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Training Manual on

Capacity Building Program on Cotton Production Technologies

Manual Edited by

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Contents:

(Click on the chapters title to fetch the chapter)

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Participants of Exposure Visit cum Capacity Building Program on Cotton Production Technologies and Scientists of ICAR-CICR

History and Development of Indian Cotton

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Introduction

Indian cotton is primordial, precedent and politically influential in nature. It persuaded the kings, kingdoms, wars, industries and common man in the country. It is the oldest textile woven by Indians. Long ago, Indians cultivated cotton, extracted fibre from it, spinned, woven, dyed and exported it to other countries. Cotton played an important role in the history of country's fight for freedom and continues to be an important commodity. The past events happened with regard to domestication of Indian cotton, the individuals / agencies / institutions fostered its growth in India have been mentioned by many historians and archeologists. Reviewing and documenting these historical events and happenings will throw correct perspectives for present day's cotton research, cultivation, development and policy setting. An attempt has been made in this paper to review the past laurels and let downs of Indian cotton.

History of Cultivation of Various Types of Cotton in India

Indian Desi Cotton

It is believed that *G. arboretum*began in the Indus Valley of India and Pakistan, and then spread over Africa and Asia, whereas *G. herbaceum* was first cultivated in Arabia and Syria. The well preserved fabrics of cotton excavated from Mohenjo-Daro was tested at CTRL, Bombay and it was concluded that on the whole, this early cotton has been produced from cotton plants closely to the present day *Gossypium arboreum* types (Gulati and Turner, 1929). Hutchinson and Stephens (1947) believed that the progenitors of early cotton of the Indus valley must have been introduced from southern Arabia or north eastern Africa. For many centuries,the world textile trade was rules by Indian Dhaka handloom muslin. They were woven from the Indian Desi tree species of *Gossypium arboreum* with mean fibre length of 18-24 mm, but the yarn was one of the finest ever heard of 345-356 counts (Kranthi *et al*., 2011).

History of American cotton in Indian soils

The American cotton variety Bourbon of *Gossypium hirsutum punctatum* race was introduced from Malt and Mauritius into Bombay and Madras provinces of India in 1790. Subsequently efforts were intensified to improve and promote the cultivation of American cotton in India. The *Gossypium hirsutum* (*latifolium* race) var. New Orelans was introduced in Gujarat, Deccan and Konkan in 1840.

In the meantime, the British discovered that it was possible to grow Bourbon in Dharwar and Hubli. In 1905, *G hirsutum var. Cambodia* was introduced successfully into Madras providency. By this time, Bourbon cotton was established parts of Punjab. Experiments in Uttar Pradesh from 1826 established American variety Cawnpore in 1909 (Kranthi *et al*, 2011). As quoted by Santhanm and Sundaram (1997), the work on American cotton with upland Georgian and New Orelans variety in Dharwar and Gudag during the first decade of the 20th century, established the Dharwar American cotton crop (Deepak Kumar, 1997). In 1912, a variety resistant to Jassids "4F" was selected from Punjabi Narma and cultivated in Punjab. In 1920-29, Hilson and Ramnatha Iyer, released Co 1 and Co 2 from Cambodia cotton. Then in 1933, late maturing Jassids resistant variety LSS was selected from F4. Thus, *G. hirsutum* took about 60-70 years to adapt to the Indian condition (Kranthi *et al*., 2011).

Egyptian Cotton and its history in India

The first clear evidence of domestication of this type of cotton comes from Ancon, a site on the Peruvian coast where archaeologists found remains of cotton bolls dating to 4200 BC. By 1000 BC Peruvian cotton bolls were indistinguishable from modern cultivars of *G. barbadense*. Archaeological examples of this type of cotton have been found in different sites of Peru and Ecuador, especially Ancón, in the central coast of Peru. In 1852, many trials were undertaken on them but without much success. The efforts in the Madras Province commenced with it at Coimbatore were also unsuccessful initially (Santhanam and Sundaram, 1997). It was introduced in India around 1790 but was able to get acclimatized only by 1940. It took 150 years for *G. barbadense* to adapt to Indian climatic conditions (Kranthi *et al*., 2011).

Hybrid cotton in India

As quoted by Santhanam and Sundaram (1997), the first cotton hybrid released for commercial cultivation in India was intra *hirsutum* Hybrid 4 by Dr. C T Patel in 1970. Since then a number of hybrids, both inter specific and intra specific have been released by both public and private organizations in the country. The private sector seed companies also made significant contributions to development of several hybrid cottons supported by an effective hybrid seed production and extension support system (Basu and Paroda, 1995).

Biotech Cotton in India

Bt cotton was first cultivated in America during 1996 and in China and Australia during 1997. It arrived in India in 1995, when the US multinational company Monsanto teamed up with India's Mahyco to import Bt cotton seeds, which would be crossed and repeatedly backcrossed with local

Back to content page

varieties to ensure the local adaptation (Scidev.net (2006)). After intensive biosafety studies and extensive field trials under the regulatory system of Review Committee on Genetic Manipulation (RCGM), as one of the milestones in the history of Indian cotton improvement, the genetically engineered Bt cotton was allowed for commercial cultivation in India by the Genetic Engineering Advisory Committee in 2002 crop season (Kranthi *et al*., 2011).

History of Institutional Developments for Indian Cotton

Santhanam and Sundaram (1997) quoted that the different problems concerning the cultivation of cotton, as of other crops in India were systematically studied with the establishment of Agricultural Departments in various provinces of India in 1904. The Department of Agriculture in Bombay, central provinces, Berar, United Provinces and Madras were pioneers in taking up research work on cotton. To meet out the demand of Lancashire industry, Indian Cotton Committee was set up in 1917, to investigate the possibilities of extending the long staple cotton in India. Based on the recommendation of the committee, Indian Central Cotton Committee was set up at Bombay in 1921 as a technical advisory board to Government. In 1924, the ICCI set up Cotton Technological Research Lab under it aegis at Bombay. From 1924 -37, the committee supported the entire expenditure for cotton R and D schemes. In 1938, the ICCI was wound up and its functions were transferred to ICAR, New Delhi. In 1966, the ICCI was abolished and in 1967, All India Coordinated Cotton Improvement Project was lunched. In 1976, the central Institute for Cotton Research was started at Nagpur under ICAR. During this period, the Government of India also established Cotton Corporation of India (CCI) in 1970 to import and distribute cotton to the needy mills. Then CCI entered into the domestic market and started procuring raw cotton.

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The centre was started in 1959 as “Project Intensification of Regional Research on Cotton, Oilseeds and Millets” (PIRRCOM) and later merged with IARI in 1965 as its regional station. In 1967, when the council started the “All India Coordinated Cotton Improvement Project” (AICCIP), the station has become its headquarters. In 1976, when the council established the Central Institute for Cotton Research (CICR) at Nagpur, the station became its regional station for south zone.

History of Cotton Extension / development Programs in India

“Cotton Extension Scheme” and “Grow More Cotton” were the pioneer schemes implemented by the independent India to expand the area under cotton and increase the production during 1950-51. These extension campaigns increased the area by 44% and production by 55% during the first plan period (1951-52 to 1955-56). After experiencing limited scope in expanding the area under cotton during second five year plan period due to competitive crops, the Government of India initiated a popular extension program "Intensive Cotton Cultivation Scheme (ICCS)" widely known as "Package Program" during third five year plan period. In this program, special field staff members were appointed to disseminate the technical knowledge to cotton farmers and incentives viz., seeds, pesticides, appliances, operational cost, ceiling prices etc., were given to the beneficiaries. In 1979-80, the centrally sponsored Intensive Cotton Development Program (ICDP) was launched as an extension initiative to increase the production, in which, the district was considered as a unit for disseminating the recommended package of practices in cotton. With the help of field staff, vast number of cotton growers in each district was covered by this program. During the year 1999-2000, Technology Mission on Cotton (TMC) with extension wing of Mini Mission II was started for cotton development works. Many extension programs viz., Front Line Demonstration (FLD) and Farmers Field School (FFS) were supported by TMC to accelerate the production and productivity of cotton. This extension program was merged with centrally sponsored National Food Security Mission (NFSM) under the head Commercial crops in 2014-15. Now, under this mission, FLDs are conducted to disseminate the novel production and protection technologies to the farmers.

Conclusion

Indian cotton is ancient, historical and political in nature. It influenced the nations and was influenced by many factors. It faced revolutions, wars, fights, exploitations and triumphs. This review document on these historical events and happenings on Indian cotton is expected to create appropriate perspective for present day's cotton research, cultivation, development and policy setting.

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High Yielding Cotton Varieties and Hybrids

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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. Qualitative and quantitative transformation has taken place in cotton production in India ever since Independence (Table 1 & 2). The production increased from a meager 2.3 million bales in 1947-48 to 36.1 million bales in 2018-19. At the time of independence, mostly short and medium staple cottons were produced. Today, India produces the widest range of cottons from 6^s to 120^s counts, from non-spinnable coarse to medium, long, extra long and superfine cotton.

Currently, the long and extra long staple cotton production is more than 75% of total cotton production, which was only 17 % before establishment of AICRP on Cotton in the country. This is mainly due to the concerted efforts of cotton breeders who developed high yielding long and extra long staple cotton varieties and hybrids suitable to different agro ecosystem of the country. The cotton productivity has been enhanced remarkably especially after the establishment of AICRP on Cotton. The productivity has been increased from a mere 90 kg lint/ha during 1947-48 to as high as 565 kg/ha during 2013-14.

Table 1. Quantitative change in area and production of cotton in India

Period	Area (million ha)	Production (million bales of 170 kg each)
1947-48	4.3	2.3
1966-67 (start of AICRP on Cotton)	7.8	5.3
2018-19	12.2	36.1

Table 2. Qualitative change in production of three staple length group of cotton

Period	Production in Million bales (170 kg each)			
	Long and Extra long	Medium	Short	Total
1947-48	--	1.53 (67)	0.76 (33)	2.29
1961-66	0.92 (17)	3.70 (68)	0.82 (15)	5.44
2016-17	27.03 (77)	7.02 (20)	1.05 (3)	35.10

(Figures in parenthesis indicate the percentage of total)

India is the only country cultivating all the four fibre yielding cotton species in commercial scale. The change in area under different species is furnished in Table 3.

Table 3. Distribution of Cotton Species in India

Species	Area (%)			
	1947	1965	2005	2017
G. arboreum	65	36	17	2
G. herbaceum	32	23	8	1
G. hirsutum	3	41	75	95
G. barbadense	Nil	Nil	Negligible	Negligible

What the mills look for in cottons is staple length, micronaire and strength, the primary characteristics on which yarn quality depends. With the establishment of AICRP on Cotton 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 long and extra long staple cotton in India. A brief account of some of the important milestones in fibre quality improvement in cotton is furnished below.

1967: All India Coordinated Cotton Improvement Project was established with head quarter at Coimbatore and all the research centers of cotton in different State Agricultural University were brought under one project.

1970: First commercial cotton hybrid of the world (Hybrid 4) was released from Surat by the noted breeder Dr. C. T. Patel.

1972: First commercial interspecific cotton hybrid of the world (Varalaxmi) was released from Dharwad by the noted breeder Dr. Katarki

1976: Infrastructure of cotton research got strengthened with the establishment of Central Institute for Cotton Research at Nagpur.

1982: Regional station of Central Institute for Cotton Research was established at Sirsa to strengthen the research efforts in North Zone.

1999: Technology Mission on Cotton was launched.

2002: Transgenic Bt Cotton was approved for commercial cultivation in India.

The list of cotton varieties suitable for Odisha State released from 2000 onwards and their characters are furnished in Table 4. Apart from these, the Extra long Staple cotton varieties like Surabhi, Suraj and Subiksha may also be tried on pilot scale for suitability in the state.

Back to content page

Table 4. Cotton varieties / hybrids suitable for Odisha State

Name	Species	Year	Institution	Average yield (q/ha)	Ginning percent	Fibre length (mm)	Mic value	Bundle Strength
CNHO 12 (Saraswati)	H	2010	CICR, Nagpur	15	35	24.6	4.8	20.9
H 1353	H	2015	CCSHAU, Hisar	13.65	35.2	26	4.3	20.5
RHC 0717 (Phule Yamuna)	H	2016	MPKV, Rahuri	18.48	34.5	27.1	4.9	22.7
NDLH 1938 (Sri Rama)	H	2016	ANGRAU, Nandyal	19.21	33.4	28.9	4.6	23.9
RHH 0917 (Phule Asmita)	H X H	2017	MPKV, Rahuri	25.09	34.1	29.7	4.1	27.9
Central Cotton NHH 250	H x H	2017	MAU, Nanded	14	35.4	27.5	4.43	22.3
Cotton CO 16 (TCH 1777)	H	2018	TNAU, Coimbatore	20.36	34.6	30.5	4.37	22.1
Suchitra (CCH 12-2)	H	2018	ICAR-CICR, Coimbatore	17.67	33.6	28	4.2	29.0
RHH 1007	H X H	2018	MPKV, Rahuri	26.06	35.9	27.9	4.5	22.2
GJ COT 102 (GJHV 516)	H	2018	JAU, Junagadh	19.55	34.7	27.6	4.4	23.7
G. Cot. 34	H	2019	NAU, Surat	23.55	36.8	28.3		26.2
G. Cot 38	H	2019	JAU, Junagadh	19.4	32.2	27.8		26.7
SCS 1061	H	2019	UAS, Raichur	14.79	37.3	27.6		24.4
NHH 715	H X H	2019	VNMKV, Nanded	16.78	36	28	4.5	21.3

Status on Extra Long Staple Cotton in India

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Introduction

Cotton is an important versatile fibre ruling as a principal raw material of the textile industry all over the world. It is used as a source of fiber, food, and feed which constitutes 49 species of the genus *Gossypium*. Among them four are cultivated; *G. hirsutum* and *G. barbadense* which are tetraploid (2n=4x=52), and *G. arboreum* and *G. herbaceum* which are diploid (2n=2x=26) (Sundram *et al.*1999; Arumugam *et al*. 2006).

The term 'Extra Long Staple' (ELS) cotton typically denotes a cotton fibre of extraordinary fibre length. The recognized industry standard for the minimum fibre length of an ELS fibre is 1-3/8" or 34.925 mm. But as per the CIRCOT, Mumbai classification, staple length of more than 32.5 mm is considered as ELS category. As well as fibre length, ELS cottons are also recognized for their superior strength and better uniformity. In technical term, ELS includes both all the varieties of *G.barbadense* and varieties of *G.hirstum* which has the defined staple length.

Gossypium barbadense, L. is commonly known as Egyptian cotton or ELS grown primarily in Egypt, Sudan and CIS countries. It is known as GISA types. Pima cotton of USA also known as extra long staple cotton widely grown in California, Arizona, New Mexico, and southwestern Texas USA which is similar to Egyptian GISA cotton. It is a tropical, frost-sensitive perennial plant that produces yellow flowers with thick maroon petal spot at the base of the petal and has black seeds. ELS cotton is generally used to manufacture high quality ring-spun yarns. Common endues of ELS cotton include sewing thread, lace yarns, and high quality dress and shirt fabric. Prior to the development of special man-made fibers, ELS had widespread industrial and military applications, including tire cord, military belting for uniforms and machine-guns, and parachute ribbing. The cultivation and ginning of ELS cotton also are different from upland cotton.

Global status on ELS Cotton

G. barbadense is grown in about 10% of the cotton area and supports about 4% of the world production. The major ELS producing countries are USA, Egypt and Sudan. The quantum jump in cotton production has helped the textile industry to get cotton at a competitive price and also the farming community to get higher income (Sankaranarayanan *et al.* 2010). ELS production accounts for less than 8 per cent of total world cotton production and is primarily concentrated in 7 countries, USSR, India, Egypt, Sudan, the United States, Peru, and Israel. These countries produce more than 95 percent of the world's ELS crop. According to the International Cotton Advisory Committee (ICAC), and the Foreign Agricultural Service estimates, worldwide ELS cotton production in the current 2020/2025 marketing year is expected to fall by nearly 900,000 bales.

ELS cotton fibers are stronger and finer than upland cotton fibers. Although there are clear genetic differences between the two cotton species, the differences are often blurred by dissimilar cotton classification techniques in ELS producing countries.The current method of estimating ELS production, consumption, and trade is to identify cotton types that are generally longer than upland varieties and report the entire crop of that type as ELS. This technique allows ELS to be described by type. Example ELS types are Pima, (produced in the United States, Peru, and Israel); Egypt's Giza 45, 70, 76, & 70; India's Suvin and DCH-32; China's Xiniang 149; Sudan's Barakat; and the USSR's Tonkovoloknistyi. U.S. exports of ELS cotton totaled over 30 percent of worldwide ELS exports. The leading importer of ELS cotton is Japan, followed by Italy and Germany.

ELS cotton in India

Currently about 2 lakh hectares of ELS cotton are grown in India mostly under DCH-32 in Dharwad, Haveri tract of Karnataka, Coimbatore, Erode, Dindugal districts of Tamil Nadu and Ratlam tract of Madhya Pradesh. The promising variety MCU-5 (Super fine) is grown in summer irrigated tract of Tamil Nadu, costal Andhra Pradesh and Navarangapur district of Orissa. The interspecific hybrids TCH-213, SIMA HB-3 and Sara-2 are grown in parts of Tamil Nadu and Karnataka. Phule-388 occupies negligible area in Western Maharastra.

The demand for the textile products made out of ELS cotton (32 mm and above) is growing exponentially and the potential for value addition of the products made out of these cotton varieties is very high. Though we have become very comfortable in the supply of indigenous short and medium staple cotton, the position of ELS has reached a precarious stage in our country (Basu, A.K. 2006). The production of ELS cotton has been continuously decreasing as against the increasing demand by the textile industry. Realizing the importance of strengthening the position of textile industry on this front, It is very essential to make the fine and superfine count cotton yarns available to the handloom weavers at a competitive price and also to improve the productivity and quality of the ELS cotton varieties to ensure remunerative price to the farmers. The demand for ELS cotton in India is about 9 lakh bales against the availability of only about 4 lakh bales. The requirement of this cotton is expected to be about 20 lakh bales by 2020. In India the cotton consumption rate is increasing lately at much faster rate as compared to that of 10 years ago. The shortage of ELS cotton from domestic production has been receiving the attention of the industry for quite some time. All along India has been the pioneer in producing fine and superfine count yarns and has a dominant share in the global textile trade in these varieties. During the last few years, China and Pakistan entered this market using the imported cotton particularly from USA and Egypt and have become the competitors for India.

In order to sustain in the global competition, it is essential to make the cotton available to the mills on par with our competitors. Therefore, it has become essential for India to give priority for increasing the ELS cotton production to retain the market share and also to improve the income of the farming community.

ELS cotton in Tamil Nadu

Two varieties belonging to *G. hirsutum* (MCU-5) and *G. barbadense* (Suvin) and a few hybrids (*hirsutum barbadense*) are presently cultivated in central and southern cotton zones of Tamil Nadu. The hybrids of India are Varalaxmi, DCH-32, TCHB-213, Phule-388, Sima-HB3 and Sara-2. In the next stage, Sujata was crossed with St. Vincent Sea Island seeds and an extra ordinary variety was produced which had a staple length of over 1-1/2 inch, stelo strength of 32 g/tex (equal to 40 g/tex t on HVI). SUVIN was successful till the end of 80's and later the size of the crop dwindled gradually and today is a very small crop of around 1000 to 1500 bales (Gopalakrishnan, *et al*. 2008). Concurrently, the Dharwad centre took up development of other varieties like Varalakshmi, DCH-32, *etc.*

ELS varieties and hybrids under cultivation

Variety/ Hybrid	Fibre quality		
	2.5% Span length (mm)	Tenacity(g/tex)	Fineness(Mic)
Suvin (V)	36-40	32-33	2.9- 3.3
Varalaxmi	32-37	23-28	2.7-3.5
DCH-32	33-38	25-30	2.5-3.4
TCHB-213	32-36	26-31	2.9-3.5
Phule 388	32-36	26-30	3.0-3.6
SIMA-HB3	38	29.3	3.3
SARA-2	35-36	27-29	3.4-3.7
MRC 69 18 (Bt)	36.5	27.6	3.5
RCHB 708 (Bt)	37.7	30.2	2.9
Nav Bharat Kranthi	36.2	27.2	4.1

A significant milestone has been achieved in cotton production in India, with a record crop of over 377 lakh bales during the last two years. However, the country produced only around 1.75 lakh bales of extra long staple cotton varieties during 2017-18 as against the requirement of around 5.34 lakh bales. The shortage is managed with imported cotton. India accounts for about 40% of the global share in the fine and superfine count yarn trade and has already established its brand in the global market. Therefore, the ELS cotton requirement is estimated to be around 15 lakh bales by 2020 in India. Self-sufficiency in ELS cotton would increase the income of the farming and handloom communities sizably. It is therefore imperative that the ELS cotton production and quality need to be improved by a Mission mode approach.

Vision

- Increase the ELS cotton production in the country from the current annual production of 1.8 lakh bales to 15 lakh bales by 2020.
- Improve the ELS cotton fibre quality parameters on par with the International varieties like Egyptian Giza, US Pima, etc., .
- Increase yield per hectare and area under ELS cotton cultivation and ensure higher income to the farming community.
- Establish Indian ELS cotton brand in the International market.
- Establish an ELS cotton Special Purpose Vehicle (SPV) with public and private sector partnership for promotion of ELS cotton.
- ELS Mission Directorate as a public-private sector partnership enterprise to undertake the ELS cotton promotion project. The Directorate will have a mandate to provide an effective mechanism for co-ordination between all the agencies involved in ELS cotton research and development and the textile industry.
- Considering the scope for export potential, employment potential to the handloom community and enhanced income to the farmers, it is recommended to make a budgetary allocation of Rs.50 crores for the project

Reasons for inconsistent in ELS cotton production

1. Long duration
2. Susceptibility to sucking pest, boll worms and severely to pink boll worms
3. Sterility, poor boll bursting and empty locules in suvin
4. Declining of yield in comparison to release period especially with suvin
5. High Labour requirement for harvesting and drudgery involved
6. Less suitable for rainfed because of longer duration
7. Sensitivity with water logging and Mg deficiency
8. Competition from high value crops and also within the species (*G.hirsutum*)
9. Higher production cost
10. Low and non staple market price
11. Low productivity

Thrust areas

1. Increasing area under ELS cotton

Based on the availability of seeds of ELS hybrids like Varalaxmi, DCH-32, Mayhco MRC 6918 BT; Rasi RCHB-708Bt; Sara-2 of Super Spinning and TCHB-213 of Tamil Nadu Agricultural University and SIMA-HB3, the coverage during the year 2015-20 is expected to be around 4.5 lakh hectares. This may result in a production of about 9 lakh bales of ELS cotton of 34 mm and above against the demand projection over 15 lakh bales. The area under ELS hybrids / varieties may be progressively extended to 8 to 10 hectares by the year 2020-25 to achieve a production level of 15 to 20 lakh bales.

2. Dissemination of technologies on ELS cotton production

- To demonstrate the modern production technology, pure and good quality seeds, essential inputs and credit through networking and link up with concerned agencies including research and development organizations
- To make them to adopt best pre and post harvest practices to minimize contamination

3. Improvement of existing ELS varieties with new fibre quality parameters

- Cotton breeding for varietal improvement is now in progress in several centers under the All India Co-ordinated Cotton Improvement Project.
- A targeted breeding programme could be carried out to develop new barbadense varieties equivalent to the latest foreign ELS cottons mentioned above.
- To induct new barbadense germplasm from Israel, Australia, CIS and Turkey, etc.

Conclusion

A significant milestone has been achieved in cotton production in India, with a record crop of over 370 lakh bales during the last two years. However, the country produced only around 2 lakh bales of extra long staple cotton varieties during 2012-117 as against the requirement of around 9 lakh bales. The shortage is managed with imported cotton, the price of which is likely to increase abnormally in the near future. India accounts for about 40% of the global share in the fine and superfine count yarn trade and has already established its brand in the global market. Therefore, ELS cotton requirement is estimated to be around 15 lakh bales by 2020 and 20 lakh bales by 2025 in India. Self-sufficiency in ELS cotton would increase the income of the farming and handloom communities sizably. It is therefore imperative that the ELS cotton production and quality need to be improved by a Mission mode approach.

Back to content page

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Protection of Plant Varieties and Farmer's Rights Act, 2001 and Status of DUS testing in cotton

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The term Intellectual Property (IP) reflects the idea that its subject matter is the product of the mind or the intellect. These could be in the form of Patents; Trademarks; Geographical Indications; Industrial Designs; Layout-Designs (Topographies) of Integrated Circuits; Plant Variety Protection and Copyright. IP, protected through law, like any other form of property can be a matter of trade, that is, it can be owned, bequeathed, sold or bought. The major features that distinguish it from other forms are their intangibility and non-exhaustion by consumption. IP is the foundation of knowledge-based economy. It pervades all sectors of economy and is increasingly becoming important for ensuring competitiveness of the enterprises.

Depending on the nature and tangibility of the intellectual property, different type of rights such as patent, copy rights, trademarks, industrial designs, plant breeders or farmers rights, protection of undisclosed information, protection of database etc., are granted by the respective competent authority. India being the signatory and founding member of world trade organization; thrust on plant variety protection has been envisaged under the provisions of Trade Related aspects of intellectual property rights (TRIPS), which is an integral part of WTO. The member countries of WTO have freedom in formulating their own system of plant variety protection either patent or an effective *sui generis* system under the provisions of article 27.3 (b) of TRIPS agreement. Accordingly, India opted for the *sui generis* system of plant variety protection that paved the way for enactment of **Protection of Plant Varieties And Farmers Rights Act, 2001.** The rationale behind the adoption of *sui generis* system in India is that it is rich in biological resources with greater amount of diversity. This concern more on the equity share of rights of farmers, rights ofvillage community and rights of village community and rights of researchers. This system also provides wider flexibility in protection of genera, species and varieties, level and period of protection, sustainable development of agro biodiversity with benefit sharing arrangement The section 14 of protection of plant varieties and farmers rights act provide immense opportunity for the registration of genera, species an extant variety, a farmers variety and a new plant variety provided it should confirm to the criteria of Novelty, Distinctiveness, Uniformity and Stability

Salient features of the Law

These can be divided into three parts. The first part considering the interests of the breeders includes: i) Researchers' rights for use of an initial variety for conducting experiment/research (Section 30), ii) Essentially derived variety [Section 2(i)], in conjunction with the requirement of authorization for repeated use under Section 30 proviso and Section 23(6) proviso; and iii) Extant variety [Section 2(j)]. The second part covers the provisions favoring the farmers in the law. These provisions are: iv) Farmers' Rights (Chapter VI), v) Benefit Sharing (Chapter IV), and vi) Compulsory License (Chapter VII). An immediate thought that comes seeing these salient provisions is that interests of the breeders are safeguarded only in small sections, whereas issues concerning interests of the farmers are described in full chapters. It will, however, be seen from the provisions that the law is fairly balanced to equally safeguard the interests of both breeders and farmers and is not tilted in favor of the farmers. The third part of the salient features relates to the Central Government and the Authority to be established under this law. This includes: vii) General functions of Authority (Section 8), viii) Gene Fund (Section 45), ix) Framing of schemes etc. (Section 46), and x) Central/State Government as the Owner of Rights on 'extant' varieties (Section 28(1) proviso). A few other sections are also cited, wherever considered relevant.

Researcher's Rights

It says – "Nothing contained in this Act shall prevent – (a) the use of any variety registered under this Act by any person using such variety for conducting experiment or research; or (b) the use of a variety by any person as an initial source of variety for the purpose of creating other varieties: Provided that the authorization of the breeder of a registered variety is required where the repeated use of such variety as a parental line is necessary for commercial production of such other newly developed variety."

The preamble of this Section along with sub-section (a) and (b) highlights that even cosmetic changes are encouraged to create new varieties, and rights can be awarded to breeders on their applications of new varieties provided they fulfill other requirements, like that of novelty, DUS (D-Distinctness, U-Uniformity and S-Stability) and suitable denomination in Section 15 on "Registrable varieties"; and of 'expected performance under given conditions' under sub-section (2) of Section 39 on "Farmers' rights". The proviso to Section 30, however, indicates that authorization of the breeder of an earlier registered variety under the Law is required in cases where repeated use of that registered variety is required as a parental line for commercial production of the new applicant variety. This largely restricts the requirement of taking authorization from another breeder to those few cases of new applicant hybrids wherein an earlier registered variety of the other breeder is used as a parental line for commercial production of the applicant hybrid. Thus, whereas Section 30 proviso protects the commercial interest of only a particular kind of earlier breeder, Section 39 (2) attempts only to protect the farmer as a consumer of seed of a variety protected under the law.

Essentially Derived Variety

The definition is: "essentially derived variety", in respect of a variety (the initial variety), shall be said to be essentially derived from such initial variety when it-(i) is predominantly derived from such initial variety, or from a variety that itself is predominantly derived from such initial variety, while retaining the expression of the essential characteristics that result from the genotype or combination of genotypes of such initial variety;(ii) is clearly distinguishable from such initial variety; and (iii) conforms (except for the differences which result from the act of derivation) to such initial variety in the expression of the essential characteristics that result from the genotype or combination of genotype of such initial variety;

A variety has thus to be inferred "essentially derived" with respect to the 'initial variety'. The 'initial variety' may be a protected variety or may not be a protected variety under this law. While some elaboration of what constitutes an 'essentially derived variety' is required in rules and regulations of the law, an essentially derived variety is, in general, as good as a new variety in terms of the requirements of benefit sharing under this law. This is so because Section 26 (1) on "Determination of benefit sharing by Authority" considers novel, 'extant' as well as 'essentially derived' varieties for the purpose. It is so also because of the wider scope under Section 30 on "Researcher's rights". The only exception is proviso to Section 30 discussed above. In addition, proviso to sub-section (6) of Section 23 on "Registration of essentially derived variety" requires for mutual agreement between such two breeders. It means a record of such mutual contractual understanding may be additionally required. Sub-section (e) of Section 18 on "Form of application" also necessitates the requirement of complete passport data (pedigree details etc.) in applications of varieties, which additionally helps in determining the essentially derived nature of an applicant variety. The requirement of complete passport data should not be considered a serious objection, since the practice in other countries requires information on the pedigree, breeding methods and selection criteria used in developing the candidate variety.

Extant Variety

The definition covers already notified varieties under Section 5 of the Seeds Act, 1966; a 'farmers' variety', a 'common knowledge' variety, or any other variety in the 'public domain'. The term 'initial variety' in the definition of 'essentially derived variety' could thus mean any indigenous and naturalized variety for benefit sharing.

Sub-section (2) of Section 15 on "Registrable varieties" requires that an 'extant' variety shall be registered under this Act within a specified period if it conforms to such criteria of DUS as shall be specified under the regulations. Clause (a) of sub-section (2) of Section 8 on "General functions of Authority" requires that the registration of 'extant' varieties is subject to such terms and conditions as may be prescribed. Therefore, it highlights the requirement of (i) development of 'special' DUS criteria for 'extant' varieties, and (ii) the delineation of terms and conditions for registration of 'extant' varieties. The terms and conditions need to be defined. The two possibilities for defining terms and conditions could be: (i) concerning the use of 'extant' varieties for ensuring benefit sharing, and (ii) ensuring that availability of seed of those 'extant' varieties to the farmers remains undisturbed as before.

Regarding the development of 'special' DUS criteria for registration of 'extant' varieties, the definition of a 'variety' and practices in other countries need to be reviewed. The UPOV Convention (International Union for the Protection of New Varieties of Plants – 55 member countries as on 15 June 2004) as well as laws of a few countries like Switzerland, Austria, UK and Ireland provides scope even for protection of heterogeneous varieties. Considering those varieties as heterogeneous as landraces have been protected, Leskien and Flitner (1997) have suggested the DI criteria (D - Distinctness, I - Identifiability) for heterogeneous varieties. The requirement is thus to finalize this criterion for 'extant' varieties. While the criteria and practices for protection of varieties in such countries can be a helpful guidance, it may be necessary to limit this criterion only to the extent of describing the specific attributes of an 'extant' variety, and the extent of presence of such specific attributes in the seed sample of that 'extant' variety. Thus, for 'common knowledge', 'public domain', and 'notified' 'extant' varieties as per Section 2(j), this criterion should require comparatively better description for identifiability of these varieties. It is suggested so because additional burden of precision in description or uniformity should not be imposed retroactively on 'extant' varieties. In case of farmers' varieties in particular, the criteria can be relatively simple, requiring only one or two specific economic attributes, along with information on extent of presence of such attributes.

Farmers' Rights

The preamble of Section 39 (1) on Farmers' rights states: "Notwithstanding anything contained in this Act-", thereby giving wide amplitude to honor Farmers' rights. However, clause (iii) of sub-section (1) of Section 39 on Farmers' rights restricts the recognition and reward from the "Gene Fund" (Section 45) only to those farmers who are engaged in conservation of genetic resources and their improvement and preservation. This is again subject to the proviso that the materials selected and preserved have been used as donors of genes in varieties registrable under this Act. Likewise, sub-section (1) and (2) of Section 41 on "Rights of communities" requires a procedure and a clear proof of evidence of the contribution of the people of a particular village or local community in the evolution of a variety registered under this law.

Clause (iv) of sub-section (1) of Section 39 states that 'a farmer shall be deemed to be entitled to save, use, sow, resow, exchange, share or sell his farm produce including seed of a variety protected under this Act in the same manner as he was entitled before the coming into force of this Act, provided that the farmer shall not be entitled to sell branded seed of a variety protected under this Act'. The explanation to this sub-section provides the meaning of 'branded seed'. The intent to allow the farmers to reuse in next season, exchange, share or sell his farm produce is thus clearly subject to entitlements of a farmer before the coming into force of this Act. In effect, it means that the law only allows leaving undisturbed the earlier practices of the farmers. Any significant violation will require strict proof of evidence of the particular farmer's earlier business.

The administrative requirement for a farmer to successfully get compensation in sub-section (2) of Section 39 if the breeder's variety does not provide the expected performance needs elaboration. Seed has to be sold along with the crop production technology capsule indicating on label of the seed packet the likely production in farmers' crop growing conditions. Work on simple and feasible mechanisms for the purpose is thus a necessity.

Section 42 is on "Protection of innocent infringement". The language in its preamble - 'Notwithstanding anything contained in this Act' - again provides the intent of the law to protect innocent infringement at any cost. Sub-section (ii) of this Section will, however, require the farmer to prove this innocent infringement in the courts of law, which is certainly not an easy proposition for the poor farmer masses.

As per PPV & FR Act, 2001 of **Novelty** means at the date of filing of the application for registration for protection, the propagating (or) harvested material of such variety has not been sold or otherwise disposed of by the breeder or his successor for the purpose of exploitation earlier than one year in India, out side India, in the case of trees (or) vines earlier than six years or in any other case earlier than four years

Distinctness: Itmeans that if the new variety applied for protection is clearly distinguishable by at least one essential characteristic from any other variety whose existence is a matter of common knowledge in any country at the time of filing of application. Filing of an application for the granting of a breeders right to a new variety or for entering such variety in the official register of varieties in any convention country shall be deemed to render that variety a matter of common knowledge from the date of the application in case the application leads to granting of the breeders right.

Uniform: A variety is considered as uniform if subject to variation that may be expected from the particular features if its propagation it is sufficiently uniform in its essential characteristics.

Stable: A variety is stable if its essential characteristics remain unchanged after repeated propagation or in the case of a particular cycle of propagation at the end of each such cycle.

The rational behind *sui generis* system

- India is rich in biological resources
- Greater amount of diversity
- Equity share of

1. Right's of farmer's
2. Right's of village community
3. Right's of researchers

This system also provide wider flexibility in protection of genera, species and varieties, level and period of protection, sustainable development of agro biodiversity with benefit sharing arrangement

Protection of plant varieties and farmer's rights authority

- The authority shall be a body corporate by name
- The head of office of the authority shall be as notified by Govt. of India
- The authority shall consist of a chairperson and 15 members
- Chairperson – appointed by GOI
- Members

1. DDG (Crop Sciences)
2. Director (NBPGR)

Mandate of PVP authority

1. Registration of plant varieties
2. Characterization and documentation of registered varieties
3. Documentation, indexing and cataloging of farmers varieties
4. Providing compulsory cataloging facility for all plant varieties
5. Ensuring that seeds of all registered varieties are made available to farmers
6. Collection of comprehensive statistics on plant varieties
7. Maintenance of national register of plant variety

Plant Varieties Registry

1. Registrar general of plant varieties to be the chief executive functionary
2. There may be number of registrars required
3. Register called the national register of plant varieties – kept at the head office of the registry

Application for registration

a. Genera and species as specified by GOI

b. Which is an extant variety

c. Which is a farmer's variety

Applicant

a. Any person claiming to be the breeder

b. Any successor of the breeder

c. Any person being the assignee of the breeder

d. Any farmer or group of farmers or community of farmers

e. Any university or publicly funded agricultural institution

A new variety shall not be registered

1. If not capable of identifying such varieties
2. Consist solely of figures
3. Liable to mislead to cause confusion concerning the characteristics
4. is not different from every denomination
5. Cause confusion public regarding identity
6. Likely to hurt religious sentiments
7. Is prohibited for use as a name of emblem for any purpose
8. Comprising of geographical name

Application

Every application for registration under section 14 shall:

a. Be with respect to a variety

b. Denomination assigned to such variety by the applicant

c. Be accompanied by an affidavit sworn by the applicant that such variety does not contain any gene or gene sequence involving terminator technology

d. Be in such form as may be specified by regulation

e. Contain a complete passport data of parental lines from which the variety has been derived along with geographical location (genetic material) and information relating to the contribution (farmer/village community/ institution/ organization in breeding, evolving or developing a variety)

f. Accompanied by statement containing a brief description of the variety bringing out its characteristics of NDUS as required for registration

g. Accompanied by fees as prescribed

h. Contain declaration that genetic material required for breeding, evolving or developing the variety has been lawfully acquired

i. Be accompanied by other particulars as may be prescribed

j. Every application shall be filed in the office of the registrar

Application for registration of plant variety protection

Application for registration of a new plant variety can be made independently or jointly by any person claiming to be a breeder, any successor of breeder of the variety, any person being the assignee of the breeder of the variety, any farmers or group of farmers or community of farmers, any person authorized in prescribed manner by a person and an university or publically funded agricultural institution claiming to be the breeders of the variety.

A new variety submitted for protection may not be considered for registration if it is not capable of identifying itself, consists solely of figures, liable to mislead to cause confusion concerning the characteristics, no different from every denomination, likely to deceive the public or cause confusion in public regarding identity, likely to hurt religious sentiments, prohibited for use as a name of emblem for any purpose and having the name of geographical location.

Acceptance of application

a. Registrar will accept the application after making enquiry, if finds the information as prescribed in regulation

b. Amendment /reject

Advertisement of application

1. Advertise in local newspaper
2. Any person with three months from date of advertisement of an application – may give notice in writing in prescribed manner to registrar
3. Opposition

a. Person opposing the application is entitled to breeder's right as against the applicant

b. Variety is not registrable under this act

c. The grant of certificate of registration may not be in public interest

d. The variety may have adverse effect on the environment

- The registrar will serve a copy of notice within two months from receipt of application
- Applicant shall send his counter statement
- Registrar will serve a copy of counter statement
- Registrar shall issue a certificate of registration and seal with seal of registry

National Test guidelines and DUS test in Cotton

Objectives

1.Establishment and maintenance of database on extant cotton varieties

2. Conduct of DUS test of New , VCK and Farmers varieties

3. Maintenance breeding of reference cotton varieties

4.Morphological characterization of cotton varieties

5. Registration of extant cotton varieties

The genus Gossypium has four cultivated species, the tetraploids viz., *Gossypium hirsutum* L., *Gossypium barbadense* L. and the diploids *Gossypium arboreum* L. and *Gossypium herbaceum* L. Separate guidelines for tetraploid and diploid have been formed for the conduct of DUS test.

Planting materials for cotton

The Protection of Plant Varieties and Farmers' Rights Authority (PPV & FRA) shall decide when, where and in what quantity and quality the seed materials are required for testing a variety denomination applied for registration under the Protection of Plant Varieties and Farmers' Rights (PPV & FR) Act, 2001. Applicants submitting such seed material from a country other than India shall make sure that all customs and quarantine requirements stipulated under relevant national legislations and regulations are complied with.

In case of tetraploids the minimum quantity of the seed to be provided by the applicant shall be 2000 grams in the case of the candidate variety or hybrid and 1000 grams for each of the parental line of the hybrid. Each of these seed lots shall be packed, sealed and properly labeled with details, in ten equal weighing packets and submitted in one lot.

In case of diploids the minimum quantity of the seed to be provided by the applicant shall be 1500 grams in the case of the candidate variety or hybrid and 750grams for each of the parental line of the hybrid. Each of these seed lots shall be packed, sealed and properly labeled with details, in ten equal weighing packets and submitted in one lot.

The seeds submitted shall have at least 75 % germination, 98 % physical purity and the highest genetic purity. The moisture content of the seed shall not exceed 10 % to meet the safe storage requirement. A certificate indicating germination percentage recorded not more than one month before the submission of sample shall be attached.

The seed material submitted shall not have been subjected to any chemical or bio-physical treatment

Duration of DUS tests

The minimum duration of DUS tests shall normally be at least two independent similar growing seasons

Test Locations

The candidate varieties are studied in a given location, over at least two successive seasons. For many crops, it is possible to complete two growing cycle in the same year. The two growing cycles should be independent of each other. In cotton also the test shall normally be conducted at two test locations. If any essential characteristics of the candidate variety are not expressed for visual observation at these locations, the variety shall be considered for further examination at another appropriate test site or under special test protocol on expressed request of the applicant. The DUS test locations for cotton are

- Central Institute for Cotton Research, Regional Station, Coimbatore-**Lead center**
- Central Institute for Cotton Research, Nagpur
- National Seeds project Unit, University of Agricultural Sciences, Dharwad
- Department of Cotton, CCS HAU, Hisar
- Regional Research Station, PAU, Bathinda
- Mahatma Phule Krishi Vidyapeeth, Rahuri

Conduct of tests in cotton

The minimum duration of DUS tests shall normally be at least two independent similar growing seasons.

The test shall normally be conducted at two test locations. If any essential characteristic of the candidate variety is not expressed for visual observation at these locations, the variety shall be considered for further examination at another appropriate test site or under special test protocol on expressed request of the applicant.

The field tests shall be carried out under conditions favouring normal growth and expression of all test characteristics. The size of the plots shall be such that parts of plants could be removed for measurement and observation without prejudicing the observations on the standing plants until the end of the growing period. Each test shall include a minimum of 300 plants in the plot size and planting space specified below across three replications. Separate plots for observation and for measurement can only be used if they have been subjected to similar environmental conditions. All the replications shall be sharing similar environmental conditions of the test location.

Test plot design:

	Tetraploid	**Diploid**
No. of rows	12	6
Row length	6 m	6 m
Row to row distance	90 cm	90 cm
Plant to plant distance	60 cm	30 cm
Expected plants/ replication	120	120
No. of plants / hill	One	One
No. of replications	3	3

- Observations should not be recorded on plants in border rows.
- Additional test protocols for special purpose shall be established by the PPV & FR Authority.

Methods and observations

1. The characteristics described in the table of characteristics (see Section VII) shall be used for the testing of varieties, parental lines and hybrids for their DUS.
2. For the assessment of Distinctiveness and Stability, observations shall be made on 30 plants or parts of 30 plants, which shall be equally divided among three replications (10 plants per replication).
3. For the assessment of Uniformity of characteristics on the plot as a whole (visual assessment by a single observation of a group of plants or parts of plants), a population standard of 0.5 % with an acceptance probability of at least 95 % shall be obtained. In the case of a sample size of 300 plants, the number of off types should not exceed 6.
4. All leaf characteristics shall be observed on the fourth fully expanded leaf from the top of the main stem at 50 % flowering stage.
5. For the assessment of colour characteristics, the latest Royal Horticultural Society (RHS) colour chart shall be used.
6. All observations on the flower shall be made on the first day of flowering and at anthesis.
7. Observations on the boll shall be made at full maturity and before boll bursting.

Reference collection

Each country maintains the reference collection for conducting DUS testing of variety submitted for protection. It may contain both living material and descriptive information's. A variety is included in reference collection only if seed / plant material is available to make a technical examination. Theoretically, the full reference collection to be used for comparison for any candidate variety is the world –wide known collection of varieties of same species and crop. However, in practices the number of varieties in reference collection can be reduced by selecting varieties from similar environmental regions. The selection can usually be further narrowed down to only the most closely similar varieties supplied by the breeder in Technical Questionnaires.

Following are the reference varieties available at Central Institute for Cotton Research, Coimbatore.

Grouping of varieties

1. The candidate varieties / hybrids for DUS testing belonging to *G. hirsutum*, *G. barbadense* and inter-specific (*G. hirsutum x G. barbadense*) hybrid will be tested separately.
2. The candidate varieties for DUS testing shall be divided into groups to facilitate the assessment of Distinctiveness. Characteristics which are known from experience not to vary, or to vary only slightly within a variety and which in their various states are fairly evenly distributed across varieties in the collection are suitable for grouping purpose.

3. The following characteristics are proposed to be used for grouping cotton varieties:

    i) Species

    ii) Leaf : Shape (Characteristic 8)

    iii) Flower: Petal colour (Characteristic 15)

    iv) Pollen colour (Characteristic 19)

    v) Boll Shape (longitudinal section) (Characteristic 23)

    vi) Fibre : Length (Characteristic 33)

Decimal Code for the growth stages

Growth stage	Code
Seedling	5
Square formation	30
50% Flowering (at least one flower should have opened in 50% of the population in the plot)	40
Boll bursting	65
First picking (20% of bolls in each plant must have opened)	75
Final harvest	95

Type of assessment of characteristics indicated in column 7 of Table of Characteristics is as follows:

MG : Measurement by a single observation of a group of plants or parts of plants

MS : Measurement of a number of individual plants or parts of plants

VG : Visual assessment by a single observation of a group of plants or parts of plants

VS : Visual assessment by observations of individual plants or parts of plants

Table of characteristics for Tetrapolid Cotton

Within the table characteristics, some characteristics are marked with an asterisk (*), which should be examined and included in the description of the varieties? It also contains additional characteristics, which are considered helpful in taking the final decision on the variety. Number of characteristics to be examined may differ from species to species. The morphological characteristics are normally arranged in chronological order of recording starting from sowing to harvesting. Under the heading 'Notes" number from 1 to 9 are allotted corresponding to each state of expression. These are for computer processing. As for as possible, example varieties are also cited for each test. "Some characteristics are marked with sign (+), which indicates that the characteristic is illustrated by explanation and drawing or that testing methods and included in a separate chapter "Explanation and methods". The table may also carry a column indicating the plant growth stage when characteristics should be recorded.

Sl. No.	Characteristics	States	Notes	Example varieties	Stage of observation	Type of assessment
1	Hypocotyl: pigmentation	Absent	1	DHY 286-1 (H)	5	VS
		Present	9	Sumangala (H)		
2 (*)	Leaf: colour	Light green	1	Abadhita (H)	40	VS
		Green	2	Sumangala (H)		
		Light red	3			
		Dark red	4	BN Red (H)		
3 (*)	Leaf: hairiness	Sparse	1	Suvin (BA)	40	VS
		Medium	5	LRA5166 (H)		
		Dense	9	DHY 286-1 (H)		
4	Leaf: appearance	Cup	1	Abhadita (H)	40	VS
		Flat	2	LRA 5166 (H)		
5	Leaf: gossypol glands	Absent	1	Acala Glandless(H)	40	VG
		Present	9	LRA 5166 (H)		
6 (*)	Leaf: nectaries	Absent	1	American Nectariless (H)	40	VG
		Present	9	Sumangala (H)		
7	Leaf: petiole pigmentation	Absent	1	G. Cot. 12 (H)	40	VS
		Present	9	Surabhi (H)		
8 (*) (+)	Leaf: shape	Palmate (Normal)	1	LRA 5166 (H)	40	VS
		Semi-digitate (Semi- Okra)	2	LHH 144(H)		
		Digitate (Okra)	3	PIL 43 (H)		
		Lanceolate (Super Okra)	4	Arizona Super Okra (H)		
9 (*)	Plant: stem hairiness	Smooth	1	Suvin (BA)	30	VS
		Sparse	3	Narasimha (H)		
		Medium	5	MCU 5 (H)		
		Dense	7	DHY 286 (H)		
10	Plant: stem pigmentation	Absent	1	Surat Dwarf (H)	45	VS
		Present	9	BN Red (H)		
11	Plant: height	Dwarf (< 60 cm)	1		75	MS
		Semi dwarf (60 - 90 cm)	3	70 E (H)		
		Medium tall (91 – 120 cm)	5	Anjali (H)		
		Tall (121–150 cm)	7	LRA 5166 (H)		
		Very tall (> 150 cm)	9	Sumangala (H)		
12 (+)	Plant: growth habit	Zero branching	1	P 4 (BA)	75	VG
		Compact (Spreading<30 cm)	3			
		Semi-spreading (31-60 cm)	5			
		Spreading(>60cm)	7			
13 (+) (*)	Bract: type	Normal	3	LRA 5166 (H)	40	VS
		Frego	5	BN Frego (H)		
14	Flower: time of flowering (50% of plants with at least one open flower)	Early (<50 days)	3	BN 1 (H)	40	VG
		Medium (50-60 days)	5	AC 738 (H)		
		Late (>60 days)	7	G 67 (H)		
15 (*)	Flower: Petal colour	Cream	1	LRA 5166 (H)	40	VS
		Yellow	2	Laxmi (H)		
		Deep Yellow	3	Suvin (BA)		

		Purple	4	BN Red (H)		
16 (*)	Flower: Petal spot	Absent	1	LRA 5166 (H)	40	VS
		Present	9	Suvin (BA)		
17 (*) (+)	Flower: Stigma	Embedded	3	Supriya (H)	40	VG
		Exerted	5	Surabhi (H)		
18	Flower: Anther Filament colouration	Absent	1	Sumangala (H)	40	VG
		Present	9	G. Cot. 12 (H)		
19 (*)	Flower: Pollen colour	White	1	LH 900 (H)	40	VS
		Cream	2	Anjali (H)		
		Yellow	3	LRA 5166 (H)		
		Deep Yellow	4	Suvin (BA)		
		Purple	5	BN Red (H)		
20	Flower: Male Sterility (Only for A and B lines)	Absent	1	MCU 5 VT (H)	40	VS
		Present	9	AK 32 A (H)		
21	Boll: bearing habit	Solitary	1	Sumangala (H)	65	VS
		Cluster	9	P 4 (BA)		
22	Boll: colour	Green	3	Sumangala (H)	65	VS
		Red	5	BN Red (H)		
23 (*) (+)	Boll: shape (longitudinal section)	Round	3	Supriya (H)	65	VG
		Ovate	5	Surabhi (H)		
		Elliptic	7	Suvin (BA)		
24 (*)	Boll: surface	Smooth	1	LRA5166 (H)	65	VG
		Pitted	9	Suvin (BA)		
25 (*)	Boll: prominence of tip	Blunt	1	Supriya (H)	65	VG
		Pointed	9	Surabhi (H)		
26 (*) (+)	Boll: opening	Semi-open	3	Suvin (BA)	75	VG
		Open	5	LRA 5166 (H)		
27 (*)	Boll: weight of seed cotton/boll	Very small (<3.0 g)	1	Suvin (BA)	75	MS
		Small (3.0-4.0 g)	3	Bikaneri Narma(H)		
		Medium (4.1-5.0 g)	5	MCU 5 (H)		
		Large (5.1-6.0 g)	7	Supriya (H)		
		Very large (>6.0)	9	JK 572 (H)		
28 (*)	Seed: fuzz	Naked	1	Suvin (BA)	95	VG
		Sparse	3			
		Medium	5	RHCb 001 (BA)		
		Dense	7	Sumangala (H)		
29 (*)	Seed: fuzz color	White	1	LRA 5166 (H)	95	VS
		Grey	2	RS 2013 (H)		
		Green	3	DCH 32 (HxBA)		
		Brown	4	Khandwa Brown (H)		
30 (*)	Seed: Index (100 seed wt.)	Very small (<5.0g)	1		95	MS
		Small (5.0-7.0g)	3			
		Medium (7.1-9.0g)	5	LRA 5166 (H)		
		Bold (9.1-11.0g)	7	G 67 (H)		
		Very bold (>11.0g)	9	VICH 5 (H x H)		
31 (*)	Ginning %	Very low(≤30)	1	Suvin (BA)	95	MG
		Low (31-32)	3	TCHB 213 (H x BA)		
		Medium (33-34)	5	MCU 5 VT (H)		
		High (35-36)	7	LRA 5166 (H)		
		Very high (≥37)	9	Supriya (H)		
32 (*)	Fibre: color	White	1	LRA 5166 (H)	75	VS
		Cream	2	B 82-1-1 (BA)		
		Green	3	Arkansas Green Lint (H)		

		Brown	4	Nankeen Spot(H)		
33 (*) (+)	Fibre: length (2.5 % span length)	Short (≤20 mm)	1	Sharada (H)	95	MG
		Medium (20.5-24.5mm)	3	LRA 5166 (H)		
		Medium long (25.0 - 27.0 mm)	5	Anjali (H)		
		Long (27.5 - 32.0 mm)	7	Supriya (H)		
		Extra long (≥32.5 mm)	9	MCU5 VT (H)		
34 (*) (+)	Fibre: strength	Very Weak (≤16 g/tex)	1		95	MG
		Weak (17.0– 20 g/tex)	3	Sumangala (H)		
		Medium (21.0-24.0 g/tex)	5	MCU 5 VT (H)		
		Strong (25.0 – 28.0 g/tex)	7			
		Very Strong (≥29 g/tex)	9	Suvin (BA)		
35 (+)	Fibre: fineness (Micronaire value)	Very coarse (≥6.0)	1		95	MG
		Coarse (5.0-5.9)	3	RHC 004 (H)		
		Medium (4.0- 4.9)	5	Savita (H x H)		
		Fine (3.0-3.9)	7	MCU 5 VT (H)		
		Very fine (≤3.0)	9	Kasinath (HxB)		
36 (+)	Fibre: uniformity (%)	Poor (<42)	1	AK 23 A (H)	95	MG
		Fair (42-43)	3	AK 32 B (H)		
		Average (44-45)	5	MCU 5 VT (H)		
		Good (46-47)	7	MCU 3 (H)		
		Excellent (>47)	9	70 E (H)		
37 (+)	Fibre: maturity (%)	Very Immature (≤31)	1		95	MG
		Immature (32-49)	3			
		Average (50-65)	5	MCU 5 VT (H)		
		Good (66-80)	7	LRA 5166 (H)		
		Very Good (≥ 81)	9	RHC 004 (H)		

Note: (H) - *Gossypium hirsutum*, (BA) – *Gossypium barbadense*

Characteristics and symbols

1. To assess Distinctiveness, Uniformity and Stability, the characteristics and their states as given in the Table of Characteristics (Section VII) shall be used.
2. Notes (1 to 9), shall be used to describe the state of each character for the purpose of digital data processing
3. Legend:

(*) Characteristics that shall be observed during every growing season on all varieties and shall always be included in the description of the variety, except when the state of expression of any of these characters is rendered impossible by a preceding phenological characteristic or by the environmental conditions of the testing region. Under such exceptional situation, adequate explanation shall be provided.

(+)See explanations on the Table of Characteristics in Section VIII.

4. A decimal code number in the sixth column of Table of Characteristics indicates the optimum stage for the observation of each characteristic during the growth and development of plant. The relevant growth stages corresponding to these decimal code numbers are described below:

Explanations and methods to characteristics

Characteristics 32 (2.5% Span Length), 33 (Fibre strength), 34 (Fibre fineness), 35 (Fibre Uniformity) and 36 (Fibre Maturity)

The major fibre properties *Viz.,* 2.5% Span Length, Fibre Strength, Fibre Fineness (Micronaire), Fibre Uniformity and Fibre Maturity (%) shall be determined under ICC mode using a standard High Volume Instrument (HVI).

Fifty grams of lint pooled equally from all the replications shall be used for determining the above fibre parameters. The samples should be conditioned for at least 2 hours at a room temperature of 27 $\pm$ 2°C and Relative Humidity of 65 $\pm$ 2 %. The moisture content of the sample should be around 7-8 %.

Calibration with HVI Calibration cotton supplied by the CIRCOT shall be done before testing the samples.

A fibrocomb containing the test sample prepared with the help of a fibre sampler is placed in the comb track. The test cycle consists of automatic brushing of the sample in the fibro comb and placing it on the comb holder. The test specimen then moves through a light beam. Using the optical mass generated and the software installed, 2.5% Span Length and Uniformity Ratio are derived.

After the test specimen passing through the sensor, the beard is positioned at the break point over a set of clamping jaws with 3mm spacing between the jaws. The force required to break the beard is calculated in units of g/tex with the help of software and is recorded as FibreStrength.

The cycle is repeated four times and the average values are taken.

To measure the Fibre Fineness (Micronaire), the lint sample is opened thoroughly after removing all the trash. Approximately 10 g of lint is weighed and inserted into the porosity chamber and the lid is closed. Compressed air is allowed to flow through the sample inside the chamber. From the measured values of mass and pressure, the microprocessor calculates the specific surface, which is converted into the Micronaire value. Using the Micronaire value the software also derives Fibre Maturity (%).

Methods and observations

The recommendations are given on

- The number of plants, or parts of plants, that should be observed when assessing distinctness and stability.

- The maximum number of aberrant plants permitted when assessing the uniformity of characteristics of plot as a whole.
- The permitted tolerance when assessing uniformity on single ear panicle rows, plants or parts of plants.

Recommendation and Grant

By the end of the second year, all the necessary recordings from the growing trials should have been taken. The examiner analyzes the data and prepares his recommendation on whether or not each candidate variety meets the DUS criteria. In the event of failure of a candidate variety to express distinctively to any one of the essential characteristics, special DUS characters may be performed under laboratory condition as per the established procedures.

Achievements of cotton DUS testing

Characterization and Seed multiplication

Year	No of varieties
2008-09	195
2009-10	45
2010-11	175
2011-12	15
2012-13	187
2013-14	119
2014-15	112
2015-16	77
2016-17	109
2017-18	142
2018-19	155

Maintenance of Reference collection

Year	*G.hirsutum*	*G.barbadense*	*G.arboreum*	*G. herbaceum*	Total
2008-09	158	12	40	11	221
2009-10	92	14	29	10	145
2010-11	136	13	3	0	152
2011-12	136	-	-	-	136
2012-13	145	6	28	8	187
2013-14	98	6	15	-	119
2014-15	129	4	27	4	164
2015-16	65	3	8	-	76
2016-17	66	-	38	5	109
2017-18	118	6	15	3	141
2018-19	108	7	36	4	155

Tetraploid and Diploid Cotton Varieties under DUS Test at CICR, Regional station, Coimbatore

Year	New	VCK	FV	EDV	IV	Total
2008-09	5	-	-			5
2009-10	42	-	-			42
2010-11	18	19	-			37
2011-12	4	5	-			9
2012-13	43	44	-	10	10	107
2013-14	84	68	-	-	-	152
2014-15	68	53	1	45	45	212
2015-16	49	12	1	19	19	100
2016-17	5	3	-	3	3	14
2017-18	7	-	-	-	-	7
2018-19	6	2	-	-	-	8
					Total	**693**

DUS testing at participating centers

Year	Species	CICR, CBE	UAS, Dharwad	CICR, NGP	HAU, Hisar	PAU, Ludhiana/ Bathinda	MPKV Rahuri
2012-13	Diploid	2	4	6	3	3	-
	Tetraploid	51	37	30	19	19	-
	EDV +IV	20	20	-	-	-	-
2013-14	Diploid	4	-	2	2	2	-
	Tetraploid	148	107	53	51	51	-
2014-15	Diploid	4	2	2	2	2	2
	Tetraploid	181	154	135	48	48	105
	EDV +IV	90	90	98	36	36	98
	FV	1	1	-	-	-	-
2015-16	Diploid	1	1	-	-	-	-
	Tetraploid	60	60	31	17	17	31
	EDV +IV	38	38	18	40	40	18
	FV	1	1	-	-	-	-
2016-17	Diploid	-	-	1	4	4	1
	Tetraploid	8	8	7	4	4	7
	EDV +IV	6	6	12	6	6	12
2017-18	Diploid	-	-	1	4	4	1
	Tetraploid	7	7	9	5	5	9
	EDV +IV	-	-	2	-	-	2
2018-19	Diploid	1	1	-	-	-	-
	Tetraploid	7	7	6	-	-	6

Overall progress across centers 2008-2018

Category	Number
New	448
VCK	309
FV	2
Total	759
EDV	183
IV	183
Total	366
G.Total	1125

Center wise details of Registration certificates received

Center	Name of Variety	Species	Category	Certificate No.
PAU, Ludhiana	F 1861	*G.hirsutum*	Extant	70 of 2011 dt. 30.9.2011
	PAU-626 H (FMDH 3)	*G.arboreum*	Extant (axa)	69 of 2011 dt. 30.9.2011
ARS, Banswara	Vagad Kalyan	*G.hirsutum*	Extant	71 of 2011 dt. 30.9.2011
	Pratap Kapi-1 (RBDV-7)	*G.herbaceum*	Extant	27 of 2011 dt. 24.6.2011
CICR, Sirsa	Shresth (CSHH-198)	*G.hirsutum*	Extant (HxH)	28 of 2011 dt. 24.6.2011
	Hybrid kalyan (CSHH-238)	*G.hirsutum*	Extant (HxH)	29 of 2011 dt. 24.6.2011
	Hy. CISAA 2 (CICR-2)	*G.arboreum*	Extant (axa)	98 of 2011 dt. 21.10.2011
	CISA 310	*G.arboreum*	New (Variety)	115 of 2012dt. 16.8.2012
	CSHH-243	HxH	New (Hybrid)	146 of 2013 dt. 12.9.2013
CICR, Coimbatore	Sumangala (CWROK-165)	*G.hirsutum*	Extant	47 of 2010 dt. 20.10.2010
	Surabhi (VRS-7)	*G.hirsutum*	Extant	48 of 2010 dt.20.10.2010
	CCH510-4 (SURAJ)	*G.hirsutum*	New	267 of 2013 dt. 16.12.2013
	CCH2623	*G.hirsutum*	Extant	Subject to the approval of EVRC of PPV7FRA
CICR, Nagpur	Pratima(CNH 120 MB)	*G.hirsutum*	Extant	30 of 2011 dt. 24.6.2011
	CNHO12	*G.hirsutum*	Extant	153 of 2013 dt.30.9.2013
	CNA1003 (Roja)	*G.arboreum*	New	Under DUS test
JNKVV, Khandwa	Jawahar Tapti	*G.arboreum*	Extant	34 of 2011 dt. 24.7.2011
	Jawahar Kapas-4 (JK-4)	*G.hirsutum*	Extant	55 of 2013 dt. 6.3.2013
	Jawahar Kapas-5(JK-5)	*G.arboreum*	Extant	93 of 2013 dt. 24.5.2013
	Jawahar Kapas-35 (JK-35)	*G.hirsutum*	Extant	80 of 2013 dt. 2.5.2013
TNAU, Coimbatore	KC2	*G.hirsutum*	Extant	67 of 2011 dt. 30.9.2011
	MCU12 (TCH-1025)	*G.hirsutum*	Extant	66 of 2011 dt.30.9.2011
	MCU13	*G.hirsutum*	Extant	68 of 2011 dt. 30.9.2011
	KC 3	*G.hirsutum*	Extant	94 of 2011 dt. 21.10.2011
	SVPR-2 (TSH 289)	*G.hirsutum*	Extant	95 of 2011 dt. 21.10.2011
	SVPR-3	*G.hirsutum*	Extant	96 of 2011 dt. 21.10.2011
	HD-123	G.arboreum	Extant	56 of 2011 dt. 24.6.2011

CCSHAU, Hisar	HD-324	G.arboreum	Extant	51 of 2011 dt. 24.6.2011
	AAH-1	G.arboreum	Extant (*axa)*	55 of 2011 dt. 24.6.2011
	H-1098	G.hirsutum	Extant	57 of 2011 dt. 24.7.2011
	H 1117	G.hirsutum	Extant	50 of 2011 dt. 24.6.2011
	H 1226	G.hirsutum	Extant	53 of 2011 dt. 24.6.2011
	HHH 223	G.hirsutum	Extant (*HxH)*	54 of 2011 dt. 24.6.2011
	HHH 287	G.hirsutum	Extant (*HxH)*	52 of 2011 dt. 24.6.2011
NAU, Surat	Gujarat cotton 18	G.hirsutum	Extant	102 of 2011 dt. 21.10.2011
	Gujarat cotton 19	G.arboreum	Extant	92 of 2011 dt. 21.10.2011
	Gujarat cotton 21	G.herbaceum	Extant	93 of 2011 dt. 21.10.2011
	Gujarat cotton hybrid 12	G.hirsutum	Extant (*HxH)*	104 of 2011 dt. 21.10.2011
	Gujarat cotton MDH 11	G.arboreum	Extant (*axa)*	103 of 2011 dt. 21.10.2011
	Gujarat cotton-23 (GBhv-179)	G.herbaceum	Extant	36 of 2012 dt.06.06.2012
RRS - Nandiyal	Narasimha	G.hirsutum	Extant	265 of 2013 dt.16.12.2013
MAU, Nanded	PA-402	G.arboreum	Extant	12 of 2013 dt. 31.1.2013
	PA-255	G.arboreum	Extant	13 of 2013 dt. 31.1.2013
	PH-348 (Yamuna)	G.hirsutum	Extant	824 of 2014 dt. 29.12.2014
	NH-545	G.hirsutum	Extant	826 of 2014 dt. 29.12.2014
MPKV, Rahuri	PHULE-388 (RHB-388)	G.hirsutum	Extant (*HxB)*	11 of 2013 dt. 31.1.2013
	PHULE-JLA-794	G.arboreum	Extant	54 of 2013 dt. 6.3.2013
	PHULE-492 (RHH-0492)	G.hirsutum	Extant (*HxH)*	87 of 2013 dt. 16.5.2013

Recent Approaches in Cotton Weed Management

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Introduction

Cotton crop is subjected to severe weed pressure due to wider spacing and slow initial growth. Though, first 60 days of cotton growth is more critical in terms of cotton yield, it is essential to keep the cotton field weed free up to harvest to produce clean cotton. The incessant rain hampers the weeding operation and many times not possible to enter the black cotton soil for weeding resulting in delayed weeding and loss of crop. Weeds are being managed by cultural, mechanical, chemical and integrated approaches. The recent successful approaches for managing weeds are discussed here.

1.High density planting System: Under HDPS system, cotton crops compete with weeds over widely spaced cotton. HDPS method of planting is a Brazil technology and successfully demonstrated to our Indian condition and weeds problem is very much reduced under this method as compared to conventional method of planting. Studies conducted at Coimbatore on HDPS revealed that the weed density and weed dry matter production was less at closer spacing of 30 x 30 and 45 x 30 cm as compared to widely spaced cotton (ArunVenkatesh et al., 2017).

Table 1. Weed Dry matter production (g/m^2) due to HDPS Cotton

Spacing (cm)	2011-12	2012-13
30x30	4.55 (44)	4.34 (75)
45 x30	4.81 (123)	4.55(93)
60x30	5.00 (148)	4.74 (112)
90x30	5.17 (176)	4.87(128)
CD (P= 0.05)	0.38	0.30
Interaction	NS	NS

Figures in parenthesis are original .subjected to Log x +2 for statistical analysis

2. Stale seed bed technique:

In this approach, one month in advance of cotton planting, ridges and furrows are formed and irrigation is given. On receipt of moisture, the weeds seeds are made to germinate and the young weed seedlings are targeted after 2 weeks by spraying with mixture of pendimethalin 1.0 kg (to kill the germinating weeds at the time of spraying and kills subsequently by residual action) ,glyphosate1.0 kg kills the germinated weed seedlings thereby reducing the weed pressure during actual cotton growing period (Nalayini and Suveetha,2016)

Table 2.Weed count, Weed dry matter production and weed control efficiency due to stale seed bed technique in Cotton

Weed control treatments	Weed count on 35- 40 DAS*	Weed DMP g/m^2 35- 40 DAS	Weed control efficiency (%) 35- 40 DAS
SSBT glyphosate 1.0 kg - HW	132.3	54.4	54.1
SSBT pendimethalin 1.5 kg- HW	40.6	21.5	81.9
SSBT pendimethalin 1.0 kg + glyphosate 1.0 kg - HW	30.9	17.6	85.2
Pre emergence weed control with pendimethalin 1.5 kg - HW	53.59	30.5	74.4
SSBT and manual removal of weeds(thrice)	44.95	29.9	74.8
Unweeded control	555.25	118.5	-
CD (p=0.05)	0.56	4.67	

Weed count was subjected to square root transformation for statistical analysis

3.Growing of leguminous cover crops:

This method could be followed in combination with stale seed bed technique for better weed control. Normally cotton is grown in one side of the ridges and the other side of the ridges are used to grow any one of the leguminous cover crops like sun hemp, forage cowpea, Thornless mimosa or Desmanthus. The legumes smother weeds and at the same time give legume effect to soil and cotton. The live mulch of legume is uprooted and spread around 45 DAS which enriches the soil (Nalayini et al 2017).

Table 3. weed count, yield attributes and seed cotton yield as influenced by stale seed bed technique and leguminous cover crops

Treatments	Weed count/m^2 on 30 DAS	Weed count/ m^2 on 80 DAS	Bolls/ plant	Boll wt (g/boll)	Seed Cotton Yield (Kg/ha)
SSBT followed by *Mimosa invisa* + one HW	67.25	174	28	6.15	2147
SSBT followed by Crotalaria juncea + one HW	63	182	33.4	6.08	2368
SSBT followed by Sesbania aculeata+one HW	46.75	171	24.8	6.28	2112
SSBT followed by *Vigna unguiculata* + one HW	49.75	158	34	6.03	2494
SSBT followed by Desmanthus *virgatus* +one HW	74	220	28.2	5.92	2275
pendimethalin 1.0 kg as pre emergence + HW (Twice)	198.7	312	24.9	5.82	2016
CD (p=0.05)	37.33 **	2.908 **	3.49	NS	226.58

Weed count was subjected to square root transformation for statistical analysis

Back to content page

4. Herbigation Technique:

Application of herbicides through irrigation water is called herbigation, can be very efficiently done through drip irrigation. In cotton, pre-emergence herbicides can manage weeds only up to 30 DAS (Nalayini and Kandasamy,2001) and controlling the late emerging weeds is really a challenge. Dadari and Kuchinda 2004 reported application of post emergence herbicides to supplement pre-emergence herbicides to have desired weed control in Cotton. As we have a very few selective post emergence herbicides , conventional spraying method for post emergence spraying is very difficult and often weeds which emerge close to cotton crop escape. Nalayini et al 2013 reported herbigation method of applying residual herbicides through drip system was more efficient than conventional spraying for post emergent weed killing. The weed dry matter production at 60 DAS revealed that herbigation recorded significant reduction in weed growth (41.02g/m^2) than in conventional spraying (51.08 g/m^2),the significant reduction in weeds growth under herbigation as compared to conventional spraying was reflected in reduced dry matter accumulation by weeds ,reduction in depletion of nutrients by weeds and favourable micro climate to crop causing 14.3 % enhanced seed cotton yield than conventional method of spraying. Excellent weed control with site specific recommendation of metolachlor and metribuzin through herbigation has been reported by Eberlen et al 2000.

Table 4.Weed DMP, weed control efficiency, nutrient depletion by weeds on 60 DAS and seed cotton yield as influenced by herbigation and weed control treatments

Treatments	Weed DMP (g/m^2) 30 DAS	Weed DMP (g/m^2) 60 DAS	WCE	Nutrients depletion by weeds (kg/ha)			Seed cotton Yield (kg/ha)
				N	P	K	
Application method (M)							
Herbigation	15.15	41.02	88.4	17.33	7.05	19.22	3998
Conventional spraying	12.77	51.08	86.5	21.80	8.54	23.92	3498
CD (p=0.05)	NS	4.07		1.75	0.647	1.75	496.4
Weed control treatments (W)							
Pendimethalin 1.5 kg (pre)+ HW 30,60 DAS)	14.2	35.98	84.2	11.39	3.97	11.86	3949
Pendimethalin 1.0 kg + metolachlor 1.0 kg (pre) + HW (30,60 DAS)	13.7	32.73	85.7	9.96	4.11	10.76	4294
Pendimethalin 1.0 kg (pre) followed by HW (30 DAS),metolachlor 1.0 kg (30 DAS)	17.5	13.95	94.0	4.14	1.93	4.57	4669
Handweeding (20,40 and 60 DAS)	3.2	32.48	86.0	9.50	3.79	11.22	4821
Unweeded control	35.4	231.8		62.83	25.19	69.43	817.3
CD (p=0.05)	5.95	7.85		1.36	0.249	1.39	460
Interaction	NS	NS		NS	NS	NS	NS

5. Polyethylene 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, plastic mulches are available which can be used as an efficient 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.,

Nalayini et al.,(2009) reported complete control of weeds except *Cyperus rotundus* in cotton using polyethylene mulch of 30 micron thickness. The beneficial effects of plastic mulch for enhanced water and fertilizer utilization and weed control (Fortnum et al., 2000) has been reported. The use of polyethylene mulching though used widely in high value vegetable crops, its use in cotton is so far limited and catching up in recent times.

6. Herbicide rotation:

We have choice for selective pre emergence herbicides to be used but selective post emergence weed killers are very few for cotton. Repeated use of same chemical in rotation is not being encouraged to avoid development of resistant weeds. Vargas and Wright (2005) suggested rotating herbicides with different modes of action to delay the development of resistance in weeds. The Choice of herbicides for broad-spectrum weed control and at the same time delaying the development of herbicide resistance in weeds is crucial. Application of , pendimethalin 1.0 kg as pre emergence herbicide followed by one hand weeding at 35- 40 DAS and mixture of pyrithiobac sodium 50g + quizalofop ethyl 50 g on 60 DAS was found to be efficient and more economical for managing weeds of irrigated cotton (Nalayini et al,2012)

Back to content page

Table. 5.Weed count, weed DMP and weed control efficiency as influenced by weed control treatments on 75 DAS

W control Treatments	Weed count /m^2	Weed DMP (g/m^2)	WCE (%)
Pendimethalin1.0 kg (pre) – HW(35-40 DAS) – fluazifop-butyl 125 g 60 DAS	63.7 8.04)	22.7	77.39
Pendimethalin1.0 kg (pre)-HW(35-40 DAS) -fenoxoprop 100g 60 DAS	49.2 (7.09)	19.9	80.24
Pendimethalin 1.0 kg(pre) –HW(35-40 DAS) -quizalofop ethyl 50 g 60 DAS	49.5(7.11)	20.1	80.02
Pendimethalin 1.0 kg(pre) - HW(35- 40 DAS) + pyrithiobac sodium 75 g 35- 40 DAS	78.3 (8.90)	25.6	74.55
Pendimethalin1.0 kg (pre) – HW (35-40 DAS) – pyrithiobac sodium 50 g +fluazifop butyl on 60 DAS	41.7 (6.53)	20.8	79.3
Pendimethalin1.0 kg –HW(35-40 DAS) -Pyrithiobac sodium 50 g +Fenoxoprop 50 g 60 DAS	33.6 (5.88)	17.8	82.30
Pendimethalin 1.0 kg – HW(35-40 DAS) - Pyrithiobac sodium 50 g + quizalofop ethyl 50 g 60 DAS	29.6 (5.53)	18.0	82.14
Pyrithiobac sodium 75 g (pre) -HW and pendimethalin 1.0 kg 35-40 DAS	83.4 (9.19)	37.2	63.02
Pendimethalin 1.0 kg (pre)-Paraquat 600 g 35-40 DAS	87.2 (9.39)	39.2	61.04
Pendimethalin 1.0 kg (pre)-glyphosate 1.0 kg 35-40 DAS	85.2 (9.28)	39.3	60.89
HW thrice (20,40,60 DAS)	18.4 (4.40)	13.4	86.64
Unweeded	290 (17.06)	100.6	-
CD (p=0.05)	**0.417**		

Figures in parenthesis are square root transformed values for statistical analysis

7.Biotechnological approach

Herbicide tolerant genetically modified crops

Recently, genetically modified crop varieties with two biotech traits (stacked trait crops) have been made commercially available and currently cultivated in several countries. Development in plant genetic engineering and knowledge of biochemical action of herbicides on plants spurred innovative approaches to engineer crops to withstand herbicides. These strategies usually involve isolation and introduction of a gene from other organisms, mostly bacteria which is able to overcome the herbicide induced metabolic blockage.Tolerance to herbicide glufosinate (Basta ^{R}) is conferred by the bacterial gene bar, which metabolizes the herbicide into non-toxic compound (Thompson et al.,1987).Glyphosate resistance is achieved by the introduction of either Agrobacterium gene from CP_4 that codes for a glyphosate-insensitive version of the plant enzyme,EPSP – Synthase or gox gene from *Achromobacter,* which codes for a glyphosate oxireductase in the breakdown of glyphosate. HTGM crops are gaining farmers' acceptance because of several advantages such as increased flexibility to manage problem weeds, prevention of multiple use of herbicides, reduction in total herbicide use, greater adoption of conservation tillage, less herbicide carry over etc.,

Concerns and apprehensions of HTGM crops

The use of herbicide resistant crops undermines the possibilities of crop diversification. In countries like India where multiple crops are grown such as under intercropping system wherein compatible intercrops are grown with cotton, the use of HTGM technology is not possible and non selective herbicides may wipe out all vegetation except the HTGM crops, Escape of transgenes from HTGM crops to weeds causing development of herbicide resistance in weeds, shift in weed flora etc., There is potential for herbicide resistant varieties to become weeds in other crops (Holt and Le baron,1990).Also, strategies have been defined to delay development of herbicide – resistance weeds in the case of conventional crop varieties. These include, combined or sequential use of herbicides with different mode of action, crop rotation, integrated weed control etc., In the case of genetically engineered HTGM varieties, these strategies are less relevant. When the herbicide could be applied at various stages of crop growth, farmers may not opt for integrated weed control measures. Similarly, when different crops carry engineered resistance to the same herbicide, use of different herbicides may not remain an option .Once the weeds develop resistance, through either acquisition of the gene from the HR variety or by mutation, they will remain resistant against the herbicide. Replacement of the herbicide is the only option in such a scenario.

Conclusion

Integration of cultural, mechanical methods with judicious use of chemical methods of weed control is recommended for effective, economical and environmentally safe weed management in cotton. In future, controlling weeds with micro encapsulated herbicides will be the potential technology to achieve season long weed control with lesser costs and risks to the environment.

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Organic Cotton Production-Techniques and Strategies

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1. Introduction

FAO suggested that "Organic agriculture is a unique production management system which promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity, and this is accomplished by using on-farm agronomic, biological and mechanical methods in exclusion of all synthetic off-farm inputs". Increasing awareness for social and environmental issues among consumers has lead to strong growth of the organic cotton market. Organic cotton is presently produced in 22 countries in all arable continents. India, Chinaand Turkey are currently the leading producers. Organic cotton is relevant to India because ofits sustainability and helps to revitalize the depleted lands. Organic cotton cultivation has shown to improve microflora, restore fertility and successfully manage insecticide resistance, while reducing health and environmental risks of contamination. The pure nature of organically produced cotton i.e. the fibre without chemical residue is another benefit of organic cotton.

India is the largest producer of organic cotton in the world cultivated over an area of about 2.53 lakh ha in 2011-12.India's contribution to global organic cotton production was only about 10-15% until 2002. Presently, it is the world leader contributing 51% of the global production (Table 1). The production increased from 2231 tones in 2003-04 to 59938tones in 2017-18.

Table 1. Organic cotton production (2017-18)

Country	Production (mt)	Percentage	Country	Production (mt)	Percentage
India	59938	51	Tajkistan	5876	5
China	22330	19	USA	4701	4
Turkey	8227	7	Tanzania	3526	3
Kyrgyzstan	8227	7	Others	4701	4
			Total	117525	100

Source: Anonymous 2018

Table 3. Organic Cotton production in India

State	Organic		In conversion	
	Qty (mt)	Area (ha)	Qty (mt)	Area (ha)
Andhra Pradesh	733	790	1504	2596
Delhi	0	0	1450	1074
Gujarat	6412	5060	10650	7959
Haryana	0	0	0	0
Madhya Pradesh	106622	74947	27189	23060
Maharashtra	37959	16568	15829	23093
Orissa	34426	30341	6376	5984
Rajasthan	0	0	3264	6338
Tamil Nadu	675	915	300	368
Total	186926	128752	66758	70839

2. Organic cotton production-techniques and strategies

2. 1 Organic nutrient management

- Manures and composts are the basic nutrient sources in organic farms for crops. Organic manures (FYM, compost, and vermicompost), *in situ* green manuring, cowpea and bio fertilisers along with fertility restoring crop rotations form the components for maintaining soil fertility.
- Farm yard manuring (FYM):FYM @ 15 t/ha must be added before preparatory tillage and mixed thoroughly. FYM should be well decomposed and should be preferably treated with composting organism such as *Trichodermaviride*. The rate may gradually be brought down 5-10 t/ha, once the farm yield stabilises over the years.
- Legumes as a companion crop for cotton contribute for carbon sequestration, organic N addition, soil stabilization and nutrient recycling (Sankaranarayanan et al 2009). A distinctive feature of most members of the fabaceae family is the capability to fix atmospheric N_2 biologically. 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. Sankaranarayanan et al (2012) estimated higher available N (198.2 kg ha^{-1}) in a multi-tier system involved with cotton with three legumes (cluster bean, vegetable cowpea and dolichos). Growing of *urdbean* as an intercrop at 1:1 ratio had additional yield of 311 kg/ha of seed cotton and higher nutrient uptake. (Sankaranarayanan et al 2011).Dhaincha: Dense stand of this legume can be raised around cotton field at a width of 2m; its lopping cut and spread between cotton rows at 65-70 DAS. Its fast decomposting leaves provide N during early boll development period and stalks act as temporary mulch, preventing soil moisture evaporation.

- Fodder cowpea: In situ green manuring with fodder cowpea and its burying at 40 days after sowing (DAS) will ensure a steady N supply during the grand growth phase and flowering period, when the N demand peaks up in the crop. It hastens microbial activity in soil, reduces weed growth and enhances natural enemy build up. This provide around 400-500 kg dry matter per hectare with 2.5 per cent N and contributes 10-12 kg N/ha during squaring. Its additional benefits include smothering of weeds, controlling seasonal, soil erosion and nurturing natural enemies of cotton pests
- Vermicompost: Vermicompost @ 1-2 t/ha should be added supplementing FYM on the furrow lines on which sowing is done. Its nutrient composition varies with substrate that is vermicomposted, but generally contains several diverse microfloras that aim in good plant growth. It offers good scope for recycling of farm waste.
- Biofertilisers: Cotton seed inoculation of Azotobacter or Azospirillum @ 500 g/seed required for sowing one hectare is recommended and soil application of 2.5 kg with 20 kg of farm yard manure.

2.2. Recommendation of National trial (AICCIP)

Application of FYM @ 5 t/ha with green manure incorporation resulted higher seed cotton yield at 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 Nandyaland 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.

3. Weed Control in organic Cotton

3.1 Stale Seed Bed

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)

3.2 Manual weeding and Inter cultivation

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.

3.4 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

3.5Mulching

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.

3.6 Solarization

. 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 (Singh, 2009).

3.7 Bioherbicides

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.

3.8 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

4.Organic crop protection measures

- Selection of resistant / tolerant varieties will help the plants to tolerate the pest attack. LRA 5166, Surabhi and Sumangala are tolerant to sucking pests and Supriya, Kanchana and LPS 141 are resistant to whitefly.
- Growing castor as trap 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*in cotton.
- Intercropping with blackgram and chillies will reduce the intensity of bollworms infestations in cotton.

- Cowpea planted as a bund crop encourages predators such as coccinellids, syrphids etc. which will keep the sucking pests under check.
- Maize grown as ecofeast crop along the border provides food and shelter for number of lepidopteran parasites. It also act as barrier crop for sucking pests.
- Crop rotation with cereals like maize / sorghum reduce the incidence of whitefly, bollworms, soil born insects and nematodes.
- Cotton double cropping and ratooning should be avoided to prevent carry over population.
- Close spacing will encourage the faster rate of multiplication of bollworms and other pests of cotton. Hence optimum spacing and density are to be maintained.
- Field sanitation should be followed. Removal of alternate weed hosts which harbour cotton pests.
- Removal of terminals of cotton crop (“Topping”) at 80-90 days of growth should be made to reduce *Helicoverpa*oviposition.
- Erection of bird perches (10 / ha) encourages the predation by carnivorous birds.
- Hand picking of grown up larvae should be done in the morning and in the evening hours. It helps to minimize heavy build up of future population.
- Pheromone traps @ 5/ha help to identify the brood emergence for synchronization of insecticide application and release of parasites.
- 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.
- Two to three releases of egg parasitoid *Trichogrammachilonis*@1.5 lakh / ha during peak egg laying of *Helicoverpa*and other bollworms will help to reduce the bollworms infestation significantly. Release of *Chrysoperla*sp. @ 500-1000 / ha according to the intensity of jassid damage between 20 – 25 days of crop growth will reduce the jassid population.
- Spraying of H-NPV @ 500 LE /ha will be targeted against young larvae of *H. armigera*. This can be repeated after 15 days for retaining good inoculum of the pathogen.

5. Integrated Disease Management (IDM) in Cotton:

- **Exclusion of the pathogen:** Preventing the pathogen from entering particular area where the disease is not prevalent.
- **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.
- **Use of resistant varieties/cultivars -** Use of disease resistant lines/hybrids is the basic tenet of any IDM programme.

- **Cultural practices:** Seeds having above 80% germination will have vigorous growth and thereby they do not suffer from infection due to soil borne organisms.
- **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 micro-sclerotial population in the soil.
- **Crop residue management / field sanitation** is another essential part of disease management.
- **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.

6. Certification Procedures Involved in Organic Cotton Production

- **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.
- **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.
- **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.
- **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.
- **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.

- **Seeds And Planting Materials**
  - 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.The use of genetically engineered seeds, pollen, transgenic plants or plant materials shall not be allowed.
- **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.
- **Materials Produced on an Organic Farm Unit**

  Farmyard & poultry manure, slurry and urine
  Vermi compost and coir compost
  Crop residues and green manure
  Straw and other mulches
- **Microbiologial Preparations**

  Bacterial preparations (bio fertilizers)
  Biodynamic preparations
  Plant preparations and botanical extracts
  Vermiculate
  Peat
- **Products which are not permitted under Certification**

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

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Conservation Agriculture in Cotton Based Cropping System

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The quality of natural resource base, especially of soil and water plays an important role in enhancing the productivity and crop quality, and sustainability of various production systems. Fertile soils with good physical properties to support root growth are essential for sustainable agriculture, but, since green revolution, the soil resource base has undergone human induced soil degradation and loss of productivity, often from poor fertilizer and water management, soil erosion and shortened turn around periods. Continuous cropping and inadequate replacement of nutrients removed in harvested materials or lost through erosion, leaching or gaseous emissions deplete fertility and cause soil organic matter levels to decline from the original levels. Among the several practices used in intensive production systems in the tropics, soil tillage and the lack of adequate organic matter input to the soil have a heavy toll in maintaining the integrity of the soil.

Soil compaction, a physical form of soil degradation, is a worldwide problem and reduces crop yield mainly due to reduction in the permeability of the soil to water, air and roots. The soil compaction can be defined as "the process by which the soil grains are rearranged to decrease void space and bring them into closer contact with one another, thereby, increasing the bulk density" (SSSA 1996). The soil compaction is responsible for the soil degradation in Europe (33 million ha), Africa (18 million ha), Asia (10 million ha), Australia (4 million ha), and some areas of North America (Hamza and Anderson, 2005; Nawaz et al., 2013). The causes for soil compaction are either natural phenomenon like rainfall, foot traffic of man, animal, etc. (Fabiola et al., 2003) or artificial phenomenon like mechanical operations (Greene and Stuart, 1985). Conventional agricultural practices can also degrade the soil by the soil compaction (Quiroga et al., 1999). Soil Organic matter maintains soil aggregate stability; therefore, addition of crop residue improves soil structure and aggregation. SOM can hold up to 20 times its weight in water. Crop residues on the soil surface create tiny dams which enhance infiltration, reduce surface crust formation, and slow water runoff, which increases water infiltration and soil moisture (Edwards, 1995). Crop residues on the soil surface form a barrier to water loss by evaporation, increasing the amount of moisture stored in the root zone. Water infiltration and soil moisture levels were greater under no-tillage with residue compared to without. Higher infiltration rates and favorable moisture dynamics supported a yield increase of up to 30% (Govaerts et al., 2007).

So, the challenge is to adopt a new agricultural paradigm that will address the twin concerns of maintaining and enhancing the integrity of natural resource base and improved productivity.

Conservation agriculture (CA) has been reported by numerous workers as sustainable and eco-friendly crop production technique in irrigated and rainfed agro systems which aims at to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs. Conservation agriculture reverses soil degradation processes and builds up soil fertility through increase in water holding capacity, facilitating better infiltration of rainwater and enhancing ground water storage, enrichment in soil organic carbon (SOC), and enhanced microbial diversity in the rhizosphere. It eliminates power intensive soil tillage, thus considerably reducing the drudgery and labour required for crop production. So, CA is having the potential of maintaining soil health in the long run and while at the same time achieving the highest productivity.

Conservation agriculture has emerged a major way forward from the existing unsustainable conventional agriculture, to protect the soil from degradation processes and make agriculture sustainable (Jat *et al*., 2012). Empirical evidences have been accumulating to show that zero/minimum tillage based agriculture along with crop residue retention and adoption of suitable crop rotations can be highly productive, provided farmers participate fully in all stages of technology development and extension (FAO, 2001). Conservation agriculture based system permits management of soils for agricultural production without excessively disturbing the soil, while protecting it against soil degradation, loss in organic matter, leaching of nutrients among others. It is hard to quantify CA adoption statistics worldwide as statistics is not available on specific use of CA. Hence, the worldwide acreage of Zero Tillage (ZT), which is 105 million ha is used as a proxy for CA (Hobbs and Govaerts, 2010, Derpsch and Friedrich, 2009). This figure is used as a proxy for CA, although not all of this land is permanently no-tilled or has permanent ground cover. Despite successful in the upland soils in the humid and sub-humid tropics, limited benefits of NT however, have been reported in the semiarid or arid tropics throughout the world (Nicou *et al*., 1993).

Short-term yield effects have been found to be variable under CA i.e., positive, neutral, or negative yield response (Lumpkin and Sayre, 2009). CA has been reported to enhance yield level of crops due to associated effects like prevention of soil degradation, improved soil fertility, improved soil moisture regime and crop rotational benefits. Baudron *et al* (2009) reported encouraging yield benefits of CA at a plot level as a result of enhanced water and nutrient use efficiency.

Conservation agriculture resulted in improved fertilizer use efficiency (10–15%) in the rice-wheat system, mainly as a result of better placement of fertilizer with the seed drill as opposed to broadcasting with the traditional system (Hobbs and Gupta, 2004). In some reports, lower N fertilizer efficiency was recorded as a result of microorganisms tying up the mineral N (immobilization) in the crop residues. However, in other longer-term experiments, release of nutrients increased with time because of microbial activity and nutrient recycling (Carpenter-Boggs *et al*., 2003). Increased aggregation and SOM at the soil surface led to increased nutrient as well as water use efficiency (Franzluebbers, 2002). Phosphorus efficiency and availability to plants can be improved if crop residues are added to soils (Sanchez *et al*., 1997). Inclusion of legumes in CA leads greater to nutrient availability to plants. Burle *et al* (1997) reported highest levels of exchangeable K, calcium (Ca), and magnesium (Mg) in systems with pigeonpea and lablab (*Dolichos lablab*) and lowest in systems containing clover. Similarly, Govaerts *et al* (2007) observed higher C, N K, and lower sodium (Na) concentration with residue retention compared to residue removal in a rainfed permanent raised bed planting system in the subtropical highlands of Mexico.

The benefits of CA include reduction of the amount and costs of labor and energy required for land preparation, and sowing due to the fact that the soil becomes soft and easy to work. Sowing directly into the soil without any prior tillage operations implies less labour requirement under CA. In fact, the reduction in cost and time required are usually the most compelling reasons for farmers to adopt conservation tillage (FAO, 2001). Rotations can also spread labor needs more evenly during the year. Direct planting into a mulch of crop residues without soil tilling can reduce labour requirements at a critical time in the agricultural calendar, particularly in mechanized systems when a direct-seeding machine is used (Giller *et al*., 2009).

The soil cover also inhibits the germination of many weed seeds, minimizing weed competition with the crop FAO (2001), which reduces the number of weeding operations required. Weeding accounts for more than 60% of the time a farmer spends on the land. In the first few years, however, herbicide may still need to be applied, making a location-specific knowledge of weeds and herbicide application important. Nurbekov (2008) observed that weed menace may be reduced as weed seed is not incorporated into the soil and seed bank gets exhausted, residues impede weed germination and growth and increased biological activity results in lower weed seed viability. However, the net effect of crop residues retained in CA on weed control is somewhat contradictory and in some cases, crop residue retention lessened herbicides efficacy (Forcella *et al*., 1994).

One of the major benefits of CA, which makes it popular among farmers is it costs less in terms of not only money but also time and labour. In the rice-wheat systems of South Asia (Hobbs and Gupta, 2004), no-till wheat significantly reduced the cost of production; farmers estimate this at about Rs. 2500 ha^{-1}, mostly due to use of less diesel fuel, less labor, and less pumping of water. Since planting can be accomplished in one pass of the seed drill, time for planting is also reduced thus; freeing farmers to do other productive work (Hobbs, 2007).

Gathala *et al* (2014) demonstrated that that adopting the principles of CA together with best crop management practices improved the system productivity and overall efficiency of rice-wheat system in the northwesten Indo-Gangetic Plains (IGP) and in turn resulted in higher profitability.

Back to content page

Ranjan *et al* (2014) evaluated a range of approaches for enhancing the productivity and economic returns of rice-wheat-based cropping systems in the Eastern Indo-Gangetic Plains. They found that avoiding tillage in wheat and including mungbean increased the yields of wheat and the succeeding rice crop by 21–31% and 5–10%, respectively. The yields of wheat and rice increased further by 46–54% and by 10–24%, respectively, with the inclusion of more CA components. This showed that there is enormous untapped potential to improve overall system performance through the adoption of CA in integration with BMP in the intensive system of the E-IGP of India.

No tillage with residues cover has higher aggregate stability, higher aggregate size values and total organic carbon in soil aggregates than conventional tillage (Das *et al*., 2013). Bhattacharyya *et al* (2013) evaluated impacts of CA (zero tillage, bed planting and residue retention) on changes in total soil N (TSN) and aggregate-associated N storage in a sandy loam soil of the Indo-Gangetic Plains. Cotton (*Gossypium hirsutum*) and wheat (*Triticum aestivum*) crops were grown during the first 3 years and in the last year, maize (*Zea mays*) and wheat were cultivated. Results indicated that adoption of zero tillage in permanent beds with crop residue addition was a better management option for improvement of soil N. They also found that this management practice has the potential to improve soil aggregation with greater accumulation of TSN within macro aggregates, and this trend would likely have additive effects with advancing years of the same management practices in this region.

Concerted efforts of Rice-Wheat Consortium for the Indo-Gangetic Plains (IGP), a CGIAR initiative in partnership with the national research system of the countries of the region (Bangladesh, India, Nepal, and Pakistan) is now leading to increasing adoption of resource conservation technologies like Zero Tillage mainly for the sowing wheat crop. In the rice–wheat (RW) areas of South-Asia, no-till planting of wheat has increased rapidly with more than 2 Mha in the IGP (Rice-Wheat Consortium, 2006). In India, resource conservation technologies are finding rapid acceptance by the farmers of Haryana, Punjab and Western Uttar Pradesh. Unlike in rest of the world, in India spread of technologies is taking place in the irrigated regions of the IGP where rice–wheat cropping system dominates.

CA systems have not been tried or promoted in other major agro-eco regions like rainfed semi-arid tropics, the arid regions or the mountain agro-ecosystems (Jat *et al*., 2012). They observed that in the long-term CA has been found to render several benefits including soil conservation with improved soil health, higher rain water use efficiency, climate change mitigation and adaptation, improved biodiversity, resilience to climate shocks, higher economic returns, and more leisure time to farmers. However, before recommending CA under given set of agro-climatic and socio-economic conditions, it is essential to undertake medium to long-term studies on CA to better guide the farmers for successful adoption.

Field experimentation is in progress at ICAR-CICR Regional Station, Coimbatore from 2015 onwards by combining land shaping with residue retention coupled with location specific remunerative cropping systems for improving system productivity and soil quality under conservation agriculture (CA) under irrigated condition. The main plots involved Farmer's practice, (M_1), CA system with minimal land reshaping and partial (50% of residue from above ground biomass and 100% roots) residue recycling (M_2) and CA system with 100% residue recycling (M_3). The subplots involved four different cropping systems (Fig 1) *viz*., S_1: Cotton-Black gram-Maize (for grain purpose); S_2: Cotton-Maize (for green cobs)+Pigeon pea (Strip cropping@4:2 ratio); S_3: Cotton-Groundnut (for table purpose)+Pigeon pea (Strip cropping@8:2 ratio) and S_4: Cotton-Fallow (Control).

Fig 1. Details of cropping systems, residue recycling and land shaping involved in the experiment

a) Prominent cropping system (Cotton-Black gram-Maize (for grain purpose))

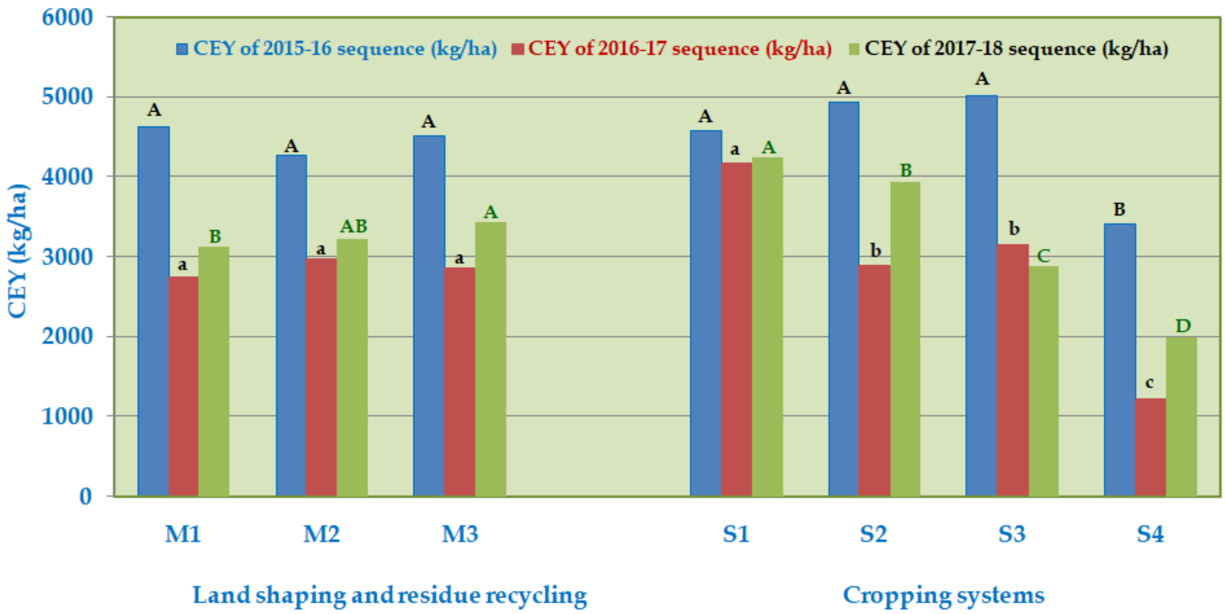
b) Cropping system for Peri-urban areas

c) Residue recycling under conservation agriculture practices

Analysis of Cotton Equivalent Yield (CEY) indicated no significant yield difference due to land shaping with residue retention treatments during the first (2015-16) and second (2016-17) years of cropping sequences while third year (2017-18) M_3 registered significantly higher CEY (Fig 2) than M_1 (Raja et al., 2019). Among the cropping systems cotton- black gram- grain maize registered significantly higher CEY of 4577, 4174 and 4247 kg ha^{-1}, respectively during I, II and III years vis-à-vis cotton-fallow (3400, 1223, 1996 kgCEY ha^{-1}, respectively).

Fig 2. Cotton Equivalent Yield (CEY) of the system (kg CEY ha^{-1}) during 2015-16, 2016-17 and 2017-18 cropping sequences

(Different upper case, lower case and coloured alphabet indicate significant difference among treatments within the group; M1: Farmer's practice, M2: CA system with minimal land reshaping & partial residue recycling, M3: CA system with 100% residue recycling; S1: Cotton - Black gram - Maize (for grain purpose); S2: Cotton - Maize (for green cobs) + Pigeon pea (Strip cropping@ 4:2 ratio); S3: Cotton - Groundnut (for table purpose) + Pigeon pea (Strip cropping @ 8:2 ratio) and S4: Cotton - Fallow (Control))



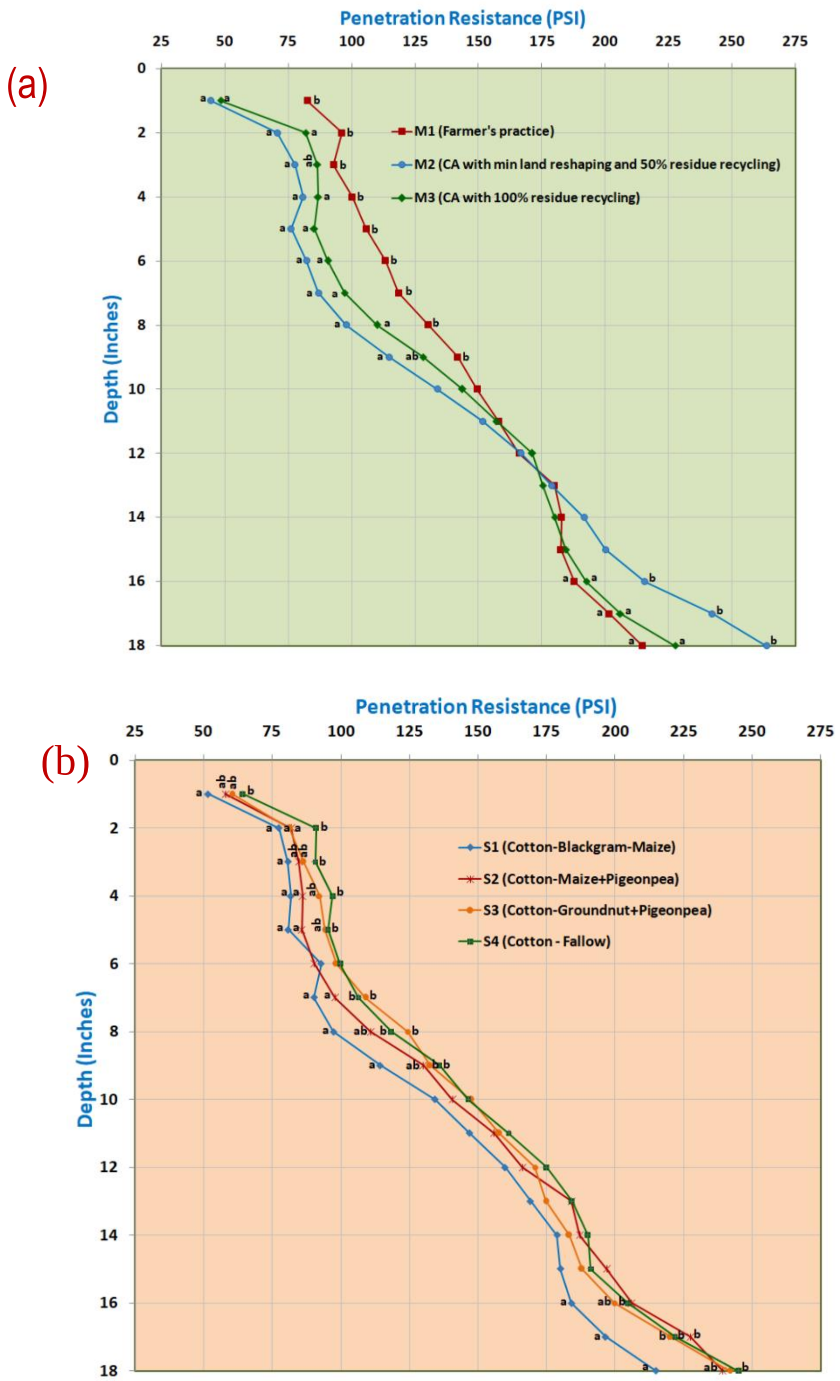
Back to content page

Pooled analysis of depth wise soil penetration resistance using MSTATC over three cropping sequences revealed that CA system with 100% residue recycling significantly reduced the soil penetration resistance upto 9” soil depth vis-à-vis Farmer’s practice (Fig 3).

The results indicated that Cotton - Black gram - Maize (for grain purpose) is a potential candidate cropping system to implement conservation agricultural practices under irrigated conditions; Beds and furrows system is found to be suitable for raising cotton and other component crops under conservation agricultural practices viz., minimum tillage and residue recycling and CA system with 100% residue recycling significantly reduced the soil penetration resistance upto 9” soil depth vis-à-vis Farmer’s practice.

Fig 3. **Soil Penetration Resistance (PSI) recorded at different soil depths (inches) in (a) different land shaping & residue recycling treatments and (b) cropping systems** (Different lower case letter indicate significant difference among treatments within the group)

Back to content page



Hence, it is clear that conservation tillage affect the physico-chemical properties of soils such as bulk density, aggregation, hydraulic conductivity, pH, and organic content. (Alvarez and Steinbach, 2009). In spite of several advantages CA offers, there is very slow adoption of CA worldwide except in countries like Brazil, Argentina, Australia, and the USA due to various problems encountered during its adoption. The major problems identified were competitive uses of crop residues, weed preponderance, lower crop yields, new implements and operating skills required, nutrient immobilization, carryover of insect-pests and disease pathogens, low investment capacity of SAT farmers, lack of sufficient research on CA in the SAT (Jat *et al*., 2012). CA can be quite helpful to achieve the goals of sustainability and improved productivity in different agro-ecologies, but concerns have been raised about slight yield decline mainly during the initial years of adoption of CA and promoting it in SAT is a challenging task before the stakeholders due to their typical agro-climatic, social and economic conditions.

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Nutrient Disorders in Cotton

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Introduction

Cotton is an important cash crop and plays a vital role in industrial and agricultural economy of our country. India stands first place in area and production among the world cotton acreage and production but the productivity is very low. The higher productivity of cotton can be achieved by minimizing the yield losses due to nutrient deficiency. In general, sixteen elements like carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, zinc, iron, copper, manganese, boron, molybdenum and chlorine are highly essential for better plant growth and development. Mineral elements have numerous functions in plants including maintaining charge balance, electron carriers, structural components, enzyme activation and providing osmoticum for turgor and growth. Soil nutrients deficit caused by extractive farming practices including removal of crop residues, *imbalanced* application of inorganic fertilizers and organic amendments, soil erosion due to poor agronomical practices and etc. Short supply and inadequate of nutrients from soil or external sources of application are the reasons for appearance of nutrient deficiency symptoms in plants. The effect of mineral nutrient deficiencies are immediate cessation of root growth or massive disruption of membranes or cell walls, reduced export or utilization of carbohydrates and poor storage of nutrients in the plant tissues. Hence, to understand how mineral nutrient deficiencies affect metabolism, growth and development and yield components of cotton is very important. A better understanding of these interactions will lead to better diagnosis of deficiencies and improved nutrient management practices.

Macronutrient deficiency symptoms

1. Nitrogen deficiency

Nitrogen (N) is one of the most essential macronutrient and required in larger quantities for all the stages of cotton growth and development. It involves in fundamental processes like photosynthesis, protein metabolism and carbon partitioning. In general, nitrogen is highly needed during squaring to boll formation stage as compared to that of initial stage of cotton. If the nitrogen supply is very poor in soil particularly where the organic matter content is low, nitrogen deficiency symptoms are appeared in older leaves of cotton due to higher mobility of the nutrient within the plant. The first sign of the nitrogen deficiency symptoms are yellowing in the older leaves, reduction in the size of young green leaves, short and stunted plant growth, faint reddish tint over the leaf blade, stems and stalks, purple spot in buds. In severe cases, brown necrosis begins at the leaf tip and progresses along the midrib; finally the entire leaf is dead. N deficiency also results in decreased root growth, suppression of lateral root initiation, increase in the C/N ratio within the plant, reduction in photosynthetic rate and early leaf senescence

N deficient plant under field condition

Photo : Dr. D. Kanjana

N deficient plant under Green house condition

Photo : Dr. M. Sabesh

2. Phosphorus deficiency

Phosphorus (P) is highly essential for vigorous root and shoots growth, promotes early boll development, hastens maturity, increases water use efficiency and is necessary for energy storage and transfer in plants. Phosphorus is absorbed by plants mainly in the form of phosphate ion and is most readily transported into the plant. In general, phosphorus nutrient is highly fixed with clay particles and precipitated as iron and aluminium phosphates in acidic soils and calcium and magnesium phosphates in calcareous soils, which render the phosphorus in unavailable from. Though phosphorus is the mobile nutrient within the plant as like N and K, entire content of phosphorus is moved from older leaves and nourished the younger parts of the plant. The main evidence of the phosphorus deficiency symptom is stunted plant growth (dwarfing) and reduced leaf size with dark green leaves in older leaves of cotton. In extreme deficient condition of phosphorus, purple pigmentation appears in leaf margins and proceeds into interveinal tissues and then leaves die and fall off prematurely. Apart from the specific symptoms, reduced number of branches, delayed flowering and fruiting and reduced yields also aroused due to P starvation of cotton plants.

P deficient leaf

Photo : Dr. M. Sabesh

3. Potassium deficiency

Potassium (K) is an important major nutrient in cotton production because it affects yield and fiber quality substantially. Potassium is a vital nutrient for biomass production by enhancing the photosynthetic rates of crop leaves, CO_2 assimilation, carbon movement, carbohydrate partitioning and translocation of photosynthates from sources to sinks. The distinct deficiency symptom of potassium in cotton is 'cotton rust'. Initially, it appears as interveinal chlorosis on older leaves, where the leaves become yellowish with white mottling, brown specks at the leaf tips, around margins and between veins. The tips of the leaf and margins break down and curl downwards as the tissue breakdown continues and then the whole leaf becomes reddish brown *ie.,* rust coloured, brittle, dries and drops prematurely from the plant affecting the normal development of bolls which results in dwarfed and immature fruit, some of which may not open altogether.

K deficient leaf

K deficient plant

Photo : Dr. M. Sabesh

4. Calcium deficiency

Calcium (Ca) plays an important role in every stage of growth and development of cotton plant. Calcium is essential for the functional integrity of root cell membranes especially plasmalemma and influence the enzyme activity and cement the cell walls in the form of calcium pectate. Calcium deficiency occurs due to competition by other cations and low transpiration rate. Calcium deficiency causes membrane damage and failure of nutrient ion uptake mechanisms. Cotton seedlings are greatly affected due to the calcium deficiency, where the leaf petioles start bending and permanent wilt occurs. In younger leaves, chlorosis is started along the veins and bleaching appearance of upper half of the leaves followed by leaf tip curling are some of the other symptoms of Ca deficiency.

Ca deficient leaf

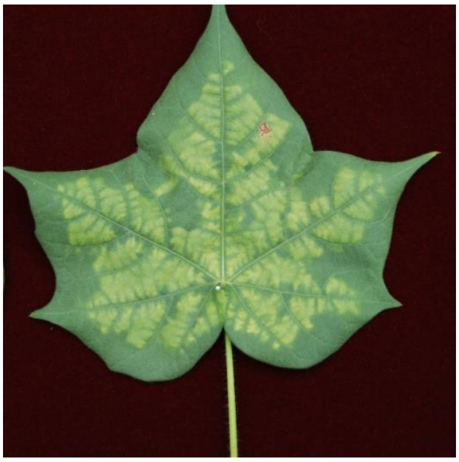

Photo : Dr.M.Sabesh

5. Magnesium deficiency

Cotton is highly response to Mg nutrient for their better growth and development. Magnesium involves in various plant physiological processes such as photo phosphorylation, enzyme activation, protein synthesis and chlorophyll formation and also it helps in translocation of cellulose and determines fibre quality in cotton. Deficiency symptoms often appear first on the lower leaves. Shortage of Mg^{2+} results in interveinal chlorosis of the leaf, in which only veins remain green. In more advanced stages the leaf tissue becomes uniformly pale yellow, then brown and necrotic. In cotton, the lower leaves may develop a reddish-purple cast, gradually turning brown and finally necrotic.

Mg deficient younger leaf

Photo : Dr. M. Sabesh

Mg deficient leaf exposed to high temperature

Photo : Dr. M. Sabesh

Mg deficient plant

Photo : Dr. D. Kanjana

6. Sulfur deficiency

Being a structural component of amino acids like cystine and thiamine, sulfur is essential for the formation of various plant proteins, enzymes and chlorophyll. Deficiency symptoms occur when soils have available SO_4-S less than 10-15 ppm per acre. Though sulfur is relatively immobile within the plant, deficiency symptoms occur in younger leaves of cotton. The younger leaves become small with chlorotic (Pale light green or yellowing) appearance including veins. If the deficiency persists and becomes severe, pale brown necrotic lesions may develop in tissues adjacent to the margins of affected leaves. In addition, the margins often become excessively wavy or cupped upward. Old leaves remain pale green and do not develop marginal symptoms. Moreover, plants show the stunted appearance with reduced branching, fewer flowers and fewer bolls set in cotton. As a result, yields of lint and seed are reduced. This yellowing symptom is confused with N deficiency, but it differs from N deficiency by showing the yellow colour in older leaves of cotton plants.

S deficient leaf (initial and middle stage)

Photo : Dr. M. Sabesh

S deficient plant

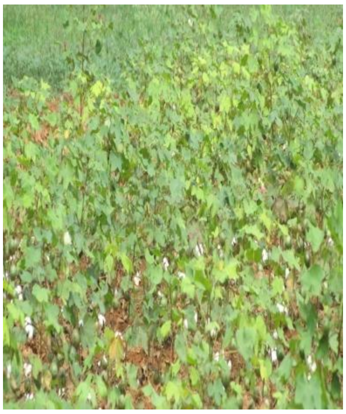

Photo : Dr. D. Kanjana

Micronutrient deficiency symptoms

7. Zinc deficiency

Zinc is a most important micronutrient for cotton growth function as like the major nutrients *viz.,* N, P and K. In India, zinc is the foremost deficient micronutrient and next to N and P. Under high alkaline soils, Zn is the most likely to be deficient nutrient as like other micronutrients except molybdenum. In plants, Zn is essential for the synthesis of aminoacid tryptophan, precursor of Indole Acetic Acid (IAA) *ie.,* growth hormone production, acts as a co-factor of carbonic anhydrase enzyme and scavenging of Reactive Oxygen Species in the form of ZnSOD. Zn deficiency symptoms usually appear in the younger leaves in the upper canopy because the nutrient is not readily translocated from older to younger leaves. Zn deficiency symptoms showed first as interveinal chlorosis (yellowing of the leaves between the veins with the veins remaining green) and bronzing appearance (chlorotic areas may turn bronze coloured) in the middle leaves. The youngest leaves are often malformed and the internodes are shortened giving the plants a rosette appearance in dicots. Later red spots appeared on the leaf blades. The leaves suffering from deficiency were thicker and brittle because of enlarged palisade cells and then their margins cupped upwards. Squares and flowers that are formed tend to shed. Deficiency in zinc might result in significant reduction in crop yields and quality. In fact, yield can even be reduced by over 20% before any visual symptoms of the deficiency occur.

Zn deficiency symptoms

Photo : Dr. D. Kanjana

Zn deficient leaf (advanced stage)

Photo : Dr. M. Sabesh

8. Boron deficiency

Boran is the second most deficient (33 %) micronutrient, after zinc in India but it plays a role in cell wall structure, formation of proteins and carbohydrate transport within plants. The uptake of boran by plants is very fast but it is immobile in phloem of the plant. So, boron deficiency is more common in younger leaf tissue with light chlorosis symptoms in cotton plants. Boron deficiency may cause a distorted, stunted terminal (apical dominance), necrosis in meristamatic tissue and abnormal uppermost leaves. Other symptoms of B shortage may be a "coon-tailed" appearance with dark rings on the leaf petiole (stem), or petioles that are shortened and thicker than in healthy plants. In severe situations, flower abortion and boll shedding may occur which can result in excessive vegetative growth and reduced yields. B deficiency affects root elongation, indoleacetic acid (IAA) oxidase activity and sugar translocation in plants. The range between boron deficiency and toxicity is very narrow. It is known that B deficiency can significantly limit cotton yields without any visible foliage and flower symptoms, characterizing the occurrence of “hidden hunger”. Boron deficiency is not easily recognized even in foliar diagnosis, since cotton plants showing 11 ppm B in the most recently mature leaves yielded the same dry matter as non-deficient plants, but the number of reproductive structures was lower.

B deficient plant

Photo : Dr. M. Sabesh

B deficient leaf (Necrosis)

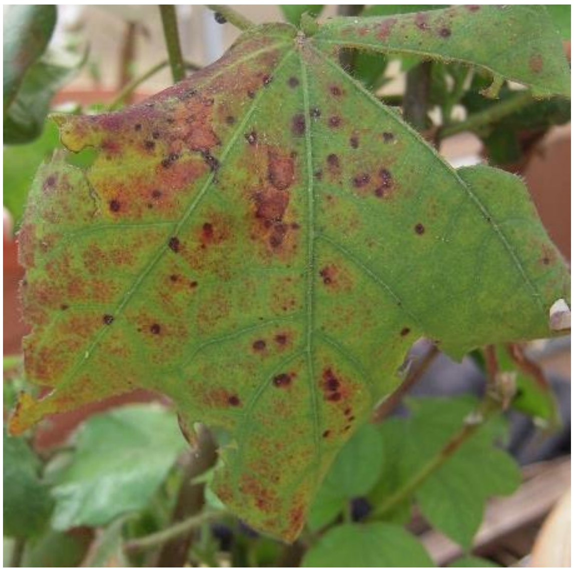

Photo : Dr. M. Sabesh

9. Iron deficiency

Iron is one of the most essential micronutrients but it is required in smaller quantity for normal growth and functioning of plants. It plays an important role in photosynthetic reactions, enzymes activation and RNA synthesis. Iron is the predominant element in cytochromes and ferredoxin which are found in the electron transfer systems in chloroplasts. Plants which are grown under calcareous soils, acid soils or sandy soils which are deprived of organic exhibits Fe deficiency symptoms. Fe deficiency results in reduction of photosynthetic rate, ribulose-1, 5-biphosphate carboxylase/ oxidase (rubisco) enzyme, stomatal conductance, and maximum quantum yield of PSII (Fv/Fm). Iron is also an immobile nutrient and it is not rapidly moved from older leaves to younger parts of the plant, and hence iron deficiency symptom is appeared in younger leaves of the plant. Initially, the younger leaves develop pale green to pale yellow interveinal chlorosis while the older leaves remain green and normal. In severe iron deficient conditions, pale yellow leaves turn dark yellow with visibly faded veins and then leaves turn almost white and the veins also disappear.

Fe deficient younger plant

Photo : Dr. M. Sabesh

Fe deficient leaf (Necrosis in advanced stage)

Photo : Dr. M. Sabesh

10. Manganese deficiency

Manganese (Mn) is an essential micronutrient but required in smaller quantity for cotton production. Also, it is involved with chlorophyll synthesis, photosynthesis and helps to improve N-utilization. Manganese has also been associated with improved resistance to root diseases. Manganese deficiency commonly occurs in some coastal plain soils and soils with high pH. Since the limited movement of manganese from older to younger leaves, manganese deficiency symptom is occurred in younger leaves of the plant. Interveinal chlorosis *ie.,* uniform yellowing in leaves with prominent dark green veins and downward curling of leaves is the major symptom of manganese deficiency in younger leaves of the cotton plant.

Mn deficient leaf

Mn deficient plant

Physiological disorders in Cotton

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Introduction

Cotton is an important cash crop grown for its fiber since time immemorial. India ranks first in area (12.9 million hectares) under cultivation however the productivity is low (420.7kg/ha) as against world average of 797 kg/hectare (Cotton Association of India, 2019). Physiological disorders are one of the causes of decline in yield. Physiological disorders are caused due to environmental, plant and soil factors. Square and boll shedding, leaf reddening, parawilt, leaf drying, square and boll drying, bad boll opening and leaf malformation due to 2,4-D are the major physiological disorders that occur in cotton.

Square and boll shedding

Square and boll shedding is quite common in cotton. Around 60 % shedding of squares, and shedding of 8% of flowers and 5 % of bolls is considered as normal under ideal growth conditions. In cotton plant, there is a strong correlation between photosynthetic supply of carbohydrates and the demand of carbohydrates for developing bolls. When the supply is lower than the sink demand, the plants tend to shed its younger bolls to protect larger bolls for which more resources are allocated. However excessive boll shedding due to biotic and abiotic stresses causes severe yield loss in cotton.

Causes

Low light due to overcast condition, high humidity, low and excess moisture, heavy rainfall, excess plant population, excessive vegetative growth, deficiency of nutrients and hormones are the major causes of boll shedding in cotton

Prevention of excessive boll shedding in cotton

1. By preventing excessive vegetative growth
    i. Timely application of recommended dose of plant growth regulators
    ii. Avoid applying excess nitrogenous fertilizers
    iii. By avoiding over irrigation
2. Adjusting the planting geometry (plant to plant and row to row spacing) so as to enable the penetration of sunlight to the lower fruiting branches)

3. Alleviating the deficiency of nutrients and hormones by need based foliar spray of 1% DAP from 60 days after sowing and /or foliar spray of Napthalene Acetic Acid (10 ppm- 10 mg/litre of water) at 60 or 70 DAS.

Leaf reddening

Causes

The major causes for leaf reddening in cotton are mineral nutrient stress, water logging, drought, low temperature stress, high light stress, incidence of sucking pests, strong winds, microbes, choice of genotype, certain insecticides, herbicides like 2,4-D and spraying of cocktail of incompatible combination of chemicals. Abiotic stresses in general create a transient nutrient deficiency in plants, as the uptake of mineral nutrients is hampered due to various reasons. Reduction in uptake of mobile nutrients like, N, P, K and Mg under abiotic stress conditions, leads to translocation of nutrients from older leaves to newer leaves at the top. These stresses thus accelerate senescence of older leaves by degradation of chlorophyll. Accumulation of anthocyanin pigment occurs to protect the leaves from further damage.

Leaf reddening due to nutrient Deficiency

Leaf reddening due to sucking pests

Possible measures which can be taken to prevent leaf reddening in cotton

- Foliar spray of 2 % DAP along with 1% Potash or Potassium Nitrate at about 90 DAS
- Foliar spray of 2 % Urea, 0.5 % Zinc Sulphate and 0.2 % Boron twice at 15 days interval
- Foliar spray of 19:19:19 (1%) or 2 % DAP with 1 % Magnesium Sulphate at peak boll formation stage.
- Avoid planting susceptible genotypes like RCH-2 Bt and Mallika Bt

- Avoid spraying insecticides like Methomyl and Thiodicarb
- Planting improved desi cotton varieties which are highly tolerant to abiotic and biotic stresses
- Planting short duration varieties which can escape biotic and abiotic stresses
- Practicing early sowing so as to enable the plants to avoid stress during the critical stages
- Planting desi varieties/hybrids with less nutrient demand under rainfed conditions
- Following moisture conservation measures like mulching and nutrient conservation measures like intercropping and crop rotation

Parawilt

Causes

- Excessive irrigation/heavy rainfall leading to water logging of cotton fields especially in heavy clayey soils
- Poor uptake of nutrients and water due to damaged roots under anaerobic conditions
- Water logging preceding prolonged dry spell with high temperature and bright sunshine hours
- Planting hybrids/varieties with heavy boll load demanding more nutrients, water and photo assimilates.
- Excessive vegetative growth resulting in more transpirational loss of water.

Symptoms of parawilt

In the affected plant, the leaves exhibit slight drooping symptoms initially. However as time proceeds leaves wilt severely and turn yellow and gradually to red in the presence of bright sunshine. The squares and young bolls already formed will be shed profusely. Damaged roots decrease water and nutrient uptake by plants. The leaves dry rapidly and stick on to the stem. Bolls also get dehydrated rapidly and open forcibly. Eventually the leaves fall off from the plant. The parawilt symptoms appear sporadically in a field. The plants may recover gradually however their growth is severely stunted with smaller leaves with almost no bolls. Parawilt generally occurs in fields, where bright sunshine and dry spell occur after water logging. Browning of conducting tissues is not observed in plants affected by parawilt unlike in *Verticillium* wilt.

Amelioration of parawilt in cotton

- Fields should be drained properly to avoid damage to roots
- Preventing excessive vegetative growth to reduce water loss by transpiration
- Providing irrigation during peak growth stage if facilities are available
- Avoid apply excess fertilizers, FYM and incompatible combination of fertilizers especially under rain fed /water limited conditions.
- Spraying of Cobalt Chloride @ 10 mg/litre on affected plants within few hours of onset of drooping symptoms
- Soil drenching of a mixture of Copper Oxy Chloride 25 g and 200 g Urea in 10 litres of water or Carbendazim 1g/litre around the root zone to prevent secondary infection
- Planting of genotypes tolerant to wilt such as LRA 5166, LRK 516 (Anjali), SRT1, MCU 5 VT, AKH 4, G 27 and Jayadhar

Water logging in cotton

Effects

- Mineral nutrient stress (N, P, K, Mg and Ca) in shoots causing chlorosis of older leaves especially due to N deficiency
- Reddening of leaves, shedding of leaves and squares under severe stress due to excessive production of ethylene, Fe deficiency, damaged roots due to lack of oxygen and build-up of toxic gases such as carbon di oxide and ethylene that are produced by the roots.
- Stunted growth and poor yield with 10 - 40 % yield loss due to reduction in number of bolls

Waterlogged Field


Fe deficiency during water logging **Lenticel formation**

Management

- Ensure proper drainage in the fields to drain out the excess water by providing adequate slope
- Avoid excessive compaction of soils by following minimum tillage practices
- Foliar application of 1.5 % Urea
- Foliar application of 50 ppm Kinetin

Drought

Effects

Water stress affects the growth rate of cotton by reducing the number and size of leaves produced and thus reducing photosynthesis. The effect of water stress in cotton depends on timing and intensity of drought.

- Exposure to water stress prior to flowering reduces the number of fruiting sites
- The peak flowering period is the most sensitive period to drought and water stress during this critical period severely affects the yield and yield components of cotton
- Induces shedding of squares and young bolls due to hormonal imbalance
- Water stress during late-bloom stages will reduce late-developing bolls and fibre strength
- Water stress during fibre-elongation stage decreases the fibre length

Ameliorative measures

- Cultivating drought tolerant genotypes of cotton
- Foliar spray of 2% DAP during peak flowering stage
- Foliar spray of 0.5% zinc sulphate + 0.3 % boric acid + 0.5 % Ferrous sulphate + 1% urea during critical stages of moisture stress
- Foliar spray of 40 ppm NAA (4 ml of Planofix in 4.5 litres of water) to prevent shedding of fruiting bodies.

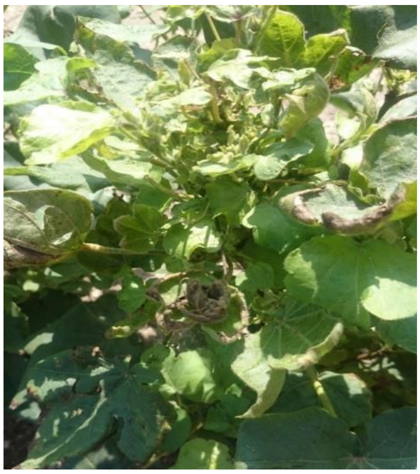
2, 4-D drift in cotton

2, 4 D is an auxin type herbicide. Major causes of 2, 4-D damage are spray drift, vapour drift and sprayer contamination. Spray drift is a major problem under windy conditions. Vapor drift is caused by volatalisation of ester containing formulation of 2,4-D. High temperatures, high soil moisture and temperature inversions increases the vapor drift and affect the cotton crop even from a larger distance. Impact of 2, 4- D drift in cotton basically depend upon the stage of the cotton plant which gets affected. A drift during seedling stage results in forced development of vegetative branches and delayed fruiting. If at pre-squaring stage, delay in squaring occurs depending upon the dose of 2-4- D. A plant affected at squaring stage will have a severe impact on yield as fruiting is severely delayed. 2-4-D drift at peak flowering stage may result in shedding of younger bolls. At late flowering stage, fibre quality will be reduced. The loss in yield due to 2-4, D drift is mainly due to delay in fruiting giving lesser time for maturation of later set bolls. Significant yield losses occur when the plants are exposed to 2,4-D at six leaf stage or at pre or early squaring stage.

Symptoms caused by 2, 4-D drift in cotton

Symptoms of 2,4-D injury are generally seen in meristematic regions of a cotton plant where leaves or squares develop. The development of interveinal tissues of newly formed young leaves is affected than in fully matured leaves resulting in the following symptoms

- Overgrown plants
- Cupping and stunting of leaves
- Brittleness, stunting and twisting of stems
- Malformation of newly formed squares, bolls
- Reddening of stems, petioles and bracts
- Yellowing of leaves and squares
- Reduction of root initiation and stem swelling in young cotton plants
- Terminal death of plant at high concentrations of 2, 4-D resulting in abnormal vegetative branching called 'candelabra effect'



2,4- D drift in Cotton

Management

The malformed leaf once formed may not be recovered. Foliar spray of water can be used to reduce the effect of 2, 4-D drift. To promote new flush, foliar spray of 1% urea is recommended. Foliar spray of 1.5 % calcium carbonate and 50 ppm Gibberellic acid can help in recovery of affected plants by low dose of 2,4-D to some extent. Avoid using sprayers contaminated with 2, 4-D for any other purpose in cotton field, unless washed thoroughly.

Square and boll drying in cotton

Square and boll drying is common in varieties with short sympodial branches and a cluster bearing habit. In other varieties this is seen under extreme weather conditions during flowering. Other factors like insect damage, pollination failure and micronutrient deficiencies contribute to square and boll drying. Non availability or decreased translocation of photosynthates to the reproductive parts may result in this disorder. This is common in problematic soils with salinity, alkalinity and also in light sandy soils with low nitrogen content. The dried squares and bolls turn black in color and immature bolls may crack. Dried bolls are eventually shed from the plant. *Gossypium hirsutum* genotypes are susceptible to this disorder. Adjustment of sowing dates, correction of nutrient deficiencies, prolonging the longevity of subtending leaves by need based spray of nutrients and plant hormones and frequent irrigation in saline soils may be done to ameliorate this disorder.

Bad Boll Opening

Bad boll opening is also called as Tirak. It is premature and improper cracking of bolls, instead of normal fluffy opening.

Symptoms

Leaves turn yellow and subsequently become red. The capsule wall of the bolls become tight and do not open completely. The affected bolls may turn black in color with time. The fibre as well as seed quality are affected.

Causes

- Soil with subsoil salinity
- Light sandy soil
- Nitrogen deficiency
- Prevalence of low humidity , warm and dry weather during fruiting period
- Low moisture and nutrient availability during boll formation

Square drying in Cotton **Boll drying in Cotton**

Management

- Adjusting sowing dates so that the boll formation stage is not affected by any environmental stress or nutritional deficiency
- Appropriate nitrogen management at critical growth stages
- Frequent irrigations to reduce effect of subsoil salinity/ alkalinity
- Timely application of nitrogen in light sandy soil
- Use of growth retardant to check excessive vegetative growth

Conclusion

Monitoring plant health and vigor by physiological indices and following the recommended need based management measures help in achieving higher productivity in cotton.

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Biological Control of Insect Pests of Cotton

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Cotton is one of the most economically important commercial crops in India, while insect pest damage is the major constraint factor for cotton production. The insect pests spectrum of cotton is quite complex and as many as 1326 species of insect pests have been listed in cotton throughout the world. However, main losses in cotton production are due to its susceptibility to about 162 species of insect pests.

Among these bollworms *viz*., American Bollworm, *Helicoverpa armigera,* Spotted bollworm *Earias vitella,* Spiny bollworm *Earias insulana,* pink bollworm *Pectinophora gossypiella* pose great threat to cotton production. Besides these, a complex of sucking pests *viz*., green leaf hopper *Amrasca bigutulla bigutulla*, thrips, *Thrips tabaci*, aphids, *Aphis gossypii*, whitefly, *Bemisia tabaci*, mealybug *Phenacoccus solenopsis* and *Paracoccus marginatus* red cotton bug *Dysdercus koengii*, dusky cotton bug *Oxycaraenus hyalinipennis* occupy major status and contribute to lower yield.

The strategy of integrated pest management (IPM), in which biological control plays an important role. The successful management of a pest by means of another living organism *i.e.* Biological control agents (natural enemies - parasitoids, predators and pathogens) is called biological control.

Predators: are mainly free-living species that directly consume a large number of preys during their whole life time. Eg: Different species of spiders, dragon flies, damsel flies, lady bird beetles, Chrysopa species, birds etc.

Chrysopa

Coccinellids

Spider

Reduvid bug

Spalgis epius- Predator of mealybug

Parasitoids: These are the organisms which lay eggs in or on the bodies of their hosts and complete their life cycles on host bodies as a result of which hosts die. A parasitoid may be of different type depending on the host developmental stage in or on which it completes its life cycle. Eg: egg, larval, pupal, adult, egg-larval and larval pupal parasitoids. Eg: Different species of *Trichogramma, Apanteles, Bracon, Chelonus,* etc.

Aphelinus

Aphidius

Encarsia

Eretmocerus

Campoletis chloridae

Aenasius sp.

Pathogens: These are micro-organisms which infest and cause diseases in their hosts as a result of which hosts are killed. Major groups of pathogens are fungi, viruses and bacteria. Examples of fungi are different species of *Beauveria, Lecanicillium* and *Metarhizium* which have been reported to infest and kill large number of insects in the fields. Among viruses, most important examples are of nuclear polyhedrosis virus (NPV). Among bacteria, *Bacillus thuringiensis (B.t.)* is very common examples.

Beauveria infected *Spodoptera*

Metarhizium infected *Phenacoccus solenopsis*

Techniques in biological control:

Biological control practices involve three techniques *viz.,* Introduction, Augmentation and Conservation.

1. Introduction or classical biological control: It is the deliberate introduction and establishment of natural enemies to a new locality where they did not occur or originate naturally. When natural enemies are successfully established, it usually continues to control the pest population.

2. Augmentation: It is the rearing and releasing of natural enemies to supplement the numbers of naturally occurring natural enemies. There are two approaches to augmentation.

a. Inoculative releases: Large number of individuals are released only once during the season and natural enemies are expected to reproduce and increase its population based on the level of pest infestation. Hence control is expected from the progeny and subsequent generations and not from the first release itself.

b. Inundative releases: It involves mass multiplication and periodic release of natural enemies when pest populations approach damaging levels. Natural enemies are not expected to reproduce and increase in numbers. Control is achieved through the released individuals and additional releases are only made when pest populations approach damaging levels.

3. Conservation: Conservation is defined as the actions to preserve and release of natural enemies by environmental manipulations or alter production practices to protect natural enemies that are already present in an area or non use of those pest control measures that destroy natural enemies.

Back to content page

List of Native natural enemies of cotton pest

Natural enemy	Pest	Stage of pest
A. Parasitoids		
Aphelinus sp	Spotted bollworm	Egg
Erythmelus empoascae	Spotted bollworm	Egg
Gonatocerus sp	Spotted bollworm	Egg
Trichogramma achaeae	Pink bollworm	Egg
	Spotted bollworm	
T. brasiliensis	Spotted bollworm	Egg
T. chilonis	Spotted bollworm	Egg
	American bollworm	
T. chilotraeae	Pink bollworm	Egg
	Spotted bollworm	
Telenomus remus	Spotted bollworm	Egg
Trichogrammatoidae sp near *guamensis*	Pink bollworm	Egg
	Spotted bollworm	
Agathis fabiae	Pink bollworm	Larva
	Spotted bollworm	
Apanteles angaleti	Pink bollworm	Larva
Bracon chinensis	Pink bollworm	Larva
Bracon greeni	Pink bollworm	Larva
	Spotted bollworm	
Bracon kirkpatricki	Spotted bollworm	Larva
Bracon brevicornis	Spotted bollworm	Larva
Bracon habator	Spotted bollworm	Larva
Camptolithlipsis gossypiella	Pink bollworm	Larva
Rogas aligarhensis	Pink bollworm	Larva
	Spotted bollworm	
Goniozus sp	Pink bollworm	Larva
Campoletis chloridae	American bollworm	Larva
Elasmus johnstoni	Pink bollworm	Larva
Pyemotes ventricosus (mite)	Pink bollworm	Larva
Chelonus sp	Bollworms	Egg-Larva

C. blackburni	Pink bollworm	Egg-Larva
Xanthopimpla punctata	Cotton leaf roller	Pupa
Brachymeria sp.n. euploeae	Cotton leaf roller	Pupa
B. apantelesi	Spotted bollworm	Pupa
B. nephantidis	Spotted bollworm	Pupa
Encarsia formosa	Whitefly	Nymph
Encarsia shafeei	Whitefly	Nymph
Eretmocerus mundus	Whitefly	Nymph
B. Predators		
Chrysoperla carnea	Sucking pests & bollworms	Egg, nymph, adult
Brumus saturalis	Sucking pests & bollworm	Egg, nymph
Coccinella septumpunctata	Sucking pests & bollworm	Egg, nymph
Menochilus sexmaculatus	Sucking pests & bollworm	Egg, nymph
Geocoris sp	Sucking pests	Nymph, Adult
Zelus sp	Sucking pests	Nymph, Adult
Spiders	Sucking pests & bollworms	Nymph/Larva, Adult
Canthecona furscellata	bollworms	Larva
Encarsia sp	Whitefly	Nymph, Adults
Syrphus confracter	Aphids	Nymph, Adults
S. baleatus	Aphids	Nymph, Adults
S. searius	Aphids	Nymph, Adults
C. Pathogens		
Aspergillus sp.	Whitefly	Nymph
Bacillus thuringiensis	Bollworms	Larva
Beauvera bassiana	Bollworms	Larva
NPV	*Helicoverpa &Spodoptera*	Larva
Nematodes	Bollworms	Larva

Biological control Practices in cotton:

i. Conservation of predators (lacewings, lady bird beetles, staphylinids, predatory wasps, surface bugs like Geocoris, Anthocorid, Nabids, Reduviids, Spiders, parasitoids like *Apanteles*, *Bracon*, *Rogas*, *Agathis*, *Campoletis*, *Eriborus*, *Trichogramma*, Telenomus) by growing two rows of maize / sorghum or cowpea along the border.

ii. Monitor the incidence of sucking pests and release eggs or first instar larvae of *Chrysoperla* @ 10,000 eggs / grubs / ha.

iii. Azadirachtin 0.15%, (Neem Seed Kernel Based EC) @ 2.5-5.0 l/ha against whiteflies and bollworms; Azadirachtin 0.3% (3000 ppm) (Neem Seed Kernel Based EC) @ 4.0 l/ha against *Helicoverpa* bollworm infestation; Azadirachtin 0.03% (Neem Oil Based EC) @ 2.5-5.0 l/ha, against *Helicoverpa* bollworm infestation and aphids;. Azadirachtin 0.03% (300ppm) (Neem Oil Based WSP) @ 2.5-5.0 l/ha against aphids, leaf hoppers, whiteflies and bollworms and Azadirachtin 5%w/w (Neem Extract Concentrate) @ 375 ml/ha for whiteflies, leafhoppers and *Helicoverpa* are recommended.

iv. Release *Trichogramma chilonis* (cotton strain) immediately after the appearance of bollworm eggs (when moth trapped in pheromone traps) @ 1,50,000/ ha / week (2–3 releases at 15 days interval) 40 – 50 days after sowing. Avoid spraying with insecticides for at least one week before and after the release of biocontrol agents.

v. Release of egg-larval parasitoid, *Chelonus blackburnii* and Predator *Chrysoperla carnea* at 1,00,000/ha at 6th, 13th and 14th week after sowing.

vi. Use of Encyrtid parasitoids, *Acerophagus papayae* @ 100 per village against *Paracoccus marginatus* and *Aenasius bambawaeli* against *Phenococcus solenopsis* are recommended.

vii. *Bacillus thuriengiensis* var *galleriae* 1593 M sero type H 59 5b @ 2.0-2.5 kg/ha for *Helicoverpa* bollworm and *Bacillus thuriengiensis* var *kurstaki* H 3a, 3b, 3c. 5% WP @ 0.50-1.00 kg/ha for *Helicoverpa* and spotted bollworm; *Bacillus thuriengiensis* var *kurstaki* strain HD-1, serotype 3a, 3b, 3.5% ES (Potency17600 IU/mg) @ 750-1000 ml/ha for control of bollworms are recommended. *Bacillus thuriengiensis* var *kurstaki* serotype H-3a, 3b, strain Z-52 @ 0.75-1.0 kg/ha is recommended for bollworm and *Spodoptera*. [recommended only for non Bt cotton).

viii. *Beauveria bassiana* 1.15% WP is recommended @ 2kg/ha in 400 lit water for bollworm and sucking pests control. Repeat spray after 10 days interval.

ix. *Lecanicillium lecanii* 1.15%WP is recommended @ 2.5 kg/ha in 500 lit water against sucking pests. Repeat spray after 10 days interval.

x. Apply *Spodoptera* NPV 250 – 500 LE/ha (1LE = $2X10^{9}$ POBs) (1LE /lit of water) on observing 1st Instar larvae. HaNPV @ 250 LE can be applied in the early infestation of *Helicoverpa*.

xi. Entomopathogenic fungi such as *Metarhizium anisopliae*, *Beauveria bassiana* and *Nomurea rileyi* can be used against *Helicoverpa*.

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Biological Control of Nematodes in Cotton

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Introduction

Plant parasitic nematodes are minute and microscopic organisms which causes 30% yield loss in crops.Apart from causing yield loss alone they are known to interact with fungus and bacteria to increase the severity of disease caused by them. Among different nematodes reported from the rhizosphere of cotton in India, Reniform nematode, *Rotylenchulusreniformis* and Root-knot nematode, *Meloidogyne incognita* are reported to cause yield loss in cotton. Reniform nematode is widely distributed in all cotton grown regions of India whereas root-knot nematode is restricted in distribution in Haryana. While reniform nematode is mostly present in fine textured soils with relatively high content of silt or clay, root-knot nematode prefers sandy soil for their multiplication. Both these nematodes interact with fungi and increases the severity of root rot and wilt caused by them.The wound made by these nematodes while feeding on roots acts as an entry point for the fungus and thereby facilitate their easy and quick entry into the root system.

Symptoms of reniform nematode infection includes dwarfing, chlorosis, premature decay and loss of secondary roots and finally plant mortality.When infested roots were seen under microscope, they show several semi endoparasitickidney shaped female nematodes with egg masses.Reniform nematodeinfested roots show brownish discoloration especially at the point of infection.These roots were thin and dried with brown lesions at the point of infection.Itcompletes one generation in 27-29 days. Each female lays about 150-200 eggs. Juveniles can survive for several months in host free soil.

General symptoms of root-knot nematode damage is stunting of plants.Fields infested with root-knot nematode show patches or spots in the field where plant size is reduced.Severely damaged cotton plants show nutrient deficiency symptom.The nematode infection produces galls on tap as well as lateral roots.High population density of the nematode at sowing can kill the plants at seedling stage itself. Mature plants exhibit temporary wilting in afternoon.Generally, life cycle of root-knot nematodein cotton lasts for 33-38 days and 32 days on *Gossypiumbarbadense*and *G. hirsutum*, respectively. Each female lays about 300- 400 eggs.

Existing nematode control methods are unable to adequately control the nematodes which results in the use of chemical nematicides for the management of the same. Selection of nematode control method depends on the type and stage of the crop, nematode and its life stage. But the nematicide residue in crop and soil can harm human being and life stock, contaminate ground water and finally cause environmental pollution. Of the various alternative methods of controlling nematodes biological control is considered to be the best method for the management of plant parasitic nematodes. This method is safer to human beings, animals and environment. Natural enemies for nematodes includes fungi, bacteria etc.. They help to keep the number of nematodes in an equal position without increasing the number. A variety of fungal parasites and bacteria attack the nematode and infect it and eventually destroying it.

Advantages

- Non toxic
- Safer to beneficial microbes.
- Safer to non target organisms.
- Selective to target organism only
- Can be used in all habitats.
- Can also be used when chemical nematicides usage is banned.
- When used in field fungus / bacteria can multiply in soil and control the nematodes in next season also.

Disadvantages

- They are susceptible to drought, heat and UV radiation.
- Knowledge about their registration, production and marketing is less

Fungal angonists

The fungal antagonists of nematodes (nematophagous fungi) consist of a variety of organisms belonging to widely divergent orders and families of fungi. They include the nematode-trapping fungi, endoparasitic fungi, parasites of nematode eggs and cysts, and fungi which produce metabolites toxic to nematodes.

Nematode-Trapping Fungi

They are soil-borne fungi that entrap moving stages of nematodes using trapping structures of various shapes and sizes. These fungi are not host specific and could trap all soil-dwelling nematodes. Different fungal species produce one or more types of different trapping devices. These structures can vary from simple fungal hyphae covered with sticky secretions to much more complex structures. They can be adhesive branches, simple loops, two-dimensional, or three-dimensional networks. Adhesive three-dimensional nets, the most common type of fungal traps, are constructed when the loops create a three-dimensional configuration (e.g. Arthrobotrysoligospora, A. superba, Dactylellapseudoclavata). Other groups of trapping fungi produce adhesive spores or adhesive knobs. Lateral branches of vegetative hyphae create non-constricting rings which entrap the entering nematodes by wedging around their body. Constricting rings (Arthrobotrysdactyloides, Monacrosporiumdoedycoides) are the most specialized trap, which has three cells that swell quickly and hold the entering nematode tightly.

Endoparasitic Fungi

Most of these fungi are obligate parasites and poor saprotrophic competitors in soil, but usually have a broad nematode host range. These obligate parasites live their whole vegetative life cycle inside their infected hosts.Endoparasitic fungi infect vermiform plant-parasitic nematodes using their spores (conidia or zoospores). The spores can be ingested by the nematode which germinate in the intestines (mostly the esophagus or mastax), or adhere firmly on the nematode cuticle when the nematode passes the fungus. The spore contents are inserted into the nematode by means of a narrow penetration tube, apparently with some mechanical pressure . Then an internal mycelium produces, and finally penetrates the cadaver to sporulate on its surface. Some endosparasitic fungi produce zoospores that swim toward the nematode, attach to the cuticle usually around the natural orifices, and then encyst. The encysted zoospores penetrate the host body via those natural openings and start their vegetative growth.

Egg- and Female-Parasitic Fungi

In contrast with the numerous migrating nematodes, some plant-pathogenic nematodes spend the majority of their life cycle inside plant roots or on their surface. These sedentary stages persist in the soil and serve as a selective substratum for fungal colonization by egg parasites. This group of fungi uses appressoria or zoospores to infect their hosts . The parasites of egg and sedentary stages have attracted more attention because of their high potential in biological control of economically important nematodes. These fungi that can saprotrophically survive well in rhizosphere, are relatively easy to mass-culture and are more effective in infecting because their host is sessile (eggs, developing juveniles and females). Among all nematode parasitizing fungi, comparatively few have been considered as promising biocontrolagents , and of these the most frequently isolated fungi are Pochoniachlamydosporia and Paecilomyceslilacinus . Species of Pochonia, Paecilomyces, Haptocillium, and Hirsutella are among the most importantbiocontrol agents against plant-parasitic nematodes .

Purpureocillium

These type of fungus secretes chemical substances which helps the mycelium to enter and kill the eggs. It also releases various chemicals and enzymes to dissolve the egg shell. This fungus plays an important role in reducing the damage caused by root knot and cyst nematodes. Both liquid and talc based formulation of this fungus is available in the market. This secretes nematode metabolites such as kitinases, serine proteases and glycoaminase.

This can be applied along with beneficial microbes. This also works as biofungicide and compatible with other beneficial micro organisms.

Trichoderma

This type of fungus destroys not only nematodes but also harmful fungi. These are capable of attacking and destroying the eggs of the nematodes and the female nematodes. It also controls nematodes and harmful fungi by exploiting toxic substances. This is available in powder and liquid form.

Pochonia

It is a type of fungus that attacks the eggs of nematodes. This spores can tolerate heat and alkalinity. This is available in powder and liquid form.

Bacterial antogonists

As a group of important natural enemies of nematode pests, nematophagous bacteria exhibit diverse modes of action: these include parasitizing; producing toxins, antibiotics, or enzymes; competing for nutrients; inducing systemic resistance of plants; and promoting plant health. They act synergistically on nematodes through the direct suppression of nematodes, promoting plant growth, and facilitating the rhizosphere colonization and activity of microbial antagonists. The nematophagous bacteria known to date includes parasitic bacteria, opportunistic parasitic bacteria, rhizobacteria, Cry protein-forming bacteria, endophytic bacteria and symbiotic bacteria. Some bacteria like fungi can control nematodes, of which Pseudomonas and Bacillus are important. These bacteria are called the rhizobacteria, because they are attracted by chemicals secreted by the roots of crops and accumulated in the soil surrounding the root.

Pasteuria

Pasteuria are obligate, mycelial, endospore-forming bacterial parasites of plant-parasitic nematodes. A number of bacterial species in this genus have shown great potential as biocontrol agents against plantparasitic nematodes. They occur worldwide and have been reported from at least 51 countries. Members of the genus have been reported to infect 323 nematode species belonging to 116 genera, including both plant-parasitic nematodes and free-living nematodes . The majority of economically important plant-parasitic nematodes have been observed to be parasitized .

Pasteuriapenetrans infects the root-knot nematode *Meloidogyne* spp. . Spores of Pasteuria can attach to the cuticles of the second-stage juveniles, and germinate after the juvenile has entered roots and begun feeding. The germ tubes can penetrate the cuticle, and vegetative microcolonies then form and proliferate through the body of the developing female. Finally, the reproductive system of the female nematode degenerates and mature endospores are released into the soil .

Psuedomonas

These type of bacteria secretes toxins which are known to kill nematode eggs and juveniles. They also significantly reduces the egg laying capacity of nematodes. This type of bacteria can stimulate crop growth and increase the resistance of plants to pests, diseases and nematodes by increasing the immune system and protecting the crop from their damage. Rhizosphere Pseudomonas strains also exhibit diverse pathogenic mechanisms upon interaction with nematodes . These mechanisms include the production of antibiotics and the induction of systemic resistance in plants. This is available in powder and liquid form.

Bacillus

A species of Bacillus ,*Bacillus subtilis* present in the soil is used to control nematodes and diseases.In addition, a number of studies have reported direct antagonism by other Bacillus spp. towards plant-parasitic nematode species belonging to the genera Meloidogyne, Heterodera and Rotylenchulus.

Recommended bionematicide for the management of nematodes in cotton

Nematode	Recommended dose
Reniform nematode and root knot nematode	***Pseudomonas fluorescens*** Seed treatment:20 g/kg seed Soil application-2.50 kg/ha ***Paecilomyceslilacinus*** Soil application-10Kg/ha with organic manure.

Future thrust

Due to increase in efficacy of these biocontrol agents and their market growth expectations are high. However they have to overcome many challenges and market needs to grow. Information on bionematicides are to be integrated and shared in a common platform. Awareness regarding these biocontrol agents are to be increased among farmers. If researchers, extension workers and farmers work together the use of biocontrol agents will increase. Because their production costs and commercialization are so high, there are very few bionematicides available in the market. Identification and commercialisation of bionematicide which can tolerate heat and ultra violet radiation can further enhance their efficacy to protect the crop from nematodeinfestation.

Identification and Management of Bacterial and fungal diseases in Cotton

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1. Bacterial blight

Causal Organism: *Xanthomonas citri* p.v. *malvaceraum*

Symptoms:

1. Seedling blight

Small, water soaked circular or often irregular lesions appear on the margins of cotyledonary leaves and become black and spread to young stem and shrivel

2. Angular leaf spot

Numerous minute, water soaked spots appear scattered on lower side of leaves restricted between veins and later can be seen both sides

3. Vein blight

Water soaked lesions appear on the sides of veins and veinlets which later turn into black in colour and gives blighted appearance to veins

4. Black arm

Blackening of stem portion due to bacterial infection which appears as black arm symptom

5. Boll rot

Initially oily spot on bolls observed. Water soaked circular spots on bolls which lead to rotting of bolls in advanced stage.

Time of occurrence: Start at18-22 days after sowing (depending up on onset of monsoon)

Loss: 5-25%

Management Practices:

- Seed treatment with carboxin or oxycarboxin @ 2 g/kg of seed.
- 2-3 Sprays of Copper oxychloride (0.25%) + Streptocycline (0.02%) at 15-20 days interval.

Regions (Zones) of prevalence: North, Central and South

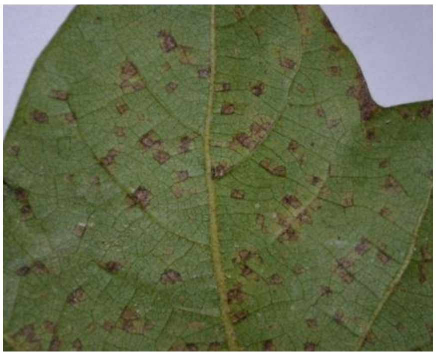
Precautionary measures:

1. Avoid excess nitrogen application (Young and succulent plants are highly susceptible)
2. Avoid excess irrigation water supply
3. Avoid late sowing
4. Adopt wider spacing

5. Remove inoculum trashes from field

6. Remove off season cotton plants and weeds

Angular leaf spot



Lower surface

Vein blight

Stem blight (Black arm)

Oily spot on bolls

2. Grey mildew

Causal Organism:*Ramularia areola*

Symptoms: Dirty white mildew coating on lower surface of leaves and in advance, it spreads to upper surface also. Infected leaves started drying from margin towards inner side and finally leaves turn yellowish brown and fall off.

Time of occurrence: 120-150 days after sowing. Especially on early senescence period

(Favoured by frequent rains coupled with high humidity)

Loss: 20-30%

Management Practices:

- Foliar application of Calixin (Tridemorph) – 1 g/l or
- Wettable sulphur @ 2-3g/l or
- Carbendazim @ lg/l of water immediately after appearance of disease or
- Spray Propiconazole @ 1ml/l of water after wide spread of disease

Regions (Zones) of prevalence: Central and South

Precautionary measures:

1. Remove infected debris
2. Avoid closer spacing and excess nitrogen application
3. Remove volunteer cotton plants
4. Cultivate grey mildew resistant cultivars like Sujatha and Varalakshmi

Grey mildew symptoms in *G. arboreum* and *G. hirsutum*

3. Alternaria leaf spot

Causal Organism: *Alternaria macrospora*

Symptoms: Small, dull, dark brown, circular or irregularly shaped spots appear on leaves which vary from 0.05-10.0 mm in diameter. Concentric zonations develop within the spots which are more pronounced on the upper surface. In advanced stage, heavy leaf shedding occurs. Spots can also be observed in flower bracts and bolls.

Time of occurrence: After 100 days of sowing

(Frequent rains facilitates the disease appearance and spread)

Loss: 30 – 40%

Management Practices:

1. Spray Copper Oxychloride @ 2 g/l or Dithane M-45 (Mancozeb) @ 2.5 g/l of water
2. Seed treatment with captan or Thiram @ 3g/kg of seed

Regions (Zones) of prevalence: North, Central and South

Precautionary measures:

1. Remove infected debris;

2. Avoid growing of bhendi, brinjal and tomato in nearby fields (alternate hosts)

Alternaria leaf spot symptoms

4. Myrothecium leaf spot

Causal Organism: *Myrothecium roridum*

Symptoms: Small, circular spots varying from 2-10 mm in diameter, light brown in the centre with a dark brown margin on leaves. The spots coalesce and form large patches. The centre of the spot may drop leaving a shot hole. There is conspicuous ring of sporodochia which are pin head size and black in colour. In advanced stage, infected leaves may fall off.

Time of occurrence: After 40 days of sowing (Favoured by high relative humidity and prolonged rainfall).

Loss: Up to 15%

Management Practices: Spray Mancozeb @ 2.5g/l or Copper Oxychloride @2.0 g/l or Carbendazim @1 g/l of water at 15-20 days interval

Regions (Zones) of prevalence: North, Central and South

Precautionary measures:

1. Remove infected crop debris
2. Adopt wider spacing

Myrothecium leaf spot symptoms

5. Rhizoctonia root rot

Causal Organism: *Rhizoctonia solani* and *R. bataticola*

Symptoms: Sudden and complete wilting of plants. Every leaf from top to bottom droops down. Affected plants can be easily pulled out of the ground and bark of roots is broken in to shreds and gives yellowish appearance.

Time of occurrence: Appears on 30 days after sowing and reaches severe at 90-120 days after sowing

Loss: 10 to 15%

Management Practices:

1. Use of resistant varieties and hybrids
2. Crop rotation, application of FYM and application of zinc sulphate @ 24 kg/ha
3. Seed treatment with Carboxin or Thiram or Carbendazim @ 4 g/kg of seed
4. Seed treatment with *Trichoderma harzianum* and *T. viride* @ 4.0 g/kg of seed
5. Soil drenching of Carbendazim @ 1 g/l of water in root zone

Regions (Zones) of prevalence: North zone

Precautionary measures: Avoid monocropping in sick fields

Rhizoctonia root rot symptoms

6. Collar rot

Causal Organism: *Sclerotium rolfsii*

Symptoms: Typical girdling at collar region causing rapid decay or roots and drying of plants. It is favoured by slightly acidic and light soils

Time of occurrence: Immediately after emergence of seedlings

Management Practices:

1. Clean cultivation
2. Rotation with paddy and sorghum

3. Use of ammonium sulphate @ 5-6.25q/ha

4. Soil drenching of Carbendazim @ 1 g/l of water in root zone

Regions (Zones) of prevalence: North, Central and South

Precautionary measures: Removal of decomposed debris

7. Damping off

Causal Organism: *Phytopthora parasitica* and *Pythium debaryanum*

Symptoms: Water soaked lesions appear on cotyledons and finally entire leaf is affected. The collar region softens, rots, gets constricted and the seedling falls over and roots rot and disintegrate. (Mostly during wet weather and water logged soils)

Time of occurrence: Appears in 2-3 weeks after sowing

Management Practices:

Seed treatment with carbendazim @ 1-2 g/kg of seed or soil drenching @1g/l of water

Regions (Zones) of prevalence: North, Central and South

Precautionary measures:

1. Planting depth should not be more than 3 cm in wet soil and around 5 cm in dry soil.

2. Under irrigated conditions planting should be on the sides of the ridges

8. Fusarium wilt

Causal Organism: *Fusarium oxysporum* f.sp. *vasinfectum*

Symptoms: Seedlings and small plants show yellowing and bronzing of cotyledons and leaves which dry and drop. Matured plants show the progress of wilting and yellowing of leaves from bottom to tip. The leaves lose turgidity, wilt, dry up and fall down. Brown to black discoloured ring is seen beneath the stem, branch, petiole and peduncle. Longitudinal split of stem shows brownish-black discolouration of woody tissues.

Time of occurence: 30 -120 days after sowing. Appears in heavy black alkaline soils and specifically on desi (arboreum) and Asiatic (herbaceum) cottons

Loss: 5.0 - 44.0%

Management Practices:

1. Drenching of carbendazim @ 1g/l in root zone of the plants

2. Deep ploughing

3. Removal and destruction of infected plant debris

4. Crop rotation with non-hosts

5. Cultivation of *G. hirsutum* cotton (*G.arboreum* is highly susceptible)

Regions (Zones) of prevalence: North, Central and South

Precautionary measures:

1. Avoid excess application of nitrogen and phosphorus
2. Increase application of potash
3. Avoid growing okra (collateral host), barley, ragi and sorghum in the same field

Fusarium wilt symptoms

9. Verticillium wilt

Causal Organism: *Verticilluim dhaliae*

Symptoms: Appears in peak flowering and boll formation stage. Bronzing of the veinlets followed by inter-veinal chlorosis and yellowing of leaves. The leaves become cup shaped and scorched. The interveinal yellowing and drying take on characteristic appearance of “Tiger stripes”. Dark brown striations appear in the vascular bundles in the split open stem.

Time of occurence: 110 days after sowing (disease is favoured by cooler temperatures)

Loss: 5-50%

Management Practices:

1. Cultivate tolerant cultivars like MCU5 VT, Savitha and Surabhi
2. Crop rotation with rice, Lucerne and Chrysanthemum for 2 – 3 years
3. Drenching of carbendazim @ 1g/l of water around the root zone of the plants

Regions (Zones) of prevalence: South

Precautionary measures:

1. Avoid growing of collateral host plants like brinjal and okra in sick soils
2. Avoid water logging in fields

Verticillium wilt symptoms

10. Boll rot

Causal Organism: Many organisms include *Alternaria, Botrydiplodia, Colletotrichum, Fusarium* etc

Symptoms: Rotting of bolls

Time of occurrence: After boll development stage

Management Practices: Spraying of Carbendazim 1g/l

Regions (Zones) of prevalence: North, Central and South

Precautionary measures: Maintenance of field sanitation

Boll rot symptoms

Identification and Management of Viral and Fungal Diseases in Cotton

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Introduction

Cotton belongs to family Malvaceae, Genus: *Gossypium*. The Genus *Gossypium* consists of 50 species. Four of these are cultivated *viz.*, *Gossypium arboreum*, *Gossypium herbaceum*, *Gossypium hirsutum* and *Gossypium barbadense*. The first two species are diploid and are confined to the old world, indigenous to Asia and Africa. The other two species are amphidiploids with centres of variability in Mexico- Central America and South America. The American cotton *G.hirsutum* and Egyptian *cotton Gossypium barbadense* are also called the new world cotton. The remaining 46 species are wild and are not cultivated. Of the species identified across the world, 45 are diploid (Desi Cotton) and other five are tetraploid (American cotton). These species are distributed in Africa, Middle East, Asia, South America, Central America, North America, Australia and Hawaii. Cotton can be regarded as **"white gold"** due to it's impact in the economy of the agricultural sector in India. India is a leading producer of cotton, competing China. Cotton crop is affected by major diseases such as wilt (*Fusarium oxysporum* and *F. vasinfectum*), Anthracnose (*Colletotrichum indicum*), grey mildew (*Ramularia areola*), blackarm or bacterial blight (*Xanthomonas malvacearum*) and Cotton leaf curl (*Cotton leaf curl virus*). The other diseases which infect cotton are listed below,

1. **Rust:**

The rust caused by *Phakospora gossypii* (Arth) Hirat. F. Occurs sporadically in Tamil Nadu, Andhra Pradesh, Gujarat and Karnataka. Yield losses ranging from 21.4 to 34.0 % were recorded at Dharwad and Guntur due to this disease during recent experiments (Monga *et al.,* 2013). The per cent disease index varies from 58.53 % PDI to 48.14 % PDI in the cotton genotypes observed at the CICR fields of Coimbatore during 2018. The disease appears late in the season often after the onset of senescence when it may be beneficial in augumenting leaf fall before harvest. However its early appearance occasionally causes considerable loss by decreasing the photosynthetic area and heavy defoliation. The pathogen initially affects the older leaves and then spreads to the younger ones. Only the uredial stage of the rust occurs in India. Uredial sori appear on the leaves as small (1-9mm) pinkish brown spots which may coalesce to form larger patches. The uredia are oval to circular on the pedicles and branches. The urediospores are exposed on rupture of the epidermis. The disease is generally observed in the dry season during December-March in India. The severe incidence of rust and leaf spots was noted in Northern Karnataka especially during the reproductive phase of crop growth.

Management : 1. Foliar sprays of Copper oxychloride 50 WP @3g or Mancozeb 75 WP @2.5g/l or Propiconazole 25 EC @ 1 ml/l of water as and when symptoms appeared.


Rust infected leaves

2. ***Cercospora* leaf spot:**

The symptoms are caused by a fungus of the Cercospora family that attacks cotton plants, *Cercospora gossypina*. It is different from those that affect other crops such as soybean or pepper. In the field it is often difficult to differentiate Cercospora leaf spot from other foliar diseases, such as target spot. Round or irregular greyish spots and Dark brown or blackish borders appear on older leaves.

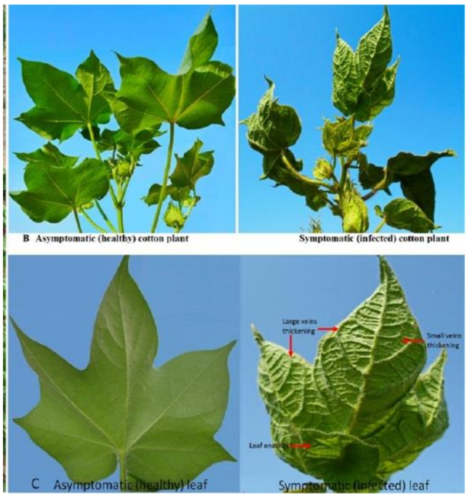
Management : 1.Removal and destruction of the infected plant residues.

2. Spraying of Mancozeb or Copper oxychloride at 2kg/ha at the intimation of the disease. 3. Two to three sprays may be given at 15 days interval.


3. ***Cotton leaf curl disease* (CLCuV):**

Cotton leaf curl disease is caused by a complex of begomovirus species, all of which incite similar symptoms in cotton and are transmitted by the whitefly *Bemisia tabaci* but are less than 89% identical to each other at the nucleotide level over the entire length of the genome and also vary in geographic distribution. Virus species causing cotton leaf curl disease in India include *Cotton leaf curl Multan virus* (CLCuMV), *Cotton leaf curl Rajasthan virus* (CLCuRV), Cotton leaf curl Bangalore virus. Genetic relationships between the begomoviruses reflect geographic distributions, with those from the same region being most closely related to each other or to other begomoviruses infecting different plant species in the same region.Characteristics of cotton leaf curl disease are from which the following symptom descriptions are derived. The first symptoms of infection in cotton appear within 2-3 weeks of inoculation and are initially characterised by deep downward cupping of the youngest leaves. This is followed by either upward or downward curling of the leaf margins and swelling, darkening and formation of enations on the veins, which frequently (depending on cultivar) develop into cup-shaped, leaf-like structures.All begomovirus species causing cotton leaf curl disease have geminate particles, approximately 18-20 nm in diameter and 30 nm long and a circular, single-stranded DNA genome (Nagrare *et al.,* 2013).

Management : 1. Seed treatment with systemic insecticides like Imidacloprid 70WS/Imidacloprid 600 FS, Thiamethoxam 70 WS for untreated seeds. 2. Spraying of neem products, *Beauveria bassiana* and insecticides like Difenthuron 50 WP @ 1.2 g or Acephate 75 SP @ 1.5g/l to control whitefly vector of CLCuD.



Symptoms of cotton leaf curl disease

4. ***Tobacco streak virus* (TSV):**

Necrosis disease caused by *Tobacco streak virus* (TSV) is the most devastating one. In the last five years, the necrosis disease caused by TSV was frequently recorded in the cotton growing regions of India. In Tamil Nadu, the disease occurrence was recorded in Dharmapuri, Perambalur and Salem districts in 2010 and the incidence was found to be 12.6 to 38.8 per cent (Ragheswari *et al*., 2016). TSV has also been found to be infected in *Gossypium barbadense* in the CICR fields at Coimbatore, Tamil Nadu. The symptoms developed due to TSV infection in cotton plant resembled almost similar to physiological or nutritional disorders and herbicide phytotoxicity which is very difficult to distinguish. In Andhra Pradesh and Maharashtra, symptom observed in cotton plants showed chlorotic, necrotic lesions, leaf purpling and drying of the young bolls. The subsequent studies carried out confirmed the etiological agent of the necrosis disease as *Tobacco streak virus* belonging to the genus *IIarvirus,* family *Bromoviridae.Tobacco streak virus* (TSV), first described by Johnson (1936), is the type species of the genus *Ilarvirus*, of the family *Bromoviridae* that includes viruses having tripartite quasiisometric particles of size 27 to 35 nm. Most common symptoms of TSV include chlorosis and necrosis of leaves, necrotic streaks on petioles, stems, floral parts and stunted growth. TSV infection at seedling stage results in premature death of the plant. Infection during mid-stage of the plant growth may result in necrosis of the leaves and severe reduction in yield. Infection at late stage of the plant growth results in mild chlorotic symptoms, with little effect on plant growth and crop yield. In several weed hosts, such as parthenium, TSV causes asymptomatic infection. Premature death of plant was the main reason for enormous yield losses during the SND/TSV epidemics. TSV is transmitted through pollen assisted by thrips (Thysanoptera: Thripidae) and experimentally by mechanical sap inoculation, grafting and dodder (*Cuscuta campestris*), but not by contact or soil.

Management :1. Control of thrips by spraying Acephate 75 SP @1.5 g/l or Imidacloprid 17.8 SL @ 0.3ml/l or Thiamethoxam 25 WG @ 0.2g/l or Acetamripid 20 SP @0.2 ml/l at weekly intervals.

2. PGPRs (Plant growth Promoting Rhizobacteria), and antiviral principles , artificially inoculated with TSV revealed that, Cotton endophyte (M2), Baillus amyloliquefaciens (VB7), and *Mirabilis jalapa* reduced the symptom development of disease.

3.Seed dressing with appropriate insecticide before sowing should be done.

4. Follow crop rotation and field sanitation. Grow suitable region-wise resistant varieties.

5. Remove affected leaves/plants from crop fields to avoid secondary spread.

6. Destroy host weeds such as parthenium, tridax and other weeds around the cotton crop, which will help limit the occurrence of this disease.

7. Inter crop with short duration non-host crops like sorghum, redgram, greengram, blackgram soyabean, pearl millet and maize.

Symptoms expression in *G. barbadense*

Symptoms expression in *G. hirustum*

5. Cotton leaf roll dwarf virus (CLRDV) :

Cotton blue disease is caused by cotton leaf roll dwarf virus (CLRDV) (an RNA virus) having positive sense single stranded RNA, transmitted by aphids (Aphis gossypii) in a circulative-persistent manner. Cotton plants affected by this disease show stunting, leaf rolling, intense green foliage, vein yellowing, brittleness of leaves, reduced flower and boll size resulting in sterility of plants. The disease is recorded in Maharashtra (Mukherjee *et al.,* 2012).

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Input Cost Trend Analysis of Cotton in India

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Introduction:

India is the largest producer of cotton in the world accounting for about 26 per cent of the world cotton production. It has the distinction of having the largest area under cotton cultivation in the world ranging between 10.9 million hectares to 12.8 million hectares and constituting about 38 to 41 per cent of the world area under cotton cultivation. The yield per hectare (i.e.504 kgs to 566 kgs per hectare) is however still lower against the world average of about 701 Kgs to 766 kgs per hectare. Cotton provides an excellent example of the interaction between technology and policy and its effects on the cultivation of a crop. Cotton cultivation in India has witnessed major technological changes over the past few years with the advent of Bt cotton.

Recent World Cotton Scenario:

The global cotton market is shifting rapidly from historical producers and consumers to new markets. About a decade ago, India was barely self sufficient to meet its cotton requirement but has now become the world's biggest producer of cotton. With annual production cost and wages rising in the developed world as a whole and in China specifically at a rate of 20 per cent, developed countries are likely to lose their competitive edge in cotton production, processing and exports of textiles in the coming years.This would open a market with an annual turnover of more than US$ 200 billion to countries like India, Pakistan, Bangladesh, Sri Lanka and Uzbekistan. In the short run, the international market for cotton is bound to be highly competitive, with India claiming the number one position in terms of production, the US striving to maintain its leadership in exports, and China looking to utilize its significant inventory to produce textiles that will compete in the global market. As the largest producer of cotton in the world, India has now become a critical factor with the prices and demand trends for world cotton as well as cotton textiles.

Based on the trend analysis, the recent scenario of cotton at the world level during the past three years portrays a transition in priority or position of countries in the situation of cotton at different categories. The major world cotton area is at India, USA, China, Pakistan, Uzbekistan, Brazil and Burkino Faso. Major world cotton producing countries shared by India, China, USA, Pakistan, Brazil, Australia, Turkey, Uzbekistan, Mexico, Turkmenistan, Burkino Faso and Greece. Major world cotton yielding countries is occupied by Australia, Turkey, China, Israel, Mexico, Brazil, Venezuela, Greece, South Africa and USA. Major world cotton exportng countries are USA, Australia, Brazil, India,

Back to content page

Uzbekistan, Mali, Greece and B.Faso whereas major world cotton importing countries are Bangladesh, Vietnam, China, Indonesia, Turkey, Pakistan, India, Thailand and Mexico.

Trend Analysis of Cotton Scenario at National Level:

Cotton plays a key role in the Indian economy in terms of income generation in the agricultural and industrial sectors by providing substantial employment and making significant contributions to export earnings. It plays very important role in State's economy also. It is an important raw material for the Indian textile industry, constituting about 65 per cent of its requirements.

The ten major cotton growing States in India are Punjab, Haryana, Rajasthan from North Zone, Gujarat, Maharashtra, Madhya Pradesh and Odisha from Central Zone and Andhra Pradesh, Karnataka and Tamil Nadu from South Zone. These States put together account for 99 per cent of the total cotton area in India.

State wise comparative trend in area were studied for the years 2007-08 (Period I) when Bt cotton spread enormously, 2012-13 (Period II) when it reached a plateau and 2017-18 (Period III) when it showed a decline.

Table I: Trends in Area under Cotton (2007-08 to 2017-18 (% to total)

Year	2007-08	2012-13	2017-18
Punjab	6.42	4.01	3.15
Haryana	5.13	5.13	5.36
Rajasthan	3.92	3.76	4.11
Gujarat	25.73	20.85	21.40
Maharashtra	33.94	34.61	34.31
Madhya Pradesh	6.69	5.08	4.90
Andhra Pradesh	12.04	20.04	19.35
Karnataka	4.28	4.05	4.62
Tamil Nadu	1.05	1.07	1.21
Odisha	0.81	0.99	1.19
North Zone	15.47	12.89	12.62
Central Zone	66.36	60.54	60.63
South zone	17.37	25.15	25.19
Total	100	100	100

The results from Table I revealed that in the Northern Zone, there has been a drastic reduction in cotton area from 6.42 to 3.15 per cent of total cotton area in Punjab whereas it has slightly increased from 5.17 to 5.36 per cent and 3.92 to 4.11 per cent in case of Haryana and Rajasthan, respectively. In case of Central Zone, there has been a drastic cotton area reduction in Gujarat (25.74 to 21.40 per cent) and Madhya Pradesh (6.69 to 4.9 per cent) with a slight increase from 31.44 to 34.31 per cent in Maharashtra and 0.81 to 1.19 per cent in Odisha, respectively. The scenario is different in South Zone with Andhra Pradesh registering a tremendous increase in cotton area from 12.04 to 19.35 per cent of the total during the comparative period followed by slight increase in case of Karnataka and Tamil

Back to content page

Nadu to the tune of 4.28 to 4.62 per cent and 1.05 to 1.28 per cent, respectively. Overall, there has been a decline in cotton area in the North and Central Zones from 15.67 to 12.63 per cent and 66.36 to 60.63 per cent, respectively with a steady increase from 14.47 to 25.19 per cent in South Zone. In case of cotton yield trend, there has been a tremendous growth rate increase in Central cotton growing States to the tune of 3 to 16 per cent over the years from 2007 to 2018. In case of North and South zones excepting Rajasthan and Andhra Pradesh, negative growth rate was registered from 4 to 30 per cent demanding serious attention to tap yield potential to achieve our goal of 1000kg/ha during 2025.

Bt cotton Scenario in India::

The compound growth rate of area of Bt cotton in India was worked out for the years 2002 to 2012 (Period I) and compared with 2012 to 2017 (Period II).

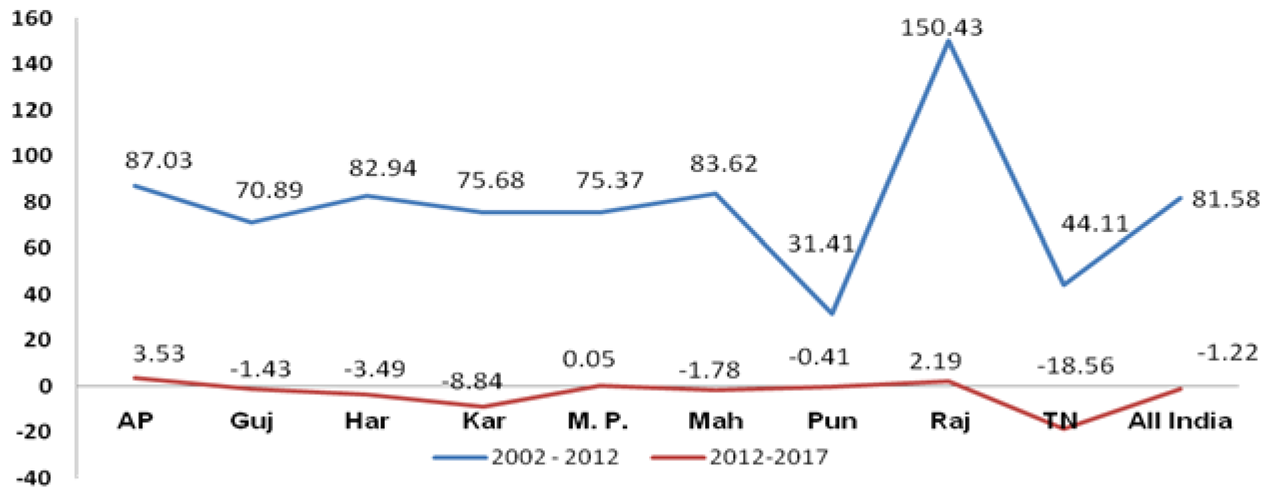

Fig.I. CGR of Bt cotton in India over years(%)

In the growth rate analysis as shown in Fig.I, during period I there was a spurt in the area of cotton in almost all the cotton growing States with growth rate of 30 to 150 per cent, the maximum reported in the North Zone followed by cotton growing States of Central and South Zones . At the National level, 82 per cent growth rate increase in area was shown during period I. In case of period II, the growth rate values presented an altogether different scenario with that of period I wherein it plunged down steeply in almost all the cotton growing States except Andhra Pradesh, Rajasthan and Madhya Pradesh ranging from 0.05 to 3.5 per cent growth rate in area with all India level to the tune of -1.22 per cent. Due to the invasion of Bt cotton in India, non Bt cotton suffered a major setback during period I with negative growth rate of 11 to 40 per cent. Overall, at the national level, it worked out to negative growth rate of 25 per cent. During 2017-18, the scenario altered in favour of non Bt

Back to content page

cotton in almost all cotton growing States highest in Tamil Nadu with 89 per cent and with overall positive growth rate of 7 per cent at All India level except in Andhra Pradesh and Rajasthan where Bt cotton is still in vogue..

Cost of cultivation trends in cotton:

The Commission for Agricultural Costs and Prices (CACP) provides data on input costs under different heads. The different categories of input costs — Cost A1, A2, B1, B2, C1, C2 and C3. Where

Cost A1 – includes

- Value of hired human labour
- Value of hired bullock labour
- Value of owned bullock labour
- Value of owned machine labour
- Value of hired machine labour
- Hired machinery charges
- Value of seed (both farm produced & purchased)
- Value of insecticides and pesticides
- Value of manure (owned and purchased)
- Value of fertilizers
- Irrigation charges
- Depreciation of implements and farm buildings
- Land revenue cess and other taxes
- Interest on working capital

Cost A2 = Cost A1 + Rent Paid for leased in-land

Cost B1 = Cost A1 + Interest on value of owned fixed capital assets (excluding land)

Cost B2 = Cost B1 + Rental value of owned land and rent paid for leased-in land

Cost C1 = Cost B1 + imputed value of family labour

Cost C2 = Cost B2 + Imputed value of family labour

Cost C3 = Cost C2 + 10 per cent of cost C2 to account for managerial input of the farmer

Though the cost of cultivation does not reflect trends in farm income, the relationship between fixed and operational cost components is indicative of the trend. As Another major component of fixed cost is interest on fixed assets. The behaviour of this component is ascertained on the basis of the actual assets created by farmers. These are in turn a function not only of current profitability, but also of expected future profits. Therefore, the interest on fixed assets might behave independently of rent on owned land and the general trend in fixed costs. In official cost of cultivation surveys, the cost of seed includes the value of farm saved, freely-exchanged, and purchased seeds. Cotton is a crop in which the seed system has undergone significant changes over the past half century. Till the advent of hybrids, cotton cultivation was undertaken with a minimum quantity of market sourced seeds. But the introduction of hybrids triggered a change, and the seed system in cotton gradually came under the dominance of the private sector. Still, the use of farm-saved and exchanged seeds continued to play a major role in cotton varieties, notably in the irrigated north Indian cotton belt. One of the most important indicators of technological change in cotton cultivation is the change in the composition of labour use. Official cost of cultivation studies take three kinds of labour into account: human labour, animal/bullock labour (power), and machine labour (power).

Input cost trend of cotton in India

The cotton production process involves use of various inputs including land preparation, inputs like seed, irrigation water, fertilizer, pesticide and labor etc. Overtime, the prices of these inputs have increased resulting in higher cost of production. In addition, the cotton crop is susceptible to various pests attack. The cotton support price trend, prices of inputs and weather play crucial role in the cotton production process. The production process involves different inputs.

Table II: State wise input Cost as percentage of Operational cost (%)

States	Seed	Labour	Insecticides	Irrigation	Fert.& Manures	Interest on Working Capital
Andhra Pradesh	8.30	64.98	7.73	0.54	15.84	2.57
Gujarat	8.08	61.00	6.29	7.57	14.67	2.38
Haryana	9.81	67.46	6.19	8.02	6.53	1.93
Karnataka	12.66	64.89	4.21	0.87	14.79	2.58
Madhya Pradesh	10.69	60.69	8.13	2.94	14.33	2.20
Maharashtra	8.30	65.84	4.32	3.18	15.66	2.58
Odisha	9.42	70.48	1.03		16.91	2.11
Punjab	13.85	61.39	11.83	1.73	8.52	2.52
Rajasthan	8.98	66.83	7.08	3.59	11.87	1.64
Tamil Nadu	5.48	71.05	3.71	2.21	15.46	2.05

Every input has its influence and plays a vital role in this process. The basic and foremost is land and its preparation has key influence on the crop condition. The other inputs include; seed, irrigational water, fertilizer and plant protection measures etc. all these inputs also play crucial role cotton production process. The cost of these inputs has influenced the cotton production in India.

Labour cost occupied major share in the total cost of cotton cultivation. Irrespective of cotton growing States from Table II, it could be revealed that in almost all the years under study from 2004 to 2016, labour has been devouring maximum share of operational cost to the tune of 60 to 72 per cent followed by seed, fertilsers and manure, insecticide and irrigation expenses. The comparative study of labour scenario during period I (2004-2010) and period II (2010-2016) showed decline in labour force to the tune of 2 to 9 per cent growth rate in States of Punjab, Haryana, Gujarat, Maharashtra, Odisha and Tamil Nadu. The reason might be due to mechanization displacing labour or reduction in cotton area in these States. Maharashtra and Andhra Pradesh registered a spectacular increase in labour hours hovering around 10 per cent during period II coinciding with increased area under cotton in these States.

To conclude, the growth rate trend in labour cost from 2004 to 2015 was highest in Karnataka and Rajasthan followed by Maharashtra, Tamil Nadu, and Gujarat. During the same comparative periods, insecticide cost was highest in Punjab around Rs.5000/- per ha during 2010-2016 whereas in other cotton growing States it was around Rs.1900/- to Rs.2900/- per ha.

Cost trends in cotton cultivation in India:

Among the cost concepts, two categories are of particular relevance viz., Cost A2 and Cost C2. Cost A2 is the aggregate of paid-out costs incurred in the cultivation process. Cost C2 is total cost at the farm and includes the imputed values of family labour, rental value of owned land, rent paid for leased-in land, and interest on the value of owned capital assets. Therefore, while gross value of output minus Cost A2 represents the margin over actual paid-out costs, the difference between the gross value of output and Cost C2 represents the margin over imputed costs as well.

The cost of cultivation data generated under the comprehensive scheme is unequivocal in establishing that coinciding with the economic reforms expenses on farming have soared to unprecedented heights. Indices were worked based on Cost C2(cost plus imputed value of rent plus interest on own land and capital) and VOP (value of product) from 2007-11 and 2011-16 based on CACP Data. The results (Table III) showed that the cotton farmers were able to make profits over cost C2 in almost all the four periods with the ratio ranging from 1.25 and more than 1.25 during the first period. But during the second period this scenario was different with Gujarat maintaining its profit during those five periods. The cotton farmers of Maharashtra, Orissa and AP could not reap the profits during four periods out of five. The cotton farmers from Rajasthan and Gujarat have reaped profits throughout the year 2007-16.

Table III : No. of years profit reaped/loss incurred by cotton farmers (2007-08 to 2015-16) in relation to

States	Cost C2 over years			Cost A2 over years		
	< 1.00	1.00 to 1.5	> 1.51	< 1.00	1.00 to 1.5	> 1.51
Punjab	2	7		1	3	5
Haryana	2	6	1		2	7
Rajasthan		3	6		3	6
Gujarat		8	1		3	6
Maharashtra	4	5			9	
Madhya Pradesh	2	5	2		2	7
Odisha	4	4			5	3
Andhra Pradesh	4	5			5	4
Karnataka	2	6	1		3	6
Tamil Nadu	3	6			4	5

In relation to cost A2 (actual paid out cost) the cotton farmers of all the States have reaped profits from 2007-16 except Punjab during the second period which incurred loss during one out of five periods which clearly brings out the fact that irrigation is not the only determinant of farm profitability.

Table IV: Farm Profitability

States	VOP		Ratio of VOP to Cost A2		Ratio of VOP to Cost C2	
	2004-2010	2010-2016	2004-2010	2010-2016	2004-2010	2010-2016
Andhra Pradesh	42132.27	66604.35	1.99	2.00	1.13	0.95
Gujarat	44101.97	82930.57	2.36	2.76	1.35	1.30
Haryana	40536.28	62792.25	2.68	2.85	1.15	1.01
Karnataka	20212.17	60558.63	1.95	2.61	1.18	1.21
Madhya Pradesh	31238.38	56341.07	2.18	3.01	1.12	1.06
Maharashtra	26068.83	67014.13	1.50	1.90	1.00	0.99
Odisha	33233.45	44841.07	2.40	2.33	1.21	0.94
Punjab	49773.12	70070.65	2.40	2.19	1.20	1.03
Rajasthan	36174.18	89909.22	4.27	5.21	1.52	1.48
Tamil Nadu	34431.43	78127.17	1.85	2.57	1.02	1.04

During 2011-12, in the profitability analysis (Table IV), all the cotton growing States have almost remained unsteady and dismal too. The farmers were struggling to garner consistent margin of profits throughout the period of analysis.

Conclusions:

India has become a major player on the world cotton market, accounting for as much as 17% of the world's cotton exports – share to decrease to 7% by 2025 due to shifts into exporting more processed textiles. The main cotton markets for Indian trade to be concentrated towards Bangladesh, Pakistan, China and Vietnam. Increasing demand for Indian cotton has to be given priority by fostering the cotton production by increasing the efficiency and productivity of Indian cotton. Varietal

Back to content page

development has to be given impetus to meet the international demand of quality cotton. High dependence on few markets would be risky in the long run. New markets are to be tapped to export our Indian cotton. Not all items of costs have increased at the same pace. While fixed costs seemed to exhibit a gradual deceleration, operational costs have continued their relentless acceleration. The former reflects the prolonged depression in farm prices during the period under analysis and the resultant decline in private investments in agriculture. On the other hand, with the slashing of subsidies and the State agencies becoming redundant in distributing inputs, farmers naturally fell into the hands of unscrupulous private operators. This was instrumental in escalating operational costs. Human labour has the largest share in variable cost structure and it has also made the largest contribution to the nominal Total Variable Cost increase between 2004 to 2016 Thus, it will have a large effect on the economics of the crop and farmers would be very sensitive to wage increases. In terms of the overall nominal cost increases and the cost pressures, it is found that the bulk of the cost increase has come not from the new technology inputs such as seeds, fertilizers, and pesticides, which have driven technological change, but from more conventional inputs such as human labour to major extent and draught power and irrigation to some extent. Suitable policies are to be framed for cost reduction in cotton through price and input policies thus favouring remunerative price to cotton farmers in India.

Need of ICT in Cotton Production System

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Introduction

Ever since the adoption of technologies in agriculture system, needs information to assess the efficacy of the technologies. Systematic adoption of agriculture technologies started from last century. Initially, researchers used to collect the data of each traits of the plant and analyze manually it in order to get valuable information out of it. The information used to improve or fine tune the technologies for the different agro-ecological conditions. Later on, the development of electronic gadgets like calculators, computers and automated data recording system in the equipment, data analyses and elicitation of information was made simple for more intensification of research goals. Subsequently, development in the Information and Communication Technologies (ICT) and Information technologies (IT) made large scale adoption of it in manufacturing, services, medical and health care, financial management, sectors. Adoption of ICT started in agricultural sector in developed countries well before it started in India. India also embraced the adoption of communication technologies in 1950s onwards initially by way of disseminating the agricultural technologies through Radio. Later on, especially after 1990s, television, internet, mobiles phones have been extensively used to disseminate the agricultural technologies in India. Today, the revolution in the ICT sector almost 60-70% of the farmers have access to mobile phones with internet facilities in the country. Parallelly, agricultural extension activities also improved with adoption ICT oriented extension modules.

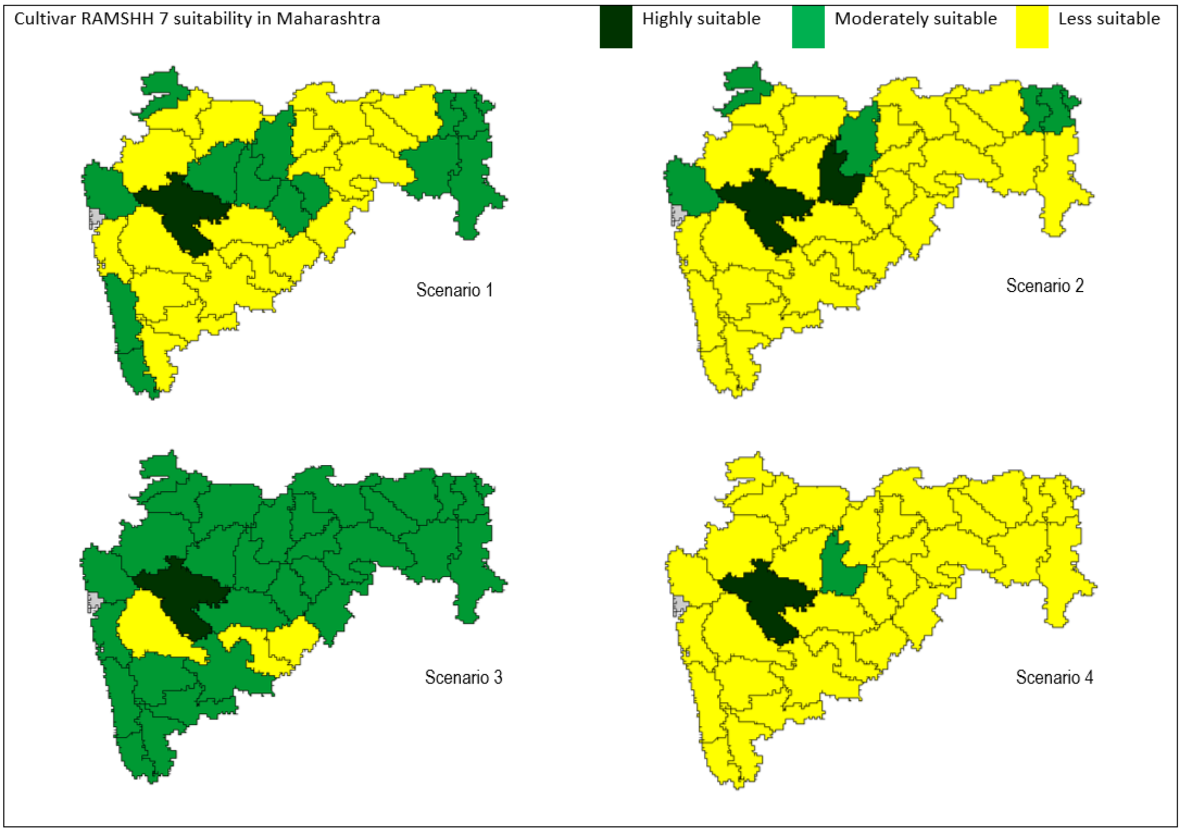
ICT Tools for farmers

India currently has several public and private ICT initiatives with objectives to support and provide assistance to farmers. ICT tools in farming encompassing both hardware and software including devices, networks, mobiles, services and mobile applications. Today ICT tools are plenty but not all tools are suitable or adoptable to Indian farmers. A study by Mittal, 2010 found that source of information for Indian farmers are mainly from ICT tools. Among five top source of information tools, four are ICT based – Mobile phones, Mobile enable services, television, and kiosk. A survey by Meera *et al.,* found that 72% respondents expects interactive type extension tool, followed by information on - post-harvest technologies (58%), market information (59%), RD programmes (46%) and package of practices (45%). The ICT based farming creating job opportunities for private sector as well as Government sector for IT specialist and aids the Agriculture Extension officers who can work with rural farmer in the development of India. ICT plays a major role in farmers requirement for better information, exclusively, new technology, good agriculture practices, Mandi rate, fertilizer and pest control related information at appropriate time in their door steps.

ICT Initiatives at CICR

Decision Support System for Cotton Cultivar Selection

India has the largest area under cotton cultivation in the world, in contrast the cotton production is much lower for the crop occupies. Additionally, the stagnation of cotton productivity at an average around 500 kg lint per ha past few years have been a concern for the stake holders despite constant increase in area under Bt cotton. It is found that the proliferation of many unchecked cotton varieties which are susceptible to major sucking pests and diseases were released and cultivated in unsuitable agro-climatic zones impedes the enhancement of cotton productivity in the country. CICR developed Decision Support System cotton cultivar selection based on prime crop traits and its suitability for the different agro-ecological zones. The cotton cultivar has been evaluated for different traits but not all the traits are prioritized to identify the ideal cultivar for different scenarios. In the developed DSS, we have identified eight crop traits, they are seed cotton yield, ginning outturn, boll weight, span length of the cotton fiber, strength of the fiber, jassid infestation, bollworm damage, cotton leaf curl virus disease (ClCuD). The suitability of the identified cultivar for different agro-ecological condition for different agro-ecological condition based on key agro-climatic indicators. Cultivar release and adoption of cotton hybrids in un-suitable agro-climatic condition leads to stagnation or low cotton productivity. The cultivar selection based on prioritized in-built traits (scenarios) of the cultivar and its suitability for varied agro-ecological regions are presented in the below map.

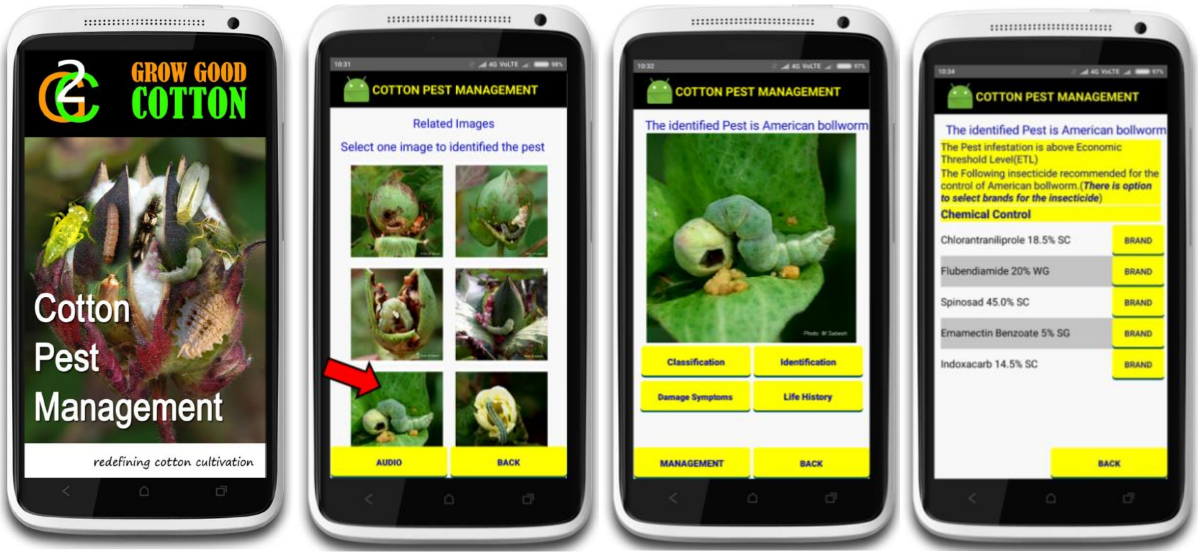


*Note: **Scenario 1:** CLCuD given more priority followed by seed cotton yield, fiber quality, and other parameters given appropriate importance; **Scenario 2:** Seed cotton yield criteria given more priority followed by ginning outturn, boll weight; **Scenario 3**: Span length given more priority followed by fiber strength; **Scenario 4:** Boll damage given more priority followed by jassid pest infestation, seed cotton yield*

Decision making: If the demand for selection of cultivar with good fiber quality, cultivar RAMSHH 7 would be the ideal choice (scenario 3). Again, the cultivar RAMSHH 7 is less suitable in Maharashtra districts for scenarios 2 and 4; moderately suitable in few districts for scenario 1.

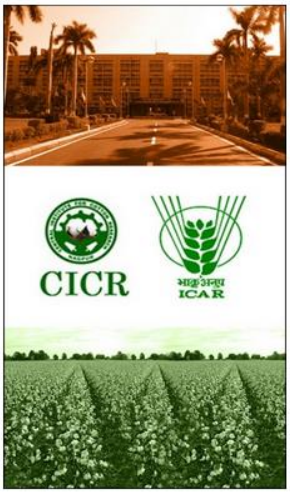
Mobile applications:

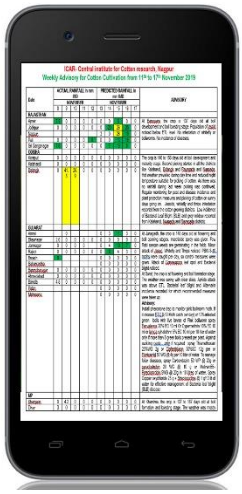
CICR, Coimbatore, developed mobile based decision support system -**Grow Good Cotton**, the tool which aids the extension personnel and farmers to identify the pest based on the symptoms of damages and also help to choose the appropriate pest control measures including selection of chemicals. The app minimizes the overall cost for plant protection as well as ensure environmental safety by administrating the chemicals for the need based for farmers; handy tool for extension personnel to propagate appropriate pest management strategies with reasonably minimum cost by extension personnel; handy tools for the students to understand different pest in cotton agro-sphere and various pest management strategies.



CICR Mobile app

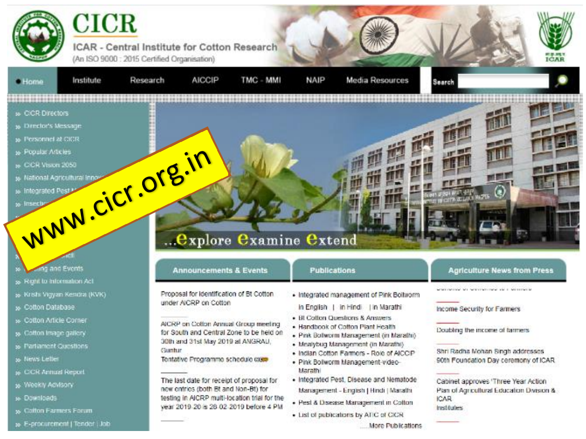
It has information on everything concerning cotton right from sowing, varieties, hybrids, cultivation and management practices including production and protection technologies. The key components in the app are information on best varieties/hybrids which should be ideally cultivated by farmers. It also has weekly advisories and regular updates on fact and figures related to cotton production, market, pricing, schemes etc. The app available at Google Play Store.





Indian Cotton Portal

The Indian Cotton Portal of CICR contains four websites (www.cicr.org.in, www.aiccip.cicr.org.in, www.tmc.cicr.org.in, www.kvknagpur.org.in). This cotton portal caters to many stakeholders including farmers, researchers, extension personnel, students, general public, etc. Besides, weekly weather-based cotton cultivation advisories have been issued through CICR website as well as in CICR mobile app in nine Indian languages.



Directions-suggested:

ICT Based suggestions

- Develop mobile based, farmers friendly, location specific information and dissemination tool for cotton cultivation exclusively for the state in local language with voice over module
- Visit Indian Cotton Portal for cotton related information and gain knowledge and adopt whichever conducive to Odisha State (if require re-examine for local condition)
- Disseminate Weekly Advisory from CICR website/app for Odisha state as much as possible

General suggestions

- Promote cotton, especially, in non-traditional areas for more remuneration for farmers
- Demand/promote for ginneries and textile mills for better returns for the produce of farmers
- Demand for approval and legalization of Transgenic cotton cultivation
- Demand for exclusive R&D institution for cotton, as cotton cultivation gaining momentum
- Demand for strict cotton seed purity and certification

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Scope and Potential of Drip Irrigation for Cotton Cultivation Under Indian Condition

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Prologue

Water is a precious commodity, everything is originated from water and everything is sustained by it too. The National water policy 2012 mentioned that a scare natural resource, water is fundamental to life, livelihood, food security and sustainable development. India has more than 18% of the world's population but has only 4% of world's renewable water. Human Development Report 2006 of the United Nations Development Programme (UNDP) acceptably identified that one of the most serious problems facing humanity today is "**Global Water Crisis"**.

Sector wise withdrawal of water

Of the available water, major chunk is utilized for agriculture. The estimated global withdrawal for agriculture is 69 per cent followed by 21 and 10 per cent by industries and municipalities respectively. The average human consumes about four litres a day. But producing the same person's daily food can take up to 5,000 litres of water, which is why agriculture claims some 70 per cent of global withdrawals. The agriculture sector in India utilises 85 per cent of the country's available fresh water.

Importance and scope of Drip irrigation in India

It is fact that irrigation efficiency of Indian agriculture is about 40 – 45 per cent. And near about fifty per cent of water is actually used by the crop and remaining water goes as waste. Indian agriculture mostly depends on traditional system of irrigation, whereas elsewhere in the world, advanced irrigation methods like drip and sprinkler methods are adopted for larger area. For example, in Israel 100 per cent area is irrigated by sprinkler method. In the world, more than 2 million hectares is under drip irrigation for 60 crops.

In India, drip irrigation is adopted in 4,00,000 hectares. Maharashtra is the leading state where 1,42,000 hectares area is under micro irrigation system followed by Karnataka in an average of 64,000 hectares. Tamil Nadu ranks third putting at least 43,400 hectares of area under drip irrigation. However, total drip irrigated area is less than one percent of the total irrigated area in India. Therefore, still there is a scope to increase the area under drip irrigation.

Central Government initiatives to promote drip irrigation in India

Recognising the importance of micro irrigation, the government has taken various initiatives since 1992. The first initiative was started from the year 2006, when the government launched a Centrally Sponsored Scheme (CSS) for Micro Irrigation. This was later upgraded to the National Mission on Micro Irrigation (NMMI) and was implemented through the year 2013-14. In 2015, a remarkable milestone in micro irrigation was that Cabinet Committee on Economic Affairs (CCEA), chaired by the Honourable Prime Minister Shri Narendra Modi, has given its approval to a new scheme the "Pradhan Mantri Krishi Sinchayee Yojana" (PMKSY) with the outlay of Rs. 50,000 Crores over the period of five years. (2015-16 to 2019-2020).

Structure of implementing agency

Different state government adopted different system to implement the Micro irrigation scheme. Among the state, Gujarat and Andhra Pradesh models are unique and effective implementing strategy. The micro irrigation programme in Andhra Pradesh is implemented in the name of Andhra Pradesh Micro Irrigation Project (APMIP) which has been created in the Horticulture Department to guide, supervise and monitor implementation of the project. In Gujarat state the Gujarat Green Revolution Company Limited (GGRCL), which is a special purpose vehicle promoted by Gujarat State Fertlizers and Chemical Limited, Gujarat Narmada Valley Fertilizers Company Limited and Gujarat Agro Industries Corporation Limited, is the implementing agency appointed by Government of Gujarat and recognised by GOI for implementing Micro Irrigation System in the state of Gujarat. The below table shows the structure of implementing agency in the sample states.

Table. 1. Structure of Implementing agency

Particulars	AP	Gujarat	Karnataka	MP	Punjab	Orissa
Agency	APMIP	GGRC	DoADoH	DoH	Dept. of Soil & Water Conservation	Horticultural Development Society (OHDS)
Main Focus	Horticulture Department	Micro Irrigation	Agriculture &Horticulture	Horticulture	Soil & Water Conservation	Nodal Agency forNHM
Nature of Association	SPV – Relatively autonomous unit within Horticulture department	Registered under Company's Act; Public Limited	Govt. Departments	Govt. Department	Government Department	Registered under Society Registration Act,1860
Structure &Outreach	III Tier *State APMIC *Dist. APMIC *Resource Center at Mandal level	Centralized; Support from GNFC Depots atDistrict level	III Tier *State *District *Blocks	II Tier *State *District	IV Tier *State *Division *District *Circles	IITier *State *District

(**Source:** Evaluation study of centrally sponsored scheme on MI- Executive summary by NABARD consultancy services private limited (NABCONS), Mumbai)

Cotton is the candidate crop for drip irrigation

Cotton is a candidate crop for drip irrigation due to the following reason viz., longer duration, suitability of growing environment, early sowing, flexible drip system, higher economic return, higher fertilizer use, enhancement of seed cotton yield, suitability to light soils, uniform germination and maturity and enhancement of fibre quality. Even though, it is having lot of advantages; cotton area under drip irrigation is still not in mode of accelerating rate.

CICR initiative to study the Drip irrigation in cotton cultivation

With the above importance of drip irrigation for cotton cultivation; ICAR – CICR initiated a field level study to explore the impact and constraints of drip irrigation in cotton cultivation in Tamil Naduand Maharashtra states. Exploratory surveys, Focused Group Discussions and case study methods have been adopted. In Tamil Nadu two-major cotton growing districts viz., Erode and Namakkal were selected based on the predominance of cotton cultivation under drip irrigation. The information about spacing, drippers distance, discharge rate in LPH, interval between different irrigations, irrigation scheduling were carefully collected from the farmers. The socio technological analysis revealed that Majority (55%) of the old category farmers are adopting drip irrigation more when compare to middle and young farmers. Majority of farmers (62.5%) had experienced in drip irrigation from 2 to 8 years. As per the land holding is concerned, majority of the farmers in both drip (86%) and non-drip (80%) category comes under small and medium size land holding. Impact analysis was studied with five indicators and the results revealed that the five indicators viz., yield efficiency (24.61%), income efficiency (24.59%), water use efficiency (31.20%), labour use efficiency (15%) and input use efficiency (1.03%) had significant impact in cotton cultivation under drip condition. Constraint analysis revealed that 91 per cent of the farmers reported that clogging of emitters was the first and foremost problem in drip irrigation. Second constraint rat biting was reported by 72.5% of the respondents, third constraint high investment cost despite subsidy was reported by 68.75 per cent and other constraints viz., poor after sale service (41%), difficult for intercultural operations (34%), difficult procedure involved in getting subsidy (29%) and unavailability of spare parts locally (14%) were also reported by the drip farmers in cotton cultivation.

Observations about drip irrigation in cotton cultivation under Maharashtra state

Field surveys were conducted in Jalgon and Jalna district of Maharashtra state. Major observations made about drip irrigation from the districts are;

- Farmers in the districtsextending the cotton crop after December as well since they don't have water for next crop. The possible reasons for extending the crop reported by the farmers are 1. From main crop they are not getting good yield, 2. Water is not available for next crop, 3. The additional yield after December month also gives additional profit for them. The extension of crop leads for pink bollworm incidence in several fields. State Government initiated several measures to preventthe extending crop beyond the season.

- Almost 65 % of the area under cotton cultivation in these districts in which 60% area under drip irrigation. Majority of the farmers cultivating cotton in the spacing of 5x3/5x2/4x3 and average number of drippers for one acre is 6000-7000,
- Since from 2012 the water availability is low, majority of the farmers prefer for cotton cultivation why because cotton is the only crop at least gives some yield under drought condition and other crops are very sensitive for drought as reported by farmers.
- Before 10 years they had drip irrigation only for horticultural crop but due to declining trend of water availability; now majority of the farmers go for drip irrigation for cotton as well.
- Important issue reported by the farmers that they have to pay Rs.45,000 as initial cost for drip installation in that nearly 50 percent as subsidy by government and 50 percent as loan from bank and they have to repay the loan in five years as term loan basis
- Another major issue reported by the farmers is that Rs. 5000 per year electricity payment to the government weather the farmers irrigate or not and uneven schedule of electricity also reported by majority of the farmers.

Epilogue

Based on the findings and personal observations of the study following implications are drawn.

- As per constraint analysis, procedural component had less agreement among respondents. It clearly depicts that procedural formalities involved in the scheme were more complex in nature. Therefore, easy and effective procedural mechanisms could be formulated by active collaboration of various stake holders such as policy makers, farmers group and personnel of micro irrigation companies.
- Majority beneficiaries had perceptual agreement that the present scheme emphasized scientific utilization of water and increased productivity of the farms. This result helps to draw important implication that beneficiaries of the scheme could be converted as 'Para-Extension Workers' (PEW) by the extension machinery for further promoting the concept of drip irrigation technology among non-drip users. Since the beneficiaries had strong conviction towards drip irrigation, they could very well act as Para Extension Worker (PEW).
- Majority of the farmers opined that existing subsidy ratio is not satisfactory. Therefore, it could be recommended that effective subsidy mechanism could be evolved by reviewing earlier micro irrigation schemes. Further, government has to take into consideration current installation cost while calculating the subsidy ratio.

- Increased yield and income had been observed among the drip users. Extension personnel who are engaged in micro irrigation scheme could make arrangement of field visits for non-drip users to show the effectiveness of drip irrigation in their fellow farmers' fields. It might be helpful to accelerate the mind set of non-drip users from the conviction stage to adoption stage for drip technology.
- In long run, drip irrigation paves way for 'zero budget' agriculture due to decreased weed growth and pest population. The advantage of drip irrigation for zero budget agriculture should be popularized among the farmers by extension agencies.
- Increased water use efficiency, input use efficiency and labour use efficiency end with environmentally safe agriculture. The monetary benefit of environmental advantages of drip irrigation has to be worked out by policy makers, researchers and water policy institutes to create awareness among farmers as well extension personnel.
- Different crops have different relative advantages under drip irrigated conditions. Cotton has an advantage of yield, income and input compared to other crops. It implies that the relative advantages could be identified by researchers as well as extension workers for effective cropping pattern design for particular area under drip irrigated conditions.
- Collaborative policy analysis studies should be taken up to evolve effective subsidy mechanism, since a majority of the respondents reported that ineffective subsidy mechanism as their foremost problem.

Implications and recommendations given above are exhaustive and they throw light on what may be done to improve the existing conditions. It is high time we realized that we are depriving our future generations of what we are enjoying at present. In this situation the above said implications will pave way towards sustainable water resource management by means of drip irrigation technology and it will pave the way for “More Crop Per Drop”.

Back to content page