dense stand of Dhaincha (*Sesbania aculeate*), a legume, can be raised around cotton field at a width of 2 m; its lopping cut and spread between cotton rows at 65-70 DAS. Its fast decomposing leaves provide N during early boll development period and stalks act as temporary mulch, preventing soil moisture evaporation (Rajendran *et al*.,2000). Even cultivation of green manure crops also supplies optimal quantities of N that is ideal for cotton production (Saraswathy, 2003).

At Dharwad (Karnataka), three rows of a few leguminous crops were intercropped in normally spaced cotton (120 x 60 cm) and incorporated after 45 days. Horse gram, sun hemp and lucerne resulted in higher lint yield of cotton. At Coimbatore, cotton yield increased by 16–20%

with the application of 12–18 t/ha of green manure. Green manuring of intercropped cowpea/sun hemp/horse gram was also beneficial in cotton and reduced N requirements by 25%.

At Coimbatore, combined application of FYM @ 5 t/ha and sun hemp seeded @ 15 kg/ha in inter-rows as Green Manure (buried at 45 DAP) with or without cotton residues @ 2.5 t/ha produced highest seed cotton yield and was significantly higher over control and NPK (Praharaj and Rajendran 2007). Thus, application of cost effective organics available locally could play as an effective substitute for inorganic fertilization and sustaining the yield.

Multi tier system

Multi tier cropping system with legumes

Intercropping of short duration vegetables forming a multi-tier system especially during initial slow growth of cotton provides ample opportunity for efficient utilization of natural scarce resources. This may transform the cost intensive cotton based production system to a more remunerative and sustainable one, thereby making the system viable and adaptable as a profitable farming enterprise. The crop growth attributes, yield traits and yield of cotton were not significantly influenced by multi-tier cropping systems (Cotton +cluster bean + v. cowpea+ dolichos). Seed cotton yield in intercropping system was 28.8 q/ha, whereas sole cotton yield was 26.2 q/ha. Maximum LAI of 2.5 was realized at 45 DAS under cotton+cluster bean+vegetable cowpea+dolichos in comparison to the minimum of 0.5 in control (sole cotton). Pooled data on light interception value and weed smothering efficiency showed highest values of 83.7 and 63 per cent respectively with the above intercropping system. This system also showed highest relative production efficiency (RPE, 102.8%) , relative economic efficiency (REE, 134 %) , water use efficiency (WUE, 77.7 kg $ha^{-1}cm^{-1}$), water productivity (Rs 15.9 m^{-3} of water), higher nutrient uptake and availability (Sankaranarayanan et al 2010)

Crop rotation

crop rotation with ragi

Cotton, when grown successively in the same land without rotation was found to result in failures of cotton crop over a period of time. Even a fallow period intervening the two successive cotton crops was not found to be yield sustaining. The technology of growing of ragi (50 kg seed rate/ha) in off season and incorporation at 45 days old crop with *Trichoderma viridi* (10 packets mixed with 25 kg of farm yard manure) is found promising as compared with cotton - fallow system (Sankaranarayanan et al 2012)..Estimation of organic carbon found that *in situ* incorporation significantly improved the organic carbon content (0.62%) as compared to cotton – fallow system (0.54%). Higher nitrogen (106.5 kg/ha) and potassium (85.3 kg/ha) uptake were observed with ragi with *Trichoderma viridi* and the least one was estimated with cotton – fallow system (N (81.3 kg/ha) and K (69.3 kg/ha).The technique registered higher seed cotton yield of 1977 kg /ha, effective rainfall use efficiency of

5.5 kg /mm, partial factor productivity of 16.5 kg /kg (of nutrients) and economic nutrient use efficiency of 1.30 kg/ Rs (invested on nutrients). Cotton-fallow system registered significantly the least seed cotton yield of 1390 kg /ha, total rainfall use efficiency of 3.9 kg/mm, partial factor productivity of 11.6 kg /kg (of nutrients) and economic nutrient use efficiency of 0.90 kg/Rs (invested on nutrients) .

Comparative performance of organic, inorganic and integrated methods

The experiment was conducted at Central Institute for Cotton Research, Regional Station, Coimbatore with an aim to evaluate the performance of cotton produced organically in comparison with integrated (organic & inorganic) and inorganic method of cultivation. The component of organic method included organic nutrient management and need based spraying of organic pesticides like neem cake, neem oil, neemazol and growth promoter (Kamadhenu). The integrated method of cultivation included 50 per cent of nutrients from organic source and remaining 50 per cent from inorganic fertilizers and pest control was done by spraying of neem product and followed by pesticide alternatively. The inorganic cultivation was done by application of inorganic fertilizers and pest control by pesticides. LRA 5166 was the test variety in the experiment.

Boll weight(g), single plant yield and seed cotton yield were not differed significantly by the different methods of cultivation .The seed cotton yield harvested respectively with organic, integrated and inorganic methods were 10.39, 10.37 and 9.20q/ha . The significantly highest fibre strength (18.4g/tex) and maturity ratio (0.77) was registered with organic method of cultivation. Significant enhancement in the available nitrogen and phosphorus was observed in the organic method of cultivation followed by integrated and inorganic methods of cultivation.

Recommendation of National trial

Application of FYM @ 5 t/ha with green manure incorporation resulted higher seed cotton yield at Guntur and Coimbatore. FYM @ 5 t/ha combined with crop residues incorporation @ 2 t/ha recorded maximum yield at Guntur. Vermicompost @ 1.25 t /ha with *azospirillum*, phosphorus solublising bacteria and crop residues @ 5 t/ha incorporation was found promising at Indore. FYM @ 10 t/ha found promising at Nandyal and Akola. FYM @ 5 t/ha with vermicompost @ 1.25 t /ha was found effective at Khandwa and Rahuri. Studies were made at Dharwad to produce organic desi cotton under rainfed condition found that crop residue 5 t/ha or FYM @ 10 t/ha with crop residue 2.5 t/ha or FYM @ 10 t/ha with vermicompost @ 2.5 t/ha were promising. Bio inoculants viz., *Azospirillum and* phosphorus solublising bacteria were found effective at Hisar.

The most revealing aspect of the paper is that application of cost effective organics available locally could play as an effective substitute for inorganic fertilization in field crop nutrition and sustaining the yield under organic cotton production programme.

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Non-Chemical Methods of Weed Control in Cotton

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Weeds are the major deterrent to the development of more sustainable agricultural systems. Sustainable agriculture aims to incorporate the long term maintenance of natural resources and agricultural productivity with nominal adverse environmental impacts. It focuses on, optimal crop production with efficient management of internal resources while minimizing the use of external inputs, particularly fertilizers and pesticides. Sustainable agriculture encompasses a wide range of physical, cultural, biological, and chemical weed control techniques and seeks to minimize off farm inputs in all phases of crop production (Labrada, 2006). Contrary to this, presently there is heavy use of chemical toxicants in defence of crops. There is also renewed interest in the traditional but time-honoured husbandry practices and other non-chemical measures.

Global Pesticides Consumption Scenario:

World over, nearly 1/3 of food grains is lost to pest, disease and weeds. The current pest control technology heavily relies on pesticides. Today, herbicides outrank insecticides and fungicides both in terms of total sale and volume. Herbicides contribute 45% followed by Insecticides 33% and fungicides 22% of the total pesticides sale in the world. The use rate is particularly high in developed nations. This increased use of pesticides, however, has resulted in multiple problems. Because of their slow and low degradability, the environmental safety has been doubted. Apart from this, weed species are developing resistance to chemical toxicants. Since the first reported case of resistant weeds in 1970, as on today,393 biotypes were reported resistant to various herbicides.

Cotton associated weeds and Non chemical weed management

Weeds of cotton fields vary widely in their floral composition as well as density depending on the ecological situation and crop management. About 100 weed species were reported as associated with cotton. But, only a dozen of them are responsible for significant yield losses.

In view of the emergence of resistance weeds, developing nations started exploring other non chemical options for managing weeds such as tillage, stale seed bed and mechanical removal, competitive crops, intercropping, cover crops, biological control, solarization, mulching etc.

Non Chemical Methods of weed management

Tillage Practices:

a. Primary Tillage

Tillage influences the weed seed bank dynamics by physical mixing or by turning under the soil. Inversion tillage, such as mould board ploughing resulting in burial of a large proportion of seeds in the tillage layer compared to a non inversion tillage such as chisel (Ball and Miller,1990). Weed seed buried deep fail to emerge resulting in low weed intensity in subsequent season. Deep ploughing can also be effectively employed against perennial weeds like *Cynodon dactylon* provided the rhizomes after tilling are collected and destroyed.

b. Secondary Tillage

Apart from primary tillage, secondary tillage such as row cultivation, harrowing, etc., also influence weed seed bank and species composition (Ball,1992).

c. Stale Seed Bed

Weeds have several requirements for germination including moisture, oxygen, temperature and light. By disturbing soil, weed seeds are often stimulated to break dormancy. This is generally observed as a flush of new seedlings following tillage (Hosmani, 1993). After fine tilth, the seed beds were prepared and irrigated 2-3 weeks in advance of sowing, upon receiving the moisture, the weed seeds start germinating and the germinated weed seedlings could be scraped by harrowing or using hand hoe before taking up cotton sowing and this method could be used to exhaust the weed seed bank before sowing so that the weed intensity could be minimized during cotton growth (Nalayini *et al.*, 2012). If irrigation facility is not available, the stale seed bed could be prepared in advance of pre monsoon showers so that the weed seeds could be induced to germinate after the receipt of monsoon and the germinated weed seedlings could be removed mechanically before sowing.

d. Manual weeding and Inter cultivation

It is an efficient method though laborious, time consuming and expensive on account of scarcity of labour. If labour is available in plenty and weather condition permits to go for manual weed control, it is considered to be very efficient than chemical method as it not only removes weeds but associated benefits like better aeration to crop growth is ensured. Normally three weeding at 15-20 DAS, 35- 40 DAS and 65 -75 DAS are needed in cotton for efficient weed control. The first two weedings are done manually with hand hoe and combined with one inter cultivation using junior hoe with animal power followed by earthing up.

Inter cultivation using animal drawn Junior hoe

e. Cover crops

An allelopathic crop can potentially be used to control weeds by planting a variety with allelopathic qualities, either as a smother crop, in a rotational sequence, or when left as a residue or mulch, especially in low-till systems, to control subsequent weed growth. Alternatively, application of allelopathic compounds before, along with, or after synthetic herbicides could increase the overall effect of both materials, thereby reducing application rates of synthetic herbicides. Iqbal and Cheema (2008) obtained 62-92% purple nut sedge control from sorgaab (natural extract of sorghum) application in combination with reduced doses of herbicide. Similarly purple nutsedge dry weight was reduced by 75-88% than untreated control indicating that sorgaab with lower S. metolachlor doses was quite effective in suppressing purple nutsedge.

The area of cover and intercropping/biological interactions is the one with much potential for exploitation in organic cultivation. Generally there is greater diversity and abundance of soil organisms under cover crop than bare soil. The cooler and more humid environment under cover crops generally favours fungi and increased weed and weed seed decay have been reported. Increased predation of weed seeds by insects has also been reported under cover crops. In addition to weed suppression and control through allelopathy, as well as a mulching effect, cover crops provide substantial environmental benefits such as reduced erosion and water runoff (Price *et al*., 2006). Legume cover crops have the ability to fix atmospheric nitrogen.

f. Intercropping

Intercropping suppresses weeds better than sole cropping and thus provide an opportunity to utilize crops themselves as tools of weed management. Many short duration pulses like green gram, black gram, soybean etc., effectively smother weeds

Weed smothering by intercropped coriander in Cotton

g. Mulching

Covering the soil with plant parts like, leaves, stem, twigs etc., to control evaporation and to manage weeds is an age old practice. However, to avoid transportation cost and drudgery, live mulches are being recommended as a weed control tool. Now a days, plastic mulches (allowed for restricted use in organic farming) are available which can be used as a tool for managing weeds beside moisture conservation and enhancing the yield of Cotton based system. Extensive studies were undertaken at Central Institute for Cotton Research, Regional station at Coimbatore to standardize the thickness, colour of mulches, spreading technique, planting technique etc., The polyethylene mulch technology and its uses are summarized as under:

- Raised bed of the size 1.2-1.5 m width with 30 cm irrigation channel around the bed formed using tractor drawn broad bed furrow maker.
- The polyethylene sheets were spread over the bed and the ends were sealed with soil.
- Two rows of cotton/raised bed were grown.
- Complete control of evaporation.
- 40% water saving with conventional irrigation and upto 85 % water saving when combined with drip irrigation
- Prevents weed growth and no additional weed management is required
- Faster mineralization and higher nutrient mobilization.
- 1.83-1.90 fold enhancement in cotton yield and 1.90-2.10 fold in maize yield than normal planting.
- Pest and disease control.
- Silver colour mulch recorded lesser pest incidence.
- A new concept of Zero tilled rotation maize was introduced after the harvest of cotton without removing the poly mulch sheet.

Nalayini et al. (2009) reported complete control of weeds except *Cyperus rotundus* in cotton using polyethylene mulch of 30 micron thickness.

Weed free cotton under black polymulching

h. Solarization

The search for new and improved method of weed control is continuous one. In 1976, a non chemical method of weed control called soil solarization was developed by Katan and his associates in Israel. This is a method of solar heating of soil by covering it with transparent polyethylene (allowed for restricted use in organic farming) during summer. The interest on soil solarization as a tool of weed management is increasing due to its effect on weed seed reserve which is main source of weed problem. Direct killing of weed seed in the soil by lethal soil temperature built under the transparent polyethylene mulch is the main mechanism of reducing weed seed population and weed emergence. The winter and summer annuals are susceptible to soil solarization. The temperature enhancement in the solarized plot is 8-12^0 C higher than corresponding nonsolarized soils (Singh, 2009). The weed species that are highly sensitive to solarization are *Trianthema monogyna*, *Dactyloctenium aegyptium*, *Acrachne racemose*, *Digera arvensis*, *Echinochloa colona*, *Digitaria spp*,*Eleusine indica* and *Commelina spp* in rainy season and *Avena ludoviciana*, *Phalaris minor*, *Chenopodium album*, *Rumex dentanus*, *Fumaria indica*, *Solanum* spp, *Xanthium sp*, etc., of winter season.

i. Bioherbicides

Bioherbicides are biological control agents applied in similar ways of chemical herbicides to control weeds. The active ingredient in a bioherbicide is a living organisms. Most commonly the fungus and its spores or mycelia are used as bioherbicides and in this case called mycoherbicides.. Till date about 20 fungal pathogen have been identified as successful for various agroecosystem. Well known commercially available mycoherbicides are Devine and Collego in USA and Bio Mal in Canada. Cast is the trade name of commercially available mycoherbicide for Cotton. It is obtained from *Alternaria cassia*. Cast is the most promising for cotton, Soybean and Peanut crops in Florida.

At present, only the potential use of fungal pathogen as mycoherbicides has been studied in depth. Exploitation of bacteria seems promising and use of virus as biocontrol agents are problematic, since they are not host specific and require vector for their transmission (Walia, 2006).

j. Natural herbicides

Many allelochemicals have been identified from plant sources to be isolated and used as natural herbicides. These chemical classes include phenolic acids, coumarins, benzoquinones, terpenoids, glucosinates and tannins (Price, 2012). Other allelochemicals under thorough investigation for herbicidal properties include benzoxazinoids, heliannuols and benzoquinones which offer potential benefits for weed control in agricultural system (Maciaz *et al*.,2005; Vyvyan, 2002). The role of naturally derived compound or synthetically produced mimics for use as pesticides has been widely adopted particularly for insect control. Several plant derived compounds such as pyrethrum, neem and nicotine are important chemicals for insect control in many areas (Isman, 2006). Herbicidal potential of isolated plant extracts have been indicated by a number of researchers but to date, a few have been marketed. Synthetic compounds such as cinmethylin and mesotrione were developed based upon plant derived allelochemicals but release of subsequent plant based herbicides has lagged (Vyvyan, 2002). Slow production and release of herbicides developed in this manner are most likely attributed to limited understanding of the mode of action for many identified allelochemicals. To date, a number of allelochemicals have been isolated and investigated to develop natural herbicides with these compounds. Such natural herbicides could be utilized in organic production system.

Conclusion

Non-chemical weed control techniques have been researched and recommended in isolation of each other and physical, thermal and biological techniques have seldom been recommended together in synergistic ways. Integration of all the non chemical methods is the need of the hour for efficient weed management and at the same time without degrading the environment.

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Physiological Constraints and its Alleviation in Organic Cotton Cultivation

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In India, cotton has been grown traditionally as an organic crop until 1960s. With introduction of hybrid cotton and green revolution higher yield potential was achieved during 1980-90 which ultimately led to self sufficiency and export surplus.

Today, cotton production depends heavily on the use of inorganic fertilizers and pesticides to control various pest and diseases, consuming almost fifty percent of the total pesticide usage in agriculture for the cotton cultivation. Fertilizers and pesticides are the two major inputs of green revolution technology that required fossil fuels and energy associated directly with serious environmental and health problems. Keeping this in view, the Intergovernmental Panel on Climate Change (IPCC) revealed that agriculture as practiced today accounts for about one fifth of the anthropogenic greenhouse effect, producing about 50 per cent and 70 per cent, respectively of the overall anthropogenic methane and nitrogen oxides emissions. Modern agricultural farming practices, along with irrational use of chemical inputs over the past four decades have resulted not only in loss of natural habitat balance and soil health but have also caused many hazards like soil erosion, decreased groundwater level, soil salinization, pollution due to fertilizers and pesticides, genetic erosion, ill effects on environment, reduced food quality and increased the cost of cultivation, rendering the farmer poorer year by year (Ram, 2003).

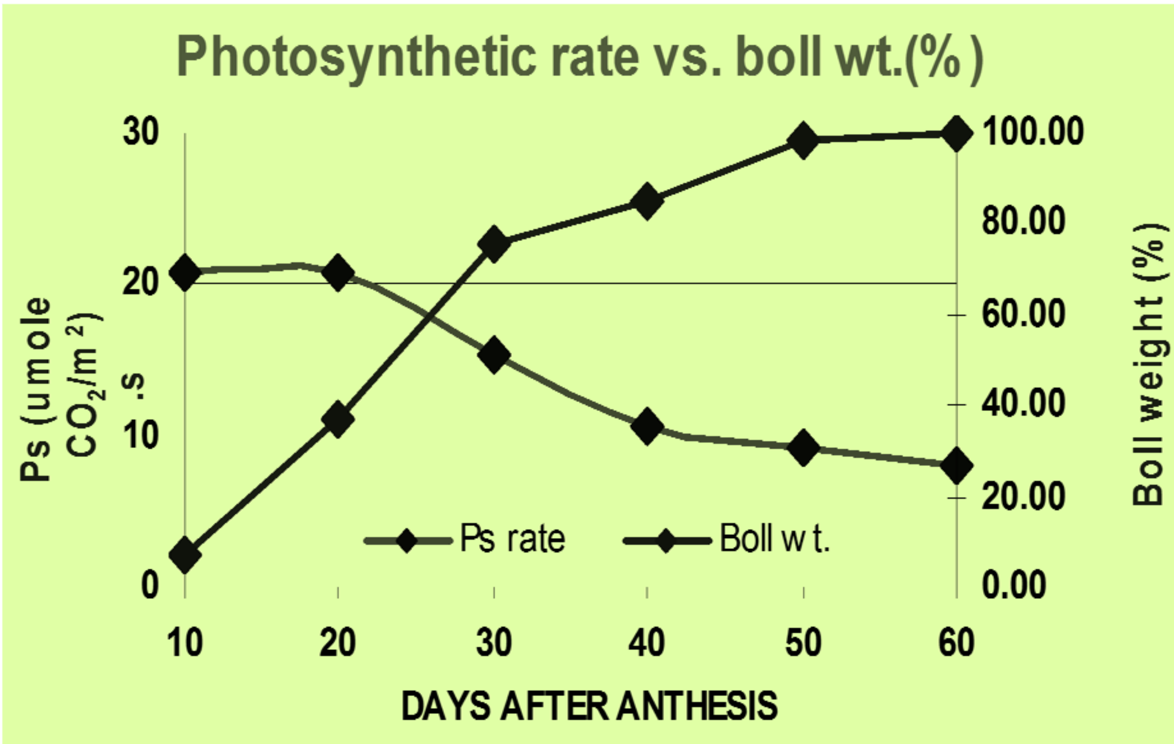
Moreover, only 25% of the pesticide spray is absorbed by the crop and 75% of the chemical either drifts in the air for contaminating the ecosystem as reported by the World Health Organization.

India is endowed with various types of naturally viable organic form of nutrients across different regions of the country which will be helpful in organic cultivation of crops (Butterworth *et al*., 2003; Reddy, 2010b). It has a strong traditional farming system with innovative farmers, vast dry lands and least use of chemicals. This has eventually initiated the need for organic cotton cultivation.

In general, cotton has tolerance to moisture stress with inbuilt adaptability and stability to perform well under all adverse conditions. In spite of this, cotton suffers from significant crop loss due to various physiological problems like leaf reddening, bud and boll shedding, rank vegetative growth and partitioning of assimilates (Perumal *et al*., 2000) particularly during the peak boll formation stage of the crop. It was also established that the photosynthetic rate of the subtending leaf started declining at a faster rate when the developing boll has just attained 60% of its final weight. Any method to sustain the photosynthetic rate for a longer period at this critical stage will be of immense help to increase the boll weight.

Nutritional problem is one among the major constraint in organic cotton production. Since chemical fertilizers cannot be used in organic cotton cultivation, large amount of Farm Yard Manure and other biomass formulation will be required to compensate (Chhonker, 2003). Other source of soil nitrogen could be from nitrogen fixing crops like soyabean, pulses and fodder crop. However, to compensate for the reduced nitrogen nutrition, foliar application of biofertilizers like Panchakavya (a formulation from cow's urine, ghee, milk, curd, jaggery fermented formulation) or and other derivatives from Fossil like Humic acid, fevulic acid may prove useful in sustaining the nutritional requirement particularly during the critical stages of the crop.

Fig. 1. Photosynthetic rate vs. boll weight (%)



Studies conducted at CICR, Regional station have shown that key metabolic activities can be triggered with foliar application of above formulation. Experiments revealed that Panchakavya at 2.0% and cow's urine at 1% were optimum for cotton without causing leaf scorching or other phytotoxic effects. Foliar application of Panchakavya increased photosynthetic rate significantly two days after application and declined by third day. The data shows that cow's urine and Panchakavya were comparable and followed the same trend (Fig.2). Similar pattern was followed in respect of Nitrate Reductase activity following the application of Panchakavya and cow's urine (Fig.3).

The chlorophyll content increased gradually upto 12 days and remained constant thereafter. The chlorophyll content increased from 3.2mg/g to 3.6mg/g by 8th day after treatment and thereafter the increase was only marginal and statistically non-significant. At harvest, Panchakavya treatment recorded 15% increase in yield (CICR, 2011). It appears that cow's urine or such formulations can be used once in 15 days to boost the metabolic function of the plant. Basic studies revealed the Panchakavya as foliar spray facilitated in opening of stomata during cloudy days thereby increasing the metabolic activity of the plant.

In another experiment, cotton stalk ash was dusted on whole plant. There was a significant increase in chlorophyll content. Specific leaf area was reduced while specific leaf weight increased significantly implying that organic ash plays an important role in plant metabolism. The results from these experiments reveal that organic booster can be used at regular interval to sustain the metabolic functions of the plant particularly during the critical boll formation phase of the cotton crop in organic cotton cultivation.

Fig. 2. Effect of organic bio fertilizers (Panchakavya) on Potosynthetic rate (micro mol CO_2 $m^{-2}s^{-1}$) in cotton

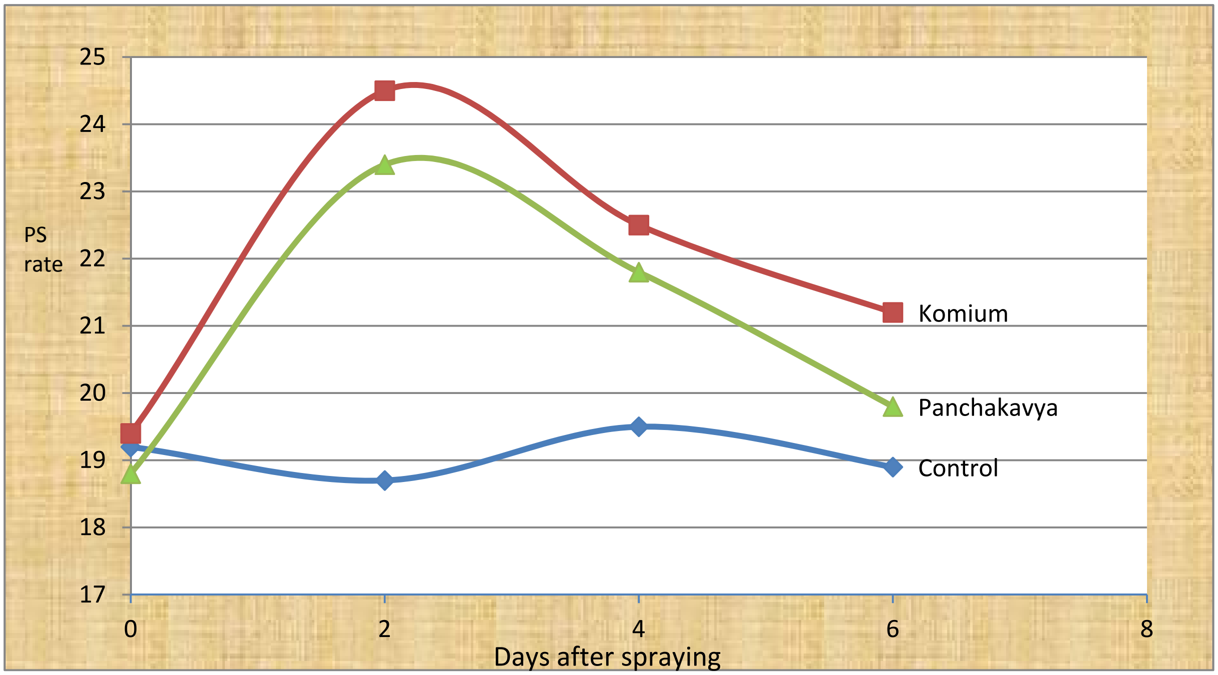


Fig. 3: Effect of organic bio fertilizers (Panchakavya) on Nitrate Reductase activity (micro mol NO_2 $g^{-2}hr^{-1}$) in cotton

Studies conducted at this station revealed that cotton plants responded favourably to elevated CO2 atmosphere upto 600 ppm. Elevated levels of CO_2 increased the plant height, number of nodes, intermodal distance, sympodia number, leaf number, leaf area and dry matter production and reduced the physiological negatives such as shedding of bud and bolls and delayed senescence of the leaves. The rate of transpiration and stomatal resistance was lowered with increase in the photosynthetic rate by 34-45% over the plants grown under ambient level. The density of stomata per unit area and opening of the aperture was comparatively lower than the control plants. Elevated CO_2 levels induced flowering earlier by 10 days.

The productivity of plant in terms of total number of bolls produced and weight of bolls increased significantly with an increase of 43 percent of seed cotton per plant. There was significant increase in fibre strength and maturity coefficient value of the fibre with fibre quality index value 0.63 as compared to 0.49 in control.

If CO_2 can be considered for organic cotton cultivation, practical ways of CO_2 input can be worked out for boosting yield. In fact, tonnes of CO_2 is let off into the atmosphere by big companies particularly the fertilizer factories as a bye product. If it can be bottled economically in large containers and let off in cotton growing area it may prove worthy. Incorporating freshly harvested green mulches produce lot of CO_2 (in the process of respiration for an extended period). This may be helpful in CO_2 enrichment for the standing crop and also conserve moisture in the soil.

Bud and Boll Shedding:

During Flowering, the crop suffers from insufficient light due to cloudy days with intermittent rainfall for several days in India. Consequently, the photosynthetic rate of the plant decreases and development of flowers and young bolls are retarded for want of proper nutrition. Besides, due to insufficient light, production of key hormones like auxin in the leaf is also limited inducing a hormonal imbalance in the plant. Under such circumstances, release of ethylene is triggered with formation of abscission layer in the fruiting zone leading to bud or boll shedding. Only one-third of the bolls are retained until harvest and the rest are shed at various intervals either due to insect-pest or due to environmental reasons like continuous drought or water logging, high humidity in the atmosphere and continuous rainfall affecting the pollination process etc. To alleviate the problem of bud and boll shedding the metabolic activity has to be maintained during this period by spraying organic stimulants like Panchakavya or cow's urine at regular intervals.

Leaf Reddening:

It is generally observed at 90 days after sowing, particularly when cotton is grown in red or laterite soils. The leaves initially start yellowing and finally the entire leaf turns red leaving the midrib and other vascular regions green. Deficiency or nutrients, high temperature during the day coupled with low temperature at night, water stress or water logging are some of the important factors attributed to leaf reddening. Generally, by 100th day, the cotton crop is heavily laden with developing bolls. During this phase, the demand for assimilate by the developing bolls is high and the plant is not in a position to meet the demands of the sink. Subsequently, the nitrogen concentration in the leaf is depleted below the critical level in the leaf and magnesium deficiency occur in the plant. Gradually the chlorophyll moiety of the cell is broken down and cells become disorganized with the formation of anthocyanin pigments giving a red appearance to the leaf. Organic spray with nitrogen content like Panchakavya and cow's urine could delay the process of leaf reddening to a great extent.

Excessive Vegetative Growth:

In cotton, it is established that only the lower two-third portion of the plant contributes to 90% of the yield and the upper one-third either remains immature or with poor quality fibre. Hence, detopping or trimming the top 10cm of the plant at 100-120 days after sowing will arrest the excessive vegetative growth and allow more penetration of light to the lower side of the plant. This also reduces lodging and facilitates easy control of pests and diseases, besides increasing boll retention and boll size

Nutritional and deficiency symptoms:

Nutritional problem and deficiency symptom in cotton depends on area of production which is directly or indirectly influenced by both soil and climate. With the introduction of new high yielding varieties and hybrids, rapid depletion of nutrients takes place in the soil thereby limiting cotton production. Hence, the cotton growers have increased the rate of application of the major plant nutrients in the form of concentrated fertilizers every year which have led to non availability of secondary and micronutrients in the soil. The amount of filler or carrier materials have been drastically reduced or eliminated in the fertilizers available nowadays, thereby reducing the secondary and micronutrients substantially. Application of farm yard manure which is a potent substitute for secondary and micronutrients besides enriching the soil health need to be given priority for organic cotton cultivation.

Control measures:

Integrated approach to reduce the physiological disorders in organic cultivation of cotton is possible through foliar application of Panchakavya 2.0% or 1% cow's urine or ash dusting and other derivatives from Fossil like Humic acid, fevulic acid. Also many organic bioformulation are available which has substantial amount of nutrients to overcome nutritional stress in organic cotton cultivation. The sprays should be given from the flowering phase of the crop at 10-15 days interval until harvest followed by detopping the upper 10cm of the plant at 100-120 days after sowing. The following precautions should also be taken without fail.

- The sprays should be done only in the evening hours.
- Ash should be prepared and left overnight to extract maximum nutrient and the extract should be filtered before spray.
- 0.1 percent teepol can be added as surfactant.
- Timely spray will help better performance of the crop.

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Panchagavya and other biological preparations

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India over several millenniums has been the treasure of biological wealth, intellectual knowledge and spiritual wisdom. Indian agriculture to some extent is much traditional and dates back to about 10,000 years. India with its traditional crop varieties and crop production technologies was able to feed its population and also export some produces to other continents. All the Indian villages had been self sufficient, self sustained and self reliant units. The development of modern agricultural production was achieved by creating large scale specialized farm production units, increased mechanization and use of chemical inputs.

Apart from the substantial increase in the crop yields through green revolution, these modern technologies have made the Indian farmers become poorer as they required heavy investment on costly external resources of uncertain future availability. These technologies with the principle of monoculture resulted in the rapid erosion of crop and livestock diversity, natural soil fertility and biological pest regulation, enhanced the soil erosion, salinization and environment problems reduced the nutrition once obtained from the wild food on farms, increased the need for expensive and poisonous chemical fertilizers and pesticides and finally made the farmers more dependent on markets and outside agencies resulting in an imbalanced growth between rural and urban areas. The impact was more on millions of small farmers and pastoralists.

In developing countries, the other alternatives *viz*., traditional methods have special advantages over modern agricultural techniques. The capital and technological skill requirements in the use of traditional technologies are generally low and their adoption often requires little restructure of the traditional societies. These traditional technologies are the indigenous knowledge. By adopting such indigenous knowledge, our ancestors did not face any problem of large scale pest out break or economic crisis unlike the today's farmers.

Indigenous Technical Knowledge

Indigenous practices in agriculture are organic in nature. They don't cause any damage to the air, water and soil, free from environmental pollution and safe to mankind. These practices are dynamic, region specific, depending upon soil type, rainfall, topography etc., and are often modified by the local farmers. Some such ITK based biological preparations used by organic crop growers are as follows;

- **Seed treatment using Cow's urine:** Dilute 500 ml of cow's urine in 2½ litres of water. Tie the seeds (paddy) to be sown in small bags and soak them in cow's urine extract for half an hour. Shade dry the seeds before sowing.
- **Seed treatment using Sweet flag extract:** Powder 500 g of sweet flag rhizome and dilute it in 2½ liters of water. This is the quantity required for treating seeds to be sown in one acre. Tie the seeds in small bags and soak them in this extract for half an hour. Dry the seeds in shade before sowing

- **Cotton seed treatment:** Cow dung is used for seed treatment of cotton
    - It helps in free flowing of seeds for sowing
    - Act as anti fungal and bacterial agent

  Sowing of cowpea along with cotton in clay soil facilitates germination of cotton by early germination and root penetration (it makes soil porus on root portion).

- **Cereals and pulses:** Before sowing, seeds of cereals and pulses are immersed in water mixed with cattle urine and powder of *Acorus calamus*. The seeds which are floating on the surface are thrown out since it indicates poor quality. Dried healthy seeds are used for sowing in drylands. It is believed that this treatment develops drought resistance in the plants. This practice is noticed in some villages adjoining Dindigul in Tamil Nadu.

Cow's milk and cow's urine on seed germination of Bhendi

Treatments	**Tap water**	**Cow's milk**				
		25%	**50%**	**75%**	**100%**	**control**
Germination %	98	98	92	84	92	98
Normal seedlings %	70	80	46	42	46	62
Abnormal seedlings %	28	18	46	42	46	36

Treatments	**Tap water**	**Cow's urine**								
		5%	**10%**	15%	20%	25%	50%	75%	100%	control
Germination%	82	92	**93**	86	77	80	61	48	27	94

Inference: Raw cow's milk shows good germination percentage and vigour at 25 % concentration. In case of cow's urine, the results show that there is no difference among the treatments.

Plant growth regulator

A. Amirthakaraisal

10% Amirthakaraisal should be sprayed before transplanting. Otherwise for 1 acre of land, 300-500 litres of Amirthakaraisal should be mixed with water and irrigated.

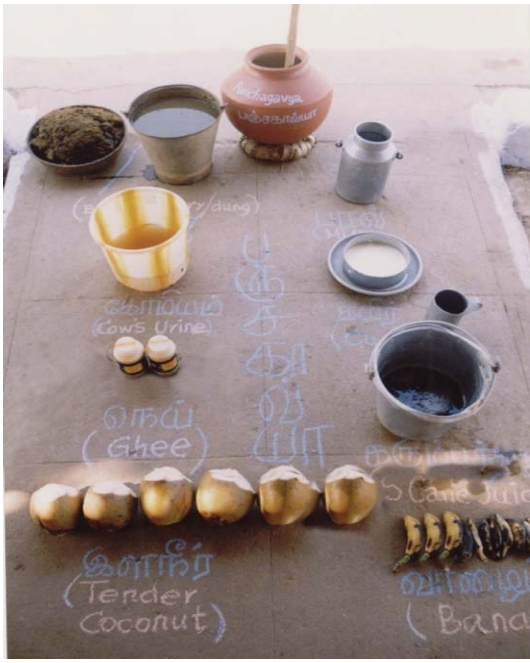
Preparation

a. Fresh cow dung - 10 kg
b. Cow's urine - 10 litres
c. Jaggery - 1 kg
d. Water - 100 litres

The above mentioned ingredients should be added in a cement tank and mixed well. The extract would be ready for use, the next day. It improves the soil fertility and gives good yield.

B. Panchakavya:

Panchakavya is a growth promoter produced with the combination of five products obtained from the cow along with few other bioproducts.



ITK 1

Panchagavya

Biogas slurry / cow dung (5 kg)
Cow's urine (3 litres),
Cow's milk (2 litres),
Cow's curd (2 litres)
Cow's clarified butter / ghee (1 litre)
Sugarcane juice (3 litres),
Tender coconut water (3 litres)
Riped banana (1 kg)

Method of Preparation

- Cow dung - 5 kg
- Cow's urine - 3 litres
- Ghee - 1 litre
- Cow's Milk - 2 litres
- Curd - 2 litres
- Tender coconut - 3 litres
- Cane juice or jaggery - 3 litres (or) 1kg Honey -½ kg

Add cow dung, cow's urine and ghee in a mud or cement tank of 30-litre capacity. Stir this well in morning and evening for a week. The methane gas gets released from this. To this mixture, add milk, curd, tender coconut, yellow plantain (ripe) and jaggery. After a week's time, this extract can be filtered and used. For coarse varieties, one spray of 3% panchakavya should be given during tillering and booting stage. For fine varieties, one spray of 3% panchakavya should be given during the booting stage.

C. Cow dung and green leaf mixture:

- 1-2 kg of cow dung - dilute it with 1 litre of water.
- 5 kg of Green leaves Neem, Pongam, Vitex, Lantana and Glyricidia (each equal quantity) in a mud pot and pour the diluted cow dung solution into the mudpot.

- Stir it daily at least once. After 16 days, add 200 g of Jaggery solution to the mixture and keep on stirring it.
- After 21 days, filter the solution and spray it on the vegetable gardens.
- It increases the yield and the vegetative growth too. For 1 litre of this mixture add 5 litres of water.

D. Spray of tender coconut and buttermilk extract: To maintain uniform flowering, one spray of 10% buttermilk extract or 3% tender coconut should be given during the bootling stage.

E. Plant based bio-pesticides

- Take 1 kg each of the following leaves - Tobacco, Mango, Neem and Adathoda. Take fresh turmeric ¼ kg and garlic 1 kg. Pound the leaves with water and make it into paste. Pound turmeric and garlic separately and mix all the ingredients together.
- Take the above mixture in a mud-pot filled with 3 litres of water and boil it for 15 minutes. Filter the extract and spray it on the crops.
- This effectively controls sucking pests, termites, root grubs etc. For 1 acre, 2 litres of extract is required for spraying.

F. Chilli garlic extract for bollworms:

Take 3 kg of green chillies and remove the pedicel. Grind this thoroughly into paste and soak it in 10 litres of water overnight. Take ½ kg Garlic, grind thoroughly soak it over night in 10 litres of water. Prepare 2 extracts separately and add khadi soap solution at the rate of 5 ml/litre. Filter the solution and add 80 litres of water and spray immediately. This controls all the bollworms and the army worms.

- Pungent taste of spray after fermentation of garlic and green chillies may not be liked by larva. Same condition may deteriorate the adult settling behavior (Anand Prakash *et al*., 2008).

G. Neem kernel powder for sucking pests:

Take 5kg of Neem Kernel powder and put in a cloth pouch. Soak this pouch in 3-4 litres of water overnight. Next day, sqeeze the pouch and filter the extract. To this, add 100 litres of water and 100 ml of Khadi soap solution. Spray this solution during morning or evening hours. This controls all the bollworms, leaf folders, defoliators and sucking pests.

- Azadirachtin content of neem leaves is known scientifically for pest control.

H. Cow dung extract to control grasshoppers

2 kgs of cow dung, 1 litre of cow's urine and 1 kg of neem cake was taken in a large vessel; To this, 20 litres of water was added. The mouth of the vessel was tied securely with a cloth and left as such. After 3 days, the cloth was removed and the extract was stirred well. Then, it was allowed to settle and the supernatant was used. To every litre of the extract, 100 ml of khadi soap solution and 9 litres of water was added and sprayed with a sprayer.

I. Neem seed kernel extract

3–5 kg of Neem kernel is required for an acre. Remove the outer seed coat and use only the kernel. If the seeds are fresh, 3 kg of kernel is sufficient. If the seeds are old, 5 kg is required.

Pound the kernel gently and place it in an earthen pot. To this, add 10 litres of water. Tie the mouth of the pot securely with a cloth. Leave it as such for 3 days. Filter it after 3 days. On filtering 6-7 litres of extract can be obtained. The shelf life of this is about one month. 500–1000 ml of this extract is used for one sprayer tank (a tank of 10 litre capacity). 500-1000ml of extract should be diluted with 9½ or 9 litres of water before spraying. Khadi soap solution @ 10 ml/litre (100 ml/tank) should be added to help the extract stick well to the leaf surface. The concentration of the extract can be increased or decreased depending on the intensity of the pest attack. It controls sap feeders and all kinds of larvae.

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Organic cotton production

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Only six countries produced organic cotton in 1992-93. Today, 23 countries cultivate organic cotton in 461000 ha involving approximately 275300 farmers. The global organic cotton production skyrocketed from 6500 tonnes in 2000-01 to 151079 tonnes in 2009-10. The value of global organic cotton market jumped from under US $300 million in 2002 to over $4.3 billion in 2009. Demand for organic cotton has been also increasing in the past years with 50 companies having significant organic cotton programmes and around 1500 brands and retailers taking a share in the international organic cotton market. The leading organic cotton consuming brands include C&A (Belgium), Nike (USA), Walmart (USA), Williams-Sonoma (USA), H&M (Sweden) and Anvil Knitwear (USA).

India's contribution to global organic cotton production was only about 10-15% until 2002. Today, it is the world leader contributing 68% of the global production (Table 1). The production increased from 2231 tonnes in 2003-04 to 19412 tonnes in 2009-10, but later decreased to **102452**. tonnes in 2010-11.

Table 1 Organic cotton production (2010-11)

Country	Production (tonnes)	Percentage
India	**102452**	**67.8**
Syria	16000	10.6
China	12385	8.20
Turkey	9613	6.36
Egypt	907	0.60
Mali	846	0.56
Uganda	336	0.22
Burkina Faso	252	0.17
Benin	229	0.15
Senegal	14	0.01
World	151079	100

Source: Textile exchange 2012

Today about 117000 farmers are engaged in organic cotton production in India. As per the estimates of Organic Exchange, there are 204 organic cotton projects. The major projects include, Ecofarms, Mahima, Rajeco, Bio-Re, Vasudha, Chetana, Agrocell, Zameen and Arvind

Mills. India is a classical case of coexistence of GM and organic cotton production systems, either by accident or by compulsion.

Principles and practices of organic cotton production

Today, organic cotton encompasses, a range of farming systems including those known as biological, low-input, organic, regenerative, green eco-friendly or sustainable. These alternate systems involve crop-rotation, bio-control based Integrated Pest Management (IPM), conservation tillage, crop diversification including cover cropping and green-manuring, genetic improvement, disease/pest prevention and soil health amelioration. Sound organic cotton production packages are developed based on the following principles:

- Promotion of natural processes –nutrient cycling, N fixation, cotton plant-pest-natural energy integration of these complementary processes into the production system.
- Avoiding the use of those off-farm inputs that are a potential threat to the soil and aquatic environment, as well as health of the farmers, farm animals and consumers.
- Allowing the biological /genetic potential of the variety/hybrid to be expressed fully with minimum interventions.
- Improved farm management to conserve soil, water, energy, and biological diversity and on –farm agro-wastes.

A fertile soil is a pre-requisite for organic cotton production. The organic C content of soil should be improved and stabilized at such a level that the anticipated production levels do not decline it. Scientific soil organic matter management is the cornerstone of successful organic cotton cultivation. Crop rotation with legumes, cover cropping,green manuring, compost (vermicompost, Trichocompost, FYM), bio-mulches, biofertilizers which are generally employed to improve fertility status. No single organic material releases N in perfect synchrony to the plant demand- giving slow initial mineralization or immobilization followed by a large rapid mineralization. High quality materials (high N, low lignin, low polyphenol/tannin) release N in a pattern similar to mineral fertilizers and a large proportion of N is available in advance to the main period of cotton plants uptake (70-130 days). Poor quality organic materials (high lignin or high polyphenol/tannin or low N) has a time lag and then releases N at a slow rate and is not followed by a period of rapid mineralization. Thus mixing of low quality and high quantity organic inputs generally results in a mineralization pattern equal to the weighted average of the patterns of the two separate materials.Soil amendments and naturally mined, permitted (or regulated) chemicals can be employed to supplement native fertility.

Weed management is primarily achieved through preventive techniques (selection of perennial weed-free field, clean seeds, completely decomposed compost/ FYM, crop rotation, cover cropping, mulching, smother crop etc.) and soil solarization. Cultural, mechanical and manual methods can be employed to supplement preventive measures. Pest management is achieved through the selection of pest tolerant varieties, conservation of natural enemies and inundative releases of predators/parasites pathogens and supplemented with botanicals.

Since promotion on locally available on-farm resources is implied in all organic production systems, no clear-cut package of practices can be prescribed. Farmers use their innovative power and experience and in consultation with any certifying agency decide on the inputs used.

Research on organic cotton production at CICR:

Scientists of Central Institute for Cotton Research (CICR), Nagpur began research in 1988 for identifying optimal practices for conserving soil moisture and also for improving organic matter content of marginal soils (Tarhalkar and Venugopalan, 1995, Venugopalan and Tarhalkar 2003) where there was a possibility for promoting organic cotton cultivation. Results indicated that the improvement in cotton yield with organic supplements was gradual and additive indicating their cumulative effect in improving productivity. Further, long term use of organic supplements, besides stabilizing rainfed cotton yields on marginal soils can also reduce the dependence on fertilizer N. Simultaneously associated technologies for farm waste recycling including cotton stalks using *Trichoderma viride*, the cellulolytic fungus were perfected. Technology for vermi-composting was also perfected. Around the same time CICR also developed alternate techniques of pest suppression in cotton through the use of bio-agents, pesticides of botanical origin etc. A bio-control based alternate pest management system was standardized. The results of these studies were translated into a package for organic cotton cultivation (Table 2) and the package was later evaluated on large plots in a long term trial at CICR farm. Comparative evaluation of the soil properties at the end of 8 years indicated a significant build up of organic C, macro and micronutrients in the surface as well as sub-surface layers under organic system (Blaise et al2004).

Table 2: Organic farming technology developed at CICR

Organic Soil Amendments	**Bio-control based Pest Management**
• Farmyard manure/compost @ 5tonnes/ ha • *In situ* green manure with fodder cowpea incorporated between cotton rows at 40 days after sowing (DAS) • Spreading loppings from *sesbania* spp. obtained from 2-m dense rows after 10 cotton rows, in the entire field. • Vermicompost or tricho-compost @ 1-2 tonnes/ha • Seed inoculation of azotobacter @ 500g commercial product/ seed required per ha • Composting farm-waste including cotton-stalks with *Trichoderma*.	• Release of C*hrysoperla* sp, @500/ ha 20-25 DAS and again at 35 DAS • Release of *Trichogramma chilonis* @ 5 cards /ha at 45 DAS • Spray of H-NPV @ 250 larval equivalent/ ha (2 x 10^8 PIBS/larval equivalent) for young bollworms of *Helicoverpa armigera* • De-topping after 80 days of growth • Alternative spray with B. t. formulation@1.5litre/ha • Application of neem- based formulations-neem oil @1.0 litre/ha and 1% neem-seed-kernel extract • Release of *Bracon hebator* to kill bollworm larvae • Bird perches @4/ha

(Source-Kairon et al 1998)

Sustainability of organic cotton production system:

To promote a sustainable organic cotton production system the dimensions of sustainability need to be closely introspected. A sustainable system must satisfy human needs, improve the quality of environment, efficiently utilize non-renewable inputs, promote natural cycles and controls and be economically viable. While organic cotton production is a virtuous endeavor and is sustainable from ecological angle the economic viability is not clearly established at all scales. Organic cotton is a business venture and business is not driven by virtues alone but rather by profitability. Cotton production in the rainfed regions of Indian and Africa are a gamble against the vagaries of rainfall and organic farmers consider organic cotton production as a risk reduction endeavor. Majority of the organic cotton farmers have poor economic access to inputs and have small or marginal land holdings. In many developing countries of India, Africa and Latin America, organic cotton is being produced small holder farmers. The system should be made more productive in order to offer better return to these farmers in view of the marginal amounts of premium being offered and need to use land, water and other inputs more efficiently. Often the use of sub-optimal inputs involves a trade off with productivity. Ensuring economic security to farmers is a real challenge to the sustainability of organic cotton production system.

For a sustainable organic cotton production system to flourish, a synergistic relationship must exist between the internal farm (soil/land, water, labour, other inputs etc.) and the external environment (market forces, prices, regulatory and support services, policies, infrastructure etc.). Quality soil and soil fertility maintenance are the essential foundation for a sustainable and productive organic farming because they enhance yields and improve the use efficiency of water and other inputs. For improving the external environment the trade relationship between farmers and other stakeholders must be improved, purchase guarantees may be provided to improve farmers security, Internal control systems and certification should be more transparent and pre-financing may be encouraged to enhance input use (*Eyhorn*, 2007*)*.

To safeguard the farmer's interest in organic cotton any developing country must focus on:-

1. Providing good quality biotic and abiotic stress tolerant non- GM seeds to organic growers on time and training farmers to produce seeds of cotton varieties on their own.
2. Improving organic farming techniques to raise yields and reduce yield gaps *vis-à-vis* Bt cotton. This is only possible through science based nutrient, water and pest management techniques. Assuring good quality organic inputs is equally important.
3. Increasing farm diversification through combinations (rotations and intercrops) of crops with strong consumer demand (domestic and international) in the organic sector.
4. Providing value addition opportunities at producer level and sustaining the interest of farmers, particularly the younger generation.
5. Bringing transparency and faith in certifying systems and promoting farmer own certifying systems to reduce certification costs. There is a need to bring in traceability into the system.
6. Creating consumer awareness and explore domestic market demand through novel initiatives.
7. Formulating and enforcing guidelines for minimizing contamination from GM cotton.

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Pest management – bio agents, parasites, predators and host plant resistance

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In conventional farming, cotton is considered a crop that is highly sensitive to pest attack. Large quantities of synthetic pesticides are sprayed to keep them under control. Organic farming methods combine scientific knowledge of ecology and modern technology with traditional farming practices based on naturally occurring biological processes. Organic farmers are restricted by regulations to use only natural pesticides and fertilizers. The principal methods of organic farming include crop rotation, green manures and compost, biological pest control, and mechanical cultivation. These measures use the natural environment to enhance agricultural productivity: Legumes are planted to fix nitrogen into the soil, natural insect predators are encouraged, crops are rotated to confuse pests and renew soil, and natural materials such as potassium bicarbonate and mulches are used to control pests. Organic farmers are careful in their selection of plant breeds, and organic researchers produce hardier plants through plant breeding rather than genetic engineering. In intensive farming systems, organic agriculture decreases yield; the range depends on the intensity of external input used before conversion

Global View

The popularity of organic farming is gradually increasing and now organic agriculture is practiced in almost all countries of the world, and its share of agricultural land and farms is growing. As per a recent report of International Federation of Organic Agriculture Movements (IFOAM) the total organically managed area is more than 24 million hectares world-wide. Organic farming is practiced in approximately 130 countries of the world and the area under organic management is continually growing. Although production of organic crops is increasing across globe, sales are concentrated in the industrialized parts of the world. In addition, the area of certified wild harvested plants is at least a further 10.7 million hectares, according to various certification bodies. The market for organic products is growing, not only in Europe and North America but also in many other countries. The demand for organic food is steadily increasing both in developed and developing countries, with annual average growth rate of 20-25%.

Indian Status

Only 35% of India’s total cultivable area is covered with fertilizers where irrigation facilities are available and in the remaining 65% of arable land, which is mainly rain-fed, negligible amount of fertilizers are being used. Farmers in these areas often use organic manure as a source of nutrients that are readily available either in their own farm or in their locality. The north- eastern region of India provides considerable scope and opportunity for organic farming due to least utilization of chemical inputs. It is estimated that 18 million hectare of such land is available in the North-East, which can be exploited for organic production. With the sizable acreage under naturally organic/default organic cultivation, India has tremendous potential to grow crops organically and emerge as a major supplier of organic products in the world organic market.

Benefits of Organic Farming

- ✓ Organic farming is beneficial for both the humans and the nature. Some of the known benefits of organic farming are:
- ✓ In organic farming, no fertilizers and pesticides are used, hence, no harmful synthetic chemicals released into the environment.
- ✓ Organic farming improves productivity of land by healing it with natural fertilizers.
- ✓ Organic farms provide support to the diverse ecosystem by producing safe and healthy environment for humans, plants, insects and animals as well.
- ✓ Organic farming is highly beneficial for soil health. Due to the practices such as crop rotations, inter-cropping, symbiotic associations, cover crops and minimum tillage, the soil erosion is decreased, which minimizes nutrient losses and boosts soil productivity.
- ✓ The beneficial living organisms used in organic farming also help to improve the soil health.
- ✓ It helps to promote sustainability by establishing an ecological balance. If organic farming techniques are used for long time, the farms tend to conserve energy and protect the environment by maintaining ecological harmony.
- ✓ When calculated either per unit area or per unit of yield, organic farms use less energy and produce less waste.
- ✓ Organic farming reduces groundwater pollution as no synthetic fertilizers and pesticides are used in this method.
- ✓ Organic farming also helps to reduce the greenhouse effect and global warming because it has the ability to impound carbon in the soil.
- ✓ In organic farming method, same crop is not cultivated in the particular farm repeatedly, which encourages the build-up of diseases and pests that plague that particular crop.
- ✓ Organic farming tends to tolerate some pest populations while taking a longer-term approach.

1. Host Plant Resistance (HPR)

Use of host plant resistance, the key component of IPM system, has greater potential than any other tactic for pest suppression. It is compatible with other insect control methods. Host plant resistance enhances the efficacy of insecticides. Generally, a lower concentration of insecticides is needed to control insects feeding on resistant varieties than the susceptible one.

1.1. Selection of varieties and time of planting

In organic cotton cultivation selection of resistant / tolerant varieties and time of planting will help the plants to tolerate the pest attack or will help to escape from harmful insect pests. Synchronized sowing in a contiguous block at proper time will reduce aggravating pest problem particularly stem weevil and pink bollworm.

1.2 Jassids

The number of hairs on veins or lamina, length of hair, and angle of insertion of hairs are important criteria to decide the resistance to the leaf hopper. Besides pubescence, thick leaves, thin mid veins of leaves, long and high density of trichomes, high number of gossypol glands and less number of stomata per unit area were also responsible for reducing the population of leaf hopper nymphs. LRA 5166, Surabhi, Sumangala, B 100, Badnawar 1, SRT 1 and NHY 12 are tolerant to sucking pests. The variety Gujarat 67 has served as a donor for jassid resistance.

1.3 Whitefly

The traits most concerning resistance to whitefly are leaf shape, pubescence and open canopy, low leaf hair density and leaf shapes i.e., okra and super okra. Chemical characteristics of cotton leaf especially pH values are reported to affect feeding preference. Supriya, Kanchana and LPS 141 are resistant to whitefly.

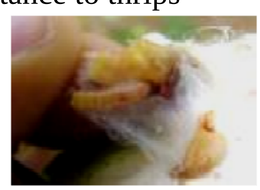
1.4 Aphids

Red plant colour is reported to confer resistance to aphids. Gossypol is reported to be highly toxic to aphids and the stem tip stiffness imparts resistance to aphids

1.5 Thrips

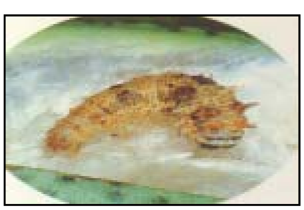
Genotypes with dense pubsence on very young leaves was reported to impart resistance to thrips. A thick epidermis on the underside of the leaf was associated with resistance to thrips

1.6 Pink bollworm



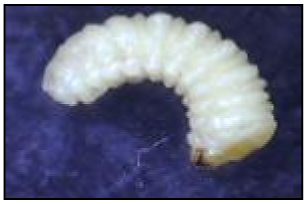
Traits used to impart resistance are nectarilessness glabrous, okra leaf, reduced bract size, bolls with rough rugate surface and earliness. The combination of the nectarilessness and glabrous traits imparts substantial resistance to Pink bollworm. Earliness in association with short bracts and small rough surfaced bolls could be factors related to resistance to Pink bollworm

1.7 Other bollworms



Bollworms prefer the pubescence cotton when compared with glabrous cotton, the glaobrosity disrupt the egg laying habits of bollworms. Nectariless cotton and the frego bract coupled with glabrous traits exhibited good field resistance to the bollworms. Utilization of the escape mechanism offered by short season cultivars is a cost effective method for cropping with late season pests. The variety Abhadita is tolerant to bollworms.

1.8 Stem weevil



Certain morphological and biochemical characters of cotton plant are found to be responsible for reducing the incidence of stem weevil through reduced egg laying, arrested larval growth and restricted movement of larvae. Influence of biochemical components *viz*., IAA, tannins, total phenols and total amino acids in the resistance mechanism of cotton plants to Stem Weevil.

1.9 Resistant cotton cultivars developed in India

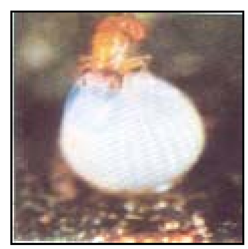
- Kanchana - A glabrous cultivar possessing resistance to whitefly
- Abhadita - early maturing and moderately glabrous culture
- Genotypes *viz*., BRS 3, BRS 5, BRS 22 and BRS 23 possessing bollworm resistant characteristics like okra leaf, frego bract, tough boll rind, moderately glabrous and early maturing, lower level of biochemical nutrients (reducing sugar and protein) and higher level of secondary metabolites (condensed tannin, phenols and gossypol) in squares

2. Biocontrol agents

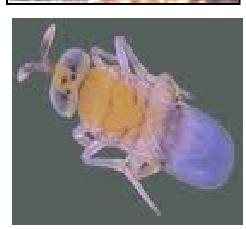
The whole concept of IPM system relies on encouraging the build up of natural enemies of pests in the cotton ecosystem. A true IPM system should conserve beneficial insects and utilize them as a basic component in the management of key pests. Inundative release of parasitoids and predators has been reported to play an important role in suppressing the bollworms particularly the pesticide resistant, *H. armigera*.

2.1 Parasitoids:

- ✓ The parasitized eggs of *Corcyra* glued on a paper strip (Trichocard) has to be pinned on the lower surface of the cotton leaves.



- ✓ The emerging *Trichogramma* adult searches and parasitize the eggs of bollworms and perpetuate to some extent in nature to suppress the bollworm population.
- ✓ Two to three releases of egg parasitoid *Trichogramma chilonis* @ 1.5 lakh / ha during peak egg laying time of *Helicoverpa* and other bollworms will help to reduce the bollworms infestation significantly



- ✓ *Acerophagus papaya:* Papaya mealy bug is parasitized by a parasite, *Acerophagus papayae*, a tiny small wasp with yellowish body, transparent wings, grey/bluish eyes with three black triangular spots in the forehead. This parasitoid is specific to papaya mealy bug and affects only second stage after hatching from the egg.

- ✓ *Aenasius bambawalei*: An important parasitoid of mealy bug *Phenacoccus solenopsis* on cotton with a parasitization ranging from 5-100% across the country with an average of 30%.

2.2. Predators

- ✓ Release of *Chrysoperla* sp. @ 500-1000 / ha according to the intensity of jassid damage at 20 – 25 days of crop growth will reduce the jassid population.

- ✓ *Cryptolaemus montrouzieri*, *Brumus suturalis*, *Coccinella septumpunctata*, *Cheilomenes sexmacualta* feeding on mealy bugs and other sucking pests.




Spalgis epius: The adult is a small butterfly with a dark brown wings and grey underside with dark striations. The larvae of the butterfly are short, slug like and covered with white waxy coating. The larvae were found feeding voraciously on the egg masses, nymphs and adults of the mealy bugs. Pupae are relatively short, attached at the anal extremity and secured by a small pad of silk with no free movement in the abdominal segments. The pupa exhibited a characteristic appearance like the face of a monkey, hence the butterfly is named as "Ape fly

2.3. Insect pathogen

- ✓ Entomopathogenic viruses are widely prevalent in nature and are specific to pests hence NPV effective against *H. armigera*.
- ✓ Spraying of HaNPV @ 500 LE / ha will be targeted against young larvae of *H. armigera*. This can be repeated every 15 days for retaining good inoculum of the pathogen.
- ✓ This may be alternated with commercial Bt formulations @ 1.5 l / ha.
- ✓ Foliar spray of *Verticillium lecanii* or *Beauveria bassiana*, *Metarhizium anisopliae* @ 10 g / l of water is effective during high humid months (Oct- Dec.) in reducing the population of mealy bug

3. Crop diversity

3.1 Trap cropping: Small plantings of a susceptible or preferred crop may be established near a major crop to act as a trap. After the pest has been attracted to the crop, the pest is destroyed or the infested plant parts or plants may be removed. Growing castor surrounding the cotton will attract *Spodoptera* for egg laying. Pigeon pea and marigold mask the odour emanated from volatile compounds of cotton and offer less preference for oviposition by *Helicoverpa armigera* in cotton.

3.2 Intercropping

Intercropping with black gram and chillies will reduce the intensity of bollworms infestations in cotton

3.3 Bund cropping:

Cowpea planted as a bund crop encourages predators such as coccinellids, syrphids etc. which will keep the sucking pests under check.

3.4 Ecofeast crop:

Maize grown along the border provides food and shelter for number of lepidopteran parasites and thus serve as ecofeast crop. It also act as barrier crop for sucking pests. Cowpea is also a good ecofeast crop encouraging multiplication of coccinellids and other predators

4.Agronomic practices:

4.1. Crop rotation:

Crop rotation minimizes pest infestation to a greater extent. Cotton should be followed body crops which are not favourable or less preferred by cotton pests. Cotton followed by cereals like maize / sorghum reduce the incidence of whitefly, bollworms, soil born insects and nematodes.

4.2. Cotton free period:

Cotton should be grown only once in a year. Cotton double cropping and ratooning should be avoided to prevent carry over population as they provide continuous food supply for the pest multiplication.

4.3. Proper spacing:

Close spacing and dense canopy will encourage the faster rate of multiplication of bollworms and other pests of cotton. Hence optimum spacing and density are to be maintained.

4.4. Nutrition management:

Proper nutrition management should be followed, apply fertilizer based on soil testing. Avoid high dose of nitrogenous fertilizers to prevent excessive vegetative growth (luxuriant green growth) which otherwise attracts more pests.

4.5. Field sanitation:

Summer ploughing to destroy the resting stages of insects in the soil should be followed. Removal of alternate weed hosts which harbour cotton pests. Collection and destruction of affected squares, dried flowers and grown up larvae will significantly reduce the pest intensity and buildup.

4.6. Harvesting

Timely harvest and stalk destruction are among the most effective method managing pink bollworm. These practices reduce the habitat and food available to the pink bollworm, *Helicoverpa* and *Spodoptera*. Efforts should be made to destroy the green bolls, cracked bolls and other plant debris left at the end of the season.

5. Mechanical measures

5.1. Topping:

- ✓ Removal of terminals of cotton crop ("Topping") at 80-90 days of growth should be practiced to reduce *Helicoverpa* oviposition and also to encourage sympodial branching which bears more fruiting bodies.

5.2. Bird perches:

- ✓ Erection of bird perches (@ 10 / ha) encourages the predation by carnivorous birds.

5.3. Hand picking of larvae:

- ✓ Hand picking of grown up larvae should be done in the morning during 6.30 to 10.0 AM and in the evening hours. It will eliminate the possible development of insecticide resistance. It also helps to minimize heavy build up of future population.

6. Scouting, monitoring and crop protection decisions:

Regular field scouting / monitoring is a vital component of any pest management programme because it is the only way by which reliable information can be obtained to decide if and when pest reaches the economic threshold level. It will determine the pest density and damage levels through the use of standardized sampling techniques. Control measures should be taken only when pest population reaches a level beyond which economic losses occur.

7. Pheromone monitoring:

A sex pheromone released by one sex only triggers off a series of behavioral patterns in the other sex of the species. It is referred to as sex attractant or sex lure. Generally females produce sex pheromone which attracts males. The sex pheromones are specific in their biological activity, the males responding only to a specific pheromone of the female of the same species. Pheromone traps @ 5 / ha help to identify the brood emergence for synchronization of insecticide application and release of parasites.

8. Botanical pesticides:

- ✓ In view of sustainable approach and to utilize the biodiversity, it is essential to promote use of locally available neem seed as a botanical pesticide.
- ✓ Neem products exert repellent, anti-feedant, ovicidal and hormonal action on insects.
- ✓ Neem products such as Neem Seed Kernel Extract (NSKE 5 %) or neem oil 0.5 % are effective in suppressing the cotton bollworm and whitefly without affecting the natural balance.
- ✓ Neem acts as anti-feedant and oviposition deterrent. So NSKE 5 % and neem oil 0.5 % can be used to prevent the egg laying of *Helicoverpa* and also to deter the adult moths from cotton.

Method of neem seed kernel extract preparation

- Five kg of dried and cleaned neem seed should be taken a day before spraying, powder the seeds by grinding.
- Soak the powder overnight in 10 liters of water. Stir with wooden plank in the morning till solutions become milky white.
- Filter through double layer of muslin cloth and make volume to 100 litre by adding fresh water. Add 200 g of detergent soap and spray the solution to cover upper as well as lower foliar portions of the crop.

9. Chemical methods using organic insecticides:

- ✓ **Spinosad 45SC** - 200ml/ha: It is a bacterial waste product produced by fermentation on a nutrient food source used by the one particular bacterium (*Saccharopolyspora spinosa).*
- ✓ **Emamectin benzoate 5SG – (Proclaim)** – 220 g/ha: It is a larvicide of the avermectin family which acts as a GABA agonist resulting in the blocking of nerve signals. This product is extracted from soil actinomycete, *Streptomyces avermitilis* Burg. It is both stomach and contact insecticide.

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Pest and nematode management using biopesticides

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Biopesticides or biological pesticides based on pathogenic microorganisms specific to a target pest offer an ecologically sound and effective solution to pest problems. They pose less threat to the environment and to human health. The most commonly used biopesticides are living organisms, which are pathogenic for the pest of interest. The potential benefits to agriculture and public health programmes through the use of biopesticides are considerable. The interest in biopesticides is based on the advantages associated with such products which are:

- inherently less harmful and less environmental load,
- designed to affect only one specific pest or, in some cases, a few target organisms,
- often effective in very small quantities and often decompose quickly, thereby resulting in lower exposures and largely avoiding the pollution problems and
- when used as a component of Integrated Pest Management (IPM) programs, biopesticides can contribute greatly.

Besides, biopesticides have the following benefits:

Factors	**Benefits of biopesticides**
Cost effectiveness	Costlier but reduced number of applications
Persistence and residual effect	Low, mostly biodegradable and self perpetuating
Knockdown effect	Delayed
Handling and Bulkiness	Bulky: Carrier based Easy:Liquid formulation
Pest resurgence	Less
Resistence	Less prone
Effect on beneficial flora	Less harmful on beneficial pests
Target specificity	Mostly host specific
Waiting time	Almost nil
Nature of control	Preventive
Shelf life	Less

Biopesticides fall into three major categories:

1. **Microbial pesticides** contain a microorganism (bacterium, fungus, virus, protozoan or alga) as the active ingredient. Microbial pesticides can control many different kinds of pests, although each separate active ingredient is relatively specific for its target pest[s].Eg.: Bacillus thuringiensis, or Bt. Certain other microbial pesticides act by out-competing pest organisms.
2. **Plant-pesticides** are pesticidal substances that plants produce.
3. **Biochemical pesticides** are naturally occurring substances that control pests by non-toxic mechanisms.

Biochemical pesticides include substances that interfere with growth or mating, such as plant growth regulators, or substances that repel or attract pests, such as pheromones. The growth of total world production of biopesticides is rising and therefore demands and use is also increasing. In India, biopesticide consumption has shown its increased use over the time.

Use of entomopathogenic fungi for the management of insect pests of cotton

Studies on the natural occurrence of native entomopathogenic fungi carried out at CICR revealed the isolation and identification off 45 isolates from mealy bug from cotton ecosystem. Molecular characterization and virulent isolates *viz*., *Lecanicillium attenuatum* (JQ327150.1), *Lecanicillium araneicola* (JN255572.1), *Lecanicillium fusisporum* (JF427909.1), *Metarhizium anisopliae (*ARSEF-9612) (JN712743.1), *Metarhizium anisopliae* (ARSEF-9613) (JQ062986.1) and *Cordyceps confragosa* (JN982329.1) have been carried out and submitted to Gene Bank.

***Lecanicillium lecanii* R. Zare & W. Gams**

Lecanicillium lecanii infected mealy bug

Kingdom: Fungi
Phylum: Ascomycota (Anamorphic Hypocreales)
Subdivision: Pezizomycotina
Class: Sordariomycetes
Order: Hypocreales
Family: Clavicipitaceae
Genus: *Lecanicillium*
Species: *lecanii*

This fungus was first described in 1861 and has a worldwide distribution.

Insects are infected when they come into contact with the sticky fungal spores which then grow and invade the body, thus the internal organs are consumed, leading to their death. Recent studies conducted at Australia revealed that the entomopathogen, *L. lecanii* readily colonised two potential hosts (Cotton aphid and as an endophyte in cotton) and transferred between the hosts under experimental conditions which helps to reduce the impact of pests in cotton .

BIOLOGICAL ACTIVITY:

Mode of action: *Lecanicillium lecanii* acts through degradation of the insects' cuticle, with subsequent fungal growth in the haemolymph and tissues of insects. Re-sporulation from dead insects leads to infection of epidemic proportions.

Biology: *Lecanicillium lecanii* is an entomopathogenic fungus that exerts its effect by invasion of the living insect. Spores adhere to the cuticle of the insect and, under ideal conditions, germinate, producing a germ tube that penetrates the host insect' s cuticle by physical and enzymic processes and subsequently invades the haemolymph and other tissues. The fungal hyphae develop in the insect and sporulation takes place through the living and dead insect' s cuticle, providing infectious spores to continue the epidemic.

Mass production: *L.lecanii* can be mass multiplied on large quantities on sterile undefined medium.

Target pests: Mealy bug, Aphid and Whitefly in cotton.

Formulation: Talc and oil based formulations.

Compatibility : *L. lecanii* is compatible with neem and other biopesticide products.

Important Features:

- *L. lecanii* does not create resistance, resurgence and residue problems
- *L. lecanii* does not affect the natural enemies (parasites and predators) of the pest and thus offers a long-lasting pest control.
- *L. lecanii* forms a good molecule for use in an IPM programme.

Environmental impact and non target toxicity: *Lecanicillium lecanii* is widespread in Nature and is not pathogenic to non-target species. It has not shown adverse effects on the environment.

Metarhizium anisopliae

Metarhizium anisopliae infected mealy bug

Kingdom: Fungi
Phylum: Ascomycota (Anamorphic Hypocreales)
Subdivision: Pezizomycotina
Class: Sordariomycetes
Order: Hypocreales
Family: Clavicipitaceae
Genus: ***Metarhizium***
Species**: *anisopliae***

The first use of *M. anisopliae* as a microbial agent against insects was in 1879, when Elie Metchnikoff used it in experimental tests to control the wheat grain beetle, *Anisoplia austriaca*. It has been reported to infect approximately 200 species of insects and other arthropods.

BIOLOGICAL ACTIVITY:

Mode of action: The spores of this fungus when come in contact with the cuticle of susceptible insects, they germinate and grow directly through the cuticle to the inner body of their host. The fungus proliferates throughout the insect's body and draining the insect of nutrients, eventually killing it.

Biology: *M. anisopliae* generally enters insects through spiracles and pores in the sense organs. Once inside the insect, the fungus produces a lateral extension of hyphae, which eventually proliferate and consume the internal contents of the insect. Hyphal growth continues until the insect is filled with mycelia. When the internal contents have been consumed, the fungus breaks through the cuticle and sporulates, which makes the insect appear "fuzzy." *M. anisopliae* can release spores (conidia) under low humidity conditions (<50%). In addition, *M. anisopliae* can obtain nutrition from the lipids on the cuticle. The fungus can also produce secondary metabolites, such as destruxin, which have insecticidal properties on moth and fly larvae.

Mass production : The successful mass culture of *M. anisopliae* and development of methods of mass-producing infective spores has led to the commercial development of this fungus as a microbial insecticide. *M. anisopliae* is grown on a large scale in semi-solid fermentation and the spores can then be formulated as a dust. The fungal spores can also be grown on sterilized sorghum / rice grains in plastic bags for small-scale production. *M. anisopliae* is sensitive to temperature extremes; spore viability decreases as storage temperatures increase and virulence decreases at low temperatures.

Target pests: Mealy bug, Aphid and Whitefly in cotton.

Formulation: Talc and oil based formulations.

Important Features:

- *M. anisopliae* was not known to create resistance, resurgence and residue problems
- *M. anisopliae* does not affect the natural enemies (parasites and predatorsin cotton ecosystem) of the pest and thus offers a long-lasting pest control.
- *M. anisopliae* is found to be compatible with most of the entomopathogenic fungi and insecticides and can be used as a component in an IPM programme.

Environmental impact and non target toxicity: *M. anisopliae* does not appear to infect humans or other animals and is considered safe as an insecticide.

Fusarium pallidoroseum

Kingdom: Fungi Phylum: Ascomycota (Anamorphic Hypocreales) Subdivision: Pezizomycotina Class: Sordariomycetes Order: Hypocreales Family: Nectriaceae Genus: *Fusarium* Species**:** *pallidoroseum*

BIOLOGICAL ACTIVITY:

Mode of action: The spores of this fungus when come in contact with the cuticle of susceptible insects, they germinate and grow directly through the cuticle to the inner body of their host. The fungus proliferates throughout the insect's body and draining the insect of nutrients, eventually killing it.

Target pests: Mealy bug, Aphid and Whitefly in cotton.

Formulation: Talc based formulations.

Environmental impact and non target toxicity: *F. pllidoroseum* does not appear to infect humans or other animals and is considered safe as an insecticide.

Cladosporium cladosporioides

 ***Cladosporium cladosporioides* infected mealy bug (Complete removal of waxy coating due to the secretion of lipase)**	Kingdom: Fungi Phylum: Ascomycota (Anamorphic Hypocreales) Class: Dothideomycetes Order: Capnodiales Family: Mycosphaerellaceae Genus: *Cladosporium* Species: *cladosporioides*

Natural occurrence of *Cladosporium cladosporioides* was reported from various insect pests like aphids , mites, mealy bug, and white flies.

BIOLOGICAL ACTIVITY:

Mode of action: when the spores comes in contact with the target insect, attaches to the cuticle (outer skin) and then germinates and grows directly through spiracle into the inner body of the host. By taking nutrients from the insect it further proliferates and colonizes the entire insect and thus drains the insect of nutrients. The infected insects eventually die.

This fungus is known to secrete lipase which removes the waxy coating present on the mealy bug thereby helps in the penetration of other entomopathogenic fungi and insecticides.

Target pests: Mealy bug and Aphid in cotton.

Formulation: Talc based formulations.

Nematodes of cotton

Two important nematodes infecting cotton in India are Root – knot nematode, *Meloidogyne incognita* and Reniform nematode, *Rotylenchulus reniformis.*

Biological control of nematodes in cotton by using nematode antagonists *viz*., nematophagous fungi like *Paecilomyces lilacinus* and bacterium like *Pseudomonas flourescens* is gaining important in the era of organic cotton cultivation.

Mode of Action

The spore of this fungus acts by infecting, parasitizing and killing eggs, juveniles and young adults of most of the phytophagous nematodes. When the spore of comes in contact with different stages of the nematode, it germinates, grow and proliferate throughout the body of nematode and paralyze it. Eventually it leads to the death of the nematode.

Method of Application

Soil Application: 10 Litres or 12 kg / hectare to be mixed with organic fertilizer / well decomposed organic manure / field soil / any other locally available agriculturally usable organic carrier and applied around the rhizosphere uniformly for existing crops in the field.

The frequency of applications also depends on the Nematode population. In the case of high nematode population pressures multiple applications are recommended.

Compatibility

P. lilacinus compatible with neem and other bio-pesticide products.

Pseudomonas fluorescens

Pseudomonas fluorescens as non-pathogenic saprophytes that colonize soil, water and plant surface environments. *Pseudomonas fluorescens* suppress plant diseases by production of number of secondary metabolites including antibiotics, siderophores and hydrogen cyanide. This microbe has the unique ability to enter the plant vascular system, reach the various parts of the plant system and act as a systemic bio-control agent against various nematode diseases. Competitive exclusion of pathogens as the result of rapid colonization of the rhizosphere by *Pseudomonas fluorescens* may also be an important factor in nematode control.

Dosage

Soil application: 5 kg /ha along with any organic fertilizer (without pathogenic contaminants).
Seed treatment: @ 4-5 gm per kg of seeds as per standard wet treatment.

Formulation : Talc

The stress on organic farming and on residue free commodities would certainly warrant increased adoption of biopesticides by the farmers. Increased adoption further depends on-

1. Concrete evidences of efficacy of biopesticides in controlling crop damage and the resultant increase in crop yield,
2. Availability of high quality products at affordable prices,
3. Strengthening of supply chain management in order to increase the usage of biopesticides. In this regard, an efficient delivery system from the place of production (factory) to place of utilization (farm) of biopesticides is quite essential.

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Management of Cotton Diseases

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Since the cotton crop remains in the field for nearly six months or more, it is affected by various diseases caused by organisms such as fungi, bacteria and viruses that grow on and with in the plant tissues. These organisms often cause stunting of the plants, defoliation, reduced vigour and yield and sometimes death. Seeds and seedlings attacked by these pathogens often die, while older plants usually survive but perform poorly. Diseases can also be caused by environmental changes such as too much or too little of water or fertilizer, air pollutants and chemical injury such as those caused by herbicides and their residues. The diseases caused due to environmental changes become localized and do not spread where as diseases caused by organisms are contagious and can be spread by wind, water or vectors. We discuss here some of the important diseases which affect the quality cotton caused and their management through an integrated approach**.**

Integrated Disease Management (IDM) in Cotton:

A plant disease occurs when there is an interaction between a plant host, a pathogen and the environment. Most plants are immune or completely resistant to almost all pathogens. However, some pathogens have developed the ability to overcome the natural resistance mechanisms of particular hosts. The host is then regarded as being susceptible to that pathogen and the pathogen is described as being virulent. When the environmental conditions are conducive, the virulent pathogen attacks the susceptible host and the disease develops. Therefore, any disease management strategy should focus on the host, the pathogen and/or the environment. Hence, an 'Integrated Disease Management' involves the selection and application of a harmonious range of control strategies that minimize losses and maximize returns.

The following are some of the steps/strategies that can be adopted for the management of the diseases.

1. **Exclusion of the pathogen:** Preventing the pathogen from entering particular area where the disease is not prevalent. Seed is the basic input for any commercial venture of agriculture. It is needless to mention the importance of good quality seed. Seed treatment with bio-fungicides is advised for elimination of disease of seed and seedlings.

2. **Elimination of alternate hosts -** the pathogens of *Verticillium* and *Fusarium* wilts, Alternaria leaf spot, bacterial blight and leaf curl virus have many alternate hosts and they should be completely eliminated in cotton fields for buildup of the disease causing organisms. The pathogens of *Verticillium* and *Fusarium* wilts, *Alternaria* leaf spot, bacterial blight and leaf curl virus have many weed/alternate hosts (e.g. Alternate hosts like Bhendi for CLCuV (and its vector) should not be grown between March to June to avoid build up of virus and vector).

3**. Use of resistant varieties/cultivars -** Use of disease resistant lines/hybrids is the basic tenet of any IDM programme.

4**. Cultural practices:** There are number ways to incorporate cultural practices in the integrated disease control system. As a general approach, the farmers should take steps to sow only high quality seed materials. Seeds having above 80% germination will have vigorous growth and thereby they do not suffer from infection due to soil borne organisms.

a. **Crop rotation** is an important aspect which should be taken into consideration especially for diseases like *Verticillium* wilt. Converting *Verticillium* infested fields to paddy crop will greatly reduce the microsclerotial population in the soil. It is also known that growing *Chrysanthemum* will be inhibitory to *Verticillium*. Elimination of alternate hosts/weed hosts.

b. **Crop residue management / field sanitation** is another essential part of disease management. The main source for the development and spread of the foliar diseases is only through previous year's crop residues in the fields. Destruction of the infected crop residue/debris by deep ploughing in summer may help to kill the resting pathogenic structures.

c. **Time of sowing** is also important. If the farmers are able to take up sowing during warmer temperature (i.e. at 65°F temperature and above) there will be better germination and seedling growth.

d. **Irrigation management** is an important factor involved in disease control. Timing and duration of irrigations should satisfy crop water requirement without allowing for excess water. Over watering will favour soil borne pathogen, where as use of over-head sprinkler systems will favour diseases affecting leaves. Accordingly the farmers should manage crops.

e. **Judicious application of organic manures** - Excessive application certain organic manures like poultry manure will induce high vegetative growth. Dense crop growth is conducive for foliar diseases like *Alternaria* leaf spot and grey mildew.

Incorporation of composts into the soil is a fundamental cultural practice in organic cotton production. Composts increase the soil fertility and also help in disease management. The disease control is possibly effected through

- Successful competition for nutrients by beneficial microorganisms
- Antibiotic production by beneficial microorganisms
- Successful predation against pathogens by beneficial microorganisms and
- Activation of disease resistant genes in plants by composts.

One can enrich composts through incorporation of beneficial microorganisms like *Trichoderma* spp. which compete against pathogens and antagonize them. It is well known that application of town compost having high percentage of cellulolytic materials will increase the population of *Trichoderma* spp. there by helping in the management of *Verticillium* wilt as well as root rot due to *Rhizoctonia solani*.

f. **Biological control -** Biological control agents (BCAs) like plant associated microbial genera such as PGPR – Plant Growth Promoting Rhizobacteria (*Bacillus*, *Burkholderia*, *Pseudomonas*, *Streptomyces*) and the fungal genera *Trichoderma* are more useful. Whether acting by competitive exclusion, biochemical antagonism or induction of host defenses, BCAs must be well adopted for survival and functional activity in the phytosphere.

BCAs are cheaper than synthetic toxins by 50 per cent. They are eco-friendly, have a high cost benefit ratio and do not induce resistance in plant pathogens. The advantages of biological agents as seed treatment are i) the saprophytic nutritional status of biocontrol agents makes large-scale production feasibility, ii) small amounts of inoculum requirement, iii) simple methods of application, iv) independent of energy sources for survival, v) systemic spread along the surface of the developing root system vi) antagonistic activity on the root surface during the economically important phase of early root infection by the pathogens, vii) ecofriendly and viii) no resistance development in the pathogen. Their versatile metabolism, fast growth, active movement and ability to readily colonize the root surface make the BCAs like rhizobacteria suitable for seed bacterization. In addition some of the PGPR have the added advantage of plant growth promoting activities also.


Bacterial leaf blight

a. Dark green, watersoaked lesions on the lower side of the leaf (angular leafspot).
b. Dark green, watersoaked lesions along the veins (vein blight).


Alternaria leaf spot

a. Brown, grey brown or tan lesions with dark or purple margins and with concentric zones.
b. Circular dry brown lesions on the bolls.

Grey mildew

A whitish frosty / powdery growth on the under surface of the infected leaf

Cotton leaf curl virus

Upward curling of leaves and leaf laminar out growth (enations) on the underside of the leaf

Fusarium wilt

Yellowing and browning of leaves leading death of individual plants.

Verticillium wilt

Yellowing between the veins and around the leaf margins (leaf mottle)

Demonstration of Promising Cotton Technologies at CICR Regional Station, Coimbatore

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Twelve promising cotton technologies are demonstrated at the Institutes' demonstration plot during the year 2011-12 and 2012-13 which encompassed Varietal Demonstration of Suraj, Surabhi, MCU 5 VT and LRA 5166 and Enhancement of Planting Quality of Seed and Stand Establishment of Cotton through Sequential Pelleting under Crop Improvement , Polyethylene Mulch Technology, Multitier Cropping System, Split Application of Nitrogen in ELS Cotton and High Density Planting system, Manipulation of Morpho-Frame through Foliar Application of Ethrel in Cotton and CICR Nutrient Consortia for boosting yield in cotton under Crop Production and Integrated pest Management (IPM) under Crop Protection.

CROP IMPROVEMENT

VARIETAL DEMONSTRATION OF SURAJ VARIETY

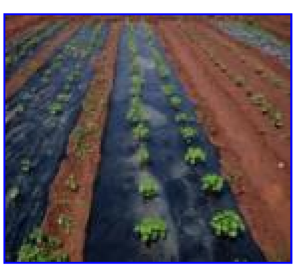
SURAJ (CCH 510-4), a new long staple *G. hirsutum* variety has been released and notified for commercial cultivation under irrigated conditions in the southern cotton growing States of Tamil Nadu, Karnataka and Andhra Pradesh. The variety has been developed and released from the Central Institute for Cotton Research, Regional Station, Coimbatore.

Salient characteristics

- ✓ Mean seed cotton yield of 1799 kg/ha as against 1548 kg/ha of the zonal check Surabhi.
- ✓ Ginning Out Turn of 36 per cent.
- ✓ Fibre length of 30 to 32 mm – belongs to Long Staple category,
- ✓ Ideal micronaire of 4.0 and fibre strength of 23g/tex – likely to find favour with the textile industry,
- ✓ Tolerant to jassids and needs minimum plant protection agaivst sucking pests
- ✓ Possibility of spinning upto 60s count yarn.

CROP PRODUCTION

POLY MULCHING – A NEW CULTIVATION TOOL FOR COTTON



A new cultivation technique of growing cotton under polyethylene mulching in raised bed was standardized for cotton crop. The raised beds were formed as 13.5 m X 1.2 m with 30cm irrigation channel on all around the beds for irrigation. The cotton crop was grown @ 2 rows/bed at 60 cm apart. Fifty per cent N and K fertilizers and full P fertilizers were given as basal before spreading the polythene sheets. The remaining N and K were given as two equal splits at flowering and boll development stages. In the irrigation channel, green gram was grown as intercrop. After the picking of seed cotton, the cotton stalks were cut below the cotyledon leaves and without disturbing the layout, fresh punchings were made at 5 cm away from cotton rows and sowing of zero tilled rotation maize was attempted.

- ✓ Complete control of evaporation.
- ✓ 40% water saving.
- ✓ Prevents weed growth
- ✓ No additional weed management is needed
- ✓ Faster mineralization and higher nutrient mobilization.
- ✓ Upto 2.4 fold enhancement on seed cotton yield than normal planting.
- ✓ Pest and disease control.
- ✓ The green gram intercrop grown between two mulched raised beds of cotton yielded 490 kg of dried grains/ha.
- ✓ Among different colours evaluated silver colour out yielded other colours both for cotton and maize.
- ✓ The water use efficiency due to polyfilm ranged from 42.7 to 53..6 kg/ha as compared to 23.1 kg/ha under no mulching.

Zero tilled rotation maize a new concept

A new technique of sowing zero tilled rotation maize after cotton harvest was standardized.

- ✓ Cotton stalks were cut leaving 5-10cm above ground level.
- ✓ The cut ends of the stalk were sprayed with glyphosate at 0.5% concentration to prevent re growth of cotton.
- ✓ Maize crop, CORH M 4 was sown 5 cm away from cotton hole.
- ✓ 2.87 fold enhancement in maize grain yield than normal planting.

HIGH DENSITY PLANTING SYSTEM IN COTTON

It is pertinent to mention that many leading cotton producing countries, tested, proved and adopted high density planting system as tool to achieve higher productivity. The principle is that under high density planting system plant does not grow to form many long sympodial and monopodial branches peculiar to many situations and in absence of long branches, the cotton plant may produce more reproductive parts. The experiment on high density planting system revealed that (45 x 15 cm, 1,48,148 plant/ha) non Bt genotypes (Anjali, CCH 7245 and C1412) had resulted in higher seed cotton yield of 3 to 8 q/ha edge over to RCH 2 Bt (planted at 90 x 60 cm); in contrast to 20-25 per cent extra yield in Bt hybrids, reported in many places over non Bt under conventional planting methods. The economic assessment found that high density planting of Anjali had arrived with the 22.5 and 24.5 per cent of higher gross return (Rs1,19,538/ha) and net return (Rs78,286/ha) respectively in comparison to RCH 2 Bt. Further add that improvement of available suitable genotypes by conventionally and transgenically, and developing suitable agronomic packages , make high density planting system is one of the futuristic technology and play a role in enhancing production from the current level of 300 to 1000 lakh bales of lint as reported in vision 2030.

MANIPULATION OF MORPHO-FRAME THROUGH FOLIAR APPLICATION OF ETHREL IN COTTON

Cotton is basically perennial plant. Through intensive breeding programmes cultivars that are photoinsensitive with determinate growth habit were developed. But in unfavourable conditions, the plant reverts back to its perennial nature. Being photo insensitive, the plant enters into the reproductive phase by 40 to 45 days after sowing. Insufficient morpho frame may not support the squares produced and leads to heavy shedding of fruiting parts. Mechanical removal of squares till 60 to 80 days enhanced flowering in the later stages and had a positive effect on the yield realised. The drawback observed is that the plant will be wasting its photosynthates on producing fresh squares which are mechanically removed. Reproductive process will not be terminated but only the flowers are removed mechanically.

EFFECT OF NUTRIENT CONSORTIA ON YIELD OF COTTON

Nutrient consortia a combination of [DAP (1%), KCl (0.5%), $MgSo_4$ (0.5%), $FeSo_4$ (0.25%), ZnSo4 (0.25%)] + Other micronutrients and surfactant forms a nutrient tonic to boost yield in cotton. This tonic improves the metabolic activities like Photosynthetic rate, Nitrate Reductase activity and improve the chlorophyll content of the leaf at critical stages of crop. Consequently, bud and boll shedding and leaf reddening process is delayed thereby, increasing the yield by 10-15%. The crop looks healthier with mature puffy bolls at harvest. Spray of this consortia should be taken up from squaring phase of the crop at 10-15 days interval.

INTEGRATED PEST MANAGEMENT IN COTTON

Trap cropping: Small plantings of a susceptible or preferred crop may be established near a major crop to act as a trap. After the pest has been attracted to the crop, the pest is destroyed or the infested plant parts or plants may be removed. Growing castor surrounding the cotton will attract *Spodoptera* for egg laying. Pigeon pea and marigold mask the odour emanated from volatile compounds of cotton and offer less preference for oviposition by *Helicoverpa armigera* in cotton.

Intercropping : Intercropping with blackgram and chillies will reduce the intensity of bollworms infestations in cotton

Bund cropping: Cowpea planted as a bund crop encourages predators such as coccinellids, syrphids etc. which will keep the sucking pests under check.

Ecofeast crop: Maize grown along the border provides food and shelter for number of lepidopteran parasites and thus serve as ecofeast crop. It also act as barrier crop for sucking pests. Cowpea is also a good ecofeast crop encouraging multiplication of coccinellids and other predators

Agronomic practices:

Crop rotation: Crop rotation minimizes pest infestation to a greater extent. Cotton should be followed body crops which are not favourable or less preferred by cotton pests. Cotton followed by cereals like maize / sorghum reduce the incidence of whitefly, bollworms, soil born insects and nematodes.

Cotton free period: Cotton should be grown only once in a year. Cotton double cropping and ratooning should be avoided to prevent carry over population as they provide continuous food supply for the pest multiplication

Proper spacing: Close spacing and dense canopy will encourage the faster rate of multiplication of bollworms and other pests of cotton. Hence optimum spacing and density are to be maintained.

Nutrition management: Proper nutrition management should be followed, apply fertilizer based on soil testing. Avoid high dose of nitrogenous fertilizers to prevent excessive vegetative growth (luxuriant green growth) which otherwise attracts more pests.

Field sanitation: Summer ploughing destroys the resting stages of insects in the soil should be followed. Removal of alternate weed hosts which harbour cotton pests. Collection and destruction of affected squares, dried flowers and grown up larvae will significantly reduce the pest intensity and buildup.

Harvesting: Timely harvest and stalk destruction are among the most effective method managing pink bollworm. These practices reduce the habitat and food available to the pink bollworm, *Helicoverpa* and *Spodoptera*. Efforts should be made to destroy the green bolls, cracked bolls and other plant debris left at the end of the season

Mechanical measures

Topping: Removal of terminals of cotton crop ("Topping") at 80-90 days of growth should be made to reduce *Helicoverpa* oviposition and also to encourage sympodial branching which bears more fruiting bodies

Bird perches: Erection of bird perches (@ 10 / ha) encourages the predation by carnivorous birds.

Hand picking of larvae: Hand picking of grown up larvae should be done in the morning between 6.30 to 10.0 am and in the evening hours. It will eliminate the possible development of insecticide resistance. It also helps to minimize heavy build up of future population.

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Visit to Ginning and Seed Processing Unit

Asha Rani,

SIMA Cotton Development & Research Association,
Coimbatore

- SIMA CD & RA is a registered non-profit making service oriented organization.
- Established in the year 1974 by the Textile Mills in the Southern States of Tamil Nadu, Andhra Pradesh, Karnataka, Kerala and Pondicherry.
- R & D activities are recognized as SIRO by the Department of Science & Industrial Research (DSIR), Government of India.
- SIMA CD & RA's land area is 16 acres at Ponneri, Udumalpet Taluk.
- SIMA CD & RA have eight project sub-centres to cater to the needs of cotton farming community and nine project officers placed in the sub centres.

Objectives:

- To promote the development of cotton farming for enhancing cotton productivity, production and fibre quality, so that the raw cotton may be made available at reasonable price to the textile mills
- To supplement the efforts of the State and Central Governments and other agencies in promoting the increased production of quality cotton to meet the demands of the textile industry.

Activities:

- Production and distribution of genetically pure quality seeds to the farming community to supplement the efforts of the Government and other agencies.
- Production and distribution of Biofertilizers for sustainable production.

Seed production and distribution:

Since seed is a vital input in productivity and quality, the Association has continued its concerted efforts to distribute genetically pure good quality certified seeds of about 500 m.t. annually. Seed farm crops of MCU-5, MCU-5 VT, LRA-5166, MCU-7, Surabhi, Suraj, Supriya, Suvin and GKS hybrid seeds are being raised in different production stages like FS I, FS II and Certified seeds.

The Association has been implementing seed multiplication programmes based on well defined scientific procedures, in which different stages of foundation and certified seeds are produced from Breeder seed and thus maintaining continuous chain of good quality production programme. The production programmes are planned and executed in identified villages on "**one variety-one village**" concept followed by getting the certified seed farm crops, as per the rules and procedures stipulated by the State Seed Certification Agency.

In order to avoid any admixture, the certified kapas procured is being ginned in the ginnery specially designed for seed extraction. The processing, cleaning, hand grading and chemical treating of seeds was undertaken by the seed processing unit under technical supervision of seed technologists.

Each and every seed lot are tested for quality parameters like physical purity, germination percentage and moisture content, so as to ensure quality standards. These lots are also being tested by the Seed Testing Laboratory of the State Seed Certification department for various quality parameters. The seed lots passing the qualifying standards of germination and genetic purity in the Government Seed Texting Laboratory and approved by the Certification Department are alone bagged after seed treatment for distribution to the farmers.

Biofertilizer input production and distribution:

In order to encourage organic farming, use of biofertilizers as renewable sources of plant nutrients are widely popularized. Production of "Biorich" is a combination of Azospirillum and Phosphobacteria in 50:50 ratio and its application reduces the cost of cultivation for all agricultural and horticultural crops, usage of chemical fertilizers and minimizes soil pollution and saves the eco system.

Cotton Research:

1. Maintenance of 390 germplasm collections
2. Renovation of MCU-5, MCU-7 and Suvin cotton varieties
3. Synthesis of new hybrids and varieties
4. Development of long, medium and extra long staple cultures
5. Development of high density cultures for machine picking
6. Development of pest resistance culture
7. Development of barbadense lines better than Suvin

Extension activities:

1. Frontline Demonstrations (FLDs)
2. Farmers' Field School (FFS)
3. Distance Education to farmers through TNAU.

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Ginning Machine

FINE CLEANER

SEPARATOR

Seed coater and drier

Seed Treatment machine

Biofertilizer Laboratory

Contract Farming- Useful Approaches for ELS and Organic Cotton Farming

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Introduction

Cotton farming is an age-old means of livelihood for millions of Indian farmers. In the country, the Transfer of Technology (TOT) programs which fostered the production of cotton have been implemented underlining the importance of problem solving, creating effective linkage between scientists and farmers and transferring the latest cotton production technologies. However, there have been few approaches in which cotton farmers were assured of a market for their produces and which proved a proper linkage between the "Farm and Market". "Contract Farming" is one such approach which merits of such a linkage with the cotton farming community and several corporate involved in cotton trading, processing and exports. This article discusses about this alternative farm business model and few successful cases in this model and gives a brief note on the bottlenecks and criticisms leveled against this model with policy initiatives and further suggestions.

Contract Farming and its Key benefits

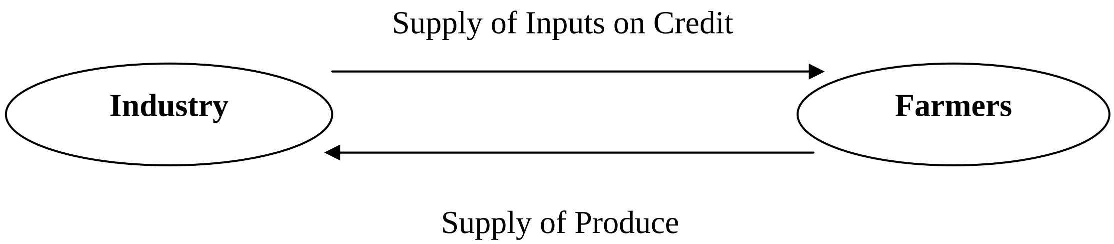
Contract Farming in general is defined as a system for the production and supply of agricultural/horticultural produce under forward contracts between producers / suppliers and buyers. The essence of such an arrangement is the commitment of the producer / seller to provide an agricultural commodity of a certain type, at a time and a price, and in the quantity required by a known and committed buyer (Spice, 2003).

A key feature of contract farming is that it facilitates backward and forward market linkages that are the cornerstone of market-led, commercial agriculture. It has the potential of combining small farmer efficiency, utilizing corporate management skills, providing assured markets and reducing the transaction costs in the value chain by ensuring vertical integration. Contract Farming is a win-win situation for both the parties lead to building a platform for improvement of farm incomes, development of agro-processing and expansion of rural economy. Well-managed contract farming is considered as an effective approach to help solve many of the market linkage and access problems for small farmers. It enables small scale farming competitive by enabling their access to technology, credit, marketing channels and information lowering transaction costs. At the same time, it offers a feasible and viable model of private sector participation in agriculture on a massive scale. It is also a system of interest to buyers who are looking for assured supplies of produce for sale or for processing. Processors are among the most important users of contracts, as they wish to assure full utilization of their plant processing capacity.

Types of Contract Farming

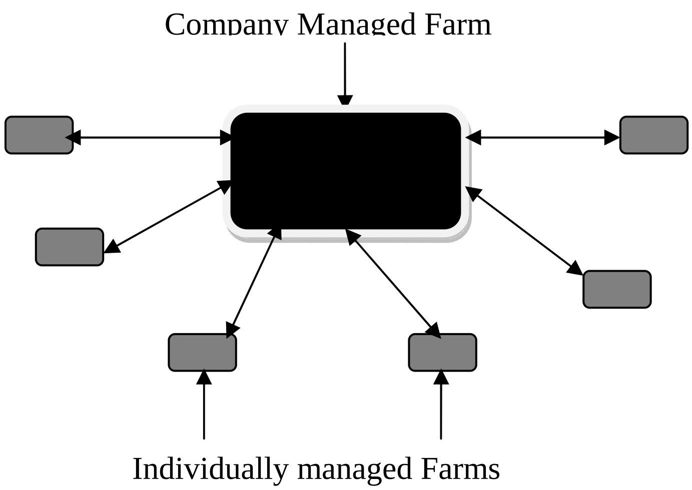
Centralized model

The contracting company provides support to the production of the crop by smallholder farmers, purchases the crop from the farmers, and then processes, packages and markets the product, thereby tightly controlling its quality. This can be used for crops such as tobacco, cotton, paprika, sugar cane, banana, coffee, tea, cocoa and rubber. This may involve tens of thousands of farmers. The level of involvement of the contracting company in supporting production may vary.



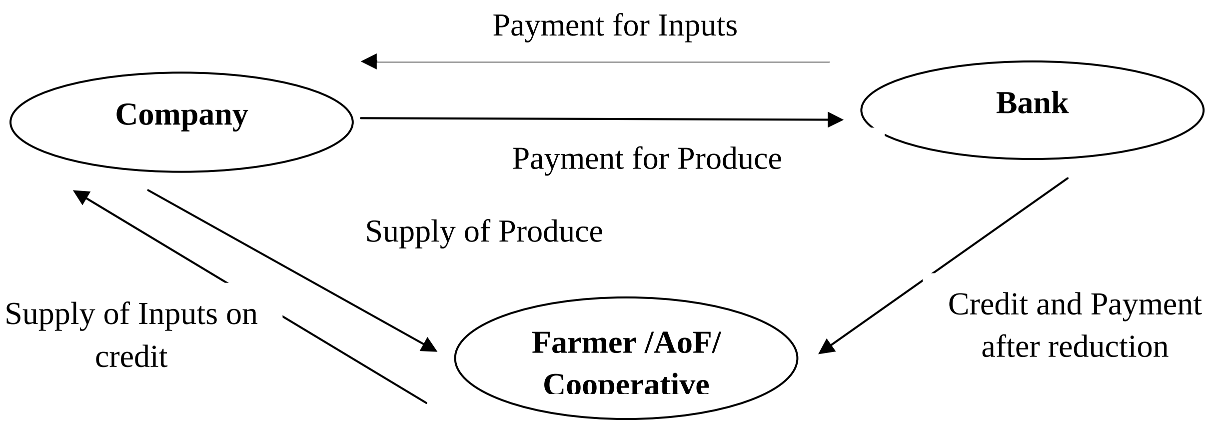
Nucleus Estate model

This is a variation of the centralized model. The promoter also owns and manages an estate plantation (usually close to a processing plant) and the estate is often fairly large in order to provide some guarantee of throughput for the plant. It is mainly used for tree crops, but can also be for, e.g., fresh vegetables and fruits for export.



Multipartite model

The multipartite model usually involves the government, statutory bodies and private companies jointly participating with the local farmers. The model may have separate organizations responsible for credit provision, production, management, processing and marketing of the produce.



Informal model

This model is basically run by individual entrepreneurs or small companies who make simple, informal production contracts with farmers on a seasonal basis. The crops usually require only a minimal amount of processing or packaging for resale to the retail trade or local markets, as with vegetables, watermelons, and fruits. Financial investment is usually minimal. This is perhaps the most speculative of all contract-farming models, with a risk of default by both promoter and farmer.

Intermediary model

This model has formal subcontracting by companies to intermediaries (collectors, farmer groups, NGOs) and the intermediaries have their own (informal) arrangements with farmers. The main disadvantage in this model is it disconnects the link between company and farmer.

Contract Farming Approaches for ELS and Organic Cotton in India

Contract farming in cotton production carried out according to an agreement between a buyer and cotton farmers, which establishes conditions for the production and marketing of cotton. Typically, the cotton farmer agrees to provide established quantities cotton, meeting the quality standards and delivery schedule set by the purchaser. In turn, the buyer commits to purchase the product, often at a pre-determined price. In some cases the buyer also commits to support production through, for example, supplying farm inputs, land preparation, providing technical advice and arranging transport of produce to the buyer's premises. Another term often used to refer to contract farming operations is 'out-grower schemes", whereby farmers are linked with a large farm or processing plant which supports production planning, input supply, extension advice and transport. Some of the successful contract farming approaches carried out in India for Extra Long Staple and Organic Cotton are discussed below.

Appachi's Integrated Cotton Cultivation for ELS cotton: Innovative Model

Appachi Cotton Company (ACC), the ginning and trading house from Pollachi, Coimbatore district, Tamil Nadu backed a model called "Integrated Cotton Cultivation (ICC)" model in contract farming which guaranteed a market support mechanism for cotton farmers for selling their cotton. ACC caters to top-bracket, quality-conscious clients from the textile industry in India and Abroad, and their client specific operation has won them laurels. ACC is the only private ginner in the country to have successfully entered backward and forward integration between the "grower" (farmer) and the "Consumer" (textile units). This model ensured that its farmer-members never went short of money and materials during the crucial 100 days of the crop cycle. The contract assured the farmers easy availability of quality seeds, farm finance at an interest rate of 12% per annum, door delivery of unadulterated fertilizers and pesticides at discounted rates, expert advice and field supervision every alternate week and a unique selling option through a MoU with the Coordinating agency.

The core principle of the formula lies in the formation of farmers' Self Help Groups (SHGs). Each farmer belonging to SHG is sanctioned Rs.20,000/ ha as crop loan @ 12 % p.a. interest. Disbursement is at the behest of the coordinating agency. Hence all requests are scrutinized, evaluated, authenticated and only then recommended to the lending bank. All the participating farmers are asked to issue PDCs (Post Dated Cheques) for the loan they avail. Hence the moral responsibility of fulfilling the bank's obligation squarely lies on the participating farmer. The Appachi formula differs significantly from other existing contract farming models on its "pricing" front in that no prior price fixing is done in this model. As cotton is a commodity prone to price fluctuations due to domestic and international market forces, ACC did not wish to create a climate of uncertainty due to pre-fixed prices with the contracting farmers. Also the formula has built some checks and balances into the system for early identification of troublemaking farmers and their elimination at an early stage to protect the interest of the group, the bank and the coordinating agency.

By integrating backward and forward with the producing and the consuming communities, ACC has attempted to address all the existing maladies of the cotton supply chain. The key principles of the ACC model were one village - one group (SHG), one village-one variety/hybrid of cottonseed, crop loan at 12 % per annum on groups' guarantee, door delivery of quality inputs at discounted rates, cotton crop insurance, synchronized sowing, integrated crop management through competent farm service centers, contamination control measures from farm to factory, assured buyback of final produce from farmers' doorsteps and the sponsor playing the role of perfect coordinator between the producer and the consumer.

Contract Farming for ELS and Organic Cotton by Super Spinning Mills (SSM) Ltd., India

In India there is an urgent need to increase productivity due to availability of cheaper and better lint through import, Cost escalation in agro inputs and farm labour and higher volume requirements of cotton for spinning industry. Also the cotton industry is facing problems on the quality front viz., Admixture of different cotton fibres at farmer level and in ginning industries , High trash content, High foreign fibre contamination (like Jute, Polypropylene and Hair) , Improper ginning & false packing and Inadequate fibre qualities to make suitable end products. In order to meet out all these requirements, the Coimbatore based Company M/s Super Spinning Mills has started growing cotton through its Integrated Cotton Cultivation Program.

Under this program, different clusters of villages are selected for growing ELS variety / hybrid of cotton based on the soil fertility, irrigation and agro climatic conditions. Progressive farmers who are willing to join our program are selected. Group Leaders are also selected to co-ordinate farmers and contract farming committee. Certified and freshly packed seeds are given which are sourced directly from the manufacturers. To protect against sucking pest attack, seeds are treated with effective pesticides. Depending on the vegetative growth and duration of hybrid/varieties, spacing is altered (row to row and plant to plant). For gap filling, extra seeds are sown in poly bags and kept as reserves. This ensured sufficient plant population for higher yield. Super Spinning Mill entered into a tie-up arrangement with one the nationalized /private banks for providing cotton crop loan to the contract farming farmers to enhance productivity. Farmers who are willing to avail crop loan have to provide required documents to the bankers. A maximum loan amount of Rs.20,000/- per hectare is recommended. Loan amount is disbursed as cash in two installments during (a) Weeding and (b) Harvesting. Kind portion is given in the form of Fertilizers, Micro nutrients, plant growth regulators and pesticides to the farmers. Mill stands as a surety to the banker for the crop loans provided to the contract farming farmers. Technical experts from Tamil Nadu Agricultural University and Government Agricultural departments are taken to the farmer fields for educating the farmers, accurate diagnosis of pest and diseases and remedial measures. Correct and timely application of agro in-puts by farmers are ensured by our field supervisors. IPM technology is implemented to reduce the usage plant protection chemicals and also to improve the fibre quality. A group of farmers are provided with imported sprayers at free of cost for spraying micro-nutrients and pest management. Cotton cloth bags are provided to the farmers for free of cost, for packing of seed cotton. Jute and polypropylene bags are strictly banned. Farmer groups are trained to harvest the seed cotton (kapas) from fully matured and open bolls only. Method demonstration to harvest clean seed cotton (kapas) in the morning time to avoid dust and dried leaves. Prevailing market price at the time of procurement is taken as base price. Procurement starts as soon as the farmers are ready to handover the stock. Farmer has to bring the seed cotton only in the cotton cloth bags provided to them. Payment is settled within three days of procurement. Sale proceeds directly remitted to the bank for those who availed loan. After closing crop loan, farmers can withdraw the balance amount from the bank. Seed cotton packed in cloth bags are segregated variety/hybrid wise and sent for ginning. Identification tags are attached. At the end of the season feedback meeting is organized. Officials from Government Agricultural departments and Tamil Nadu Agricultural Universities are called for the meeting.

This effort had enabled reduction of contamination levels in all varieties of cotton from 18 -20 grams to less than 1 gram per bales (170 Kg). Productivity also increased to an average of 20-25 quintals per hectare from 12.5 – 15 quintals per hectare.

Companies Involved in Contract Farming of Cotton and other crops

Some of the MNCs, Indian companies, the States they are operating in and products handled by them are as follows: PepsiCo (Punjab, Tamil Nadu – Tomato, Chilies, Groundnut, Basmati rice and Seaweed), Rallis India (Punjab, Uthra Pradesh, Madhya Pradesh, Maharashtra, Karnataka and Tamil Nadu – Fruits, Vegetables, Basmati and wheat), Suguna Poultry farm Limited (Andhra Pradesh, Tamil Nadu – Broiler), Unicorn Agrotech (Karnataka – Gherkin), Super Spinning Mills (Tamil Nadu – Cotton), CG Herbals (Chattisgarh, Odisha – aromatic crops, veiver, patchouli), Sanjeevani Orchards (Madhya Pradesh – Pomegranate), Hindustan Lever (Mathya Pradesh – Wheat), ICICI Bank (Madhya Pradesh – Wheat), State Bank of India (Andhra Pradesh – Paddy, groundnut, sunflower in Kurnool district in collaboration with Mahindra Shubh Lab), Appachi Cotton Company (Tamil Nadu – Cotton), ugar Sugar works (Karnataka – Barley), Cotton Corporation of India (Andhra Pradesh, Maharashtra, Haryana – Cotton), Field Fresh Foods of Sunil Mittal (Punjab, Himachal Pradesh, Jammu and Kashmir, Uthra Pradesh, Haryana, Uttarachal – Fresh fruits), Reliance (Gujarat – Herbal gardens), Nader and Ebrahim Group (NEG) of Baharain (Maharashtra – Banana) and ACIL / Adeshwar Cotton Industries (Gujarat - Organic cotton).

Issues of concern related to contract farming

Under the present dispensation, there is no security of continuity of contract farming or tenure of land use for the sponsoring companies; as a result the companies are reluctant to go in for long term capital investment in the contracted land to enhance productivity and improve quality of product. The problem of monopsony, where a buyer buys produce of hundreds and thousands of farmers, is observed in some cases of contract farming. A study on unsuccessful cases of contract farming points to the problem of enforceability of contracts. Both the parties – sponsoring company and the farmers tend to renege on the contracts, whenever the market conditions suit them. Pricing under the present dispensation, is mostly as per convenience of the sponsoring company – contract price or open market price. There is often rejection of farmers' produce on the basis of quality and often delay in payment to farmers by the sponsoring company.

Also the present legal system prevailing in the country makes it impossible to enforce the performance under contract. In all the models, the initiative / empowerment come from the user rather than the farmers. Another moot point is that in the existing models, farmers are largely "price takers" while the contracting firm "makes" the price. Other criticisms leveled against contract farming in India include less generation of employment, labour saving farm practices, low level of commitment of corporate over rural employment, lack of transparency and communication etc., Enforcement of the agreement, and standardization and operationalisation of contract farming agreements are the major bottlenecks plaguing contract farming ventures in India.

Policy Initiatives and Future Suggestions

The Government of India's National Agriculture Policy envisaged that "Private sector participation will be promoted through contract farming and land leasing arrangements to allow accelerated technology transfer, capital inflow and assured market for crop production, especially of oilseeds, cotton and horticultural crops". It has also recognized contract farming as an important aspect of agri-business and its significance for small farmers. The Inter-Ministerial Task Force on Agricultural Marketing reforms observed that contract farming was becoming increasingly important. Recognizing the potential and benefits of contract farming arrangements in the agricultural sector, National Bank for Agriculture and Rural Development (NABARD) took the important initiative of supporting such arrangements by the banking sector and developed a special refinance package for contract farming arrangements aimed at promoting increased production of commercial crops and creation of marketing avenues for the farmers.

In future, policies should be initiated to register the contracts, mange the risks, create effective linkage between the farmers and sponsors, create a dispute resolution mechanism, manage the contract in a transparent and participatory manner, develop lease market, give incentives to the sponsoring companies, preserve bio-diversity and form suitable legal framework for contract farming.

Conclusion

Contract farming is generally an agreement between farmers and a sponsor. In cotton contract farming, typically, the cotton farmer agrees to provide established quantities cotton, meeting the quality standards and delivery schedule set by the purchaser. In turn, the buyer commits to purchase the product, often at a pre-determined price. The approaches adopted by

ACC and SSM are the successful approaches of cotton contract farming carried out in India for Extra Long Staple and Organic Cotton farming. Initiating proper policies may sustain these successful approaches with a win-win situation for both the farmers and the contractors in near future.

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