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International Congress

on

"Cotton and Other Fibre Crops"

at

ICAR Research Complex for NEH Region,
Umiam (Barapani) - 793 103, Meghalaya

20-23 February, 2018

Book of Oral Presentations

Organised by

Cotton Research and Development Association (CRDA)
CCS Haryana Agricultural University, Hisar - 125 004

ICAR Research Complex for NEH Region,
Umiam (Barapani) - 793 103. Meghalaya

In collaboration with :
Indian Council of Agricultural Research (ICAR), New Delhi
and
Indian Association of Hill Farming (IAHF), Umiam

Complied and Edited by :
Dr. M. S. Chauhan
Dr. R. S. Sangwan

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PREFACE

Cotton is one of the most ancient and very important commercial crop of global importance with a significant role in Indian agriculture, industrial development, employment generation and improving the national economy. It is cultivated for domestic consumption and also exported in about 111 countries worldwide and hence called **"King of Fibres"** or **"White Gold"**. Millions of people depend on cotton cultivation, trade, transportation, ginning and processing for their livelihood. India is the only country in the world growing all the four cultivated species of cotton alongwith their hybrid combinations in the vast diverted agro-climatic situations. Cotton is basically cultivated for its fibre which is used as textile raw material. It is cultivated from Punjab in the north to Kanyakumari in the south and Assam in the east to Kutch (Gujarat) in the west.

India, the second largest producer, consumer as well as exporters of cotton next to China with 34 per cent of world area and 21 per cent of world production and continue to maintain the largest area under cotton. Within a span of fifteen years, the cotton production in the country has gone more than double with the increase of the productivity. The productivity of cotton has not made headway because of more than 70 per cent area is under rainfed cultivation and appearance of new diseases and insect pests in transgenic cotton. However, new emerging threats in terms of biotic and abiotic factors are to be understood properly and effective strategies need to be evolved for their proper redressal. The problems and prospects of *Bt* cottons in the country need to be put in a proper perspective. Therefore, there is an urgent need to properly understand the IPR issues in the best interest of farmers and scientists.

In order to maintain pace with the increased demand for the commodity, both in national and international market, it is imperative to give impetus for development of new cotton and fibre crops varieties and hybrids with appropriate cultivation technologies. Introduction of large number of private sector *Bt* cotton hybrids have brought a welcome change in recent times as far as production gains are concerned. However, to meet the ever increasing demand both in the domestic and international markets, an effective strategy needs to be developed.

The Jute, flax, cotton, ramie, Mesta, agave, banana, pineapple etc. are the important fibre crops of north eastern region of India. However, the productivity and area coverage is very low. Technological backstopping and adequate policy support would pave the way for improving fibre crop scenario in the region. The Congress would give the scientists, experts and officials working in the region a platform to share their ideas with experts from other parts of the country and abroad which would be helpful in developing a strategy for the fibre crop development in the region.

The research papers included in the **"Book of Oral Presentations"** are related to **"Crop Improvement, Biotechnology, Post Harvest Technology, Crop Production, Mechanization, Economic Development, Crop Protection and Biosafety"** which were the theme areas of the congress. Present compilation on **"Cotton and Other Fibre Crops"** is a compendium of holistic advancements and other relevant information related to cotton and other fibre crops covering different disciplines. We hope that the information contained in this **"Book of Oral Presentations"** will be useful to all the stakeholders *viz.,* researchers, students, developmental officers, planners and farmers. All these manuscripts have been pre reviewed by eminent scientists of the respective disciplines/ fields before publishing in this **"Book of Oral Presentations"**. We are thankful to the authors of individual chapters/papers for their contribution, time and diligence without which this volume would not have been possible.

We deem it a rare privilege to place on record our sincere gratitude to Dr. D. P. Biradar, Vice Chancellor, UAS, Dharwad and President, CRDA for his valuable guidance and directions in the general functioning of CRDA. We take this opportunity to thank all concerned and hope this **"Book of Oral Presentations"** will serves the purpose of cotton research workers for furthering the cause of cotton and fibre crops farmers.

Place: ICAR Research Complex for NEH Region,
Umiam (Barapani) - 793 103. Meghalaya

Dated: 20-02-2018

Editors
Dr. M. S. Chauhan
Dr. R. S. Sangwan

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ORAL PRESENTATIONS

CROP IMPROVEMENT, BIOTECHNOLOGY AND POST HARVEST TECHNOLOGY

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Extra long staple diploid cotton (G.*arboreum*): Retrospect, present status and strategies

K.S. BAIG*, K.R. KRANTHI, D.P.WASKAR, V. N. CHINCHANE, A.R. GAIKWAD AND L.A. DESHPANDE

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Indigenous Cotton *Gossypium arboreum* originated in India about 6 million years ago. According to evidence 8000 years ago people were able to make fabric out of cotton in place called Mehrangarh which is now in Pakistan, it is the earliest part of Mohenjo-Daro civilization; this was the first record where *G. arboreum* was found to have contributed in making of fabric (Kranthi, 2016)

In India cotton is grown on area of 110 lakh hacters with the production of 320 lakh bales and average lint productivity of 520 kg/ha (Anonymous, 2016). At global level India is the only country growing all the four cultivated species of cotton *viz., G. arboreum, G. herbaceam, G. hirsutum and G. barbadence.* Apart from deviation in species composition, India is the only country where hybrid cotton is grown on more than 95 per cent area (104 lach ha). Country had witnessed drastic changes over last seven decades with respect to shift in species composition from straight variety to hybrid and rapid shift in acreage under transgenic *intra hirsutum* hybrid in last two decade.

By the middle of 19th century with the emergence of America as a major supplier of raw cotton to the textile industry at Liverpool, the East India Company introduced Exotic American Upland and Egyptian / Sea Island cotton representing tetraploid cotton in India. Hutchinson *et al.*, (1947) warned unsuitability of *G. hirsutum* (tetraploid cotton) cultivation under Indian conditions and suggested to make improvement in Indian cotton through selection in indigenous varieties. Thereafter, efforts were continued to replace indigenous cotton with that of American cotton (Anonymous, 1961). At the time of independence, the diploid cottons were grown to the extent of 97 per cent of the cotton growing area of the country (65 % *G. arboreum and* 32 per cent *G. herbaceum* cotton). With the introduction of American cotton, drastic erosion in area under diploid cotton was observed.

Effect of partition of cotton scenario : The partition of the country in August, 1947, reduced the northern region to a minor position in cotton production. The fertile, rich cotton-growing areas of Sindh, West Punjab, Bahawalpur and Khairpur were cut off and added to Pakistan, with the result that in the truncated Northern Region, the acreage of cotton fell from 40.05 lakh to 3.08 lakh bales. The production of medium and long staple cottons was also reduced from 13.8 lakh to 0.28 lakh bales (Sikka *et al.,* 1961). During 1999-2000, hardly 28 per cent area (17% under *G. arboreum* and 11 per cent under *G. herbaceum*) in the country was remained under diploid Asiatic cotton. The present species composition of cotton grown in India is presented in Table 1.

Table 1. Percent species composition of cotton grown in India over last eight decades (1947-1948 to 2017-2018)

Type of cotton	1947-1948	1999-2000	2017-2018
G. arboreum	65	17	1.5*
G. herbaceum	32	11	0.5*
G. hirsutum	-	29	
Negligible(straight varieties)			
G.barbadence	-	-	Negligible
Intra hirsutum hybrids			
Non *Bt*	-	43	-
Bt	-	-	98

* Approximate

The area under tetraploid cotton was increased rapidly mainly due to their superior fibre qualities as compared to diploid *desi* cotton. Moreover, there is a false assumption amongst the farmers that the varieties and hybrids of the tetraploid cotton have higher production than traditional varieties of diploid *desi* cotton (Deshpande *et al.,* 2001). Inspite of strenuous efforts taken by diploid cotton breeders, the area under diploid cotton is replaced by tetraploid cotton mainly due to their superior fibre properties and high productivity.

During 1960s, cotton acreage of India was mainly divided on the basis of soil, climate, and variety into six regions, *viz.,* (*i*) Northern *hirsutum-arboreum* region; (*ii*) Central *arboreum* Region; (*iii*) Southern *hirsutum-arboreum* region; (*iv*) Central *herbaceum-arboreum-hirsutum* Region; (*v*) Western *herbaceum* region; and (*vi*) Eastern region (Sikka *et al.,* 1961).

Table 2. Staple wise production of cotton (1956-57) in central *arboreum* region (Approx.)

Staple class	Official estimate (thousand bales of 178 kg.)				Per cent of central *arboreum* Region production compared to that class in whole India
	Number of bales produced	Per cent of total production	Indian production	Per cent of Indian production	
Superior long staple (25.4 mm and above)	-	-	329	7	-
Long staple (22.20 to 24.60 mm)	353	18	1,549	33	23
Superior medium staple (20.6 to 21.4 mm)	958	50	1,539	32	62
Medium staple (below 20.60 mm and above 17.40 mm)	236	12	599	13	40
Short staple (17.40 and below)	373	20	707	15	52
Total	1,920	100	4,723	100	-

(Cotton In India- A Monogram Vol. IV- 1961)

The Northern *hirsutum-arboreum* region, prior to the partition of the country, included the fertile plains of West Punjab and Sind. Here, cotton covered an area of 40 lakh acres, forming 27 per cent. Of the total cotton acreage of the Indian sub continent and contributing 45 per cent to its total production. The quality of cotton

Table 3. Characteristics of *Desi*/American cotton varieties grown in the Central *arboreum* Region during 1960-70

Strain	Pedigree	Yield of *kapas* (kg/ac)	Ginning (%)	Staple length (mm)	Spinning value (H.S.W.C.)
Khandesh and Buldhana					
N.R. 6	Selection	279	40.0	17.27	6.0
Banilla	Bani x Comilla	307	38.5	19.05	16.0
Jarila	Selection in V.262	335	35.0	21.34	24.0
Virnar	Jarila x N.R. 5	339	39.0	22.10	22.0
Mathio region					
Mathio	-	200	30	18.29	13
Pratap	-	170	32	20.83	30
C.J. 73	-	200	34	22.86	30
Erstwhile states of central provinces and Berar					
Local Jadi	-	-	35	12.85	8
Roseum	Selection in local	-	36	15.14	10
Verum 262	do.	136	32	20.57	25
Verum 434	do.	159	31	22.10	32
H. 420	Bani x *cernuum*	-	33	23.01	31
Malini	Selection in local	-	36	22.10	34
No. 91	Bani x *cernuum*	-	36	21.59	31
Local Cambodia	-	163	32	21.34	22
Buri 107	Selection	155	28	22.10	40
Buri 0394	Selection in Buri 107	229	33	22.86	42
Marathwada					
Bani	-	136	28	20.32	29
Gaorani 6	-	191	32	21.59	36
Gaorani 12	-	141	32	21.59	32
Daulat	-	150	36	21.59	35
Parbhani-American 1	-	-	32	23.37	30
Malwa and west Nimar					
Local Malvi	Selection in Malvi bulk	172	28	-	12
Malvi 9		200	32	20.07	20
Bhoj		219	32	19.56	21
Dhar-Cambodia	Bulk	233	31	20.83	23
Indore 2	Selectionin X-ray pedigree	311	33	22.61	29
Local Nimar	-	184	33	21.08	28
Maljari	Malvi × Jarila	261	36	21.84	30
Mewar					
Vana (American local)	-	422	31	17.53	16
Indore I	Selection	449	31	22.10	26
Vani (*Desi* local)	-	-	33	11.43	8-10

(Cotton In India- A Monogram Vol IV- 1961)

produced was also superior. Out of 30.38 lakh bales of medium and long staple cotton produced in undivided India, 13.58 lakh bales, *viz.,* 44 per cent came from the northern region. In fact, none of the other five cotton-growing regions of India was so important as the northern region both in respect of the quantity and the quality of cotton. The poor position to which the resultant Northern *hirsutum-arboreum* Region was thus reduced created a serious situation not only for the farmers of the northern region, but also for the entire spinning industry of the Indian Union. The details of staple wise cotton production during 1960's in India are presented in Table 2.

The Central *arboreum* region at that time was designated in view of its location in the country and the predominance of *Gossypium arboreum* L. species. Nevertheless, it also cultivates *Gossypium hirsutum,* both as pure crop in pockets where soil and rainfall conditions are favourable, and mixed with *Gossypium arboreum* in almost the entire region except where seeds of pure Asiatic *arboreum* strains are under distributions.Central and south zone belongs to diploid Asiatic cottons (*Gossypium arboreum* L.) popularly called as *desi* cotton. The details of varieties grown during 1960's to 1970s in central *arboreum* region are presented in Table 3.

Off late, the cotton cultivation in India was further divided into mainly three zones *viz.*,

Table 4. Performance of quality *arboreums* in comparison with varieties / hybrids of *hirsutum* cotton on research station trials (2000-2001 to 2002-2003)

Strain	Seed cotton yield (kg/ha)				Percentage increase over			
	2000-2001(6)*	2001-2002(4)*	2002-2003(6)*	**Mean**	LAC	LHC	LHHC	Bunny
Quality *arboreums*								
PA-255	876	972	1352	**1066**	3.8	74.2	66.0	18.1
PA-402	818	864	1265	**982**	-	60.4	52.9	10.4
MDL-2463	879	979	1473	**1110**	8.2	81.4	72.9	28.6
DLSA-17	927	864	1233	**1008**	-	64.7	57.0	7.7
Checks								
LAC	850	875	1353	**1026**	-	67.6	59.8	-
LHC	525	417	895	**612**	-	-	-	-
LHHC	-	439	845	**642**	-	-	-	-
Bunny	-	-	1145	**-**	-	-	-	-

*No. of locations

north zone, central zone and south zone. The genetic erosion of the diploid *desi* cotton in the eco-system of the country was mainly due to their poor fibre qualities, small boll size and false assumptions amongst cotton breeders regarding their low productivity as compared to tetraploid cotton. Moreover, with the introduction and spread of tetraploid cotton the genetic enhancement work of diploid *desi* cotton has been over looked by Indian cotton breeders since last four decades.

The traditional old varieties of diploids, evolved by selection in local land races (*G. arboreum* and *G. herbaceum*) were low yielder mainly because of their small boll size (1.5 to 2.0 g) and were shy bearers. In addition, they possess coarse and inferior fibre length (21 to 22 mm) and were spinnable upto 10-20^s count. These varieties mainly includes G 12, G 22, G 46 (Maharashtra), Maljari, Zarilla (Madhya

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A high yielding upland cotton genotype GJHV-516 : Potential for irrigated tract of central zone of India

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ABSTRACT : The overall mean performance indicated that genotype GJHV-516 recorded seed cotton yield of 1955 kg/ha which was registered 29.5 and 18.0 per cent higher seed cotton yield than the zonal check CNHO 12 (1509 kg/ha) and local check G.Cot 20, (1668 kg/ha), respectively. The GJHV 516 was adjudged as the best quality in the eight trials out of fourteen trials conducted of different locations in respect to yield and yield attributing characters. Likewise, this genotype performed excellent fiber properties *viz.,* ginning percentage (34.7), long fiber length (27.6 mm), average fiber strength (23.7 g / tex), average micronaire (4.4 ug/inch), excellent uniformity ratio (48-50) and good maturity co-efficient (85%) which were suitable for medium stable cotton. This genotype was found resistance against Alternaria leaf spot and bacterial leaf blight under field conditions. This genotype also found moderately resistant to sucking pests *viz.,* jassids, aphids and thrips and in bollworms founds numerically lower percent damage to open bolls and locule as compared to other checks. Therefore, this genotype is recommended for commercial cultivation under irrigated condition of central zone of India comprising Gujarat, Maharashtra and Madhya Pradesh.

Key word : Cotton, *G. hirsutum*, variety

Cotton is the **"King of Fiber"** and one of the most ancient and very important commercial crop of global importance with a significant role in the Indian agriculture, industrial development, employment generation and improving the national economy. It is a large diverse and economically variable genus, which includes many diploid and tetraploid species indigenous to most of the tropical regions of the world (Fryxell *et al.*, 1992). India is the only country in the world growing all the four cultivated species of cotton along with their hybrid combinations in the vast diverted agro-climatic situations. The cultivated tetraploid species *G. hirsutum* accounts for about 95 percent of the global cotton production. With the increasing global demand for textile products, interties competition from synthetic fiber and textile industry's modernization, the need for higher yielding American cotton cultivars with improved fibre quality has never been more critical (Vindhiyavarman, 2015).

India is the leading country in terms of area under cotton cultivation and raw cotton production in the world. As per CAB estimate, cotton production in India during 2016-2017 is expected to produce 351 lakh bales of 170 kg from 105 lakh ha with a productivity of 568 kg lint/ha (CAB as on 24/10/2016). During the *Kharif* 2016-2017 Gujarat, Maharashtra and Telangana were major cotton growing states covering around 70% (74.5 lakh ha) in area and 67 per cent (232 lakh bales) of cotton production in India (Anonymous, 2016).

Looking to the inconsistent performance of *Bt* cotton hybrids since last few years under changing scenario of climate, groups of farmer's particularly cultivating cotton on marginal soils under rainfed / irrigated condition are looking forward for non *Bt* varieties / hybrids of American cotton. In India presently more than 90 per cent area has been occupied by *Bt* cotton. In rest of the area, non *Bt* cotton variety / hybrids of *G. hirsutum* / *G. barbadence* / *G. arboreum* / *G. herbaceum* are struggling for survival. At this juncture flow of releasing non *Bt* varieties / hybrids is need of the day, otherwise in coming years, these non Bt varieties may be diminished completely. Likewise, in the present scenario of *Bt* cotton, release of non *Bt* cotton varieties are extremely essential for using as a present in crossing programme by the breeders for creating genetic variability.

MATERIALS AND METHODS

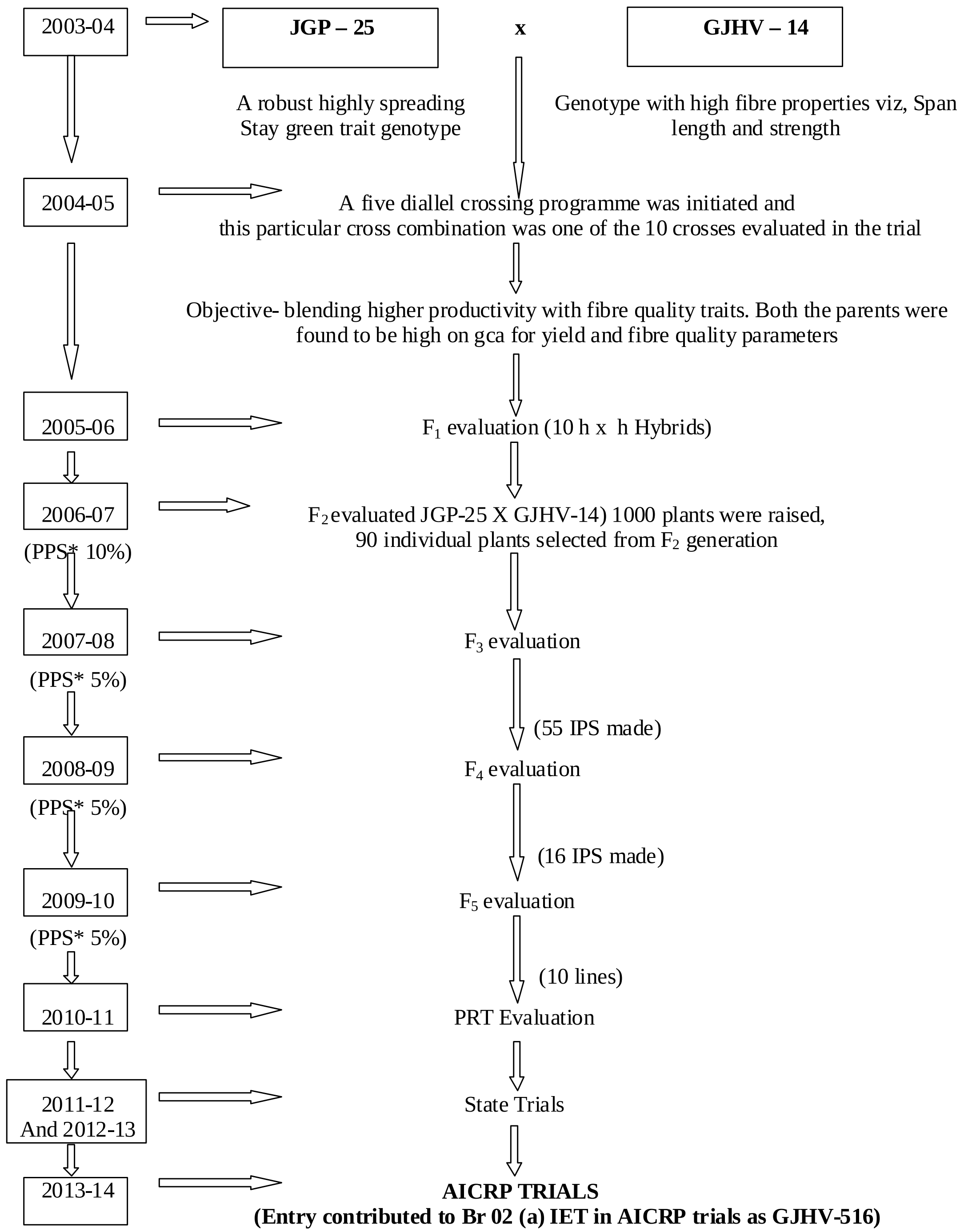
Gujarat is one of the main cotton producing states in India. Presently more than 80 per cent area has been occupied by *G. hirsutum* (*i.e. Bt* cotton). In rest of the area, *G. arboreum* and *G. herbaceum* are struggling for survival. Thus basic requirement of the state is to have high yielding, stable genotype having tolerance to biotic and abiotic stresses with desirable fibre qualities. *G. hirsutum* basically possess good fibre properties used to be commercially rated than the *G. arboreum* and *G. herbaceum.* Development of such a high yielding stable genotype with desirable fibre qualities will help to improve cotton productivity and income of farmers in Gujarat, Maharashtra and Madhya Pradesh. So, efforts were made at Cotton Research Station, JAU, Junagadh during the year 2003-2004 and the strain GJHV 516 was developed by pedigree method of selection as per flow chart.

The genotype was initially tested in PRT and state trials during the years 2010-2011 and 2011-2012 and then tested consecutively for three years under AICCIP trials. The coordinated trials were conducted at five locations (Junagadh, Surat, Talod, Ruhari and Bhavanipatna) for three consecutive year i.e. 2013-2014, 2014-2015 and 2015-2016 but trials was failed at Talod during the year 2015-2016. The fibre properties through HIV *viz*, 2.5 per cent span length, uniformity, micronaire, strength, elongation as well as full spinning results were tested at CIRCOT, Mumbai. The genotype was tested for recommended spacing (120 x 45 cm) as well as higher doses of fertilizers. It was also tested for major pests and diseases at Cotton Research Station, JAU, Junagadh as well as in coordinated trials. The statistical analysis was carried out according to Panse and Sukhatme (1985).

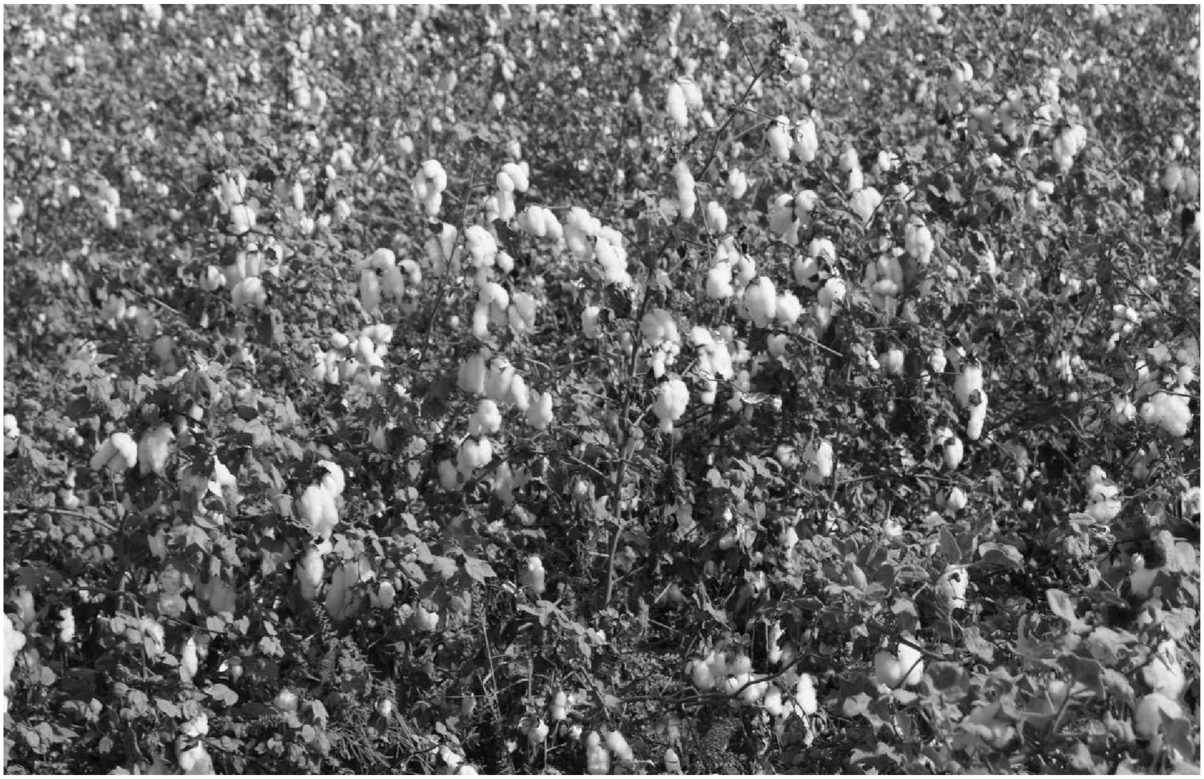
RESULTS AND DISCUSSION

For development of genotypes selection pressure was applied for yield and fibre quality traits on segregating population during 2006-

Flow chart showing the methodology while exercising selection during the development of the genotype GJHV-516



- **Proportion of plants selected during the segregating generations**



FIELD VIEW OF GJHV-516

INDIVIDUAL PLANT OF GJHV – 516

Table 1. Detailed Dus description of GJHV 516 and the quality check Suraj

Sr. No.	Characteristics	GJHV-516	Suraj Quality check
1	Hypocotyl : Pigmentation	Present	Present
2	Leaf : Colour	Green	Dark green
3	Leaf : Hairiness	Medium	Medium
4	Leaf : Appearance	Flat	Flat
5	Leaf : Gossypol glands	Present	Present
6	Leaf : Nectaris	Present	Present
7	Leaf : Petiole pigmentation	Present	Present
8	Leaf : Shape	Palmate	Palmate
9	Plant : Stem hairiness	Medium	Medium
10	Plant : Stem pigmentation	Present	Present
11	Plant : Height (cm)	Tall (130-150 cm)	Tall (150-160 cm)
12	Plant : Growth habit	Spreading	Spreading
13	Bract : Type	Normal	Normal
14	Flower : Time of flowering (50 % of plants with at least one open flower)	60-70 days	40-50 days
15	Flower : Petal colour	Cream	Light yellow
16	Flower : Petal spot	Absent	Absent
17	Flower : Stigma	Exerted	Exerted
18	Flower : Anther filament coloration	Absent	Absent
19	Flower : Pollen colour	Yellow	Yellow
20	Flower : Male sterility (only for A and B lines)	-	-
21	Boll : Bearing habit	Solitary	Solitary
22	Boll : Colour	Green	Dark green
23	Boll : Shape (Longitudinal section)	Ovate	Round
24	Boll : Surface	Smooth	Smooth
25	Boll : Prominence of tip	Pointed	Pointed
26	Boll : Opening	Open	Open
27	Boll : Weight of seed cotton / boll (g)	3.3-3.9	3.4-4.2
28	Seed : Fuzz	Present	Present
29	Seed : Fuzz colour	White	White
30	Seed : Index (100 seed wt. in g)	9.0-10.2	9.8-10.8
31	Ginning percentage	33.9-35.6	34.4-35.3
32	Fibre : Colour	White	White
33	Fibre : Length (2.5% span length)(mm)	26.0-29.0	30.0-31.9
34	Fibre : Strength (g/tex)	21.3-27.4	24.1-31.9
35	Fibre : Fineness (Micronaire value)	4.4-4.5	4.3-4.5
36	Fibre : Uniformity (%)	48-50	49-51
37	Fibre : Maturity (%)	85	84

2007 to 2009-2010, superior plant were selected up to F_5 generation and then tested under different trials. The details description of existing strain along with checks is presented in different tables and field view and individual plant photo of this genotype is also given.

GJHV 516 is a tall, spreading genotype with cream petal colour with exerted stigma and

Table 2. Performance of GJHV -516 in comparison with checks over season in Co ordinated varietal trials

Yield and quality characters	Genotype/ checks	Coordinated varietal trials Pr Br 2(a) IET 2013-2014	Pr Br 03(a) PVT 2014-2015	Pl Br 04(a) CVT 2015-2016	**Mean**	Percent Increase over checks
Seed cotton yield (kg/ha)	GJHV 516	1993	2211	1662	**1955**	-
	CNHO 12(ZC)	1480	1725	1322	**1509**	29.5
	G.COT 20(LC)	1775	1912	1318	**1668**	18
	Suraj (QC)	1296	1540	1262	**1366**	43
Lint yield (kg/ha)	GJHV 516	699	785	568	**684**	-
	CNHO 12(ZC)	515	631	462	**536**	21.6
	G.COT 20(LC)	628	705	421	**585**	14.5
	Suraj (QC)	471	526	434	**477**	30.3
GOT (%)	GJHV 516	34.6	35.6	33.9	**34.7**	-
	CNHO 12(ZC)	34.2	36.7	34.9	**35.3**	-1.7
	G.COT 20(LC)	35.3	36.6	31.8	**34.6**	0.3
	Suraj (QC)	35.3	34.6	34.4	**34.8**	-0.3
Boll/plant	GJHV 516	38.3	37.8	31.9	**36.0**	-
	CNHO 12(ZC)	32.2	34.8	29.2	**32.1**	10.8
	G.COT 20(LC)	36.9	35.6	28.2	**33.6**	6.7
	Suraj (QC)	23.9	30.2	25.9	**26.7**	25.8
Boll weight (g)	GJHV 516	3.9	3.4	3.3	**3.5**	-
	CNHO 12(ZC)	3.3	3.1	3	**3.1**	11.4
	G.COT 20(LC)	3.5	3.3	3.1	**3.3**	5.7
	Suraj (QC)	4.2	3.8	3.4	**3.8**	-8.6
2.5 Per cent span length(mm)	GJHV 516	29	28	25.9	**27.6**	-
	CNHO 12(ZC)	24.6	25.4	26.3	**25.4**	8
	G.COT 20(LC)	26.3	27.9	27.1	**27.1**	1.8
	Suraj (QC)	31.9	31.4	30	**31.1**	-12.7
Micronaire	GJHV 516	4.5	4.4	4.4	**4.4**	-
	CNHO 12(ZC)	5.1	4.8	5	**5**	13.6
	G.COT 20(LC)	4.9	4.5	4.5	**4.6**	4.5
	Suraj (QC)	4.4	4.4	4.4	**4.4**	0
Bundle strength	GJHV 516	22.4	21.3	27.4	**23.7**	-
	CNHO 12(ZC)	20.5	20.8	28.4	**23.2**	2.1
	G.COT 20(LC)	22.8	23.1	30.2	**25.4**	-7.2
	Suraj (QC)	24.1	24.7	31.9	**26.9**	-13.5

yellow coloured pollen, slightly elongated green bolls with a prominent tip and ovate boll shape which is distinct from quality check Suraj (Table 1).

The performance of existing genotypes for different qualitative characters in different trials is presented in Table 2. During 2013-2014 to 2015-2016, the strain GHJV 516 recorded a mean seed cotton yield of 1955 kg/ha as compared to 1509 kg/ha of CNHO 12, 1668 kg/ha of G. Cot 20 and 1366 kg/ha of Suraj, which is 29.5, 18.0 and 43.0 per cent increase over check varieties, respectively. Likewise lint yield of GJHV 516 was 684 kg/ha as compared to 536

Table 3. Full scale spinning report of *G. hirsutum* variety GJHV-516 at CIRCOT, Mumbai.

Sr.No.	Entry	Location	UHML(mm)	UI	MIC	Str.g/tex	E(%)	Count1	CSP1	Count2	CSP2
1	GJHV 516	Surat	27.7	83	4.2	24.4	6.0	30	19.47	40	18.22

kg/ha of CNHO 12, 585 kg/ha of G.Cot 20 and 477 kg/ha of Suraj. The bolls/plant of existing genotype were 36 as compared to 32.1, 33.6 and 26.7 of CNHO-12, G. Cot 20 and Suraj, respectively. For all other characters *viz.,* ginning outturn, boll weight, 2.5 per cent span length, micronaire and bundle strength, the genotype GJHV 516 recorded more or less equal mean values. The fibre quality traits tested for GJHV-516 culture under full spinning test by ICC mode revealed that the span length of 27.7 mm and strength 24.4 g/tex which can span in between 30-40 counts (Table 3).The culture GJHV 516 was evaluated under field conditions at different locations of central zone during 2013-2014 to 2015-2016 for diseases and pest reaction. The test variety showed resistance against alternaria leaf spot and bacterial leaf blight under field condition (Table 4). Likewise the genotype found moderately resistance to sucking pests *viz*, jassids, aphid and thrips and in bollworms found numerically lower per cent damage to open bolls and locules as compared to other checks. (Table 5).

In view of superior fiber properties and yield potential over the *G. hirsutum* check varieties CNHO-12, Local and Suraj, the genotype GJHV 516 was identified and recommended for commercial cultivation in irrigated tract of central zone of India in the year 2017.

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Table 4. Screening of GJHV 516 against major diseases in coordinated varietal trials

Proposed variety**: GJHV 516** — Adaptability Zone **: Central zone**; Production condition : **Irrigated**

Disease Name	Year	Location	Proposed variety (GJHV 516)	Zonal check (CNHO 12)	Local check (s)	Quality check (Suraj)	Qualifying variety (TCH-1777)
1) Alternaria	2013-2014	Rahuri	0	2	1	2	1
leaf spot (Grade)	2014-2015	Junagadh	3	3	3	3	3
		Rahuri	0	2	1	2	1
	2015-2016	Junagadh	3	3	3	3	3
		Rahuri	1	2	3	1	2
2) Bacterial	2013-2014	Khandwa	1	1	1	1	1
leaf blight (Grade)	2014-2015	Junagadh	2	1	2	2	2
		Surat	2	2	2	2	2
	2015-2016	Junagadh	1	1	1	1	1
		Surat	0	0	1	1	0

Note: Grade 0 = Immune (I), 1= Resistance (R), 2 = Moderately Resistance (MR), 3 = Moderately Susceptible and 4 = Susceptible

Table 5. Screening of GJHV 516 against sucking pest complex and Bollworm

Name of proposed variety: **GJHV 516**

Adaptability Zone : **Central zone**

Production condition : **Irrigated**

Disease Name	Year	Location	Proposed variety (GJHV 516)	Zonal check (CNHO-12)	Local check (s)	Quality check (Suraj)	Qualifying variety (TCH 1777)
1) Jasids/3 leaves	2014-2015	Junagadh	10.70 (3.28)*	9.40 (3.06)*	14.00 (3.75)*	15.60 (3.95)*	9.20 (3.04)*
		Surat	2.30 (1.66)	1.00 (1.21)	0.60 (1.04)	3.30 (1.92)	3.60 (2.02)
		Bhawanipatana	3.63 (2.03)	4.54 (2.24)	4.79 (2.30)	6.04 (2.56)	3.13 (1.90)
		Rahuri	8.06 (2.93)	7.31 (2.79)	6.03 (2.56)	6.14 (2.58)	5.00 (2.35)
	2015-2016	Junagadh	7.70 (2.77)	10.30 (3.21)	9.50 (3.08)	10.00 (3.16)	7.80 (2.80)
		Surat	2.10 (1.60)	3.50 (1.99)	2.10 (1.97)	3.10 (1.90)	3.30 (1.94)
		Bhawanipatana	5.75 (2.50)	8.88 (3.06)	8.13 (2.93)	6.13 (2.57)	4.13 (2.15)
		Rahuri	3.89 (2.09)	4.39 (2.21)	3.72 (2.05)	7.06 (2.75)	5.11 (2.37)
2) Jasids injury grade	2014-2015	Junagadh	II	I	II	III	I
		Surat	I	I	I	I	I
		Bhawanipatana	I	II	II	III	I
		Rahuri	I	II	II	III	I
	2015-2016	Junagadh	I	III	II	II	I
		Surat	I	III	I	II	II
		Bhawanipatana	II	III	III	II	I
		Rahuri	III	IV	IV	III	IV
3) Aphid/3 leaves	2014-2015	Junagadh	57.50 (7.59)*	35.50 (5.96)*	57.40 (7.58)*	50.60 (7.12)*	61.60 (7.85)*
		Surat	54.70 (7.40)	28.90 (5.42)	86.40 (9.32)	28.30 (5.37)	28.40 (5.33)
		Bhawanipatana	12.88 (3.65)	14.33 (3.84)	5.46 (2.44)	13.25 (3.71)	18.50 (4.36)
	2015-2016	Junagadh	38.20 (6.18)	58.40 (7.65)	36.70 (6.06)	63.30 (7.96)	52.10 (7.22)
		Surat	25.80 (5.12)	3.30 (1.94)	8.30 (2.96)	7.50 (2.82)	1.30 (1.34)
		Bhawanipatana	17.13 (4.19)	21.88 (4.71)	26.50 (5.20)	17.63 (4.26)	13.63 (3.76)
4) Thrips/3 leaves	2014-2015	Junagadh	35.10 (5.93)	32.90 (5.74)	33.40 (5.78)	43.60 (6.60)	24.30 (4.93)
		Surat	2.30 (1.66)	5.10 (2.36)	3.20 (1.91)	2.90 (1.83)	0.50 (0.97)
		Bhawanipatana	1.75 (1.50)	2.25 (1.66)	4.50 (2.23)	2.00 (1.57)	2.75 (1.80)
	2015-2016	Junagadh	24.70 (4.97)	43.70 (6.61)	32.5 (5.71)	38.60 (6.22)	30.30 (5.50)
		Surat	47.50 (6.93)	80.00 (8.65)	52.2 (7.26)	68.50 (8.28	43.70 (6.65)
		Bhawanipatana	5.75 (2.50)	8.88 (3.06)	8.88 (3.06)	7.50 (2.83)	5.00 (2.34)

contd...

Table 5 contd.

5) Whitefly/3 leaves	2014-2015	Junagadh	36.00 (6.00)	48.50 (6.97)	35.1 (5.93)	29.50 (5.43)	33.30 (5.77)
		Surat	2.30 (1.61)	3.40 (1.87)	3.30 (1.83)	3.70 (2.04)	8.70 (2.98)
		Rahuri	11.89 (3.52)	9.78 (3.21)	10.28 (3.28)	17.61 (4.26)	12.84 (3.60)
	2015-2016	Junagadh	26.40 (5.14)	13.90 (3.73)	13.40 (3.66)	14.90 (3.86)	13.10 (3.62)
		Surat	2.00 (1.58)	1.20 (1.30)	1.40 (1.38)	1.30 (1.32)	1.00 (1.22)
		Rahuri	1.17 (1.29)	1.06 (1.25)	1.83 (1.53)	1.22 (1.31)	1.56 (1.43)
6) Open boll damage (%) by bollworm	2014-2015	Junagadh	82.88 (65.56)**	80.25 (63.61)**	85.95 (67.98)**	84.25 (66.62)**	78.42 (62.32)**
		Surat	17.04 (24.37)	9.40 (17.82)	20.74 (27.04)	12.79 (20.91)	19.70 (26.34)
		Rahuri	11.91 (20.19)	13.88 (21.87)	9.76 (18.20)	13.07 (21.19)	10.38 (18.79)
	2015-2016	Junagadh	44.36 (41.76)	52.52 (46.45)	42.83 (40.88)	44.78 (42.00)	38.60 (38.41)
		Surat	5.71 (13.82)	13.18 (21.26)	14.28 (22.18)	24.78 (29.84)	14.06 (21.77)
		Rahuri	24.91 (29.94)	25.71 (30.47)	32.38 (34.68)	19.35 (26.09)	15.26 (22.99)
7) Locule damage (%) by bollworms	2014-2015	Junagadh	48.29 (44.02)	41.02 (39.83)	54.42 (47.54)	63.38 (52.76)	51.41 (45.81)
		Surat	12.67 (20.87)	7.64 (15.99)	14.64 (22.46)	7.67 (16.08)	14.76 (22.57)
		Rahuri	6.70 (15.00)	8.05 (16.48)	5.10 (13.05)	8.33 (16.78)	5.61 (13.70)
	2015-2016	Junagadh	23.24 (28.82)	28.52 (32.28)	23.29 (28.86)	23.48 (28.98)	21.92 (27.92)
		Surat	4.00 (11.53)	9.33 (17.75)	5.48 (13.47)	17.70 (24.87)	6.30 (14.53)
		Rahuri	10.26 (18.68)	11.64 (19.94)	15.50 (23.19)	8.65 (17.10)	7.42 (15.80)

*= Figure in parenthesis are square root transformed value

**= Figure in parenthesis are Angular transformed value

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REFERENCES

Anonymous, 2016. AICRP on Cotton *"Annual Report",* 2015-2016.

Bharud, R. W., Aher, A. R. and Nagawade, D. R. 2015. Book of Oral presentations National symposium on *"Future Technologies: Indian cotton in the Next Decade"* :18-23.

Fryxell, P. A., Craven, L. A. and Stewart, J.M.C.D. 1992. A revision of *Gossypium* sect. Grandi Caylx *(Malvaceae)*, including the description of six new species. *Syst. Bot.*, **17 :** 91-114.

Panse, V. G. and Sukhatme, P. V. 1985. Statistical methods for Agricultural Workers. ICAR, New Delhi, Forth Ed.

Vindhiyavarman, P., Gunasekaran, M., Thangaraj, K. and Amalabalu, P. 2015. TCH- 1716 An Extra Long staple *G. hirsutum* cotton Genotype. *Electronic Jour. Plant Breed.* **6 :** 838-41.

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Evaluation of cotton genotypes for whitefly (*Bemisia tabaci* (Gennadius) infestation under field conditions

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ABSTRACT : Forty cotton genotypes with two checks were evaluated against whitefly (*Bemisia tabaci* (Gennadius)*)* in uncontrolled condition adopting all possible measures to maintain whitefly adults population per plant in field conditions during *kharif* 2013. On the basis of whitefly population count and leaf injury grades were recorded for fortnight intervals and whitefly resistance index (WRI) calculated. The genotypes BCT 091 and BCT 110 were categorized as resistant as they recorded WRI of 1.00. The genotypes BCT 031, BCT 036, BCT 059, BCT 71, BCT 211 and BCT 238 recorded WRI ranging from 1.01 to 1.50 and hence were categorized as moderately resistant. The remaining thirty two genotypes recorded the highest WRI ranging from 1.60 to 5.60 and thus, were categorized as susceptible to highly susceptible to *B. tabaci*. All these genotypes, except BCT 031, BCT 036, BCT 059, BCT 071, BCT 091, BCT 110, BCT 211 and BCT 238, scored leaf injury grade V after 120 days. Hence, it can be concluded that the optimum period for the complete differentiation of susceptible and resistant cotton genotypes could be taken between 120 and 135 days after sowing under field conditions.

Key words : *Bemisia tabaci*, cotton, leaf injury grades, whitefly population, whitefly resistance index

Though, India ranks second in the world in cotton production after China, even its best productivity of 566 kg/ha, places it at 24th rank in the list of 80 cotton producing countries. Despite the good progress made by public and private sector research and development, it is a matter of concern that productivity started to decline and/or stagnate from 566 kg/ha in 2007 to 522 kg/ha in 2008, 486 kg/ha in 2009,475 kg/ha in 2010 and 566 kg/ha in 2016-2017. Several factors including erratic rainfall and emerging biotic and abiotic stress were found to have influenced the decline in yields.

The major constraints for lower yield in the country is attributed to a large number of insect pests during different stages of crop growth of which whitefly *Bemisia tabaci* (Gennadius) emerged as a major pest in recent past. Cotton losses were estimated to be in the range of 15-20 per cent and sometimes up to 30 per cent (Kranthi, 2015). The whitefly was first reported in Greece 125 years ago. It became a major pest on cotton in India only after 1984. There was a severe outbreak in 1987-1988 in Andhra Pradesh and later in Maharashtra, Gujarat and Punjab. Clearly the trigger was a group of insecticide called synthetic pyrethroids that were introduced into the country in 1981. This pest has attained a serious pest status in various states putting in jeopardy, the fortunes of a large number of farmers in the cotton growing areas. There is a tremendous increase in its population in cotton system year to year. It is evident that unilateral and continued use of synthetic pyrethorids has led to problems like resistance, replacement and resurgence and mainly environmental pollution. Growing cotton hybrids that are resistant to insect is the ideal way to protect the crop against insect losses and at the same time prevent pollution of the environment.

Therefore, host plant resistance offers a low-cost, practical, long-term solution for maintaining lower whitefly population and reducing crop losses (Bellotti and Arias, 2001) and is accepted as an important component of integrated pest management. Dowell (1990) stated that host plant resistance is the best long term solution for controlling whiteflies. For this purpose, an efficient method for identifying insect-resistant germplasm is very essential.

A good deal of research efforts have been directed towards screening cotton germplasm against *B. tabaci* for the identification of resistant sources under diverse en- vironmental conditions. Till date, no definite method is available for screening the cotton germplasm against *B. tabaci*. The current methods employed for screening the germplasm under field conditions are solely based on population counts and that, too are not uniform, besides, being cumbersome (Butter and Kular, 1986; Butter and Vir. 1991: Kular *et al.,* 1995; Kular and Butter, 1996; Butter *et al.*, 1992; Kulkarni *et al.*, 2002; Kavita and Dharma Reddy, 2012). Therefore, a new technique was developed and used for screening cotton genotypes against whitefly based on the leaf injury grades.

MATERIALS AND METHODS

For maintaining *Bemisia tabaci* adults in the field, 42 cotton genotypes were planted in closer spacing (3'x 1') with brinjal and hairy cotton genotypes infester rows, unsprayed for pest control, 2 per cent urea sparing done to maintain succulence in cotton genotypes to attract whiteflies and irrigation provided based on the field condition to maintain high humidity in plant canopy.

Based upon the kind and intensity of leaf injury symptoms due to the feeding of *B. tabaci* in cotton, the leaf-injury grades (I-V) were categorized (Fig. 1) as follows:

Grade	Score	Description
I	1	Healthy plant
II	2	Distribution of chlorotic spots on the upper surface of the middle canopy leaves
III	3	Honeydew on the upper surface of the leaves in middle canopy leaves
IV	4	Sooty mould partly covering the leaves of lower canopy
V	5	Sooty mould partly covering the leaves of lower canopy with drooping of leaves

Forty cotton genotypes along with standard check Bunty and 7351-2 were screened against *B. tabaci* in field conditions randomized block design (RBD) with three replications during *kharif,* 2013 at Bioseed research Farm in

Guntur, Andhra Pradesh. Five plants of each genotype/replication counted for number of whitefly adults/three leaves on 30, 45, 60, 75, 90, 105 and 120 days after planting. Test genotypes were scored for the appearance of leaf injury grades at 60, 75, 90, 105, 120 and 135 days after sowing grouped into different categories of resistance/ susceptibility after working out whitefly resistance index (WRI) based on leaf injury grades at 135 days after sowing as under:

$$\text{Whitefly Resistance Index (WRI)} = \frac{G1 \times P1 + G2 \times P2 + G3 \times P3 + G4 \times P4 + G5 \times P5}{P1 + P2 + P3 + P4 + P5}$$

Where,

G=Number of the leaf-injury grade P=Number of plants falling under that grade

Each grade was given a range of score for grouping different genotypes into resist- ant/ susceptible categories as follows:

Leaf Injury Grade	Symptoms	Score	Category/Reaction
I	No damage	<1.00	Resistant (R)
II	Appearance of yellow chlorotic spots	1.01-1.50	Moderately Resistant (MR)
III	Starting of black sooty mould	1.51-2.50	Moderately Susceptible (MS)
IV	Severe blackening of leaves	2.51-3.49	Susceptible (S)
V	Complete drying of leaves	>3.50	Highly Susceptible (HS)

RESULTS AND DISCUSSION

The experiment on the screening of forty two cotton genotypes against *B. tabaci* was conducted under field conditions during *kharif* 2013 and the data for the same have been presented in Table 1. Analysis of variance for whitefly population dynamics and leaf injury grade were highly significant. The data indicated that whitefly infestation was very less at 30 days after sowing and gradually increased during the period of observation. Whitefly population was crossed its economic threshold level at 75 days after sowing. The susceptible check 7351-2 recorded 31.78, 38.78, 45.85 and 46.18 whitefly population at 75, 90, 105 and 120 respectively. Whitefly population was above ETL in all the tested genotypes except, resistant check Bunty, BCT 031, BCT 059, BCT 071, BCT 091, BCT 110 and BCT 238.

All genotypes remained in leaf injury grade I and II for the first 60 days after sowing. Thereafter, the genotypes scored leaf injury grade I, II, III within 15 days after first grading. The differentiation of genotypes based on reaction to whitefly injury was happened during 105, 120 and 135 days after sowing. The genotype BCT 031, BCT 071, BCT 091, BCT 110, BCT 211, BCT 238 and Bunty recorded Grade I after 105 days of sowing. BCT 091 and BCT 110 were to score the leaf injury grade I after 135days of sowing, followed by BCT 031, BCT 211, BCT 238 and Bunty, which scored leaf injury grade II after 135 days of sowing. The genotypes BCT 091 and BCT 110 scored leaf injury grade I after 60, 75, 90, 105, 120 and 135 days after sowing, respectively. However, genotypes BCT 031, BCT 211 and BCT 238 scored maximum leaf injury grade II up to the last observation recorded after 135 days of

Table 1. Whitefly population dynamics and leaf injury grades on 42 cotton genotypes during 2013 kharif at Guntur Bioseed Research Farm.

Genotypes	Whitefly population (/3 leaves) days after sowing							Whitefly leaf injury grades						WRI
	30	45	60	75	90	105	120	60	75	90	105	120	135	
BCT 010	9.59	15.96	24.74	32.63	40.63	46.08	46.48	1.00	2.00	2.00	3.00	4.00	4.00	4.20
BCT 014	9.96	15.19	24.67	32.52	40.52	46.67	46.45	1.00	2.00	2.00	3.00	3.00	4.00	4.40
BCT 017	9.52	15.22	25.67	33.15	41.15	45.37	46.18	2.00	3.00	3.00	4.00	4.00	5.00	4.73
BCT 023	10.26	15.11	25.37	33.52	41.85	46.15	45.70	2.00	2.00	2.00	3.00	4.00	5.00	4.80
BCT 024	7.21	11.15	17.63	24.01	30.31	32.41	32.67	1.00	1.00	1.00	1.00	2.00	2.00	2.60
BCT 026	6.92	10.45	17.32	23.46	29.76	32.43	31.76	1.00	1.00	2.00	2.00	3.00	3.00	3.00
BCT 027	10.11	16.33	25.41	33.74	42.74	46.44	46.15	2.00	2.00	3.00	4.00	4.00	5.00	4.60
BCT 031	4.74	7.97	12.49	16.19	20.60	22.83	22.69	1.00	1.00	1.00	1.00	2.00	2.00	1.50
BCT 036	7.03	11.10	17.66	23.44	29.74	32.43	32.90	1.00	2.00	2.00	2.00	3.00	3.00	1.50
BCT 041	10.18	16.00	25.89	32.85	41.85	45.15	46.00	2.00	2.00	2.00	3.00	3.00	4.00	3.20
BCT 053	9.85	16.03	24.96	32.74	41.74	46.96	47.15	2.00	3.00	3.00	3.00	3.00	4.00	3.00
BCT 056	10.15	16.63	25.48	31.15	38.15	46.81	45.41	2.00	2.00	3.00	3.00	4.00	5.00	4.20
BCT 059	6.84	11.67	16.93	22.27	27.17	32.28	32.30	1.00	2.00	2.00	2.00	3.00	3.00	1.50
BCT 061	10.19	17.18	24.93	31.96	38.96	45.30	46.41	2.00	2.00	3.00	3.00	4.00	5.00	3.20
BCT 064	9.93	16.67	24.85	31.55	38.55	45.41	46.18	2.00	3.00	3.00	3.00	4.00	5.00	3.20
BCT 070	7.21	12.16	17.63	22.55	27.45	32.05	33.00	1.00	1.00	1.00	1.00	2.00	2.00	2.27
BCT 071	7.05	12.08	17.71	22.63	27.53	32.31	32.15	1.00	1.00	1.00	1.00	2.00	3.00	1.50
BCT 073	10.00	16.92	25.11	32.33	39.33	46.97	45.74	1.00	2.00	2.00	3.00	3.00	4.00	3.07
BCT 081	10.22	17.03	24.60	32.59	39.59	46.15	46.48	2.00	2.00	3.00	3.00	4.00	4.00	3.60
BCT 082	10.26	17.00	23.85	32.56	39.56	46.97	46.45	1.00	2.00	2.00	3.00	4.00	4.00	3.40
BCT 085	10.11	17.41	24.33	33.04	40.04	46.56	46.18	1.00	1.00	2.00	3.00	3.00	4.00	3.73
BCT 091	3.72	5.92	8.73	11.43	13.95	16.76	16.69	1.00	1.00	1.00	1.00	1.00	1.00	1.00
BCT 094	10.04	16.41	24.15	32.15	39.15	46.52	46.37	1.00	2.00	2.00	3.00	3.00	4.00	3.80
BCT 098	10.30	15.96	23.41	32.26	39.59	46.48	46.33	1.00	2.00	2.00	3.00	4.00	5.00	4.67
BCT 106	10.11	17.41	24.56	32.63	40.63	46.19	46.33	1.00	1.00	2.00	3.00	3.00	4.00	3.67
BCT 110	3.67	6.12	8.95	11.91	14.91	16.48	16.61	1.00	1.00	1.00	1.00	1.00	1.00	1.00

contd...

Table 1 contd...

BCT 118	10.22	16.37	24.78	33.74	42.74	46.96	46.74	1.00	2.00	2.00	2.00	3.00	4.00	4.00
BCT 140	10.29	16.81	25.52	33.67	42.67	46.52	46.67	2.00	2.00	3.00	3.00	4.00	4.00	3.60
BCT 146	10.22	16.81	25.00	34.67	43.67	47.00	45.63	1.00	2.00	2.00	3.00	4.00	4.00	3.60
BCT 148	10.15	16.63	25.48	34.37	43.37	46.33	46.26	2.00	2.00	2.00	3.00	4.00	5.00	4.67
BCT 167	9.93	16.67	25.33	34.19	43.19	45.89	45.63	2.00	2.00	3.00	4.00	4.00	5.00	4.60
BCT 168	7.23	12.03	17.53	23.62	29.92	32.28	32.43	1.00	2.00	2.00	2.00	3.00	3.00	5.60
BCT 201	9.74	16.67	24.59	34.41	43.41	46.52	46.37	2.00	2.00	3.02	4.00	4.00	5.00	4.73
BCT 206	9.26	17.37	25.11	32.48	39.48	46.63	45.59	1.00	2.00	2.33	3.00	4.00	5.00	4.47
BCT 211	6.74	12.08	17.53	22.56	27.46	31.50	31.76	1.00	1.00	1.00	1.00	1.00	2.00	1.50
BCT 221	9.56	16.92	25.00	32.89	39.89	45.70	45.74	1.00	2.00	3.00	3.00	4.00	4.00	3.60
BCT 238	4.66	8.35	12.54	15.66	19.09	22.98	22.59	1.00	1.00	1.00	1.00	2.00	2.00	1.30
BCT 252	9.59	17.00	25.15	32.48	39.48	46.37	46.41	2.00	3.00	3.00	4.00	4.00	4.00	3.47
BCT 260	9.00	17.41	25.41	31.18	38.18	46.74	46.37	2.00	2.67	3.00	3.00	4.00	4.00	3.13
BCT 263	9.63	16.44	26.00	31.81	38.81	46.67	46.92	2.00	2.00	3.00	3.00	4.00	4.00	3.60
7351-2	9.59	16.41	25.63	31.78	38.78	45.85	46.18	2.00	2.33	3.00	3.00	4.00	5.00	4.80
BUNTY	4.43	7.82	12.01	15.90	19.33	22.32	22.79	1.00	1.00	1.00	1.00	1.00	2.00	1.50
Mean	**8.70**	**14.50**	**21.90**	**28.73**	**35.59**	**40.53**	**40.50**	**1.40**	**1.83**	**2.15**	**2.57**	**3.19**	**3.74**	
C.V. (%)	4.41	3.51	2.46	2.04	1.76	1.70	1.46	5.88	8.38	5.93	2.08	2.59	1.31	
C.D. (p=0.05)	0.62	0.83	0.87	0.95	1.02	1.12	0.96	0.13	0.25	0.21	0.09	0.13	0.08	

Grade I : Healthy plant

Grade II:Appearance of yellow chlorotic spots

Grade III : Starting of black sooty mould

Grade IV: Severe blackening of leaves

Grade V : Complete drying of leaves

Fig. 1. Whitefly leaf-injury grades (I-V) in cotton

sowing.

The test genotypes were categorized as resistant/susceptible against *B. tabaci* on the basis of whitefly resistance index (WRI) based on leaf injury grades at 135 days after sowing. All the cotton genotypes except BCT 091 and BCT 110 recorded WRI in the range of 1.50 to 4.80 indicating their relative resistance or susceptibility levels. On the basis of WRI, the eight genotypes were selected and presented in Table 2. BCT 091and BCT 110 was categorized as resistant (R) which recorded WRI of 1.00. The genotypes BCT 238, BCT 031, BCT 036, BCT 059, BCT 071, BCT 211 and Bunty scored WRI of 1.30 to 1.50 and hence were categorized as moderately resistant (MR). The susceptible check 7351-2 scored the highest WRI of 4.80 thus, categorized as highly susceptible (HS) to *B. tabaci*.

On the basis of the study conducted for the evaluation of cotton genotypes for whitefly resistance under field conditions during 2013 *kharif* it was observed that genotypes scored leaf injury grade I to V after 135 days of sowing indicating their relative reaction. Two genotypes BCT 091 and BCT 110 were persistent to whitefly injury and exhibited resistant in the period of observation. The genotypes BCT 031, BCT 211, BCT 238 and Bunty scored leaf injury grade II at 135 days after sowing and were thus categorized as moderately resistant since they recorded WRI of 1.50. Whereas, the genotypes BCT 036, BCT 059 and BCT 071 scored leaf injury grade III in the same period of observation, while these genotypes were categorized as moderately resistant since they recorded WRI of 1.50. The genotype 7351-2 recorded the highest leaf injury grade V in the same period of observation and WRI of 4.80 thus categorized as highly susceptible to *B. tabaci*. Hence, it can be concluded that the

Table 2. Whitefly resistance index for the selected cotton genotypes against *B. tabaci* under field conditions during *kharif,* 2013

Genotypes	Whitefly population(per 3 leaves) (DAS)					Leaf injury grades	WRI reaction
	105	120	105	120	135		
BCT 031	22.83	22.69	1.00	2.00	2.00	1.50	MR
BCT 036	32.43	32.90	2.00	3.00	3.00	1.50	MR
BCT 059	32.28	32.30	1.00	3.00	3.00	1.50	MR
BCT 071	32.31	32.15	1.00	2.00	3.00	1.50	MR
BCT 091	16.76	16.69	1.00	1.00	1.00	1.00	R
BCT 110	16.48	16.61	1.00	1.00	1.00	1.00	R
BCT 211	31.50	31.76	1.00	1.00	2.00	1.50	MR
BCT 238	22.98	22.59	1.00	2.00	2.00	1.30	MR
7351-2	45.85	46.18	3.00	4.00	5.00	4.80	HS
Bunty	22.32	22.79	1.00	1.00	2.00	1.50	MR
Mean	**40.53**	**40.50**	**2.57**	**3.19**	**3.74**		
C.V.	1.70	1.46	2.08	2.59	1.31		
C.D. (p=0.05)	1.12	0.96	0.09	0.13	0.08		

DAS= Days after sowing,WRI=Whitefly Resistance Index; R=Resistant; MR=Moderately Resistant; S=Susceptible; HS=Highly Susceptible optimum period for the complete differentiation of susceptible and resistant cotton genotypes could be taken between 120 and 135 days after sowing.

The screening of cotton germplasm on the basis of leaf injury grades represents a more realistic picture as compared to the screening based on population counts, since a particular genotype may either escape the pest population in the field or may sometimes be labeled as promising due to insufficient pest pressure in the field.

Many workers have also laid stress on the importance of screening germplasm based on pest damage ratings and have successfully developed screening techniques. Kular. *et al.*, (1995) and Kular and Butter (1996) screened cotton germplasm against *B. tabaci* on the basis of five injury grades (I-V) and concluded that under multiple-choice test conditions at least 45-51 days must elapse after the release of *B. tabaci* population to differentiate cotton genotypes into different categories of resistance. Taggar and Sandhu (2013) evaluated nine black gram genotypes to the attack of whitefly under screen-house conditions and scored leaf injury for six weeks. They concluded that the optimum period for the complete differentiation of susceptible and resistant genotypes could be taken between 5th and 6th week after release of 100 adult whiteflies per plant. They also opined that screening of black gram genotypes on the basis of leaf injury grades represents a more realistic picture as compared to the screening based on population count. Similarly, field evaluations of cassava germplasm for resistance to *B. tabaci* at the International Center for Tropical Agriculture (CIAT), Columbia, used a whitefly population (nymph and pupae) scale combined with a leaf-damage scale (1-6), where '1' indicated the absence of whitefly damage and population and '6' indicated the severest damage and highest population. More than 6000 cassava genotypes have been evaluated using these scales and different sources of resistance have been detected in several genotypes (Bellotti and Arias, 2001).

LITERATURE

Anonymous 2016. All India Coordinated Cotton Improvement Project (AICCIP): Annual Report (2016-17). Central Institute for Cotton Research, Nagpur.

Bellotti,A.C. and Arias,B. 2001. Host plant resistance to whiteflies with emphasis on cassava as a case study.*Crop Protection* **20** : 813–23.

Butter, N.S.and Kular, J.S. 1986. Economic threshold of whitefly, *Bemisia tabaci* Genn on cotton *J. Res. Punjab agric. Univ.* **23** : 66-70.

Butter, N.S. and Vir, B.K. 1991. Response of whitefly, *Bemisia tabaci Genn.* To different cotton genotypes under screen house conditions. *Indian J Ent.* **53 :** 115-19.

Butter, N.S., Vir, B.K., Kaur,G., Singh,T.H. and Raheja, R.K 1992. Biochemical basis of resistance to whitefly, *Bemisia tabaci Genn.* (Aleyrodidae: Hemiptera) in cotton. *Tropi. Agric.* **69** : 119-22.

Dowell, R.V. 1990. Integrating biological control of whiteflies into crop management systems. In: D. Gerling (ed.): Whiteflies: Their Bionomics, Pest Status and Management. *Intercept, Andover*, U.K. : 315–35.

Kavita.K. and Dharma Reddy, K. 2012. Screening techniques for different insect pests in crop plants. *International Jour. Bio Res. Stress Manage.* **3** : 188-95.

Kranthi, K.R., 2015. Whitefly- A black story. Cotton statistics and news. Weekly publication No. **23**.

Kular, J.S., Butter,N.S. and Chahal,G.S. 1995. A new technique to measure the resistance in cotton against whitefly. *Bemisia tabaci. Pl.Prot. Bull*, **47 :** 15-19.

Kular,J.S. and Butter,N.S. 1996. An improved technique for screening cotton germplasm against whitefly,*Bemisia tabaci*. *Ind. J. Entomol.* **58** : 210–14.

Kulkarni,G.G., Khurana,A.D. and Sharma,P.D. 2002. Evaluation of upland cotton (*Gossypium hirsutum)* genotypes for their reaction to major insect pests. *Ind. J. Agric. Sci.* **72** : 565-67.

Taggar, G.K. and Sandhu, J.S. 2013. Evaluation of black gram (*Vigna mungo (L) Hepper)* genotypes to the attack of whitefly, (*Bemisia tabaci* Genn.) under screen-house conditions. *Acta Phytopath. Ent. Hungarica.* **48** : 53-62

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Morphological analysis of trispecies hybrid between *Gossypium arboreum* L. x *Gossypium capitis viridis* Mauer x *Gossypium devidsonii* Kellogg

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ABSTRACT : Inter specific hybrid between *Gossypium arboreum* L. cv. JLA 794 (A_2A_2) x *Gossypium capitis-viridis* Mauer (B_3B_3) x *Gossypium devidsonii* Kellogg ($D_{3\text{-}d}B_{3\text{-}d}$) along with parents were characterized at morphological level. The first parent *Gossypium arboreum* cv. JLA 794 (Female of first cross) had erect growth habit, Lanceolate (super okra) leaves, green stem, yellow petals, yellow anthers, prominent petal spot, non serrated bract, ovate boll with pitted surface. The second parent *Gossypium capitis-viridis* Mauer (B_3B_3) (Male of first cross) had spreading growth habit, Semi digitate (Semi okra) leaves with dense hairs, green stem, cream petals, cream anthers, prominent petal spot, serrated bract, ovate boll with pitted surface. The growth habit, leaf shape, leaf hairiness, boll shape and size of inter-specific first F_1 hybrid were found intermediate. The specific petaloidy character and partial fertility was observed in first F_1 hybrid. These two species are genetically closely resemble hence the partial fertility was obtained. The direct hybrid between *Gossypium arboreum* L. x *Gossypium devidsonii* Kellogg was not obtained. Hence, F_1 was crossed with *Gossypium devidsonii* Kellogg. During 2017-2018, tri-species hybrid *Gossypium devidsonii* Kellogg ($D_{3\text{-}d}B_{3\text{-}d}$) x [*Gossypium arboreum* L. cv. JLA 794 (A_2A_2) x *Gossypium capitis-viridis* Mauer (B_3B_3)] was obtained. Which was closely resembled to *Gossypium devidsonii* Kellogg ($D_{3\text{-}d}B_{3\text{-}d}$) for stem colour, leaf hairiness. The characters *viz*. leaf shape, petal colour, petal spot intensity, stigma length, bract shape and size were found to be intermediate. The tri-species hybrid was highly male sterile with 1-2 per cent pollen fertility. Significant differences were observed between the pollen size of the parents and hybrids. Both dispecies and tri species hybrid was observed to be resistant to sucking pest *viz.* aphides, jassides, whitefly and diseases like ALB and BLB.

Key words : *Gossypium arboreum* L., *Gossypium capitis-viridis* M., *Gossypium devidsonii* K., morphology, trispecies

This genus *Gossypium* consists of 50 species of which 44 are diploid (2n = 2x = 26) and fall into A, B, C, D, E, F, G and K genomes [Stewart, 1995.] and the remaining are allotetraploids (2n = 4x = 52 AADD). Only four species of *Gossypium* are presently cultivated - two new world tetraploid species G. *hirsutum* L. and G. *barbadense* L. and two old world diploid species G. *arboretum* L. and G. *herbaceum* L. Problems of interspecific and distant hybridization in cotton were discussed

(Mehetre and Aher, 2004). Cotton is susceptible to biotic and abiotic stresses and genetic variability in the cultivated species for these characters is limited. Wild *Gossypium* species are rich source of resistance genes and interspecific hybridization of cultivated *Gossypium* species followed by subsequent breeding will result in genotypes with improved characters. Wild species are also useful in improving technological properties of fibre and verification with resistance.

The exotic species of cotton have provided useful variability for improvement of fibre properties, cold tolerance, disease resistance and insect resistance (Fryxell, 1976, Kohel, 1977). Hybridization between species is resorted to secure genes or gene combinations that are not available within species (Sikka and Joshi, 1960). In addition, it may be possible to obtain increase or improvement in certain characters through transgressive breeding (Stephens, 1944) since genes favourable for intersification of a particular character may occupy independent loci in the parental species and may also act independent of one another (Richmond, 1951). There is a wide scope for incorporating desired characteristics from cultivated or wild forms into the species of commerce. Narayanan *et al.*, (1984) discussed the role of wild species in improving technological properties of fibre and verification with resistance.

The present investigation study reports the production of such useful interspecific hybrids between *Gossypium arboreum* L., *Gossypium capitis-viridis* M. and *Gossypium devidsonii* K. Though, these types are not of immediate economic use, they are useful for further hybridization work.

MATERIALS AND METHODS

Gossypium arboreum L. cv. JLA 794 (A_2A_2), *Gossypium capitis-viridis* Mauer (B_3B_3), *Gossypium devidsonii* Kellogg ($D_{3\text{-}d}B_{3\text{-}d}$), hybrid between *Gossypium arboreum* L. cv. JLA 794 (A_2A_2) x *Gossypium capitis-viridis* Mauer (B_3B_3) and tri-species hybrid between *Gossypium devidsonii* Kellogg ($D_{3\text{-}d}B_{3\text{-}d}$) x [*Gossypium arboreum* L. cv. JLA 794 (A_2A_2) x *Gossypium capitis-viridis* Mauer (B_3B_3)] were used in the study. These plants were grown and maintained at Cotton Improvement Project. MPKV, Rahuri. Pollen at anthesis from *Gossypium capitis-viridis* plants were collected and dusted on stigmas of previous day bagged flowers of *Gossypium arboreum* L. cv. JLA 794 as seed set after pollination. Pollens from F_1 hybrid were dusted on stigma of *Gossypium devidsonii* and vice versa. Parents and both the hybrids were raised and observations on the various morphological characters were recorded.

RESULTS AND DISCUSSION

In present study, successful production of hybrid has raised hopes for further introgression of desirable traits like drought resistance from all three species, resistance to sucking pest and bollworm from *G. devidsonii* and fibre strength and micronaire from *G. capitis-viridis*. The detailed morphological characters of the parents and hybrids are presented in Table 1. It appeared that the both the hybrids showed either dominance or intermediate expression of the characters, which confirms its hybridity.

In present study, the hybrid between *G. arboreum* L. cv. JLA 794 x *G. capitis-viridis* was

Table 1. Morphological characteristics of parents and their F_1's

Characteristics	*G.arboreum* L. cv. JLA 794	*G. capitis viridis*	*G.arboreum* L. cv. JLA 794 x *G. capitis-viridis*	*Gossypium devidsonii*	*G. devidsonii x* [*G.arboreum* L. cv. JLA 794 x *G. capitis-viridis*]
Plant	Annual Shrub. Good bearing. Dark green. Good bearing.	Perennial much branched shrub. Pale green. Medium bearing.	Perennial much branched shrub. Dark green. Poor bearing.	Perennial much branched shrub. Yellowish green.	Perennial much branched shrub. Yellowish green. No bearing.
Leaf	Lanceolate (Super okra). 4 to 5 long narrow loab. Sparse hairy. Glanded.	Semi-digitate (Semi okra). 3-5 medium broad loab. Medium hairy. Glanded.	Lanceolate (Super okra). 6 to 7 long narrow loab. Sparse hairy. Glanded.	Ovate shape, unloabed. Sinus spot present. Dense short trichoms. Glanded.	Semi-digitate (Semi okra). 2 to 5 medium broad loab. Dense short trichoms. Glanded.
Epicalyx or Bract	Gamosepalus. Three broad, united bract.	Polysepalus. Three separated frego bracts.	Polysepalus. Three narrow separated bracts.	Polysepalus. Three broad, separated bracts.	Polysepalus. Three narrow separated bract.
Calyx tube	Green. Five pointed at apex. Prominent and dark well distributed glands.	Whitish green. Five pointed tip at apex. Prominent well distributed glands.	Green. Five pointed tip at apex. Prominent well distributed glands.	Very small, Yellowish green. Small prominent well distributed glands.	Green. Five pointed tip at apex. Prominent and dark well distributed glands.
Corolla	Deep yellow. Aestivation of corolla: twisted.	Cream. Petal claw small. Aestivation of corolla: twisted.	Yellow. Aestivation of corolla: twisted.	Deep yellow. Petal claw small. Aestivation of corolla: twisted.	Yellow. Aestivation of corolla: twisted.

contd...

Table 1 contd...

Blotch or petal spot	Medium spot present. Dark magneta petal. Start from base of petal.	Large spot present. Dark magneta usually ½ length of petal. Start from base of petal.	Medium spot present Magneta petal. . Start from base of petal.	Small and strong spot present. Red and does not start from base of petal.	Very large spot present. Feint red and start from base of petal.
Androecium	Staminal column long. Loosely arranged. Filament long and non pigmented. Fertile, deep yellow anthers.	Staminal column short and compact. Filament short, all about the same length and non pigmented. Fertile, cream anthers.	Staminal column long. Loosely arranged. Filament long and non pigmented . Partially fertile, yellow anthers. Petaloidy anthers.	Staminal column and compact. Filament short, all about the same length and non pigmented. Fertile, yellow anthers.	Staminal column short long. Loosely arranged. Filament long and non pigmented. Sterile, whitish yellow, shriveled anthers.
Gynoecium	Style medium long. Embedded stigma united to the top. Glands present on stigma, absent on style and ovary	Style projects ½ length of androecium beyond the stamens. Exerted stigma united to the top. Glands present on ovary and stigma, very few on style.	Style long and straight. Exerted stigma united to the top. Glands present on style and ovary absent on stigma.	Style short slightly bended. Exerted stigma united to the top. Glands present on stigma, absent on style and ovary.	Style long and coiled at centre. Stigma united to the top. Glands present on style, stigma and ovary.
Boll	Ovate. Blunt tip. Smooth surface.	Round. Pointed tip. Pitted surface.	Elliptic, Pointed tip. Pitted surface.	Round. Blunt tip. Smooth surface.	-

Plate 1 : Morphological characters of parents and hybrids 1. Leaf shape and size 2. Bract size, shape and colour 3. Flower shape and size, Petal colour 4. Petal spot, anthers and filaments, stigma size and shape 5. Boll colour, shape and size, surface, boll tip 6. Open boll, lint colour
A. G.arboreum L. cv. JLA-794
B. Gossypium capitis-viridis
C. G.arboreum L. cv. JLA-794 x *Gossypium capitis-viridis*
D. Gossypium devidsonii
E. Gossypium devidsonii x [*G.arboreum* L. cv. JLA-794 x *Gossypium capitis-viridis*]

obtained easily as both the species are closely resembles to each other. However, not a single seed was obtained after hundreds of effective crosses made between *G. arboreum* L. x *G. devidsonii.* Hence, crosses made between [*G. arboreum* L. cv. JLA 794 x *G. capitis-viridis*] F_1 x *G. devidsonii* and their reciprocal. But only one boll was obtained between *G. devidsonii* x [*G. arboreum* L. cv. JLA 794 x *G. capitis-viridis*]. From one boll, four developed seeds were obtained, out of which only one germinated.

The comparative studies of quantitative characters of all three parents and their hybrids are presented in Table 2. The F_1 *G. arboreum* L.

Table 2. Comparison of *G. arboreum* L., *G. capitis-viridis* M., *G. devidsonii* K. and their hybrid plants on the basis of quantitative traits.

Characteristics	*G.arboreum* L. cv. JLA 794	*Gossypium capitis viridis*	*G. arboreum* L. cv. JLA 794 x *G. capitis-viridis*	*Gossypium devidsonii*	*G. devidsonii x* [*G.arboreum* L. cv. JLA 794 x *G. capitis-viridis*]
Plant height (cm)	185.4	168.9	180.1	93.5	**319.7**
Monopodia (no.)	4 to 5	3 to 4	4 to 5	>6	4
Sympodia (no.)	22 to 23	10 to 12	9 to 10	10 to 12	**25-27**
Length of Monopodia (cm)	121.0	46.7	75.6	53.4	**269.4**
Length of Sympodia (cm)	25.6	39.2	**50.1**	23.5	**59.4**
Leaf length (cm)	5.7	4.5	6.9	3.9	**8.2**
Leaf width (cm)	4.5	5.8	7.8	3.3	**7.3**
Leaf thickness (mm)	0.67	0.85	0.50	0.60	0.73
Leaf nectari/leaf	1	1	**3**	1	1
Leaf petiole length (cm)	3.7	3.8	**5.9**	1.65	3.8
Leaf petiole thickness (mm)	1.9	1.4	1.6	1.3	1.5
Lobe length (cm)	4.2	3.1	**4.8**	-	**4.3**
Lobe width (cm)	1.3	2.0	1.6	-	**3.1**
Peduncle length (cm)	1.8	0.6	1.4	2.0	**2.1**
Petal length(cm)	4.7	4.6	4.5	3.3	4.4
Petal width (cm)	2.9	3.2	3.0	3.0	**4.6**
Length of petal spot (cm)	1.8	2.4	2.0	0.8	**2.9**
Width of petal spot (cm)	1.6	1.8	1.8	0.5	**2.7**
Calyx length (cm)	0.9	0.7	**1.1**	0.4	0.6
Length of bract (cm)	2.5	1.4	2.3	3.1	2.9
Width of bract (cm)	2.2	0.4	1.6	1.8	1.4
Teeth (no)	3 to 4	2 to 3	3	8	6 to 7
Anther no.	56.5	83.7	36.3	48.6	60.0
Style length (cm)	1.8	2.3	**2.8**	1.9	**2.6**
No. of ovules	30.0	20.0	24.8	20.0	20.4
No of locules	3 to 4	3	3	3	-
Locule length (cm)	4.2	2.1	3.3	1.9	-
Locule width (cm)	2.5	0.9	1.6	1.0	-
Seed / locule	8.0	6.0	1 to 2	3 to 4	-
Pollen size diameter (ì)	112.5	79.46	93.1	90.9	48.4

cv. JLA 794 x *G. capitis-viridis* hybrid was superior to both parents in length of sympodia (50.1 cm), leaf nectari/leaf (3 No), leaf petiole length (5.9 cm), lobe length (4.8 cm), calyx length (1.1 cm) and style length (2.8 cm) likewise, the tri-species hybrid *G. devidsonii* x [*G.arboreum* L. cv. JLA 794 x G. *capitis-viridis*] was superior in plant height (319.7 cm), sympodia (25-27 no.), length of monopodia (269.4 cm), length of sympodia (59.4 cm), leaf length (8.2 cm), leaf width (7.3 cm), lobe length (4.3 cm), lobe width (3.1 cm), peduncle length (2.1 cm), petal width (4.6 cm), length of petal spot (2.9 cm), width of petal spot (2.7 cm) and style length (2.6 cm) indicating exhibition of heterosis for these characters.

All these observations of F_1 hybrids

between *G. arboreum* L. x G*. capitis-viridis* conformed to those of Mehetre *et al.,* (2003). Use of *G. capitis viridis* will prove to be an additional advantage for improving fibre length, fineness, strength and other economic qualities. In the direct cross *G. arboreum* x *G. davidsonii,* failure of endosperm that led to death of embryo was observed. The similar results were reported by Stephens and Cassidy (1949). They attempted to culture a *G. arboreum* x *G. davidsonii* hybrid in vitro, but failed to obtain a viable plant. This may be due to the general genotype disharmony between these two species (Silow, 1941 and Stephens, 1945). Earlier reports (Sikka and Joshi, 1960) indicated that none of the crosses except *G. davidsonii* x *G. anomalum* and with *G. klotzschianum* produce viable seeds, even though *G. davidsonii* and *G. stocksii* crosses easily and produce many but lower production of viable seed.

The present studies using morphological analysis have clearly indicated that *G. devidsonii* x [*G. arboreum* L. cv. JLA 794 x *G. capitis-viridis*] offspring is a true hybrid.

REFERENCE

Fryxell, P. A. 1979. The natural history of the cotton tribe. College Station, Texas A & M University Press, USA.

Kohel, 1977. The role of race sources G. hirsutum. In: Proc. Beltwide cotton *Prod. Res. Cont.* P. 40.

Mehetre, S. S. and Aher, A. R. 2004. Embryo rescue· A tool to overcome incompatible interspecific hybridization in Gossypium - A. Review. *Indian J. Biotech.,* **3:** 29-36.

Mehetre, S. S., Michalles Gomes, Eapen Susan, Aher, A. R. and Shinde, G. C. 2003. RAPD and cytomorphological analyses of F_1, F_2 and amphidiploid (A_1) enerations of *Gossypium arboreum* x *Gossypium capitis-viridis. Cytologia* 69 : 367–79.

Narayanan, S. S., Singh, J., and Vema, P. K. 1984. Introgressive gene transfer in Gossypium: Goals, problems, strategies and achievements. *Cotton fibre Trop.* **390 :** 123-35.

Richmond, T. R. 1951. Procedures and methods of cotton breeding with special reference to American cultivated species. *Adv. Genet.* **4 :** 213-45.

Sikka, S. M. and Joshi, A. B. 1960. Cotton Breeding In: Cotton in India, *a monograph*, 1 : 336-402, ICAR, New Delhi.

Silow, R. A. 1941. The comparative genetics of *G. anomalum* and the cultivated Asiatic cotton. *J. Genet.* **42 :** 259-358.

Stephens, S. G. 1944. The application of genetics to plant breeding. *Trop. Agric.* (Trin) **21 :** 126-29.

Stephens, S. G. 1945. Colchicine produced polyploids in Gossypium. II. Old world tripoid hybrids. *J. Gent.* **46 :** 303-12.

Stephens, S. G. and Cassidy, B. J.1949. Cotton genetics, Ann. Rep. Dept. Genet. Carnegie *Inst. Wash. Yearb.* **45** (1945-1946): 186-90.

Stewart, J. Me D. 1995. Potential for crop improvement with exotic germplasm and genetic engineering. In: Challenging the future: Proceedings of the World Cotton Research Conference-1. Brisbane Australia Feb. 14-17, 1994 G.A. Constable and NW. Forrester (Eds), CSIRO, Melbourne, Australia, pp. 313-27.

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Development of long linted fine quality *desi* cotton (*Gossypium arboreum* L.) genotypes to meet the demand of textile industry

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Diploid asiatic (*desi*) cotton is being grown traditionally since times immemorial in India. The antiquity of Indian cotton can be traced from excavations at Mohanjo Daro representing Indian civilization of 3000 B.C. In 17th century, during the English empire the Indian cotton Decca Muslins was exported for weaving fine fabrics and was fashioned in England. Nature has bestowed the cotton species, *Gossypium arboreum* with some unique and peculiar characteristics, which have been widely studied and documented. Moisture stress is the main problem under rainfed conditions and therefore,abiotic stress resistance is of utmost significance, especially in India, where more than sisty percent of total area is under rainfed conditions. Cotton species,*G.arboreum* successfully withstands moisture stress (abiotic stress) and responds positively to moisture availability and other agronomic manipulations.

The input requirements in respect to agronomic and plant protection practices are minimal in case of *G.arboreum*. Hence,the net gain for the farmer is often higher with *G. arboreum* than with many of the *G.hirsutum* strains and hybrids which perform well only under most favourable conditions and demand high agricultural inputs.

General belief that *G.arboreum* is low yielding needs reconsideration. Even under the poorest management and wrost growing conditions, *G.arboreum* yields quite competitively with upland cotton. Commertially cultivated *G.arboreum* is usually identified with poorer fibre quality, coarser fibres and shorter fibres, restricting its utilization in the textile industry. Which in turn results in less monetary gains to the grower. Lint obtained from *G.arboreum* is utilized mainly for the production of surgical cotton, coarse fabrics, and to some extent for mixing purposes. The spread of tetraploid cotton was due to their superior fibre qualities as compared to diploid cottons. If improvements in the boll size and fibre quality parameters is brought about, *G.arboreum* could be an economically viable alternative to the tetraploid genotypes in the rainfed cotton ecology of central and south India. Prof. S. C. Harland, a noted cotton breeder from U. K. who was working as consultant for Government of Indian his report mentioned that if *arboreum* cotton with a staple length of one inch or more was bred, they would spin better than *hirsutum* of similar staple.

Among the fibre properties which contribute most to spinning value are staple length, fibre fineness and strength. Fibre length is an important parameter for the textile industry and universally reconised as a major contributor to yarn strength and processing performance. Also the commercial value of cotton is mainly governed by fibre length. Longer fibre length is *desi*rable for the production of finer and low twist yarns. With respect to Indian cottons, fibre length is reported to make the greatest contribution towards spinning performance followed by fibre fineness. Fineness of cotton fibre expressed in micronaire units, determines its texture, depending on which, it may be classified as soft and silky, or coarse and harsh. The quality characteristic is important in the selection of fibre for its suitability to manufacture a particular yarn. Fibre bundle strength is perhaps the most important fibre property next to length that contributes to the utilization of cotton as a textile fibre. This quality character is related to spinnability.

Strenuous efforts were made at Cotton Research Station, Mahboob Baugh Farm, VNMKV, Parbhani to improve the productivity and fibre qualities of *G.arboreum* to bring them to the level of tetraploid cotton. These efforts resulted in the development of *G.arboreum* genotypes *viz.*, PA 08,PA 528,PA 740,PA 741,PA 760,PA 785,PA 810 and PA 812 and many more having high productivity and superior fibre qualities. The yield potential of these quality *arboreums* has been critically evaluated in different experiments conducted.

The comparative yield performance of quality *desi* cotton genotypes and *hirsutum* variety and hybrids was also studied in breeding trials where both the species were tested in same trials for three years. In these trials, the recommended package of practices for respective species were followed. The *desi* cotton were protected with minimum plant protection with 1 to 2 sprays as and when required,where as *hirsutum* were protected with minimum 5 to

Table 1. Yield performance of long linted *desi* cotton genotypes in comparison with *G.hirsutum*

Year/Location	Long linted *G.arboreum* cotton genotypes						*G.hirsutum* varieties and hybrids		CD (p=0.05)	CV (%)
	PA 740	PA 785	PA 809	PA 812	PA 810	PA 808	NH 615	NHH 206		
2014-2015 (2a)										
Parbhani	1869	1963	1819	2153	-	-	1462	1476	373.06	10.25
Somnathpur	1178	1270	1635	1359	-	-	926	982	538.02	19.48
Parbhani (2c)	-	-	-	-	1883	1429	1420	-	270.31	7.93
2015-2016										
Parbhani (2a)	1802	1545	1479	1882	1740	-	1379	1259	301.14	8.58
Parbhani (2c)	-	-	-	-	-	1814	1467	-	288.85	7.85
2016-2017										
Parbhani (2a)	-	-	1357	1495	1441	1223	1310	1222	220.68	8.05
Mean	**1616**	**1593**	**1573**	**1722**	**1688**	**1489**	**1327**	**1235**		
Per cent increase over										
NH 615	21.77	20.04	18.53	29.76	27.20	12.20				
NHH 206	30.85	28.98	27.36	39.43	36.68	20.56				
Mean boll weight										

Table 2. Yield performance of long linted *desi* cotton genotypes in comparison with regional checks

Year/Location	Long linted *G.arboreum* cotton genotypes					Regional check varieties					CD	CV (%)
	PA 740	PA 760	PA 741	PA 785	PA 812	PA 402	PA 08	AKA 7	AKA 8	JLA 794	(p=0.05)	
2013-2014												
Parbhani	1380	1279	1425	-	-	1142	1115	1-64	966	1110	144.41	8.01
Somnathpur	1454	1360	1428	-	-	1151	1042	1355	1280	1246	512.71	17.50
2014-2015												
Parbhani	1765	1678	1901	-	-	1408	1395	1074	1401	1299	237.64	10.51
Somnathpur	848	1066	1062	-	-	753	836	707	931	1025	290.31	19.89
2015-2016												
Parbhani	2050	-	-	1870	1942	1616	1676	1507	1517	1612	202.15	8.11
Nanded	628	-	-	652	741	610	677	508	676	710	177	17.49
2016-2017												
Parbhani	1367	-	-	1255	1408	1106	1138	1004	1002	1082	163.4	9.36
Mean	**1356**	**1346**	**1454**	**1259**	**1364**	**1112**	**1126**	**1031**	**1110**	**1155**		
Per cent increase over												
AKA 7	31.52	30.55	41.02	22.11	32.29							
JLA 794	17.40	16.53	25.88	9.00	18.09							
Mean boll weight												

6 insecticidal sprays for boll worm and sucking pest control.

The Table 1 reveals that the quality *desi* cotton genotypes depicted higher yields ranging from 12.20 to 29.76 per cent than *hirsutum* variety NH 615 and 20.56 to 39.43 per cent than *hirsutum* hybrid check NHH 206.The yield levels of *desi* cotton ranged from 1489 kg/ha (PA 808) to 1722 kg/ha (PA 812) as against 1327 kg/ha (NH 615) and 1235 kg/ha (NHH 206) yield potential of *hirsutum* cotton. The data clearly suggests that the newly developed quality *arboreums* had higher yield potential than *hirsutum* under rainfed situation. The indications of higher yield potential of *desi* cotton ranging from 27.5 to 129.0 per cent *hirsutum* was also reported by Ansingkar and Pawar (1992) after critical analysis of the data collected from 1972 to 1992.However,their indications were based mostly on data pertaining to short staple *desi* cotton. Mostly, short staple species of cotton may be arboretum or *hirsutum* are higher yielder than long staple. This is mainly because of negative correlation of yield with that of staple length. The study revealed that, inspite of such negative correlation the productivity of quality arboretum is definitely higher than *hirsutum* like that of short staple *arboreum.*

Table 2 reveals that the long linted *desi* cotton genotypes have higher productivity than regional checks *viz.,* PA 08, PA 402,AKA 7,AKA 8 and JLA 794.These long linted genotypes expressed yield potential ranging from 22.11 (PA 785) to 41.02 (PA 741) per cent higher than AKA 7.The yields of genotypes ranged from 1259 kg/ha (PA 785) to 1454 kg/ha (PA 741) as against

Table 3. Performance of *G.arboreum* genotypes for fibre quality characters 2016-2017

Sr. No.	Genotypes	Upper half mean length (mm)	Uniformity ratio (%)	Micronaire value (µg/inch)	Fibre strength (g/tex)	Elongation (%)
1	PA 801	30.7	85	5.0	29.6	5.9
2	PA 808	32.0	87	4.7	34.1	5.7
3	PA 809	33.7	88	4.1	29.6	5.6
4	PA 810	32.7	87	4.1	29.4	5.6
5	PA 812	32.2	86	4.8	29.7	5.7
6	PA 825	30.0	84	4.8	31.2	6.0
7	PA 828	29.8	83	5.1	31.1	6.4
8	PA 835	32.5	86	4.9	27.8	4.9
9	PA 837	30.7	85	4.8	29.3	5.8
10	PA 841	30.2	83	4.6	27.6	6.3
11	PA 847	31.3	84	4.6	28.8	5.8
12	PAIG 377	32.1	87	4.3	28.2	5.4
13	PAIG 378	29.4	85	4.3	26.7	5.9
14	PAIG 380	33.1	87	4.3	31.6	6.0
Checks						
15	PA 08 (c)	30.5	85	4.9	28.6	6.0
16	PA 402 (c)	27.2	83	5.1	28.5	5.7
17	NH 615 (c)	29.5	86	4.1	27.0	5.7
18	NHH 206 (c)	29.1	85	4.1	27.2	5.9

Table 4. Performance of *G.arboreum* genotypes for fibre quality characters 2015-2016

Sr. No.	Genotype	Upper half mean length (mm)	Uniformity ratio (%)	Micronaire value (µg/inch)	Fibre strength (g/tex)	Elongation (%)
1	PA 785	29.4	82	4.9	28.4	5.9
2	PA 760	30.4	82	4.8	28.2	5.8
3	PA 808	30.1	83	5.0	29.7	6.0
4	PA 809	32.4	84	4.3	31.6	6.2
5	PA 810	31.4	83	4.9	27.9	5.9
6	PA 812	30.8	83	4.7	29.3	5.9
7	PA 835	32.0	83	5.0	28.0	5.8
8	PA 837	31.0	83	5.1	26.3	5.7
Checks						
9	PA 08 (c)	28.6	82	5.0	26.8	6.0
10	PA 402 (c)	26.5	81	5.3	26.5	6.0
11	NH 615 (c)	27.5	81	3.9	25.0	5.7
12	NHH 206 (c)	26.6	81	4.0	25.5	5.6

Table 5. Performance of productive long linted *desi* cotton genotypes PA 760 and PA 741 in central and south zone Year : 2012-2013

G.arboreum genotypes	Locations						**Mean Central zone**	Nandyal
	Khandwa	Amrelli	Akola	Parbhani	Jalgaon	Nagpur		
1. AICCIP trial : Br.22 a/b 1. 2.5 per cent span length (mm)								
PA 760	29.8	27.7	30.4	29.5	32.8	29.0	**29.9**	29.6
PA 741	28.5	28.3	28.7	30.5	31.5	28.7	**28.2**	29.9
ZC (AKA 7)	25.5	25.1	24.2	24.2	25.1	23.5	**24.6**	28.3
LC	23.6	25.2	25.5	27.2	25.1	25.0	**25.3**	24.7
2. Micronaire (µg/inch)								
PA 760	2.9	4.6	3.8	4.7	3.9	4.3	**4.0**	4.5
PA 741	3.6	4.8	4.5	5.2	4.7	5.0	**4.6**	4.5
ZC (AKA 7)	4.2	5.2	5.2	5.6	5.6	5.4	**5.2**	4.7
LC	3.8	5.2	5.3	5.7	5.4	5.4	**5.1**	5.4
3. Fibre strength (g/tex)								
PA 760	24.4	24.6	22.6	21.0	21.5	22.0	**22.7**	22.7
PA 741	22.1	19.5	21.7	22.3	21.6	21.1	**21.4**	24.1
ZC (AKA 7)	22.0	22.0	21.5	17.9	20.1	19.5	**20.5**	21.1
LC	21.5	20.9	21.4	21.2	20.4	19.7	**20.9**	20.6
4. Seed cotton yield (kg/ha)								
PA 760	277	1671	881	1343	808	1813	**1132**	3027
PA 741	418	1685	898	884	752	2129	**1128**	2476
ZC (AKA 7)	453	1098	1178	1282	803	1915	**1122**	2707
LC	270	1769	1030	1199	999	1750	**1170**	2855

LC (Local check) : Khandwa JK 5,Amrelli G.Cot 19, Akola AKA 8, Parbhani PA 402,Jalgaon JLA 794, Nagpur AKA 8,Nandyal Sri Nandi

1031 (AKA 7) and 1155 (JLA 794).

Yield performance of newly developed quality *arboreum* was also assessed in breeding trials conducted on various locations in Central and south zone under All India Co ordinated Cotton Improvement Project during 2012-2013 to 2016-2017.In these trials ,yield performance of quality *desi* cotton varieties evolved from Parbhani *viz.*, PA 760,PA 741,PA 785,PA 740,PA 810 and PA 812 were compared with zonal checks and local checks variety of respective centre, Parbhani, Nagpur ,Akola, Jalgaon (MS), Amrelli, Junagarh,Bharuch(Gujrat), Khandwa (MP), Dharwad, Nandyal, Raichur (Karnataka) and Kovilpatti (TN).It gives clear cut indication regarding the superior productivity of quality *arboreum* in comparison with zonal and local checks in central and south zone.(Table 5,6,7,8.9 (4)).The yield potential of *desi* cotton ranged from 1067 kg/ha (PA 740) to 1344 kg/ha (PA 810).

In addition to higher productivity, the fibre properties like fibre length, fibre fineness, uniformity ratio, fibre strength and fibre elongation of the newly developed *desi* cotton genotypes are superior than *hirsutum*. the fibre and spinning test reports of newly developed *desi* cotton genotypes in comparison with recommended *G.hirsutum* varieties and hybrids received from CIRCOT have been presented in Table. Data in the Table reveals that in no way the quality *arboreums* had inferior fibre qualities and spinning potential than *hirsutum*. More over, they had superior upeer half mean length ranging from 29.4 (PAIG 378) to 33.7 mm (PA 809) as against 29.5 and 29.1 mm of *G.hirsutum* variety NH 615 and hybrid NHH 206. In addition

Table 6. Performance of productive long linted *desi* cotton genotypePA 785 in central zone AICCIP trial : Br.24 (b) Year : 2015-2016

G.arboreum genotypes	Locations					**Mean Central zone**
	Amreli	Junagarh	Akola	Jalgaon	Parbhani	
1. Upeer half mean length (mm)						
PA 785	30.4	27.9	30.3	27.7	29.8	**29.2**
ZC (AKA 7)	26.1	24.4	26.5	24.7	24.1	**25.2**
LC	27.6	23.6	25.7	25.9	24.6	**25.5**
2. Micronaire (µg/inch)						
PA 785	4.8	5.8	4.5	4.1	5.3	**4.9**
ZC (AKA 7)	5.9	5.9	5.5	3.9	5.6	**5.4**
LC	5.8	5.8	5.3	3.9	5.5	**5.3**
3. Fibre strength (g/tex)						
PA 785	31.1	30.3	30.6	28.2	28.4	**29.7**
ZC (AKA 7)	29.6	26.6	28.7	29.0	25.6	**27.9**
LC	30.1	29.3	28.4	27.7	27.2	**28.5**
4. Seed cotton yield (Kg/ha)						
PA 785	888	1040	633	1901	1263	
ZC (AKA 7)	945	1073	804	1181	1218	
LC	1157	1382	873	1504	1472	

LC (Local check) : Junagarh G.Cot 19, Akola AKA 8, Parbhani PA 402, Jalgaon JL794

Table 7. Performance of productive long linted *desi* cotton genotypePA 740 in south zone AICCIP trial: Br.24 (b) Year : 2015-2016

G.arboreum genotypes	Locations			**Mean**
	Dharwad	Nandyal	Kovilpatti	**south zone**
1. Upeer half mean length (mm)				
PA 740	28.3	28.6	29.6	**28.8**
ZC (DLSa 17)	28.7	28.5	29.3	**28.8**
LC	26.2	25.2	27.5	**26.3**
2 Micronaire (µg/inch)				
PA 740	5.3	4.5	4.6	**4.8**
ZC (DLSa 17)	4.9	5.1	5.1	**5.0**
LC	5.4	5.5	5.9	**5.6**
3. Fibre strength (g/tex)				
PA 740	31.2	30.0	33.3	**31.5**
ZC (DLSa 17)	30.1	29.6	32.1	**30.6**
LC	28.5	26.8	30.1	**28.5**
4. Seed cotton yield (kg/ha)				
PA 740	1330	482	1389	**1067**
ZC (DLSa 17)	1481	639	1365	**1162**
LC	1447	472	1417	**1112**

LC (Local check) : Dharwad AKA 235,Nandyal-Yaganti,Kovilpatti K11

to fibre length, fibre strength and fibre elongation of *arboreums* was superior than *hirsutum*. The uniformity ratio and micronaire were at par with *hirsutum*.

During 2012-2013, based on the mean performance over 6 locations in central zone, the genotype PA 760 and PA 741 recorded 2.5 per cent span length of 29.9 and 29.3 mm respectively as compared to 24.6mm of zonal check AKA 7 and 25.3 mm, of local check of respective locations. Similarly, the genotypes PA 760 and PA 741 recorded fibre fineness of 4.0 and 4.6 µg/inch far superior than zonal and local checks.

In project trial Br.24 (b) during 2015-2016, based on the mean performance over 4 locations in central zone, the genotype PA 785 recorded UHML of 29.2 mm, micronaire of 4.9 µg/inch and fibre strength of 29.7 g/tex as against UHML of 25.2 and 25.5 mm, micronaire of 5.4 and 5.3 µg/inch and fibre strength of 27.9 and 28.5 g/tex for zonal check AKA 7 and local check of respective locations ,respectively.

The genotype PA 740 recorded UHML of 28.4 mm, micronaire of 4.8 µg/inch and fibre strength of 31.5 g/tex in AICRP trial Br.24 (b) in south zone during 2015-16.

In project trial Br.22 a/b during 2015-16,the genotype PA 812 recorded UHML of 30.5 and 30.3 mm, micronaire of 4.6 and 4.7 8 µg/inch and fibre strength of 29.7 and 31.0 g/tex in central and south zone, respectively. . It has recorded far superior fibre properties as compared to zonal and local checks of respective locations.

The genotype PA 810 recorded UHML of 30.6, 32.5 and 31.3 mm, micronaire of 4.9,4.3 and 4.8 8 µg/inch and fibre strength of 31.3, 30.3

Table 8. Performance of productive long linted desi cotton genotype PA 812 in central and south zone AICCIP trial : Br.22 a/b Year : 2015-16

G.arboreum genotypes	Locations											
	Khandwa	Amrelli	Akola	Parbhani	Jalgaon	Nagpur	**Mean central zone**	Dharwad	Raichur	Nandyal	Kovilpatti	**Mean south zone**
1. Upeer half mean length (mm)												
PA 812	29.2	29.8	31.2	31.7	30.8	30.3	**30.5**	30.4	29.7	30.4	30.8	**30.3**
ZC	24.6	25.4	26.6	24.7	26.2	24.5	**25.3**	26.7	28.0	28.7	28.7	**28.0**
LC	24.0	24.7	27.6	24.5	24.3	26.6	**25.3**	26.6	27.7	25.3	26.8	**26.6**
2 Micronaire (µg/inch)												
PA 812	3.8	5.1	4.9	4.5	4.1	4.7	**4.6**	4.9	3.8	4.7	5.3	**4.7**
ZC	4.2	5.5	5.9	5.4	5.8	5.6	**5.4**	5.6	4.8	5.2	5.4	**5.3**
LC	4.8	5.5	5.6	5.4	5.5	5.1	**5.3**	5.9	5.0	5.4	6.1	**5.6**
3. Fibre strength (g/tex)												
PA 812	29.8	29.8	32.1	30.2	30.7	25.5	**29.7**	32.7	27.0	30.7	33.5	**31.0**
ZC	27.4	27.8	30.8	25.0	28.4	25.3	**27.5**	28.2	25.0	29.0	32.0	**28.6**
LC	24.3	25.8	30.1	28.2	28.9	27.5	**27.5**	28.2	27.0	27.2	29.1	**27.9**
4. Seed cotton yield (kg/ha)												
PA 812	3133	837	2080	781	1046	**1337**						
ZC	2706	803	1147	1227	637	**1108**						
LC	3751	826	1377	635	743	**1255**						

LC (Local check) :Amrelli G.Cot 19, Akola AKA 8, Parbhani PA 402, Jalgaon JLA 794, Nagpur AKA 8 **ZC (Central zone) :** AKA 7 **ZC (South zone) :** DLSa 17

Table 9. Performance of productive long linted desi cotton genotype PA 810 in central, north and south zone AICCIP trial : Br.22 a/b Year : 2016-2017

G.arboreum genotypes	Locations									
	Akola	Parbhani	Nagpur	**Mean central zone**	Shriganga-nagar	Faridkot	Bhatinda	Sirsa	**Mean north zone**	Nandyal
1. Upeer half mean length (mm)										
PA 810	34.4	30.0	33.1	**32.5**	30.4	32.6	**30.4**	28.9	30.6	**31.3**
ZC	27.4	25.9	26.6	**26.6**	23.7	21.6	**22.1**	20.1	21.9	**28.8**
LC	27.3	25.0	25.2	**25.8**	23.3	22.1	**20.5**	19.7	21.4	**23.9**
2 Micronaire (µg/inch)										
PA 810	4.4	4.7	3.7	**4.3**	5.1	4.7	5.1	4.6	**4.9**	**4.8**
ZC	5.0	5.3	5.0	**5.1**	7.0	7.0	7.0	7.0	**7.0**	**5.4**
LC	5.5	5.0	5.0	**5.2**	7.0	6.5	7.0	7.0	**6.9**	**6.1**
3. Fibre strength (g/tex)										
PA 810	31.7	25.7	33.5	**30.3**	30.4	31.8	33.8	29.1	**31.3**	**33.0**
ZC	29.5	26.5	27.9	**28.1**	-	-	-	-	**-**	**30.1**
LC	29.0	26.7	26.5	**27.4**	-	24.5	-	-	**24.5**	**25.3**
4. Seed cotton yield (kg/ha)										
PA 810	611	2367	1209	1257	1958					
ZC	782	2107	1150	1064	1335					
LC	286	2600	1139	1121	1916					

LC (Local check) : Bharuch-G.Cot 19,Amrelli- G.Cot 19,Akola-AKA 8,Parbhani-P402,Nagpur-AKA 8 **ZC (Central zone) :** AKA 7 **ZC (South zone) :** DLSa 17 and 33.0 g/tex in north, central and south zone ,respectively. It has recorded far superior fibre properties as compared to zonal and local checks of respective locations.

Futuristic cotton production system has to be competitive in terms of quality and cost of production. With the release of such long linted quality *arboreums* having high productivity, the rainfed cotton growers can produce quality fibre as per the requirements of modern textile industry.

REFERANCES

Ansingkar, A.S. and Pawar, K.P. 1992. Retrospect and prospect of *desi* cotton for productivity in relation with hybrids in Maharashtra In : *"Proceedings of the first Vasantrao Naik Memorial National Seminar on Cotton Development"* 5-6 Dec,Nagpur.

Basu A.K. 1995. Current genetic research in cotton in India.*Genetica,* **97 :** 279-90.

Bolek,Y., Cokkizgin, H. and Bardak, A. 2010. Combining ability and heterosis for fiber quality traits in cotton. *Plant Breed. Seed Sci.,* **62** : 3-16.

Deshpande L.A., Kokate, R.M., Kulkarni, U.G. and Nerkar, Y.S. 1992. Cytomorphological studies in induced tetraploid G.arboreum × G.hirsutum L. *"Proceedings of the first Vasantrao Naik Memorial National Seminar on Cotton Development "* 5-6 Dec,Nagpur pp 38-47.

Khadi, B.M. and Kulkarni V.N.1998. Cultivar development and seed problems in cotton : In *"Proceedings of Seminar on Cotton Cultivation and Problems of Marginal Farmers"* at Guntur, 10-11 April, pp. 35-42.

Singh,Phundan and Narayanan,S.S. 1991. Genetic improvement of arboreum cotton in India. *Jour. Ind. Soc. Cotton Improv.* **16 :** 81-96.

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Gujarat Navsari cotton 22 – A jassid immune *Gossypium hirsutum* variety

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ABSRACT : Gujarat has unique position for cotton production, productivity as well as cotton research at national level. This centre has great credit for its pioneer cotton research work at global level. The first hybrid cotton, Hybrid 4, first interspecific variety Deviraj and first budded cotton G.Cot.101 and first public sector *Bt*, G.Cot.Hybrid 6 BG II and G.Cot.Hybrid 8 BG II are few examples. In *Bt era* the cotton area, production and productivity of Gujarat increased rapidly. Bt cotton has many more benefits but, some minus points like jassid, pink bollworm infestation and reddening became an addressable issue. In *Bt era*, farmers demanded for jassid resistant variety. Cotton leaf hopper, being the key pest of cotton appeared throughout the crop season leading to substantial increase in its management costs with many of the *BT* hybrids. The multidisciplinary team efforts of 15 years (1996-1997 to 2012-2013) lead to the development of leaf hopper immune/resistant variety involving 7 species cross (4 cultivated and 3 wild spp. of cotton) through conventional breeding at Main Cotton Research Station, NAU, Surat and rigorous evaluation at SAUs and ICAR-CICR, Coimabatore and Nagpur. The genotype GISV 218 was developed through the cross of G.Cot.10 x GISV 140. This genotype was extensively evaluated for seed cotton yield at state as well as national level. Considering the seed cotton yield, it was observed promising. The immune/resistance nature of this variety against leaf hopper mainly attributed to feeding and oviposition hindrances of leaf hopper due to traits *viz.*, leaf thickness, more number of trichome density on leaf lamina and veins as well the leaf geometry possessing more height of the palisade cell, compact structure and more distance of phloem from lower epidermis compared to susceptible variety against leaf hopper.

The first cotton hybrid, Hybrid 4, the first interspecific variety Deviraj, the first *desi* cotton hybrid G.Cot.DH 7, the first budded cotton, G.Cot.101, the first public sector *Bt* cotton hybrid, G.Cot.Hy 6 and G.Cot.Hy 8 (BG II) are the few examples.

The cotton leafhopper found distributed in India, Pakistan, Bangladesh, China, and North Africa. The adults and nymphs suck the sap from leaves and inject toxic saliva resulting in 'hopper burn' symptoms, which ultimately result in the loss of plant vigour and significant yield losses. Earlier, it appeared in particular part of the season, but, now found throughout the cotton season and need at least two to three sprayings by the farmers. Since, Government of India approved *Bt* cotton cultivation and its seed multiplication and marketing in the country in 2002. Numbers of *Bt* cotton hybrids approved for cultivation. but on several other hosts *viz.*, okra, brinjal, castor *etc.* Since decade, the leaf hopper, *Amrasca bigguttulla bigguttulla* Ishida continued to thrive and damaging the cotton. Earlier, it appeared in particular part of the season, but, now found throughout the cotton season and need at least two to three sprayings by the farmers. The development of variety or hybrids resistant or tolerant to this key pest was herculean task as the traits governing the resistance or tolerance was found in distantly related wild species. The multidisciplinary team efforts of 15 years (1996-1997 to 2012-2013 lead to the development of leaf hopper immune resistant variety as **Gujarat Navsari Cotton 22 (GN.Cot.22)** involving 7 species cross (4 cultivated and 3 wild spp of cotton) through conventional breeding and rigorous evaluation.

MATERIALS AND METHODS

Through conventional breeding techniques, the crosses were made for developing introgressed material from the wild species (*G.stocksii, G.armorianum* and *G. anomalom)* and the variety was developed using these introgressed material as shown in pedigree. The strain, GISV 218 had been developed from a cross of G.Cot.10 x GISV 140 in the year 1996-1997. The pedigree of GISV 218 is as under:

The developed GISV 218 was tested under various breeding trials. The GISV series of hirsutum cotton at Surat has plenty of merits it may improve seed cotton yield and fiber quality, it may work for insect pest resistant hence, GISV 140 was develop from introgressed material. G.Cot.10 which is familiar as one of the best general combiner, thus, both parents was selected on merit basis. In 1996-1997 the Cross was made between G.Cot.10 x GISV 140. The detail is as under. It was tested through well knit standard channel as shown below:

[{(Karangani 1 x *G.stocksii*) x G.Cot.10} x G.Cot.10]

x

[{(SIV 135 x *G.armorianum*) x G.Cot.100} x G.Cot.100] F_8

x

[{(Co2 x *G. anomalom*) x Sl} x G.Cot.100] x SDMI 8]

x

Surat Dwarf

↓

GISC 91-9 x Surat Dwarf

↓

G.Cot.10 x GISV-140

↓

GISV 218 (GN.Cot.22)

Sr. No.	Year	Details
1	1996-1997	Cross was made between G.Cot.10 x GISV 140
2	1997-1998	F_1 was raised
3	1998-1999 to 2003-2004	Evaluated and selected in various generation viz; F_1 to F_6

Then, the material was tested in station trial, multi location trial and finally All India trial The material was observed homozygous after F_6 then it was tested in station/state trials at various locations (Table 1).

The entomological testing, screening, evaluation and mechanism of resistance were studied during different years of experimentation. The preliminary testing was

Table 1. Evaluation of GISV 218 under evaluation trials (2004-2005 to 2011-2012)

Sr. No.	Year	Name of trial	Name of checks
1	2004-2005	TMC MM 1.3	G.Cot.10, G.Cot.16, G.Cot.18, LRA 5166
2	2005-2006	TMC MM 1.3	G.Cot.10, G.Cot.16, G.Cot.18, LRA 5166
3	2006-2007	TMC MM 1.3	G.Cot.10, G.Cot.16, G.Cot.18, LRA 5166
		SSVT	G.Cot.10, G.Cot.16, G.Cot.18, LRA 5166
4	2007-2008	AICCIP 02 (a)	G.Cot.10, G.Cot.16, G.Cot.18, LRA 5166
5	2008-2009	AICCIP 03 (a)	G.Cot.10, G.Cot.16, G.Cot.18, LRA 5166
6	2009-2010	AICCIP 04 (a)	G.Cot.10, G.Cot.16, G.Cot.18, LRA 5166
		MLT (State)	G.Cot.10, G.Cot.16, G.Cot.18, LRA 5166
7	2010-2011	AICCIP 04 (a)	G.Cot.10, G.Cot.16, G.Cot.18, LRA 5166
8	2011-2012	MLT	G.Cot.10, G.Cot.16, G.Cot.18, LRA 5166

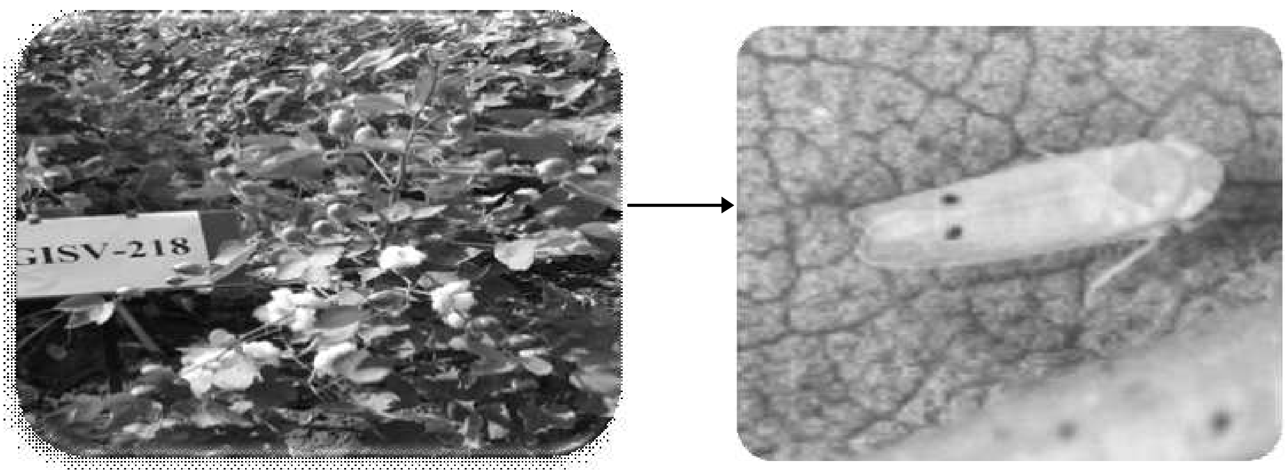
carried out by comparing the incidence of leaf hopper population from tested genotype recorded throughout the season at one week interval in comparison to susceptible and resistant check. For the purpose, the number of leaf hopper populations was recorded from five randomly selected plants on all the genotypes. Based on the preliminary evaluation, the promising genotypes were further screened for resistance in advance trials meant specific for leaf hopper resistance at few stations of hotspot locations. The advance trials were conducted in the large field experiments with artificial infester rows of okra and population counts of leaf hopper were assessed along with the leaf hopper injury grade in comparison to susceptible and resistant checks. Simultaneously, the tested genotype was also evaluated rigorously under cage condition at Main Cotton Research Station, Surat and under artificial bombardment of leaf hopper populations at ICAR-CICR, Coimbatore and Nagpur. The associated mechanism of resistance was evaluated by counting number of trichomes under stereo-binocular microscope on 2x2 cm area of leaf lamina and 0.5 sq. cm length of vein/midrib and compared with the resistance and susceptible genotypes. Further, the leaf anatomical characters/structures were also studied at CICR, Coimbatore for four promising genotypes in comparison to susceptible check, DCH 32.

The agronomic evaluation was also carried out and fibre quality analysis was also carried out by sending samples to CIRCOT, Mumbai. The genotype was then proposed for notification and release.

RESULTS AND DISCUSSION

From the overall performance (**Table 2**), it was observed that the new strain under irrigated conditions gave 2029 kg yield as against 1326 kg of G.Cot.10, 1957 kg of G.Cot.16, 1759 Kg of G.Cot.18, 1803 kg of G.Cot.20 and 1354 Kg of LRA 5166. In rainfed conditions, the GISV 218 recorded 1443 kg/ha seed cotton yield as against 1056 kg of G. Cot -10, 1385 kg of G.Cot.-16, 795 kg of G.Cot.-18, 883 kg of G.Cot.20 and 1054 kg of LRA 5166. In the overall assessment, the GISV 218 yielded 1834 kg seed cotton which was 45.7, 8.1, 11.0, 27.8 and 45.4 % higher, than G.Cot-10, G.Cot-16, G.Cot-18, G.Cot.20 and LRA-5166, respectively. The genotype was tested in 43 trials, out of 43 trials, only 3 trial showed non

PERFORMANCE OF GISV 218 AGAINST LEAF HOPPER



GISV 218's RESISTANCE AGAINST LEAF HOPPER

significant differences. The result of 40 trials which had significant difference indicated that the proposed genotypes GISV 218 (GN.Cot.22) were significantly superior to checks in 23 trials and *at par* in 18 trials.

Pest reaction : The proposed genotype (GISV 218) was found resistant to jassid at national level and moderately tolerant to aphid and thrips. It was moderately tolerant to boll worm damage and recorded low damage to open boll and locule compared to G.Cot.10 and LRA 5166. The tentative economics of GISV 218 over susceptible and resistant check revealed the cost benefit ratio of 3.42 and 3.89, respectively. The overall performance of GISV 218 against leaf hopper at different locations are summarized in

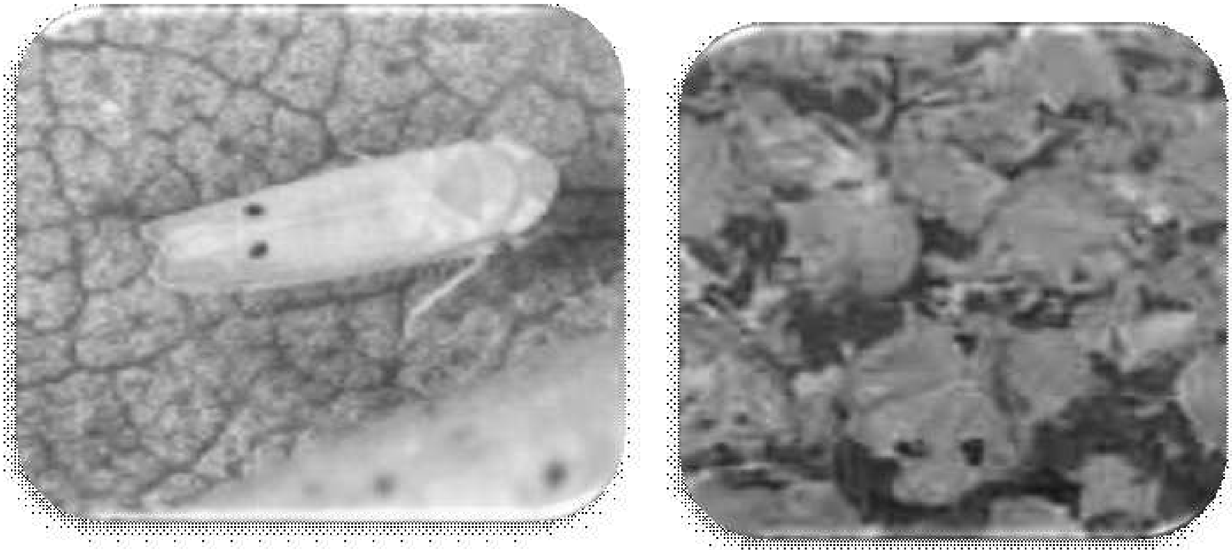


Plate I: Leaf hopper (Adult) and the burning of margin as Jassid Injury Grade

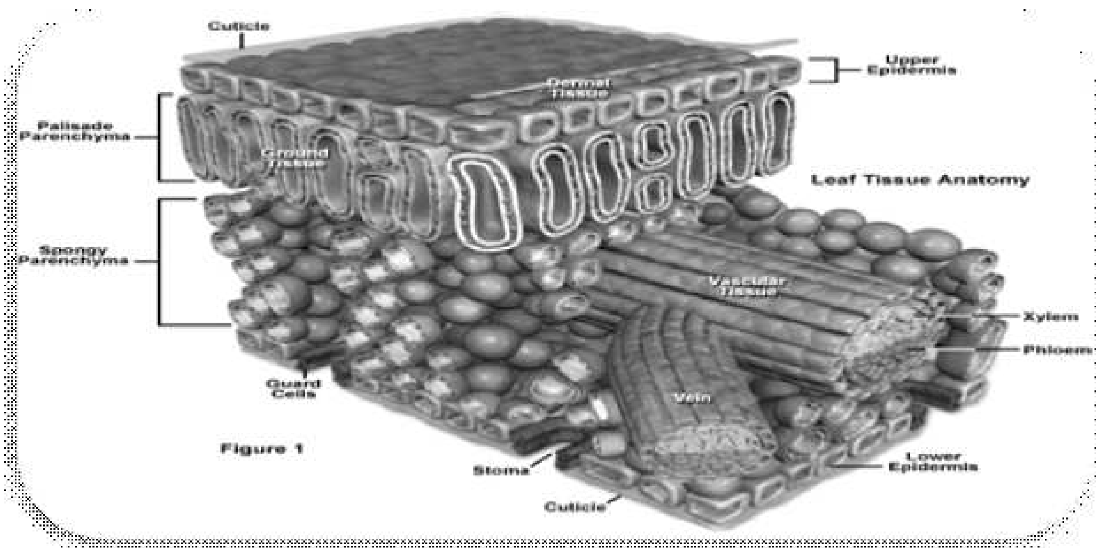
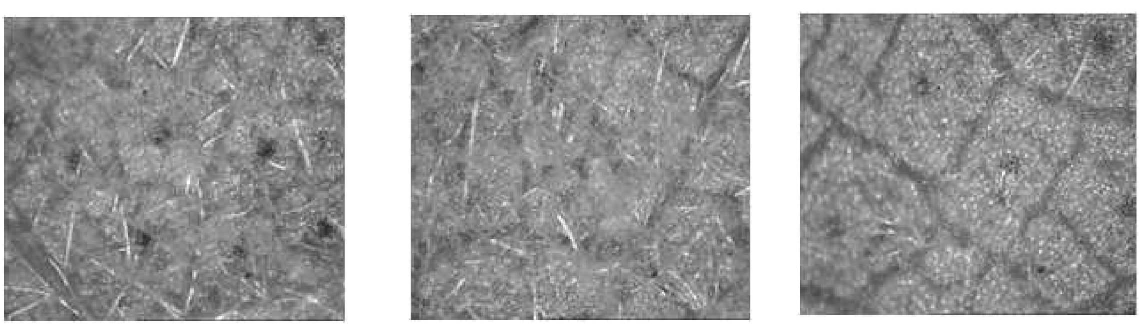
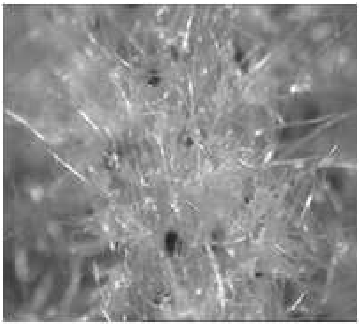


Plate II: The Leaf Anatomy showing distance idea of palisade layer to cuticle and phloem to leaf epidermis (wider distance hindering feeding by leaf hopper) (Courtesy: Google image)



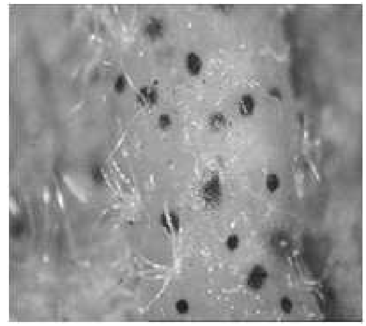
GISV-218 DHY-286(Ch-R) DCH-32 (Ch-S)

Plate III: Trichome density on leaf lamina (0.5 sq. cm area)



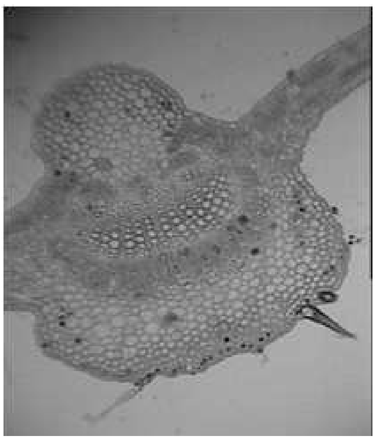
GISV-218

DHY-286(Ch-R)

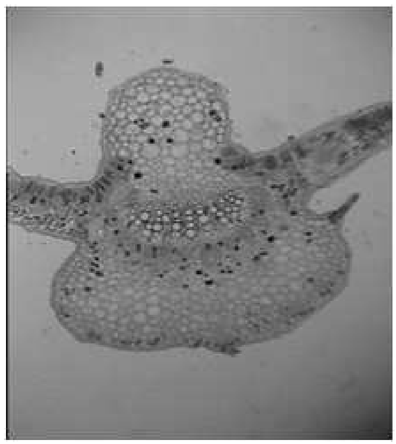


DCH-32 (Ch-S)

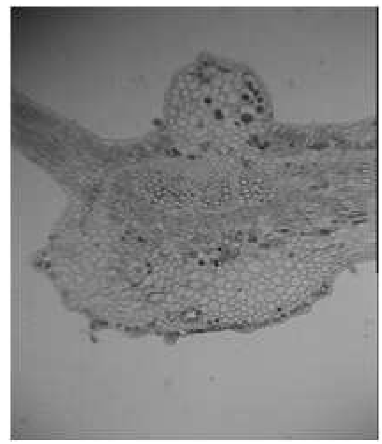
Plate IV: Trichome density on midrib (0.5 cm length)



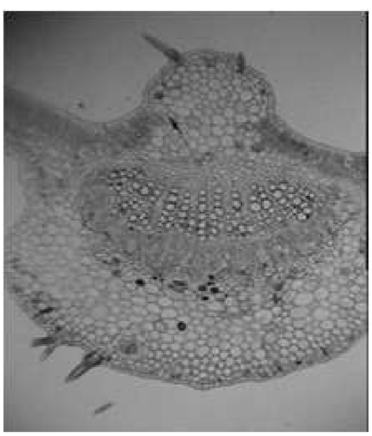
GISV 218 (Best Entry)



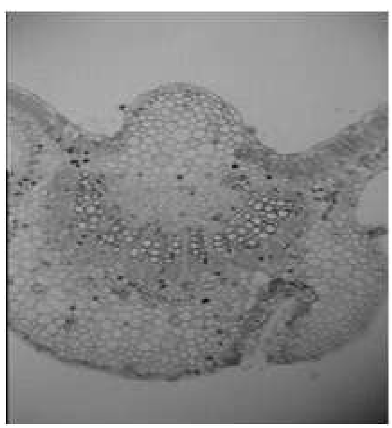
RAH 6



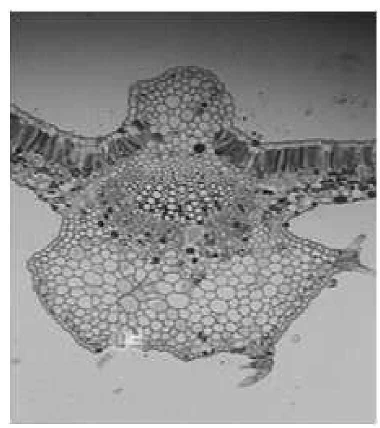
RAH 216



ARBH 813



DCH 32 (Highly Susceptible)



KC 2 (Resistant)

Plate V: Compact structure of Palisade cell

Table 2. Overall performance of proposed genotype for seed cotton yield in different zones / locations across years.

Year	Trial	Location	State / AICCIP trials	Seed GISV 218	Cotton yield (kg/ha) (Irrigated) G.Cot 10(LC)	G.Cot-16(LC)	G.Cot-18(LC)	LRA-5166(ZC)	G.Cot-20(CC)	CD (P=0.05) (kg/ha)	C.V. (%)
A. Station Trial											
2004-2005	TMC MM 1.3	Surat	Station trial	1489	1171	...	...	...	...	390	14.0
		Achhalia	Station trial	2036		2023	...	...	...	212	15.3
		Mean		**1763**	**1171**	**2023**					
2005-2006	TMC MM 1.3	Surat	Station trial	1060	1070	...	...	...	...	467	16.7
		Achhalia	Station trial	2250	1350	1822				371	11.2
		Mean		**1655**	**1210**	**1822**					
2006-2007	TMC MM 1.3	Surat	Station trial		Flood						
		Achhalia	Station trial	1408		1350				NS	25.3
		Mean		**1408**		**1350**					
B (South Guj-II)											
2006-2007	SSVT	Surat	State trial		Flood						
2006-2007	SSVT	Achhalia	State trial	1918	...	1831	...	1503		203	12.7
2007-2008	Pr.Br.02(a)	Surat	AICCIP trial	1900	1083			1074		204	12.0
2008-2009	Pr.Br.03(a)	Surat	AICCIP trial	1940	1573			1094		286	10.5
2009-2010	Pr.Br.04(a)	Surat	AICCIP trial	2591	1892			2052		303	7.4
2010-2011	Pr.Br.04(a)	Surat	AICCIP trial	1834	1543			1617		176	10.0
2009-2010	MLT	Surat	State trial	1953	1487			1672		394	11.5
2010-2011	MLT	Surat	State trial	2270	1556			1370		336	11.4
2011-2012	MLT	Surat	State trial	1125	814				981		
Mean (B)	**1941**	**1421**	**1831**		**1483**	**981**					
No. of trials / (%) increase over checks			[08]	**36.6**	**6.0**	**...**	**30.9**	**97.9**			
C (South Sau-VII)											
2006-2007	SSVT	Junagadh	State trial	1451	...	...	2009	787		355	15.8
2007-2008	Pr.Br.02(a)		AICCIP trial	1821	...	...	1628	748		362	17.0
2008-2009	Pr.Br.03(a)		AICCIP trial	1182	...	...	1780	888		290	13.1
2009-2010	Pr.Br.04(a)		AICCIP trial	1307	...	...	1415	1009		322	11.8

2010-2011 Pr.Br.04(a)		AICCIP trial	2202	...	...	1980	1313		399	12.0
2009-2010 MLT		State trial	1395	...	...	1389	658		410	17.7
2010-2011 MLT		State trial	1906	...	...	1844	1520		478	13.5
2011-2012 MLT		State trial	2618	...	...	2023		2312	414	12.9
Mean (C) 1735	**...**	**...**	**1759**	**989**	**2312**					
No. of trials / (%) increase over checks		[8]	...	...	**-1.3**	**75.5**	**-24.9**			
D (North Guj-IV)										
2004-2005 TMC MM 1.3	Thasra	Station trial	2986	...	1898	**...**	**...**		304	10.9
2005-2006 TMC MM 1.3	Thasra	Station trial	1628	999	1115				265	12.8
2006-2007 SSVT	Talod	State trial	2379	1369	...	...	718		420	18.1
2008-2009 Pr.Br.03(a)		AICCIP trial	3088	...	2068	...	2112		892	14.6
2009-2010 Pr.Br.04(a)		AICCIP trial	2527	...	2494	...	2412		386	17.2
2010-2011 Pr.Br.04(a)		AICCIP trial	3218	...	2658	...	1718		475	8.7
2009-2010 MLT		State trial	1858	...	1685	...	1074		561	13.0
2010-2011 MLT		State trial	3185	...	2265	...	1750		479	13.1
2011-2012 MLT		State trial	2342	...	2275	...		2117	431	12.8
Mean (D) 2579	**1184**	**2057**	**...**	**1631**	**2117**					
No. of trials / (%) increase over checks		[9]	**117.8**	**25.4**	...	**58.2**	**21.8**			
Mean (A to D) (Irrigated)	**2029**	**1326**	**1957**	**1759**	**1354**	**1803**				
No. of trials	**[30]**	**[12]**	**[12]**	**[8]**	**[20]**	**[3]**				
per cent increase/decrease over checks			**53.1**	**3.7**	**15.4**	**49.8**	**12.5**			
E (South Guj-II)										
2004-2005 TMC MM 1.3	Bharuch	Station trial	1324	...	1385	...	...	...	NS	6.3
2005-2006 TMC MM 1.3	Bharuch	Station trial	1367	932	1323	...	...	...	211	13.6
2006-2007 SSVT	Bharuch	State trial	1931	...	1477	...	855		241	19.4
2007-2008 02(b)	Bharuch	AICCIP trial	844		...		926		86	10.0
2008-2009 03(b)	Bharuch	AICCIP trial	2163		1804		1581		230	13.1
2009-2010 03(b)	Bharuch	AICCIP trial	1665		1157		1086		113	9.2
2010-2011 04 (b)	Bharuch	AICCIP trial	1414		1468		1174		149	11.0
2009-2010 MLT	Bharuch	State trial	1132		1309		1190		181	9.8
2010-2011 MLT	Bharuch	State trial	883		876		824		160	12.6
2011-2012 MLT	Bharuch	State trial	1089		1314			959	261	15.7

Mean (South Guj-II)	**1381**	**932**	**1346**		**1091**	**959**				
No. of trials (%) increase over checks		[10]	**48.2**	**2.6**	**...**	**26.6**	**44.0**			
F (Bhal and Coastal-VIII)										
2004-2005 TMC MM 1.3	Dhandhuka	Station trial	1570		1732				NS	20.5
2005-2006 TMC MM 1.3	Dhandhuka	Station trial	1312	1080	...	...	...	...	321	12.2
Mean (Bhal and Coastal-VIII)		**1441**	**1080**	**1732**						
No. of trials (%) increase over checks		[2]	**33.4**	**-37.6**						
G (North West Guj-V)										
2010-2011 MLT	Targhadia	State trial	1381	1605			1010			
MLT	Viramgam	State trial	1055	607	...	...	836		NS	33.5
2011-2012 MLT	Targhadia	State trial	1073			795		806	219	19.1
Mean (North West Guj-V)	**1218**	**1106**		**795**	**923**	**806**				
No. of trials (%) increase over checks		**[3]**	**10.1**		**53.2**	**32.0**	**51.1**			
Mean E to G (Rainfed)	**1443**	**1056**	**1385**	**795**	**1054**	**883**				
No. of trials	[15]	[4]	[10]	[1]	[09]	**[2]**				
per cent increase / decrease over check			**36.7**	**4.2**	**53.2**	**37.0**	**63.5**			
Overall Mean (A to G)	**1834**	**1258**	**1697**	**1651**	**1261**	**1435**				
No. of trials	[45]	[16]	22]	[09]	[29]	[05]				
per cent increase / decrease over check			**45.7**	**8.1**	**11.0**	**45.4**	**27.8**			

Table 3. Performance of GISV-218 in comparison to checks against insect pests in various trials (2007-08 to 2010-11)

Year	Trial	Variety	Sucking pest / 3 leaves				Boll worm damage (%)		
			Aphids	Jassids	Thrips	Whitefly	Squares	Open bolls	Locules
Pest reactions in GISV-218								**Location: Surat**	
2007-2008		Br.02(a)	GISV-218	_	3.0(1.8)	—	8.0(2.8)	—	23.7(24.9)
19.5(26.4)									
		G. Cot-10 (C)	_	4.7(2.3)	—	6.8(2.7)	—	32.5(34.7)	22.8(28.3)
		LRA-5166 (C)	_	3.0(1.9)	—	8.6(3.0)	—	54.7(047.8	30.9(33.8)
2008-2009		Br.03(a)	GISV-218	19.20(4.44)	1.30(1.34)	7.30(2.79)	-	10.32(18.71)	29.59(32.91)
24.77(29.77)									
		G. Cot-10 (C)	52.00(7.25)	4.50(2.23)	7.90(2.68)	-	9.16(17.47)	34.58(35.97)	25.64(30.30)
		LRA-5166 (C)	28.90(5.42)	3.80(2.07)	15.80(4.04)	-	11.46(19.73)	25.40(30.24)	19.50(26.18)
2009-2010	Br.04(a)	GISV-218	39.9(6.4)	6.3(2.6)	31.6(5.7)	35.1(6.00	-	32.1(34.51)	19.9(26.5)
		G. Cot-10 (C)	46.7(6.9)	10.0(3.2)	33.1(5.8)	53.3(7.3)	-	34.4(35.9)	21.2(27.4)
		LRA-5166 (C)	8.8(3.0)	15.6(4.0)	43.0(6.6)	38.7(6.3)	-	47.5(43.6)	29.3(32.7)
2010-2011	Br.04(a)	GISV-218	—	5.4(2.4)	-	4.9(2.3)	-	29.2(32.6)	17.9(24.9)
		G. Cot-10 (C)	—	5.5(2.5)	-	4.8(2.3)	-	53.5()47.0	37.7(37.9)
		LRA-5166 (C)	—	5.6(2.5)	-	6.2(2.6)	-	57.2(43.3)	35.8(30.7)
2009-2010	MLT	GISV-218	1.98(3.60)	-	4.54(20.73)	1.76(2.68)	-		
		G. Cot-10 (C)	2.28(5.20)	-	4.94(24.45)	1.59(2.18)	-		
		LRA-5166 (C)	2.36(6.50)	-	4.61(21.60)	1.69(2.53)	-		
2010-2011	MLT	GISV-218	12.44(3.30)	-	9.73(3.11)	2.60(1.74)			
		G. Cot-20 (C)	12.72(3.37)		10.64(3.23)	3.14(1.90)			
		LRA-5166 (C)	-	-	-	-			
Pest reactions in GISV-218									**Location: Junagadh**
2008-2009	Br.03(a)	GISV-218	75.4(8.7)	7.9(2.8)	-	-	—	12.64(20.76)	10.96(19.32)
		G. Cot-10 (C)	86.11(9.3)	8.9(3.0)	-	-	—	11.71(19.96)	10.45(18.85)
		LRA-5166 (C)	58.8(7.7)	12.4(3.5)	-	-	—	12.18(20.43)	10.34(18.75)
2009-2010	Br.04(a)	GISV-218	62.6(7.9)	10.7(3.3)	52.1(7.2)	19.9(4.51)	—	20.0(26.5)	14.0(21.9)
		G. Cot-10 (C)	60.0(7.7)	9.8(3.1)	42.4(6.5)	23.7(4.9)	—	22.5(28.3)	16.0(23.6)
		LRA-5166 (C)	69.1(8.3)	11.6(3.4)	56.1(7.5)	23.1(4.8)	—	17.3(24.6)	12.5(20.7)
2010-2011	Br.04(a)	GISV-218	-	10.8(3.3)	-	21.1(4.6)	—	9.3(17.7)	3.4(10.6)
		G. Cot-10 (C)	-	7.8(2.8)	-	20.7(4.6)	—	6.7(15.0)	3.5(10.7)
		LRA-5166 (C)	-	10.3(3.2)	-	26.1(5.1)	—	11.2(19.2)	4.2(11.9)
Pest reactions in GISV-218									**Location: Bharuch**
2009-2010	MLT	GISV-218	4.24(18.00)	2.0(4.0)	—	3.74(14.00)	32.33(14.0)	39.05(39.68)	22.03(14.07)
		G. Cot-10 (C)	4.47(20.0)	2.0(4.0)	—	4.18(17.50)	21.03(12.88)	20.73(12.53)	16.80(8.36)
		LRA-5166 (C)	3.24(10.50)	3.24(5.0)		3.00(9.0)	23.32(15.68)	25.61(18.68)	19.78(11.45)
2010-2011	04(b)	GISV-218	3.24(10.5)	2.55(6.50)		3.24(10.50	23.57(15.99)	39.41(38.88)	6.10(14.30)
		G. Cot-16(C)	3.39(11.50)	2.55(6.50)		3.81(14.50)	26.42(20.80)	23.17(28.77)	3.61(10.95)
		LRA-5166 (C)	3.32(11.0)	1.58(2.50)		3.39(11.50)	22.79(15.00)	32.67(34.86)	5.12(13.08)

Table 4. Screening of promising entry at MCRS, NAU, Surat under advance screening trial

Sr. No.	Entries	JIG	Number of Jasids/ plant * (DAS) 30		45		60		75		90		105		120		**Mean**		Seed cotton yield (kg/ha)
			OV	TV	OV	TV	OV	TV	OV	TV	OV	TV	OV	TV	OV	TV	**OV**	**TV**	
	2009-2010																		
9	GISV 218	1	0.80	1.14	1.20	1.29	2.70	1.79	2.20	1.64	4.20	2.16	0.10	3.10	6.60	2.66	**2.54**	**1.97**	2076
12	DHY 286 (Ch-R)	1	0.60	1.01	0.70	1.09	4.70	2.28	3.90	2.09	3.00	1.87	6.30	2.60	6.80	2.69	**3.71**	**1.94**	1560
13	DCH 32 (Ch-S)	4	2.50	1.73	3.40	1.97	8.00	2.92	9.20	3.11	9.60	3.18	14.50	3.87	11.50	3.46	**8.39**	**2.89**	406
	C.D. (p=0.05)			0.31		0.4		0.33		0.31		0.18		0.26		0.29		0.32	476
	2010-2011																		
4	GISV 218	1	2.00	1.57	1.13	1.28	0.33	0.89	3.60	2.01	0.07	0.75	1.07	1.25	1.73	1.47	**1.42**	**1.32**	951
7	DHY 286 (Ch-R)	1	3.00	1.86	1.13	1.24	0.67	1.04	2.73	1.79	0.07	0.75	1.13	1.28	1.60	1.42	**1.48**	**1.34**	637
8	DCH 32 (Ch-S)	4	4.93	2.31	4.33	2.20	5.60	2.47	9.67	3.19	2.40	1.70	9.67	3.06	8.07	2.91	**6.38**	**2.55**	311
	C.D. (p=0.05)			NS		0.44		0.26		0.48		0.18		0.76		0.67		0.19	387
	2011-2012																		
4	GISV 218	1	0.60	1.02	0.73	1.11	0.67	1.05	1.67	1.46	0.40	0.94	0.93	1.20	1.40	1.38	**0.91**	**1.17**	1010
11	DHY 286(JR)	1	0.47	0.97	0.40	0.94	1.40	1.35	1.47	1.40	0.27	0.87	0.33	0.91	1.40	1.38	**0.82**	**1.12**	589
12	DCH 32(JS)	4	5.00	2.34	5.93	2.53	6.13	2.57	13.40	3.72	10.80	3.35	6.40	2.62	2.33	1.68	**7.14**	**2.69**	365
	C D (p=0.05)			0.28		0.32		0.39		0.5		0.26		0.25		0.16		0.12	463
	2012-2013																		
5	GISV 218	1	1.33	1.35	1.33	1.35	0.87	1.16	2.73	1.80	0.53	0.99	1.87	1.54	3.67	2.03	**1.76**	**1.46**	3535
11	DHY 286(JR)	1	0.87	1.17	1.13	1.27	1.27	1.33	2.27	1.66	1.00	1.22	1.93	1.56	1.93	1.55	**1.49**	**1.39**	1928
12	DCH 32(JS)	4	6.53	2.48	8.33	2.95	6.40	2.63	7.13	2.76	8.73	3.00	9.87	3.22	17.20	4.20	**9.17**	**3.03**	603
	C.D. (p=0.05)			0.58		0.27		0.24		0.27		0.50		0.27		0.68		0.27	1190

No. of Jassids/3 leaves, JIG= Jassid Injury Grade

Grade I: Entire foliage free from crinkling or curling with no yellowing,

Grade II: Crinkling and curling of few leaves in the lower portion of plant+ marginal yellowing of leaves,

Grade III: crinkling and curling of leaves almost all over the plant. Plant growth hampered ,

Grade IV: Extreme curling, crinkling, yellowing, bronzing and drying of leaves *

Table 6, Other sucking pests in promising entry at MCRS, NAU, Surat (2009-2010 to 2012-2013)

Sr. No.	Entries	Av.No. of sucking pests and predators/ plant *									
		Aphid		Thrips		Whitefly		LBB		Spider	
		OV	TV	OV	TV	OV	TV	OV	TV	OV	TV
	2009-2010										
9	GISV 218	3.60	1.98	20.73	4.54	2.68	1.76	1.17	1.29	0.80	1.13
12	DHY 286 (Ch-R)	4.90	1.84	20.10	4.50	3.18	1.85	0.50	0.97	0.60	1.05
13	DCH 32 (Ch-S)	3.83	2.18	19.33	4.36	3.10	1.89	0.83	1.13	1.00	1.22
	C.D. (p=0.05)		NS		NS		NS		NS		0.18
	2010-2011										
4	GISV 218	12.44	3.30	9.73	3.11	2.60	1.74	0.53	0.99	1.10	1.26
7	DHY 286 (Ch-R)	6.83	2.37	8.19	2.84	9.37	3.09	0.27	0.87	0.47	0.97
8	DCH 32 (Ch-S)	2.09	1.43	5.44	2.36	2.00	1.51	0.22	0.84	0.30	0.89
	C.D. (p=0.05)		0.78		0.46		0.8		0.14		0.21
	2011-2012										
4	GISV 218	10.37	3.02	5.93	2.51	1.00	1.22			0.87	1.14
7	DHY 286 (Ch-R)	2.27	1.36	8.37	2.90	2.73	1.79			0.50	0.98
8	DCH 32 (Ch-S)	1.10	1.20	3.30	1.83	1.47	1.40			1.00	1.20
	C.D. (p=0.05)		0.86		0.63		0.27			0.14	
	2012-2013										
4	GISV 218			12.56	3.63	4.07	2.12			0.47	0.97
7	DHY 286 (Ch-R)			11.76	3.11	6.93	2.71			0.33	0.91
8	DCH 32 (Ch-S)			8.07	2.49	0.33	0.88			0.00	0.71
	C.D. (p=0.05)				NS		0.57				0.16

OV- Original mean values TV- Transfoemed values (Square root X+0.5 transformation)

DAS- days after sowimg

Data on Thrips and whitefly are population/ plant whereas mealy bug is mean grade of infestation.

Table 7. Leaf anatomical features of tested genotypes against leaf hopper resistance/tolerance

Sl.	Characters	Entries				
		DCH 32	RAH 61	GISV 218	ARBH 813	RAH 216
1.	Distance of phloem from lower epidermis (μ)	214.76	207.49	**215.78**	241.25	208.70
2.	Palisade cell structure compact / semi-compact	Semi - compact	Compact	**Compact**	Semi compact	Semi compact
3.	Palisade cell height (μ)	36.98	33.70	**51.33**	35.83	34.62
4.	Thickness of phloem (μ)	59.13	55.32	**78.94**	76.63	92.44
5.	Leaf thickness (μ)	96.57	95.93	**110.31**	88.21	94.65
6.	Trichomes / sq.cm	17.0	27.4	**169.6**	86.6	142.4

Source: Principal Investigator (Cotton Entomology), ICAR-CICR, Coimabatore, AICRP on Cotton Entomology, Salient Findings (2011-12).

218 compared to susceptible variety imparted resistance to leaf hopper (Anon., 2011). The images given in the **Plate I to V** clearly revealed the trichome density, compact structure of leaves and the palisade and phloem distance which hindered the feeding and oviposition of

Table 5. Basis of resistance against jasids in different entries at Surat (2009-2011)

Sr. No.	Entries	Jasids (Mean of 7 observation) / plant)	Morphological parameter No (trichomes)./ 0.5 cm length midrib	No.(trichomes) / 0.25 sq cm area of leaf lamina)
	2009-2010			
9	GISV 218	2.54	120	148
12	DHY 286 (Ch-R)	3.71	133	153
13	DCH 32 (Ch-S)	8.39	45	45
	r’ Value		-0.6487*	-0.5859*
	2010-2011			
4	GISV 218	1.42	117	152
7	DHY 286 (Ch-R)	1.48	138	151
8	DCH 32 (Ch-S)	6.38	42	45
	r’ Value		.-0.7180*	.-0.7121*
Sr. No.	Entries		Biochemical Parameters	
		Tannin content (%)	Phenol content (%)	Total Sugar (%)
	2009-2010			
9	GISV 218	0.07	1.54	1.00
12	DHY 286 (Ch-R)	0.07	1.35	1.39
13	DCH 32 (Ch-S)	0.02	1.76	1.63
	r’ Value	-0.4477	-0.1365	0.407

Table 3, 4, 5 and 6 which showed minimum population of leaf hopper and its injury grade during different year of testing at different locations.

Testing, screening, evaluation for leaf hopper résistance or tolerance and mechanism of resistance/tolerance to leafhopper : The preliminary testing of the different genotypes against sucking pests were carried out for three years at different locations including Main Cotton Research Station, NAU, Surat as well as other centres of central and south zones and 11 genotypes were short listed as tolerant against leaf hopper at NAU, Surat. These short listed genotypes were screened under advance large scale trials of screening and evaluation with artificial infester rows of okra as well as screening under artificial pressure of leaf hoppers in caged condition, Maisuria *et al.,* (2011) identified GISV 218, GSHV 152, GSHV 97/59, GSHV 155 and GJHV 448 as tolerant to leaf hopper in comparison to the resistant check, DHY 286. Further, they found lowest injury grade of leaf hopper to these identified genotypes and the trichome density on leaf lamina and veins attributed to resistance against leaf hopper. Further, under large scale advance field trials, GISV 218, RAH 61, RAH 213 and ARBH 813 were evaluated in comparison to susceptible check, DCH 32 at ICAR-CICR, Coimbatore and Nagpur during 2009-2013 (Table 7), GISV 218 stood as at top against leaf hopper based on large scale field testing, cage studies and leaf anatomical structures. They revealed that the leaf anatomy possessing more height of the palisade layer, compact structure of palisade cells and more distance of phloem from lower epidermis in GISV

Table 8. Reaction to major diseases of GISV 218

Sr. No.	Name of Disease	2008-2009	2009-2010	2010-2011	2010-2011	Av.Grade	Reaction
1.	Alterneria Leaf Spot (Junagadh)	2	2	3	-	2	MR
	Alterneria Leaf Spot (Bharuch)	-	0	0	0	0	DF
	Average	**1**	**1**	**1.5**	**0**	**1**	**R**
2.	Bacterial blight (Surat)	1	4	4	-	3	MS
	Bacterial blight (Junagadh)	1	0	0	-	0	DF
	Bacterial blight (Bharuch)	-	1	1	1	1	R
	Average	**1**	**2**	**2**	**0**	**1**	**R**
3.	Grey mildew (Junagadh)	2	3	2	-	2	MR

Where,

0= Disease Free (DF); 1= Resistant (R); 2= Moderately Resistant (MR); 3= Moderately Susceptible (MS) ; 4= Susceptible (S).

Table 9. The morphological characters of GISV 218 and Its Parents

A. Traits of GISV 218

a.	Plant height (cm)	:	155 cm
b.	Range	:	145-165 cm
c.	Distinguishing morphological characters		
i.	Foliage	:	Dark Green
ii.	Habit	:	Semi open growth habit – Monopodia 3 to 5 - Sympodia 22 to 28
iii.	Leaf character and colour	:	Normal leaves with nectary and three to four lobes
iv.	Flower	:	Pale Yellow and Stigma embedded
v.	Pollen	:	Creamy White colour
vi.	Petal spot	:	Absent
vii.	Boll characters	:	Round shape with pointed
d.	Maturity (range in number of days) Seedling/transplanting to flowering Seed to seed	:	Sowing to flowering: 65-70 days Sowing to boll opening: 120-130 days Sowing to pulling: 160-180 days
e.	Maturity group	:	early, medium and late: Medium late (160-180 days–weather such classification exist)

B. Traits of parents

Sr.No.	**Characters**	**G.Cot-10**	**GISV-140**
Distinguished morphological characters			
1	Plant height (cm)	120-130	140-160
2	Habit	Semi open	Open growth, monopodial
3	Foliage	Dark green	Dark green
4	Flower	Pale Yellow	Creamy white
5	Boll	Round	Round big and pointed
6	Maturity Days	140-160 days	170-190 days
Quality Traits			
7	G.P. (%)	34.8	35.7
8	S.I.	8.8	9.4
9	L.I.	5.2	5.3
10	2.5 per cent span length (mm)	25.2	25.6
11	Fibre fineness (mv)	4.4	4.3
12	Fibre Strength (g/text)	22.5	22.4
13	LUR (%)	50.8	49.0

leaf hopper.

Disease reaction : GISV 218 was observed resistant to alternaria moderately resistant to grey mild dew and resistant to bacterial blight (Table 8).

Agronomy features : GISV 218 was evaluated for its agronomic performance and gave optimum seed cotton yield with 90 Kg N/ ha at 90:45 cm spacing. The comparison cost of cultivation of GISV 218 with check in irrigated and rainfed condition revealed less input cost and profit of Rs.6617/- and Rs.5165/- respectively (Table 9).

Characteristics/Traits of the GISV 218: The morphological traits of the developed GISV 218 and its parents are given in Table 9.

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REFERENCES

Maisuria I. M., Patel C. J., Desai H. R., Solanki B. G. and Kumar V. 2011. Performance of promising G. hirsutum genotypes on incidence of leaf hopper, *Amarasca biguttula biguttula* (Ishida) and its basis of tolerance. In: *World Cotton Research Conference on Technology for Prosperity)*.

Anonymous 2012. Annual Report of AICCIP of Cotton Entomology (2011-12). All India Co-ordinated Cotton Improvement Project, ICAR-CICR, Coimbatore. Presented in *Group Meeting of AICCIP-Cotton Entomology* by Dr. S. Mohan, Principal Investigator, Cotton Entomology, AICCIP-Cotton Entomology held at TNAU, Coimbatore

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Improved method of retting for quality fibre production of jute

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Abstract : Jute is the very important fibre and cash crop of Dakshin Dinajpur district of West Bengal with an areas of 14,085 ha and producing 1,81,336 bale of fibre. Jute is becoming non-remunerative because of poor quality and lower price. The quality of jute fibre is largely determined by the efficiency of the retting process. The present study envisaged the quality of fibre with improved retting process. With a view to produce quality fibre and increase farmers income a comparative study between conventional and improved retting of jute (*Corchorus olitorius* L.) with a microbial formulation 'CRIJAF SONA' was carried out for two consecutive retting trials in the water during 2016 and 2017. With the introduction of the microbial formulation consisting of three different pectinolytic bacterial strains of *Bacillus pumilus* in the improved method, duration of retting reduced by 5–6 days, fibre recovery increased by 9.5–11.2 per cent and the improvement of fibre quality (colour, lustre, strength) as compared to conventional retting method of jute. The net return of farmers also increased by Rs. 8,980.00/ha over conventional jute retting method. In conventionally retted jute root content is about 16-20 per cent reduced in improved microbial retting method of about 4-5%. Reduced retting duration might be due to higher enzymatic activities in the retting water and uniform retting obtained good quality fibre faced better price in the market. The microbial jute retting technology have the potentiality to meet the demand of quality jute fibre by jute industries and also to increase the net income of resource poor jute farmers with minimum initial input investment.

Key words: Conventional retting, improved microbial retting, jute

Jute (*Corchorus capsularis* and *Corchorus olitorius*) is a natural vegetable fibre under the category of bast fibres like flax, hemp, ramie etc. Jute, an important natural fibre crop occupy second place in economic importance only to cotton and have many important mechanical, thermal and electrical properties (Sinha *et al.*, 2010). Jute, as a commodity, is facing competition on two fronts. India and Bangladesh account for 56 and 30 per cent of the world area and production, respectively (Munshi and Chattoo, 2008). Jute is facing stiff competition from synthetics at the consumer's end, while on the other, from more remunerative crops at the grower's end. Jute is becoming non-remunerative because of poor quality and lower price (Satpathy *et al.*, 2014). The quality of jute fibre is largely determined by the efficiency of the retting process. In retting pectin materials are broken down and the fibres are liberated (Bhattacharyya, 1973-1974). Fibre quality is dependent on retting in different natural conditions and the duration of retting (Chi *et al.*, 1966; Ahmed and Akhter, 2001). Retting is a biological process in which the jute fibres are extracted by decomposing the plants through combined action of water and micro-organisms, mostly bacteria (Ahmed and Akhter, 2001). Retting process determine the quality of fibre like strength, colour, lustre and fibre recovery percentage. Thus with the growing demand of high quality fibre the economic significance of fibre quality is also increasing on which the future of jute will ultimately depend to a great extent (Sinha *et al.*, 2010). But unfortunately the amount of quality fibre is not increasing at the desired level. This is mainly because the farmers after putting all their efforts in cultivating the crop are least bothered or negligent about the post harvest techniques and are using the same age old retting practices without caring about its impact on the fibre quality mainly due to lack of proper knowledge and awareness about its benefit or adequate incentive/financial benefit (Ahmed and Akhter, 2001). Serious attention is increasingly being focused on the increased and sustained production of quality jute fibre, particularly, in the major jute producing countries like India (Das *et al.*, 2017).

Jute constitute very important fibres and cash crops of Dakshin Dinajpur district of West Bengal with an areas of 14,085 ha and producing 1,81,336 bale of fibre. In order to face the dual challenge confronting jute both at consumers' end and at the producers' end, we have to adopted a strategy which consists of agricultural research and development, industrial research and development and market promotion of both traditional and diversified jute products. Accordingly some significant successes have been achieved. Among the developed jute retting techniques, covering jute ret with water hyacinth, ribboning and ribbon- retting techniques (for water scarce areas) etc. are mostly recommended in the jute growing countries. Retting being the most important single factor which dominates the quality of fibre of jute and allied fibre plants it has been felt to be one area where the farmers are to be convinced to adopt useful techniques for upgrading fibre quality (Sharma *et al.*, 1992). With the available technology for producing finer/ higher quality of yarns and fabrics and the scope for increased competitiveness with synthetic substitutes demand for more and higher quality fibre is inevitable. Jute farmers of west bengal are characterised as marginal with small land holding, large family size, and weak financial status. As a result their stock holding and bargaining powers are poor. The primary market remains active for a few months only as the marginal farmers cannot hold on to their produce for a long time (Sinha *et al.*, 2010). Due to lack of knowledge of different grades / grading systems of jute fibres, the jute growers, quite often, are deprived of proper grade wise price for their produce. There exist price differentials for the various grades of jute fibres mainly for secondary and tertiary domestic markets and export markets but not as much in the primary markets.

Considering the importance of retting as single key determining factor for fibre quality, there have been lot of research and development works especially in the major jute producing countries like India (Sinha *et al.*, 2010). But hardly any of these techniques or machines has become popular among the growers or is being practiced in the farmers' level. As such there has not been any useful extension success through acceptance /adoption of those techniques by the jute growers. The microbial retting formulation consists of three pectinolytic bacteria (*Bacillus pumilus)* having high xylanase activity without any cellulase activity (and can ret the jute and mesta within 12 to 15 days with improvement in fibre quality compared to 18–21 days required under convention method of retting (Das *et al.*, 2017). By using this microbial formulation farmers can earn higher income by selling their jute and mesta fibre in the market because of improvement in the fibre quality. In stagnant water retting, when there is less rainfall during retting period, jute farmers are compelled to ret their jute in the muddy water, resulting very low quality fibre which face a very low price in the market. Under such situation, this formulation can be used for quick retting of jute with improvement in fibre quality. The same water can be used for 2-3 times retting for quality fibre production in stagnant water. With a view to produce quality fibre and increase farmers income a comparative study between conventional and improved retting of jute (*Corchorus olitorius* L.) with a microbial formulation 'CRIJAF SONA' was carried out for two consecutive retting trials in the water during 2016 and 2017.

MATERIALS AND METHODS

The field experiment was conducted at the Instructional Farm of Dakshin Dinajpur Krishi Vigyan Kendra, Uttar Banga Krishi Viswavidyalaya, Majhian, Patiram, Dakshin Dinajpur, west bengal during the pre *kharif* season of 2016 and 2017. The farm is situated under Old Alluvial Zone at 26^0 35'15''and 25^0 10'55''N latitude and 89^0 0' 30'' to 87^0 48'30'' E longitude at an elevation of 15 m above mean sea level. The average annual rainfall is 1690 mm with about 66 rainy days. The soils are light, medium and heavy in texture, upland being lighter and medium to lowlands being heavier. The characteristic feature of this zone is inundation caused by sudden heavy rainfall due to lack of proper drainage facilities. The soils are low in nitrogen, phosphorus and potassium content and the fertilizer consumption (N, P, K) is 89.88 kg/ ha.

Line sowing of jute seed (variety JRO 524) is done through seed drill on April 20 and April 25 in the year 2016 and 2017 respectively with a seed rate of 5 kg/ha. FYM was applied @ 5 t/ ha and chemical fertiliser was applied @ 40:20:40 kg NPK/ha in the form of urea, single super phosphate and muriate of potash. Crops are harvested at the age of 120 DAS in both the year. Harvested crops are then taken for retting through microbial formulation containing microbial retting formulation consists of three pectinolytic bacteria (*Bacillus pumilus)* having high xylanase activity without any cellulase activity to obtain good results. Yield of jute fibres, net return, retting duration and jute fibre quality (fibre recovery %, root content in fibre etc.) were recorded at harvest.

Conventional retting : Under conventional retting, harvested jute bundles after defoliation were kept in clean stagnant water with wooden jak materials. Banana plants and mud were used as covering materials which degrades the quality of fibre. After the completion of 'Jak', fibres ware extracted manually by single plant extraction method, washed in water and sundried.

Improved retting with microbial formulation : In the improved retting, at the time of giving 'Jak' with defoliated jute bundles, microbial formulation (consists of three pectinolytic bacteria *i.e. Bacillus pumilus*) was applied in each layer on the jute bundles. Other processes after completion of retting like extraction of fibre, washing and sun drying of fibre were same as followed in the conventional method. In the second retting at the same retting tank, the microbial formulations was used half of the amount applied for first retting and for 3rd retting, no microbial formulation was used.

RESULTS AND DISCUSSION

Jute grown under improved retting with microbial formulation 'CRIJAF SONA' recorded comparatively higher fibre yield (2.8t/ha and 3.1 t/ha for year 2016 and 2017, respectively) as compared to conventional method of retting (2.3t/ha and 2.5 t/ha for year 2016 and 2017, respectively) (Table 1). The increase in yield under retting with microbial mixture might be due to presence of highly effective microbes which can extract the fibre by dissolving the cementing agents present in jute fibre very efficiently (Majumdar *et al.*, ; Das *et al.*, 2017). The net return was also recorded to increase under microbial formulations (Rs. 8790 and 9170 enhanced due to microbial formulation in 2016 and 2017, respectively). It might be due to additional recovery of fibre and higher market price for quality fibre for microbial inoculated fibre as compared to conventionally retted fibre (Majumdar and Satpathy 2014; Das *et al.*, 2017).

With the introduction of the microbial formulation, duration of retting reduced by 5–6 days (Table 2). Similar observations were also recorded by Das *et al.*, 2017. The microbial formulation containing different kinds of bacteria speed up the the retting process by secreting some important enzymes like polygalacturonase, pectin lyase and xylanase which degrades the cementing agents present within the jute plants like pectin and xylan. Whereas under conventional retting, relatively less amount of retting efficient microbes present and subsequently need more time in retting. The risk of non-retting of jute and quality degradation under stagnant water retting can be overcome by using this microbial formulation (Majumdar *et al.*, 2012; Das *et al.*, 2017). In conventionally retted jute root content is about 13-17.5 per cent over the years of 2016 and 2017, whereas under improved method of microbial

Table 1. Fibre yield and return from different retting methods of jute

Treatments	Fibre yield (t/ha)		Total return (Rs. /ha)	
	2016	2017	2016	2017
Conventionally retting	2.3	2.5	61900	63050
Improved retting with microbial formulation 'CRIJAF SONA'	2.8	3.1	69690	72050
Increase over conventional method (%)	21.7	24.0	12.6	14.3

retting, the root content reduced to 4.2 to 5.7 per cent only. Reduced root content in jute fibre due to improved method of retting over conventional method was also reported by several workers (Majumdar *et al.*, 2014; Das *et al.*, 2015; Das *et al.*, 2017). Improved method of retting in jute produce golden-yellowish and bright fibre as compared to greyish and dull fibre in conventional retting method (Table 2). The use of banana plants and mud as jak materials for retting may led to the production of inferior quality of fibre as against superior quality obtained under microbial inoculated retting (Mukherjee *et al.* 1990).

Table 2. Retting duration and root content in fibre under different method of jute retting

Treatments	Duration of retting (days)		Root content (%)		Colour	Lustre
	2016	2017	2016	2017		
Conventional retting	15-16	14-16	14.5-17.5	13.0-17 .2	Golden yellow	Bright
Improved retting with microbial formulation 'CRIJAF SONA'	20-21	19-20	4.2 – 4.7	4.8 – 5.7	Gyeish yellow	Dull
Reduction in retting duration (days)/ root content (%)	5-6	4-5	10.3-12.8	7.2-11.5	-	-

CONCLUSION

Microbial retting method will reduce retting duration by 6-8 days and increase jute fibre yield, improve colour (golden yellow) thereby improve the fibre grade at least by 1-2 grades better which will ultimately fetch higher price and increase profitability from jute farming. The microbial jute retting technology have the potentiality to meet the demand of quality jute fibre by jute industries and also to increase the net income of resource poor jute farmers with minimum initial input investment. The farmers were very eager to get more packets of CRIJAF Sona for use in their other jute retting ponds of Dakshin Dinajpur distict.

REFERENCES

Ahmed, Z., Akhter, F. 2001. Jute retting: An overview. Online *J. Biol. Sci.* **1** : 685–88.

Basak, M.K., Ghosh, S.K., Jain, A.K. and Ghosh A. 1993. Efficiency of microbes in softening of jute root cuttings. *The Indian Textile J.*, **43** : 74-79.

Bhattacharyya, S.K. 1973-74. Retting of jute-key process that needs more attention. *Jute Bull.*, 194-98.

Chi, C.Y., Sun, I.M. and Wang, T.F. 1966. Jute in Taiwan, Rep. Taiwan *Fibre Crop. Exp. Station Bul* **No. 27** : 1-11.

Das, S., Majumdar, B., Saha, A.R. 2015. Biodegradation of plant pectin and hemicelluloses with three novel *Bacillus pumilus* strains and their combined application for quality jute fibre production. *Agric Res* **4** : 354–64.

Das, S., Majumdar, B., Saha, A.R., Sarkar, S., Jha, S.K., Sarkar, S.K., Saha, R. 2017. Comparative Study of Conventional and

Improved Retting of Jute with Microbial Formulation Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci. (2017). https://doi.org/10.1007/s40011-017-0872-x

Majumdar, B., Das, S., Bhadra, A., Saha, A.R., Sarkar, S., Kundu, D.K. 2012. Large scale demonstration of improved retting technology. *JAF News* **10** : 11.

Majumdar, B., Sarkar, S., Biswas, D., Saha, A.R., Jha, S.K. 2014. Impact of field demonstrations of improved microbial jute retting technology using CRIJAF SONA. *JAF News* **12** : 24–25.

Majumdar, B., Satpathy, S. 2014. Improved retting technology of jute for quality fibre production. *Ind. Farm.* **64** : 18–20

Mukherjee, M.K., Halder, G., Ghosh, S., Dua, D.B. 1960. Retting of jute: X. Influence of covering material on the colour of foibre and the retting period under Assam conditions. *Proc Ind Sci Cong* **III** : 541.

Munshi, T.K. and Chattoo, B.B. Microb Ecol 2008. 56 : 270–78

Satpathy, S., Selvaraj, K., Gotyal, B.S., Biswas, C., Gawande, S.P., Sarkar, S.K., De, R.K., Tripathi, A.N., Ramesh Babu, V., Mandal, K., Meena, P. 2014. Problems and prospects of pest management in jute and allied fibre crops. In: Invited lecture and book of abstracts of *international conference on natural fibres* (theme: jute & allied fibres) held at Kolkata from 1–3 Aug, pp 30–36

Sharma, H.S.S., Lefevre, J., Boucaud, J. 1992. Role of microbial enzymes during retting and their effect on fibre characteristics. In: Sharma HSS, Van Sumere SF (eds) *The Biology and Processing of Flax.* M Publications, Belfast, Northern Ireland, pp 199–212.

Sinha, M.K., Ramasubramanian, T., Palit, P. 2010. Jute and allied fibres research: present and future. In: Palit P, Sinha M, Meshram JH, Mitra S, Laha SK, Saha AR, Mahapatra BS (eds) *Jute and allied fibres, production, utilization and marketing.* Indian Fibre Society, Eastern Region, ICAR-Central Research Institute for Jute and Allied Fibres, Barrackpore, Kolkata, pp 27–34.

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Genetic improvement in American cotton (*Gossypium hirsutum* L.) through heterosis breeding and combining ability studies

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ABSTRACT : A study was conducted in American cotton (*Gossypium hirsutum* L.) by adopting line x tester mating design involving 4 females and 16 males to estimate the magnitude of heterosis and to elucidate the nature and magnitude of gene action involved in the inheritance of seed cotton yield and its related characters. Sixty four cross combinations were developed and evaluated against one standard check HHH 223 at CCS Haryana Agricultural University, Cotton Research Station, Sirsa. The analysis of variance indicated the presence of variability among hybrids and their parents. Heterosis for seed cotton yield ranged from -30.37 per cent to 31.74 per cent and the highest were recorded for the hybrid H1117 x SAHANE. Heterosis for yield attributing characters *viz.*, bolls/plant in H1226 x H841 (32.5%), for boll weight in HS 182 x P12 (24.44%), for plant height in H 1117 x L759 (11.19%), for monopodia in H1117 x okra (45.9%), for number of sympodia in H1117x MC86 (21.7%), for seed index in HS182 x H1180 (29.7%) for ginning percentage in H1226 x H841 (7.85%) and lint index in cross HS182 x H1180 (34.44%) were recorded.

Combining ability analysis revealed that the parents namely, H655C, EC543423, H841and HS30 among males and H1117 and HS182 among females were good combiners for seed cotton yield and number of bolls. For boll weight H1098 and P12, for plant height PK 54, for number of monopodia H655C, MC 86 for number of sympodia and ginning percentage, for seed index P12 and H1180 for lint index were found to be best general combiners. Out of 64 crosses significant SCA for seed cotton yield was recorded by eight hybrids only. Highest SCA was recorded for the hybrids H1117x Sahane followed by H1098 x F2035. Study also revealed good scope for commercial exploitation of heterosis as well as isolation of pure lines among the progenies of other heterotic F_1 hybrids.

Key words : Gene action, Combining ability, *Gossypium hirsutum*, cotton, heterosis, line x tester, seed cotton yield

Cotton is one of the most important cash crops in India. On account of its agricultural as well as industrial importance, it is also called as "White Gold". In India, cotton is grown on about 12 million hectares, which represents 27 per cent of the world cotton area. The average cotton productivity of cotton in India is about 482 kg/ha which is 64 per cent of world average of 754 kg/ha (Anonymous 2017). Millions of people depend on cotton cultivation trade, transportation, ginning and processing for their livelihood. Therefore, there is a need to improve the productivity of cotton crop by developing a high yielding adaptable cotton variety or hybrid.

The Line × Tester (L x T) analysis is one of the simplest and efficient methods of evaluating large number of inbreds/parents for their combining ability and moreover provides information regarding genetic mechanisms controlling polygenic traits to produce commercially viable hybrids. A good tester is a genotype that combines the following attributes: large variation between testcrosses; positive combining ability; high and significant correlation with average of the testers used and has acceptable per se performance (Castellanos *et al.,*1998). The success of any hybridization program depends on the ability of the parents (lines and testers) having greater potential in the hybridization to yield desirable segregants/ recombinants.

The phenomenon of heterosis of F_1 hybrids can also reflect SCA and GCA of parental lines. Heterotic studies can also provide the basis for exploitation of valuable hybrid combinations and their commercial utilization in future breeding programs

Heterosis is the superiority of the hybrid over the mid-parent or better parent values. It is the allelic or non allelic interaction of genes under the influence of particular environment. Heterosis has been observed in many crop species and has been the objective of considerable importance as mean of increasing productivity of crop plants. It is now well established fact that heterosis does occur with proper combination of parents. Cotton is highly amenable for heterosis breeding and commercial exploitation of heterosis has achieved a spectacular success in India. Therefore the present study was undertaken to find out the extent of useful heterosis over the check hybrid HHH 223 for seed cotton yield and its component traits in 64 hybrids obtained from 4 x 16 line x tester mating fashion involving genetically diverse parents.

MATERIALS AND METHODS

The experimental material consisted of 64 American cotton hybrids developed on four females *viz.*, H 1117, H 1098, H 1226 and HS 182 using 10 males H 655C, Okra, H 841, JP 8, F 1980, GBHV 148, Sahane, MC 86, F 2035, L 759, PK 54, LH 1995, EC 543243, P 12, HS 30 and H 1180 crossed in line x tester fashion during 2012-2013 to generate a total of 64 hybrids. These 64 hybrids along with one check hybrid HHH 223 were grown in a Randomized Block Design (RBD) with three replications and a spacing of 100 x 45 cm between row to row and plant to plant respectively during 2013-2014. Five random plants were selected to record the data on seed cotton yield/plant, bolls/plant, boll weight, monopods, sympods, seed index ginning percentage and lint index. The data were statistically analyzed for estimation of economic heterosis over check hybrid HHH 223 as per standard method suggested by Rai (1978).

RESULTS AND DISCUSSION

The analysis of variance (Table 1) indicated that the mean squares of genotypes for all the characters investigated were significantly different, indicating the pres-ence of variability among hybrids and their parents.

Heterosis estimates over best check for different characters of highest heterotic hybrid combinations is presented in Table 2. The results indicated that the phenomenon of heterosis was observed for all the characters, however, its magnitude varied with the characters. Heterosis for seed cotton yield ranged from -30.37 to 31.74, the highest heterosis was recorded for the hybrid H1117 x Sahane (31.74%) followed by H1117 x EC 543423 (27.85%). Among 64 cross combinations nine crosses recorded significant positive heterosis for seed cotton yield over the check hybrid HHH 223 and other crosses which recorded heterosis of more than 20 per cent are H1117 x MC 86 (25.11%), H 1117 x H 655C (24.66%), HS 182 x HS 30 (21.23%), H 1226 x H 841 (21.23%) and H 1098 x F 2035 (20.32%). Heterosis for seed cotton yield in American cotton was also repoprted by Tuteja *et al.* (2005), Patil *et al* (2011), Savarkar *et al* (2015) , Sharma *et al* (2016) and Lingaraja *et al* (2017).

Table1. Analysis of variance for nine characters in upland cotton

	DF	Bolls/ plant	Boll weight	Seed cotton yield/ plant	Plant height	Ginning outturn	Seed index	Lint index	Monopodia	Sympodia
Replications	2	71.39	0.074	486.3	106.4	0.92	0.08	0.03	0.28	4.76
Treatments	64	191.15*	0.281*	1439.1*	198.9*	3.01*	1.44*	0.44*	4.03*	8.49*
Error	128	41.27	0.054	302.9	60.8	0.67	0.23	0.08	0.48	2.44

Heterosis for SCY was mainly due to high heterosis for boll number and/ or boll weight. Heterosis for boll number ranged from -32.9 to 32.5 per cent and for boll weight range was -18.7 to 24.44 per cent. The hybrids showing highest heterosis for these traits were H 1226 x H 841 (32.5%) and HS 182 x P 12 (24.44%), respectively. Other hybrids showing high heterosis for bolls per plant were H 1117 x Sahane (26.3%), H 1117 x MC 86 (25.6%), H 1117 x H 655C (24.2%), H 1117 x EC 543243 (22.1%) and H 1226 x HS 30 (20%) while for boll weight H 1098 x P 12, H 1117 x Sahane and HS 182 x F 1980 crosses showed highest heterotic value. Similar finding were reported by Basal *et al.,* (2011), Sharma *et al.,* (2016) and Sivia *et al.,* (2017).

In case of plant height, only 2 cross combinations exhibited positive and significant heterosis values but the maximum being in case of H 1117 x L 759 (11.19%) followed by HS182 x HS 30 while for dwarfness hybrids H 1098 x H 841 (-14.99%) and H 1098 (-14.32%) showed negative and significant heterosis values. Heterosis for plant height has also been reported by Sharma *et al.,* (2016) and Sivia *et al.,* (2017).

Nine cross combinations showed positive and significant heterotic values and 16 showed negative significant heterotic values for number of monopods ranging from -77.4 to 45.9 per cent. Maximum heterosis effects were observed for H 1117 x Okra, H 1117 x EC 543243 and HS 182 x MC 86 crosses. For number of sympods, only four cross combinations H 1117 x MC 86 (21.7%), H 1226 x JP 8 showed positive and significant

Table 2: Heterosis of hybrids showing highest heterosis for seed cotton yield and other characters in upland cotton.

	Bolls/ plant	Boll weight	Seed cotton yield/ plant	Gin-ning outturn	Seed index	Lint index	Monopodia	Sympodia	Plant height
H1117 x H655c	24.2*	10.00	24.66*	4.62*	0.0	7.21	6.8	18.4*	7.38
H1117 x Okra	7.4	8.89	6.39	7.30	8.7	21.59*	**45.9***	-7.3	-2.01
H1117 x SAHANE	26.3*	16.11*	**31.74***	2.78	9.6	14.20*	14.3	-11.1	3.36
H1117 x MC 86	25.6*	5.00	25.11*	3.70*	5.9	12.08*	2.3	**21.7***	2.01
H1117 x L 759	3.5	-4.81	2.51	4.62*	-5.0	1.87	30.1	-0.8	**11.19***
H1117 x EC 543423	22.1*	-3.15	27.85*	2.59	7.8	12.05*	39.1*	-12.5	3.13
H 1098 x F 2035	12.7	4.07	20.32*	1.49	2.3	4.59	-22.6	3.1	-1.57
H 1226 x H 841	**32.5***	-10.37*	21.23*	**7.85***	-7.3	4.45	26.3*	14.4	-5.37
H 1226 x LH 1995	-30.2*	1.67	**-30.37***	0.84	3.2	4.39	-77.4*	-5.9	-2.01
HS 182 x P 12	-17.2	**24.44***	5.48	-3.59	29.2	21.95	-32.3	-8.7	-5.59
HS 182 x HS 30	20.0	3.70	21.23*	5.64	19.6	30.35	12.8	11.8	10.74
HS 182 x H 1180	-3.5	13.33	10.05	2.32	**29.7***	**34.44***	-25.6	-0.6	8.05
C.D. (p=0.05)	10.39	0.375	25.21	1.321	0.768		0.459	1.12	2.529
SE(d)	5.245	0.189	14.2	0.667	0.388		0.232	0.57	1.276
C.V.	14.374	6.2	11.9	2.217	6.103		6.262	16.6	9.323

heterosis values while only 2 cross combinations *viz.*, H 1117 x P12 (-20.4%) followed by H 1098 x HS 30 showed negative and significant heterosis effects for number of sympodial branches per plant. These findings are confirmed by the findings of Sivia *et al.,* (2017).

Among sixty four crosses low heterotic values ranging from -8.11 to 7.85 per cent were observed for ginning percentage but the maximum heterotic effects were observed from H 1226 x H 841, HS 182 x MC 86 and H 1117 x Okra. Positive and significant heterosis for seed index was observed for 22 cross combinations and only two hybrids showed significant negative exhibited heterosis. The range was -13.2 to 29.7 per cent the maximum heterotic hybrids being HS182 x H 1180 followed by HS 182 x P 12 and H 1098 x P 12. Similarly, for lint index range of heterosis was -7.34 to 34.44 per cent. Best crosses showing heterosis for this character were HS182x H 1180, HS 182 x Sahane and H 1098 x H 1180. Heterosis for this trait was also reported by Lingaraja *et al.,* (2017). The above results shows the scope of heterosis breeding for exploitation of heterosis. High yielding hybrid also showed heterosis for many characters. However, none of the hybrid was found to record heterosis for all the characters.

Combining ability studies elucidate the nature and magnitude of gene action involved in seed cotton yield and its related characters, which is useful to follow the segregating material. In its study material should be selected with utmost care to have successful hybridization programme. The selection based on variability and combining ability is likely to be more successful.

The combining ability analysis (Table 3) revealed that variance were highly significant for lines, tester and line x tester for all the characters revealing highly significant differences among the genotypes for all the characters under study and sufficient variability among experimental material.

The mean squares for general combining ability as well as specific combining ability were also significant for all the characters indicated that both additive and non additive gene action played role for inheritance for these traits. The ratio of ó^{2}gca/ ó^{2}sca was less than unity for number of monopods, number of sympods boll number and seed cotton yield, indicating preponderance of non additive and dominance type of gene action for these characters while for height, boll weight, GOT, seed index and lint index ó^{2}gca/ ó^{2}sca was greater than unity suggesting importance of additive type of gene action for these traits. These results are in agreement with the observations of Patel *et al.,* (2005) and Lanjewar *et al.*, (2017).

A summarized account of the parents with significant GCA effects along with crosses showing significant SCA effects are presented in Table 4. For seed cotton yield significant GCA effects were recorded for the male parent H 655C followed by EC 543423, H 841and HS 30 while females H 1117 and HS 182 were found to be best general combiner. These parents thus can be used for improvement in seed cotton yield. All the parents showing high GCA for seed cotton yield also showed high GCA for boll number. For boll weight H 1098 and HS 182 recorded significant GCA effects among females and JP 8, P 12, Sahane and H 1180 were good among males. For increased height H 1117 among females and PK 54 and H 1180 were best. While for dwarfness H 1098 among females and P 12, okra and GBHV 148 among males were found to possess high +ve GCA effects. For number of monopods and sympods H 1117 and H 1226 respectively among females were found good combiners. While H 655C, Okra, H 841 and HS 30 for monopods and MC 86, L 759 and PK 54 for sympods among males recorded significant positive GCA. For quality characters ginning out turn H 1117 and HS 182 were found to have high GCA among females, while MC 86, H 841 and Okra were better among males. For seed index only HS 182 was found to have high significant GCA effects while among males P12 was best general combiner followed by H 1180 and Sahane. Similarly, for lint index H 1180 followed by Sahane and P 12 among males and HS 182 female recorded highest GCA effects pin pointing them to be good general combiner for these traits. Similar results were obtained by Preetha and Ravindran (2008), Patil *et al.,*(2011) and Lanjewar *et al.*, (2017).

Table 3. Combining ability analysis for seed cotton yield and other traits in upland cotton

	DF	Bolls/ plant	Boll weight	Seed cotton yield/ plant	Gin-ning outturn	Seed index	Lint index	Monopodia	Sympodia	Plant height
Blocks	2	76.6	0.08	490.3	1.084	0.084	0.039	0.27	5.49*	104.5
Due to Males	15	306.7*	0.36*	1802.1*	6.265	3.078	0.688	6.17*	8.59*	248.9*
Due to Female	3	326.2*	2.87*	3207.7*	12.866	7.862	3.240	5.09*	28.29*	1,226.6*
Male X Female	45	147.5*	0.09*	1232.2*	1.306	0.477	0.171	3.33*	7.32*	117.0
Error	126	41.7	0.05	306.5	0.649	0.229	0.080	0.48	2.44	61.6

Table 4. Best parents, best general combiners, best specific heterotic crosses and best specific combiners for yield and its component characters in *hirsutum* cotton

Sr. No.	Characters	Best General Combiners	Crosses with significant SCA effect	Parent Combination
1	Seed cotton yield	H 1117 (6.95), HS 182(6.91)H 655C (24.54), EC 543234(19.95), H 841(11.87), HS 30 (10.45)	H 1117 x Sahane (43.88) H 1098 x F 2035 (34.63) H 1117 x MC 86 (33.30) H 1098 x L 759 (32.96)	G x PP x GG x PP x P
2	Boll number	H1117 (2.09), H1226 (1.76) H 655C (10.85), EC 543423 (5.02),HS 30 (4.98), H 841 (4.73)	H 1117 x SAHANE (15.77) H 1117 x MC 86 (12.69)H 1098 x LH 1995 (11.91)H 1226 x H 841 (11.23)	G x PG x GP x PG x G
3	Boll weight	HS 182 (0.22), H 1098 (0.11)JP 8(0.30), P 12(0.24), SAHANE (0.22), H 1180 (0.17)	H 1226 x LH 1995 (0.30)HS 182 x P 12 (0.28)HS 182 x F 1980 (0.26) H 1117 x H 655c (0.24)	P x GG x GG x AA x G
4(a)	Plant height (Tallness)	H 1117 (5.70)PK 54 (8.08), H 1180 (7.33)	HS 182 x HS 30 (17.57)H 1226 x EC 543423 (11.55)H 1117 x L 759 (11.46)H 1098 x F 2035 (8.17)	A x AP x AG x AP x A
4(b)	Plant height (Dwarfness)	H 1098 (-6.51), P 12 (-7.34), Okra (-6.76), GBHV 148(-6.01)	H 1117 x H 1180 (-10. 79) H 1226 x HS 30 (-8.70)	G x GA x A
5	Monopodia/plant	H1117 (0.39), H 841 (1.11), Okra (1.02), HS 30 (0.59), EC 543423 (0.49), H 655C (0.41)	HS 182 x MC 86 (2.08)H 1098 x LH 1995 (1.93)H 1226 x P 12 (1.59) H 1226 x F 1980 (1.40)	A x AP x PA x AA x A
6	Sympodia/plant	H1226 (1.15)MC 86 (1.66), PK 54 (1.53), L 759 (1.20)	H 1117 x H 655C (3.41) HS 182 x HS 30 (3.05)H 1117 x MC 86 (2.44)H 1226 x JP 8 (2.08)	P x AP x PP x GG x A
7	GOT	H 1117 (0.433), HS 182 (0.281)MC 86 (0.973), H 841 (0.931), Okra (0.74)	H 1226 x H 841 (1.167)H 1117 x H 1180 (0.883)H 1226 x P 12 (0.883) HS 182 x MC 86 (0.827)	A x GG x GP x AG x G
8	Seed index	HS 182 (0.495)P12 (1.095), H 1180 (0.853), SAHANE (0.411), JP 8 (0.303)	H 1098 x EC 543423 (0.716)HS182 x HS 30 (0.697)H 1117 x MC 86 (0.641) H 1226 x LH 1995 (0.589)	A x AG x PP x PP x A
9	Lint index	HS 182 (0.349), H 1117 (0.004) H 1180 (0.496), SAHANE (0.269), P12 (0.227)JP 8 (0.211)	HS 182 x HS 30 (0.553)H 1098 x EC 543423 (0.368)H 1226 x LH 1995 (0.364)H 1226 x JP 8 (0.335)	G x PP x AP x PP x G

(G-Good, P-Poor, A-Average)

Out of 64 crosses significant SCA for seed cotton yield was recorded by eight hybrids only. Highest SCA was recorded for the hybrids H 1117 x Sahane followed by H 1098 x F 2035 and H 1117 x MC 86. For boll number 11 hybrids recorded significant SCA effects highest was recorded for hybrids H1117 x Sahanae followed by H 1098 x LH 1995. Similarly for boll weight highest SCA was recorded for the hybrids H 1226 x HS 30 followed by HS 182 x P 12. For increased height cross HS 182 x HS 30 recorded highest SCA followed by H 1226 x EC 543243 while for dwarfness cross H 1117 x H 1180 was best. Similarly for monopods higher SCA was recorded by cross combination HS 182 x MC 86 whereas, for sympods it was H 1117 x H 655C (3.41). For ginning outturn, the cross H 1226 x H 841 recorded highest GCA effects followed by H 1117 x H 1180 and H 1226 x P 12. For both seed index and lint index the crosses H 1098 x EC 543243 and HS182 x HS 30 recorded highest SCA effects.

None of the crosses recorded high SCA for all the characters. Most of the crosses showing high SCA effects for various characters were in combinations of good x poor, poor x average or poor x poor, indicating a limited utility of parental GCA in producing crosses with high SCA effects. Thus, it was evident that a good cross combination is not necessarily the result of good x good combination of parents indicating the interaction of additive and dominance effects as well. Similar results were reported earlier by Patil *et al.*, (2011). The hybrid showing highest SCA effects was a combination of good x poor combining parents

Heterosis for seed cotton yield (SCY) was mainly due to high heterosis for boll number and/ or boll weight. Heterosis for boll number ranged from -32.9 to 32.5 per cent and for boll weight range was -18.7 to 24.44. The hybrids showing highest heterosis for these traits were H1226x H841 and HS182 x P12, respectively. For the plant height, no. of monopods, no of sympods, the heterosis ranged from -14.99 to 11.19, -77.4 to 45.9 and -20.4 to 21.7 per cent, respectively. Low heterosis were recorded for the quality character, ginning out turn percentage (GOT %) ranged from -8.11 to 7.85 per cent. For seed index and lint index the corresponding values were -13.2 to 29.7 per cent and -7.34 to 34.44 per cent respectively. High yielding hybrid also showed heterosis for majority of the characters. However, none of the hybrid was found to record heterosis for all the characters. Combining ability analysis revealed that variance were highly significant for lines, tester and line x tester for all the characters. For seed cotton yield significant gca effects were recorded for the male parent H655C (24.54) followed by EC 543423 (19.95), H841(11.87) and HS30(10.45) while for female H1117 (6.95) and HS182 were found to be best general combiner. These parents thus can be used for improvement in seed cotton yiled. H655C also recorded higher GCA effects (10.85) boll weight for boll no. Other male parents possess higher GCA effects for boll no were HS 30(4.98) and H 841. This study shows that the scope of heterosis breeding is for commercial exploitation of hybrid vigour.

REFERENCES

Anonymous 2017. Annual Report- All India Coordinated Cotton Improvement Project. ppA4.

Basal, H., Canavar, O., Khan, N.U. and Cerit, C.S. 2011. Combining ability and heterotic studies through line x tester in local and exotic upland cotton genotypes. *Pakistan Jour. Bot.* **43** : 1699-1706.

Castellanos, J.S., Hallauer, A.R and Córdova,H.S. 1998. Relative performance of testers to identify elite lines of corn (*Zea mays* L). *Maydica*, **43** : 217-26.

Lanjewar, S.B., Mokate, A.S., Aher,A.R. and Bharudl, R.W. 2017. Combining ability studies for yield and yield contributing characters in cotton (*Gossypium hirsutum* L). *J. Cotton Res. Dev.,* **31** : 34-37.

Lingaraja, L., Sangwan, R.S., Nimbal, S., Sangwan, O. and Sukhdeep Singh. 2017. Heterosis studies for economic and fibre quality traits in Line X Tester crosses of upland cotton (*Gossypium hirsutum* L.) . *Internati. Jour. Pure Appli. Bioscie.* **5 :** 240-48

Patel, K.G., Patel,U.G., Patel,J.C., Patel,D.H. and Patel, R.B. 2005. Line x tester analysis for combining of introgressed Asiatic cotton. *J. Indian Soc. Cotton Improv.*, **30** : 105-09.

Patil, S.A., Naik, M.R., Chaugule,G.R.,Pathak,V.D. and Patil, A.B. 2011. Combining ability analysis for yield and fibre quality traits in upland cotton (*Gossypium hirsutum L*). *J. Cotton Res. Dev.*, **25** : 171-75.

Patil, S.A., Naik, M.R., Patil, A.B. and Chaugule,G.R. 2011. Heterosis for seed cotton yield and its contributing characters in cotton (*G. hirsutum* L). *Internat J. Plant Sci.,* **6**: 262-66.

Pavasia, M. J., Shukla, P.T. and Poshiya, V.K. 1997. Heterobeltiosis for some economic characters over environment in upland cotton (*G. hirsutum* L.) *GAU Res. J.* **23** : 32-37.

Rai. B. 1978. *Heterosis Breeding*. Agro Biological Publications. New Delhi

Savarkar, M., Solanke,A., Mhasal, G.S. and Deshmukh, S.B. 2015. Combining ability and heterosis for seed cotton yield, its components and quality traits in *Gossypium hirsutum L. Indian J. Agric. Sci.*, **49**: 154-59.

Sharma, R., Gill, B.S. and Pathak, D. 2016. Heterobeltiosis for yield its component traits and fibre properties in upland cotton (*Gossypium hirsutum L*). *J. Cotton Res. Dev.,* **30** : 11-15.

Siddiqui, M.A. and Patil, R.A. 1994. Heterosis in crosses of *hirsutum* cotton. *J. Maharashtra agric. Univ.* **19** : 241-44.

Singh, Hanuman, Singh, S. and Prakash, O.M. 1995. Measurement of heterosis for yield and its component characters in American cotton. *J. Cotton Res. Dev.* **9**: 1-6.

Sivia, Sukhdeep Singh, Siwach, S. S., Sangwan, R. S., Sangwan, O. and Nimbal, S. 2017. Genetic improvement through standard heterosis for seed cotton yield in upland cotton (*Gossypium hirsutum* L.) . *J. Cotton Res. Dev.,* **31**: 164-70.

Tuteja, O.P., Kumar Sunil, Singh Mahendar and Kumar Manoj, 2005. Heterosis in single cross hybrids of *Gossypium hirsutum* L. *J. Cotton Res. Dev.* **19**:165-67.

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Assessment of inter specific crosses of cotton (*G. hirsutum x G. barbadense*) for yield and quality traits

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ABSTRACT : Investigation of inter-specific hybrid production strategy is needed to enhance the productivity and profitability. A field experiment was conducted in deep soil during kharif 2016-2017 to evaluate the effect of interspecific hybrid on yield and quality at Cotton Improvement Project, MPKV, Rahuri. The experiment was led out in randomized block design consisting of eighteen crosses along with eight parents and standard check Phule Dhara. The hybrids RHB 1517, RHB 1515, RHB 1512 and RHB 1510 recorded high seed cotton yield (kg/ha) and heterosis over mid parent, better parent and standard check Phule Dhara. Among the lines RHC 1441, RHC 1416, RHC 1422, tester NDGB 5, Phule Rukhmai and Giza-7 exhibited significant GCA effect for yield and quality characters in desirable direction. Likewise the hybrids RHB 1517, RHB 1501, RHB 1510 produced significant positive SCA effect for seed cotton yield. The hybrids involving the parents with good *per se* performance and high GCA effects in desirable direction recorded high heterosis for yield and quality traits. The SCA varinces were higher in magnitude than GCA variances for majority of characters indicating the performance of non additive gene action in the expression of characters.

Key words*: G. hirsutum*, *G. barbadense*, yield, quality traits

Cotton is a major fibre crop of global importance value. It belongs to the family malvaceae and consists of 50 species. Out of these, two diploid species *viz., Gossypium arboreum* L. and *Gossypium herbaceum* L. and two tetraploid species i.e. *Gossypium hirsutum* L. and *Gossypium barbadense* L. are cultivated while rests of the species are found in wild forms. The first ever hybrid in world that is intra *hirsutum* hybrid H_4 was released during 1971 and India is pioneer country for the commercial cultivation of hybrid cotton. In India, hybrid cotton occupies more than 98 per cent of total cotton area and contributes about 55 per cent to national annual cotton production. The world cotton production is estimated at 105.72 million bales of 480 lb in 2016-2017, around 9.3 per cent more than last year. The estimate of USDA indicates that India continued to be the leading producer of raw cotton followed by China and the United States. India also maintains the largest area under cotton in the world and second largest exporter of cotton next to the United States. Cotton production in India during 2016-2017 was 351 lakh bales of 170 kg from 105 lakh hectares with a productivity of 568 kg lint/ha (Anonymous, 2016-2017).

Development of new variety with high yield and fibre quality is the primary objective of all cotton breeders. The first step in successful breeding program is to select appropriate parents. Line x Tester analysis provides a systematic approach for detection of appropriate parents and crosses in terms of investigated traits. This method was applied to improve self and cross-pollinated plants (Kempthorne, 1957). Keeping in view, the present study was undertaken to identify best heterotic combinations with high fibre length and strength.

MATERIALS AND METHODS

The field experiment was conducted at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri during *kharif*, 2016. The nine parents (three lines of *G. hirsutum* L. and six testers of *G. barbadense* L.) inter-mated in line x tester mating design and the resulting eighteen crosses were evaluated in randomized block design with three replications along with parents and standard check. All recommended package of practices were followed as an when required. The biometrical observation on growth and yield attributes were recorded as per the standard procedure I fourteen characters and subjected to statistical analysis to draw the valid conclusions.

RESULTS AND DISCUSSION

The mean sum of squares due to treatments for all characters was highly significant. Similarly mean sum of squares due to parents and crosses for all characters were highly significant. Line x tester interaction was also significant for all the characters except average boll weight. The contrast parents vs. crosses were also highly significant for all characters. Also the mean sum of squares due to lines were significant for plant height, seed cotton yield /ha and lint yield /ha while testers were significant for only average boll weight (Table 1).

Heterosis was calculated over better parent and standard check by following Rai (1979) and expressed in percentage. The hybrids RHB 1517, RHB 1515, RHB 1512, and RHB 1510 recorded high seed cotton yield (kg/ha) and heterosis over mid parent, better parent and standard check RHB 0711 (Phule Dhara) (Table 2). The high magnitude of heterosis for seed cotton yield has been reported by Kannan *et al.*, (2016).

The mean sum of squares due to GCA and SCA were significant for majority of the characters studied indicating variability in combining ability of various lines and testers and their hybrids. Among the lines, RHC 1441 was the best general combiner followed by RHC 1416 and RHC1422 exhibited significant GCA effects in desirable direction for seed cotton yield and yield contributing characters. However among the testers, NDGB 5 was the best general combiner followed by RHCb 011, Giza 7 exhibiting high GCA effects for average boll weight, ginning per cent, seed index, lint index, seed cotton yield /ha, lint yield /ha, for fibre quality characters fibre strength and fibre elongation in desirable direction (Table 3).

The hybrids RHB 1517, RHB 1501, RHB 1510 produced significant positive SCA effects

Table 1. Analysis of variances for fourteen characters in 3 x 6 (L x T) of cotton.

Sr. No.	Source of variation	D. F.	Seed cotton yield / (kg/ha)	Lint yield (kg)/ha	Plant height (cm)	Sympodia / plant	Bolls / plant	Average boll weight (g)	Seed index	Ginning (%)	Lint Index	UHML (mm)	Uniformity index	Micronaire (µ)	Fibre sterngth (g/txt)	Fibre elongation %
1	Replication	2	7092.65	885.32	47.15	0.35	0.87	0.32	0.01	0.01	0.01	0.25	0.46	0.01	0.18	0.01
2	Treatments	26	502281.58**	57752.43**	753.91**	15.83**	65.73**	0.87**	4.73**	10.33**	1.21**	21.90**	13.83**	0.63**	26.05**	0.67**
3	Parents	8	399665.28**	49719.77**	520.00**	10.03**	38.99**	1.52**	4.52**	6.39**	1.29**	29.46**	19.89**	0.59**	68.07**	0.04**
4	Par vs cros	1	4133898.64**	405707.30**	9202.72**	180.50**	792.02**	3.64**	18.13**	76.14**	0.03*	112.67**	0.15**	5.56**	4.84**	0.03**
5	Crosses	17	336947.06*	41064.58**	366.99**	8.88**	35.59**	0.39**	4.05**	8.32**	1.24**	13.01**	11.77**	0.36**	7.52**	1.01**
6	Lines	2	1876131.79**	242701.31**	1286.89*	28.44	122.44	0.02	3.11	13.12	0.51	26.98	1.72	0.05	2.59	0.35
7	Testers	5	134764.3	15219.99	125.63	1.11	3.85	1.13**	7.19	3.11	2.29	9.76	12.39	0.48	6.82	1.39
8	L x T	10	130201.49**	13659.52**	303.69**	8.85**	34.09**	0.11	2.67**	9.96**	0.85**	11.84**	13.48**	0.36**	8.86**	0.94**
9	Error	52	10964.42	1340.95	60.13	0.82	3.59	0.07	0.01	0.02	0.01	0.15	0.52	0.01	0.18	0.01

Table 2. Range of heterosis and number of hybrids showing significant heterosis in desirable direction in 3 x 6 (L x T) of cotton

Sr. no.	Name of characters	Heterosis (%) over M.P.		Heterosis (%) over B.P.		Heterosis (%) over S.C.	
		Range	No. of significant crosses	Range	No. of significant crosses	Range	No. of significant crosses
1	Seed cotton yield /ha	-39.55 to 180.86	15 (83.33)	-50.98 to 102.48	6 (33.33)	-61.61 to 8.82	00 (00)
2	Lint yield/ha	-39.57 to 152.35	13 (72.22)	-51.23 to 80.27	6 (33.33)	-61.63 to 5.26	00 (00)
3	Plant height (cm)	-14.03 to 64.76	16 (88.89)	-23.17 to 41.43	12 (66.67)	-27.98 to 6.25	00 (00)
4	Number of sympodia /plant	-17.65 to 78.23	15 (83.33)	-28.41 to 75.40	12 (66.67)	-39.42 to 6.25	00 (00)
5	Number of bolls /plant	-15.06 to 72.48	15 (83.33)	-24.60 to 70.29	13 (72.22)	-36.20 to 6.33	00 (00)
6	Average boll weight	-12.12 to 43.48	7 (38.89)	-24.46 to 36.54	3 (16.67)	-31.82 to -7.79	00 (00)
7	Seed index	-15.94 to 40.94	13 (72.22)	-23.64 to 31.91	12 (66.67)	-27.13 to 7.84	3 (16.67)
8	Ginning (%)	-12.45 to 2.49	2 (11.11)	-15.19 to -0.32	00 (00)	-10.93 to 2.27	3 (16.67)
9	Lint index	-15.75 to 34.24	9 (50.00)	-22.81 to 28.46	6 (33.33)	-27.00 to 7.60	1 (5.57)
10	UHML	-3.13 to 24.92	17 (94.44)	-13.76 to 15.3	10 (55.56)	-14.47 to 6.28	2 (11.11)
11	Uniformity index	-5.2 to 6.75	7 (38.89)	-7.17 to 5.24	4 (22.22)	-3.15 to 5.51	7 (38.89)
12	Micronaire	-31.73 to 1.67	00 (00)	-37.04 to -4.69	00 (00)	-20.75 to 6.60	2 (16.67)
13	Fibre strength	-3.92 to 17.69	15 (83.33)	-17.7 to 3.95	3 (16.67)	-22.09 to -7.11	00 (00)
14	Fibre elongation	-16.35 to 15.05	12 (66.67)	-16.58 to 14.44	7 (38.89)	-33.05 to -9.32	00 (00)

Table 3. Estimation of general combining ability effects for fourteen characters in 3 x 6 (L x T) of cotton

Sr. No.	Parents	Seed cotton yield /ha	Lint yield/ha	Plant height	Sympodia / plant	Bolls / plant	Average boll weight	Seed Index	Ginning (%)	Lint Index	UHML	Uni-formity index	Micro-naire	Fibre strength	Fibre elong-ation
GCA(Lines)															
1	RHC-1416	-245.758**	-82.246**	-9.000**	-1.326**	-2.748**	-0.013	-0.410**	0.259**	-0.156**	0.49**	0.28	0.06	0.12	0.01
2	RHC-1422	-119.880**	-50.584**	1.222	0.152	0.307	-0.024	0.421**	-0.953**	-0.021	0.91**	0.06	-0.01	0.31**	0.13**
3	RHC-1441	365.638**	132.830**	7.778**	1.174**	2.441**	0.037	-0.011	0.694**	0.178**	-1.39**	-0.33	-0.05	-0.42**	-0.14**
	S.E. ± (gi)	***24.681***	***8.631***	***1.827***	***0.214***	***0.447***	***0.063***	***0.019***	***0.033***	***0.017***	***0.09***	***0.17***	***0.03***	***0.1***	***0.02***
	CD (p=0.05)	***50.157***	***17.541***	***3.714***	***0.435***	***0.908***	***0.129***	***0.04***	***0.068***	***0.034***	***0.19***	***0.36***	***0.06***	***0.2***	***0.04***
	CD (p=0.01)	***67.338***	***23.549***	***4.986***	***0.584***	***1.219***	***0.173***	***0.053***	***0.092***	***0.046***	***0.25***	***0.46***	***0.08***	***0.27***	***0.05***
GCA(Testers)															
1	RHCb-011	117.750**	37.541**	-2.611	0.107	0.33	0.498**	1.395**	-0.152**	0.688**	-0.25	0.06	0.39**	-1.21**	-0.04
2	NDGB-5	87.646*	37.755**	0.611	0.174	0.396	0.276**	0.768**	0.332**	0.482**	-1.58**	-1.61**	0.14**	0.60**	0.47**
3	GSB-40	61.162	23.558	4.278	0.485	0.885	0.098	-0.132**	0.396**	0.022	-0.34*	-0.72**	-0.09*	0.28	0.36**
4	EC-97638	-34.308	-21.061	-5.278*	-0.27	-0.493	-0.224*	-0.505**	-0.606**	-0.420**	0.46**	1.17**	-0.03	0.16**	-0.62**
5	ICB-178	-12.601	-10.644	-0.944	0.019	-0.226	-0.191*	-0.868**	-0.717**	-0.607**	0.12	-0.39	-0.23**	-0.73**	-0.04
6	Giza-7	-219.649**	-67.149**	3.944	-0.515	-0.893	-0.457**	-0.658**	0.747**	-0.165**	1.59**	1.50**	-0.18**	-0.12	0.20**
	S.E. ± (gi)	***34.904***	***12.206***	***2.584***	***0.303***	***0.632***	***0.09***	***0.027***	***0.047***	***0.024***	***0.13***	***0.25***	***0.04***	***0.14***	***0.02***
	CD (p=0.05)	***70.932***	***24.806***	***5.253***	***0.615***	***1.284***	***0.182***	***0.056***	***0.097***	***0.048***	***0.26***	***0.49***	***0.08***	***0.29***	***0.05***
	CD (p=0.01)	***95.23***	***33.303***	***7.052***	***0.826***	***1.724***	***0.245***	***0.076***	***0.13***	***0.065***	***0.35***	***0.66***	***0.11***	***0.39***	***0.07***

Table 4. Estimates of specific combining ability effects for fourteen characters in 3 x 6 (L x T) of cotton

Sr. No.	Parents	Seed cotton yield /ha	Lint yield/ha	Plant height	Sympodia / plant	Bolls / plant	Average boll weight	Seed Index	Ginning (%)	Lint Index	UHML	Uni-formity index	Micro-naire	Fibre strength	Fibre elong-ation
1	RHB-1501	227.857**	-82.246**	10.444*	3.015**	6.037**	0.035	1.000**	1.008**	0.821**	1.10**	1.17**	-0.49**	-1.75**	-0.01
2	RHB-1502	82.464	-9.013	9.556*	1.481**	2.704*	-0.243	0.461**	-3.256**	-0.590**	1.86**	1.83**	0.22**	0.84**	-0.49**
3	RHB-1503	85.674	29.244	9.889*	-1.03	-2.052	0.269	0.288**	-0.256**	0.100*	2.43**	2.28**	0.22**	0.36	-0.34**
4	RHB-1504	-209.896**	-55.751*	-11.222*	-1.874**	-3.607**	0.024	-0.603**	1.488**	0.049	-2.21**	-2.94**	0	1.72**	0.63**
5	RHB-1505	-166.172**	-48.601*	-11.222*	-0.296	-0.541	-0.143	-0.023	0.826**	0.179**	-1.57**	-2.39**	0.13	-0.56*	0.37**
6	RHB-1506	-19.928	-7.743	-7.444	-1.296*	-2.541*	0.057	-1.123**	0.189*	-0.557**	-1.61**	0.06	-0.09	-0.62*	-0.16**
7	RHB-1507	18.029	11.915	-3.444	-1.930**	-3.885**	-0.154	0.009	0.548**	0.109*	-0.69**	-0.94*	0.37**	0.82**	0.60**
8	RHB-1508	78.38	23.405	-10.333*	-0.596	-1.019	0.235	0.470**	0.200*	0.271**	-2.26**	-1.61**	0.15*	-2.29**	-0.14**
9	RHB-1509	-207.483**	-54.779*	-2.667	-0.174	-0.307	0.013	-1.317**	1.573**	-0.292**	-1.76**	-1.17**	-0.12	-0.19	0.17**
10	RHB-1510	167.307**	46.980*	4.222	1.381*	2.670*	-0.031	0.582**	-0.999**	0.057	1.74**	2.94**	-0.47**	-0.51*	-0.42**
11	RHB-1511	-132.177**	-50.210*	5.222	-0.107	-0.263	0.035	-0.135**	-0.874**	-0.246**	0.80**	1.83**	0.06	-0.39	-0.66**
12	RHB-1512	75.944	22.688	7	1.426*	2.804*	-0.098	0.392**	-0.448**	0.101*	2.17**	-1.06*	0.01	2.56**	0.46**
13	RHB-1513	-245.886**	-103.779**	-7	-1.085*	-2.152	0.119	-1.009**	-1.556**	-0.930**	-0.42	-0.22	0.12	0.92**	-0.59**
14	RHB-1514	-160.845*	-14.392	0.778	-0.885	-1.685	0.007	-0.931**	3.056**	0.319**	0.4	-0.22	-0.37**	1.45**	0.63**
15	RHB-1515	121.809	25.535	-7.222	1.204*	2.359*	-0.281	1.029**	-1.317**	0.192**	-0.66**	-1.11*	-0.11	-0.16	0.18**
16	RHB-1516	42.589	8.77	7	0.493	0.937	0.007	0.021	-0.489**	-0.105*	0.47*	0	0.47**	-1.21**	-0.21**
17	RHB-1517	298.349**	98.810**	6	0.404	0.804	0.107	0.158**	0.048	0.068	0.77**	0.56	-0.19**	0.95**	0.29**
18	RHB-1518	-56.017	-14.945	0.444	-0.13	-0.263	0.041	0.731**	0.258**	0.456**	-0.56*	1.00*	0.08	-1.94**	-0.30**
	S.E. ± (gi)	***60.455***	***21.142***	***4.477***	***0.524***	***1.094***	***0.155***	***0.048***	***0.083***	***0.041***	***0.23***	***0.42***	***0.07***	***0.25***	***0.04***
	CD (p=0.05)	***122.857***	***42.965***	***9.098***	***1.065***	***2.224***	***0.316***	***0.098***	***0.168***	***0.084***	***0.46***	***0.85***	***0.14***	***0.5***	***0.09***
	CD (p=0.01)	***164.944***	***57.683***	***12.215***	***1.43***	***2.985***	***0.424***	***0.132***	***0.226***	***0.113***	***0.62***	***1.14***	***0.18***	***0.67***	***0.12***

Table 5. Components of genetic variances for fourteen characters in 3 x 6 (L x T) of cotton

Sr. No.	Parents	Seed cotton yield /ha	Lint yield/ha	Plant height	Sympodia / plant	Bolls / plant	Average boll weight	Seed Index	Ginning (%)	Lint Index	UHML	Uni-formity index	Micro-naire	Fibre strength	Fibre elong-ation
1	?^{2} GCA	73665.45**	9453.311**	47.861*	1.032	4.411	0.037**	0.381*	0.599	0.103*	1.35	0.48	0.018	0.33	0.064
2	?^{2} SCA	39745.68**	4106.191**	81.184**	2.677**	10.167**	0.011	0.886**	3.313**	0.283**	3.90**	4.32**	0.12**	2.89**	0.31**
3	?^{2} A	294661.8	37813.24	191.444	4.133	17.645	0.149	1.524	2.398	0.414	5.4	1.94	0.07	1.34	0.25
4	?^{2} D	158982.8	16424.76	324.738	10.708	40.668	0.045	3.546	13.253	1.132	15.59	17.28	0.46	11.58	1.25
5	A : D ratio	1.853	2.302	0.589	0.386	0.434	3.32	0.429	0.181	0.365	0.35	0.11	0.16	0.12	0.21
6	h2 (ns) %	77.245	80.592	48.602	41.176	43.704	67.833	46.161	26.533	42.108	40.61	17.73	23.79	18.51	29.03

for seed cotton yield. Likewise the hybrids RHB 1517, RHB 1501 for lint yield /ha, RHB 1514, RHB 1509, RHB 1504, RHB 1507, RHB 1518 for ginning per cent, RHB 1515, RHB 1501, RHB 1518, RHB 1510 for seed index, RHB 1501,RHB 1502, RHB 1512, RHB 1510, RHB 1515 for number bolls per plant and number sympodia exhibited significant positive SCA effects for respective characters. (Table 4). The hybrids involving the parents with good *per se* performance and high GCA effects in desirable direction recorded high heterosis for yield and yield contributing characters.

In the Table 5 predominance of additive gene action with high heritability (ns) estimates for average boll weight, seed cotton yield and lint yield, fibre strength, micronaire suggested the possibility of selecting better recombinations through simple selection. Predominance of non additive gene action with low heritability (ns) in case of number of bolls/plant, number of sympodia, ginning per cent, plant height, seed index, lint index and fibre quality characters such that upper half mean length, uniformity index, micronaire, fibre strength and fibre elongation indicated need of exploiting the characters through hybrid breeding.

The SCA variances were higher in magnitude than GCA variances for majority of characters indicating the predominance of non additive gene action in the expression of characters.

Based on present study it may be concluded that the hybrids RHB 1517, RHB 1515, RHB 1514, RHB 1518 were the best for high seed cotton yield and need to be exploited. However they may be used to isolate better recombinants from advanced generations. The line RHC 1441 and tester NDGB 5 was identified as the best combiner and could be used in further cotton breeding programmes aimed for the improvement of fibre yield along with fibre quality characters.

REFERENCE

Anonymous, 2016-17. "Annual report", All India Coordinated Cotton Improvement Project, Coimbatore, Tamilnadu – 641 003.

Kannan, N. and Saravanan, K. 2016. Heterosis and combining ability analysis in tetraploid cotton (*G.hirsutum* and *G.barbadense* L.). *Electronic Jour. Plant Breed.* **7 :** 928-75.

Kempthorne, O. 1957. *"A introduction to Genetical Statistics"* John Willey and Sons Ionc., New York, pp. 458-471.

Rai, B. 1979. *Heterosis Breeding.* Agro Bio. Pub. Delhi. pp.183.

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Women empowerment through capron to mitigate drudgery

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ABSTRACT : Women in Haryana work for long hours as they are engaged in home, farm and animal husbandry activities.They perform most of the agricultural operations, *viz.,* transplanting, weeding, harvesting, cotton picking and plucking, post-harvest activities, while in other activities, they share the burden of men folk. Various types of face masks *i.e.* capron, hood mask, scarf mask and pleated beak masks were developed by CCS Haryana Agricultural University, Hisar in response to health problems reported by rural women engaged in various field activities like wheat harvesting/ threshing, etc. Capron, hood mask and scarf mask are almost similar in design and covers head along with mouth, nose and neck of field workers while pleated beak mask covers mouth, nose and neck of field workers. For field testing, these two different types of face masks *i.e.* scarf mask and pleated beak masks were given to 100 rural women from four districts, *viz.,* Hisar, Fatehabad, Jhajjar and Sonipat for its suitability assessment on functional and designing aspects and overall acceptability. Suitability of developed masks was assessed, especially during wheat harvesting/ threshing using self-structured interview schedule on five point scale *i.e.* highly suitable, suitable, somewhat suitable, least suitable and not suitable, scoring 5, 4, 3, 2 and 1, respectively. Weighted mean scores (WMS) were categorized as highly suitable (4.21- 5.00), suitable (3.41-4.20), somewhat suitable (2.61-3.40), least suitable (1.81-2.60) and not suitable (1.00-1.80). The color and cotton fabric used to stitch scarf mask was assessed highly suitable scoring 4.80 and 4.95, respectively. Size and shape of mask was assessed highly suitable scoring 4.25 and 4.82, respectively as it provided comfortable breathing. In terms of overall appeal, the masks were found highly suitable. Assessment of face masks *i.e.* scarf and pleated beak mask on the basis of functional aspects revealed that both were highly functional as they provided protection (4.90, 4.82) against sun, dust, husk, etc. thereby increasing the efficiency of work (4.97) while pleated beak mask was found more comfortable and easy to use (4.90). Overall, the masks were easy to maintain (4.97) and scarf mask was easy to stitch (4.82) also. Cost of masks was found to be highly acceptable among respondents with WMS 4.75.

Key words: Drudgery,face masks, women empowerment

The occupational health and safety of farmwomen is one of the most neglected areas in agriculture and animal husbandry. Farmwomen in Haryana devote long working hours for home, farm and animal husbandry activities.For wheat harvesting, use of different harvesters, especially combine harvester, is mainly restricted to farmers with large land holdings. It has generally been observed that women are less likely to be involved in more mechanized and capital intensive form of agriculture geared to market-oriented production (Dahiya and Yadav, 2017). They undertake more labour intensive work that requires pain staking physical effort, patience and perseverance. Harvesting of wheat crops is, therefore, performed manually,predominantly by the women workforce in Haryana.Power supply, availability of human labour and locally available tools are the other limiting factors prompting them to manually carry out the harvesting of wheat crops. Harvesting of wheat crops is, therefore, a highly drudgerous activity for farmwomen in Haryana (Jyotsna *et al.*, 2014).

While carrying out agricultural operations, farmers are exposed to a number of biological, physical and chemical factors harmful to their health. Organic dust is extremely harmful due to the huge variety of components including ingredients of plants, animal proteins, bacteria, molds and their metabolites as mycotoxins (Wittczak *et al.*, 2012). Farmers in the workplace are in contact with many molds belonging to the group called “field molds” that grow on plants and can cause allergic diseases among farmers working in the field (Dutkiewicz *et al.*, 2000). Traditionally, to protect themselves from sun, husk, dust, etc., farmwomen in Haryana use *odhni*/head cloth for covering their face during wheat harvesting and threshing activity.

Keeping in view the various problems faced by farm women engaged in harvesting, threshing /winnowing, different types of face masks *i.e.* capron, hood mask, scarf mask and pleated .beak masks were developed by CCSHAU, Hisar (Rani *et al.*, 2015). Capron, hood mask and scarf mask are almost similar in design and cover the head along with mouth, nose and neck of field workers while pleated beak mask is different and covers mouth, nose and neck of field workers. These two different types of face masks *i.e.* scarf mask and pleated beak masks were tested on farm women in different districts of Haryana.

MATERIALS AND METHODS

Face scarf mask and pleated beak mask developed by CCSHAU, Hisar for women engaged in wheat harvesting and other activities were used for this study. These were tested on 100 farmwomen belonging to four districts of Haryana, *viz.,* Hisar, Fatehabad, Jhajjar and Sonepat, for assessment of their suitability on functional and design aspects along with overall acceptability. A self structured interview schedule on five-point scale, *i.e.* highly suitable, suitable, somewhat suitable, least suitable and not suitable, with the respective scoring of 5, 4, 3, 2 and 1 was used to test the suitability of masks during wheat harvesting/threshing/ winnowing. Weighted mean scores (WMS) and average mean scores were categorized as highly suitable (4.21- 5.00), suitable (3.41-4.20), somewhat suitable (2.61-3.40), least suitable (1.81-2.60) and not suitable (1.00-1.80).

RESULTS AND DISCUSSIONS

AICRP report (2009-2010) published by CCSHAU, Hisar had highlighted the problems encountered during wheat threshing as eye irritation/itching, headache, skin irritation/ itching, breathlessness, sweating, running nose, skin allergy/ailment, sneezing and bronchitis. The health problems identified at the time of pesticide application were: headache, eye irritation, nausea, breathlessness, loss of appetite, dizziness, skin allergy, vomiting and scorching. This was due to the reasons that farm workers did not wear appropriate protective clothing while performing these activities. Personal protective equipmentincludes all clothing and other work accessories designed to create a barrier against work place hazards. The clothing creates an effective barrier between the hazard and the wearer(Nadiger and Samuel, 2004).

The data regarding assessment of face masks on various designing and functional parameters have been presented in Table 1. The data revealed that type and colour of the fabric used to stitch scarf mask and pleated beak mask, was assessed highly suitable scoring 4.80 and 4.95, respectively as dark and dull colour of the cotton fabric provided resistance against soiling. Size and shape of both scarf and pleated masks was assessed highly suitable scoring 4.25 and 4.82, respectively. In terms of appeal, both masks were found highly suitable (4.72, 4.80).

The data regarding assessment of face masks on the basis of functional features revealed that both masks *i.e.* scarf mask and pleated beak mask were highly functional as they provided protection with WMS 4.90 and 4.82 respectively, against dust, dirt and sun during wheat harvesting/threshing activities, thereby increasing the efficiency of work (4.97).

Table 1. Suitability assessment of developed masks against various designing and functional features

Designing features	Masks		Functional Features	Masks	
	Scarf WMS	Pleated beak WMS		Scarf WMS	Pleated beak WMS
Type of fabric	4.80	4.80	Protection	4.90	4.82
Color of fabric	4.95	4.80	Work efficiency	4.97	4.97
Shape and Size	4.25	4.82	Comfortable to use	4.85	4.90
Appealing	4.72	4.80	Easy to use	4.85	4.90

Highly suitable - 4.21-5.00; Suitable - 3.41-4.20; Somewhat suitable -2.61-3.40; Least suitable-1.81-2.60; Not suitable -1.00-1.80.

Scarf mask

Pleated beak mask

Moreover, they were also comfortable and easy to use (4.85, 4.90).

Thus, both masks were increasing the efficiency of work (4.97) but scarf mask was comparatively more functional with WMS 4.90, while pleated beak mask was found to be more comfortable and easy to use (4.97).

Data regarding overall assessment of face masks have been presented in Table 2.

Overall assessment revealed both masks to be highly suitable as these were easy to maintain (4.97) and stitch (4.82, 4.75). Scarf mask and pleated beak masks were also found highly modest with WMS 4.85 and 4.87, respectively. Cost of masks was found highly acceptable among respondent with WMS 4.75.

The findings in the present study are corroborated by those reported in another study that highlighted that scarf mask and pleated masks were foundhighly suitable by female and male farmers, respectively. Perceived adoption feasibility was found 81.20 per cent for all protective masks. All the respondents reported that pleated masks increasedthe efficiency of users. Majority of the respondents (MS 2.37) found cambric fabric to be most suitablefor preparation of masks. All the respondents (MS 3.00) reported that initial cost of masks was low.Farmers preferred cambric cotton fabric rather than voile and poplin with thin elastic at sides of masks (Dahiya and Yadav, 2017). In our study, both the face scarf mask, as well as pleated beak mask, were found suitable for use by female farmers.

Table 2. Overall suitability assessment of face masksn=100

Parameters	Masks	
	Scarf WMS	Pleated beak WMS
Easy to maintain	4.97	4.97
Easy to stitch	4.82	4.75
Modest	4.85	4.87
Cost acceptance	4.75	4.75

Highly suitable - 4.21-5.00; Suitable - 3.41-4.20; Somewhat suitable -2.61-3.40;
Least suitable- 1.81-2.60; Not suitable -1.00-1.80.

Gandhi *et al.*, (2012) also conducted a study on 20 farmworkers to find out occupational healthhazards & efficacy of protective masks in threshing operation. Respondents reported respiratory health problems, mainly due to heat and organic dust in the surroundings. All respondents reported irritation in eyes and throat followed by nose (85%) and ears (75%). Majority of the respondents (90%) always covered their nose and mouth by tying a piece of cloth during activity to protect themselves from the organic dust entering their respiratory track. Majority of the respondents used to wear full sleeved clothing (85%) followed by drinking plenty of water (80%), while only 5 per cent respondents reported using eye glasses sometimes to protect their eyes.

CONCLUSIONS

Farm women are exposed to several health hazards during agricultural operations especially wheat harvesting/threshing. These operations are mostly performed manually by them. Two types of face masks namely face mask and pleated beak masks developed by CCSHAU were tested on 100 farm women at field level in four districts of Haryana. These were found highly suitable by the farmwomen against various designing and functional features.In terms of overall acceptability, both masks were found highly suitable.

REFERENCES

Annymous 2009-2010. *"Annual Report"* All India Co-ordinated Research Project on Home Science.Department of Family Resource Management, CCSHAU, Hisar.

Dahiya, R. and Yadav, S. 2017. On farm trials on cotton fabric based protective masks for farmers.*Jour. Cotton Res. Dev.* **31 :** 327-33.

Dutkiewicz, J., Skórka, C., Mackiewicz, B. and Cholewa, G. 2000. Prevention of diseases due to organic dust in agriculture and food industry [Polish] Lublin: Instytut Medycyny Wsi.

Gandhi, S., Dilbaghi, M., Mehta, M. and Pruthi, N. 2012. Occupational health hazards and efficacy of protective masks in threshing operation. *Internat. Jour. Sci. Res. Publications* **2 :** 1-4.

Jyotsna, Rana, K. and Dilbaghi, M. 2014. Occupational constraints analysis of women engaged in wheat harvesting. *Studies Home Community Sci.* **8 :** 53-58.

Nadiger, G. S. and Samuel, J. 2004. Focus on textiles for protective clothing and related application. *Textile magazine.* **45 :** 38-39.

Rani, P., Pruthi, N., Singh, S and Makkar, P. 2015. Protective clothing for women engaged in threshing. Pamphlet.

Wittczak, T., Walusiak-Skorupa, J. and Pa³czyñski, C. 2012. Allergic diseases and toxicological hazards in farmers' work environment. *Alergia.***1 :** 12–14.

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Impact of clean cotton picking practices on trash and contamination in cotton

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ABSTRACT : Excessive trash and contamination in cotton grown in north India have been a major cause of concern for textile mills. Most of the contaminations occur during farm operations *viz.,* picking, storage and transportation, and ginning process. In 2010-2011, an experiment was conducted to study the impact of clean cotton picking technology on trash and contamination under National Agricultural Innovation Project (Cotton Value Chain). 25 Small and marginal farmers from Neza Dela and Jhonpra villages in Sirsa district were adopted and provided all technological interventions during crop production, harvesting and post-harvest operations. The farmers were given training in clean cotton picking practices and related post harvest operations. They were also provided cotton picking aids *viz.,* headgears, aprons, bags, tarpaulins etc. The seed cotton was ginned at TMC modernised ginning factory in Sirsa and 63 bales (170 kg each), thus prepared were processed in a textile mill for yarn manufacturing. Samples were drawn from all the bales and analysed for trash content. It was found that trash content reduced to around 2 per cent as against normal range of 4-5 per cent. Clean cotton picking practices also resulted in an increased ginning outturn (GOT) by 3 per cent. Contamination level at blow room level was checked manually and found almost absent. It may be concluded that clean cotton picking technology can be an effective tool to control trash content and contamination in cotton.

Cotton is an important cash crop in north zone comprising of states of Punjab, Haryana and Rajasthan. This zone occupies an eminent place on the cotton map of the country. Rising from a productivity level of 226 kg lint/ ha with a production of 12.44 lakh bales in 1965-1966 it touched an all time high productivity level of 729 kg lint/ha contributing 59 lakh bales to the national pool in 2013-2014. Though much progress has been made in terms of productivity and production but cotton produced in north zone suffers from high level of trash content and contamination. Besides producing inferior quality yarn, it lowers the profit margin of ginners and spinners by increasing production cost at one hand and reduced production of yarn per kg of cotton spun on the other hand. This also leads to farmers fetching lesser value of the produce in the market. The quality of cotton is adversely affected by inappropriate harvesting, storage, marketing, ginning and pressing practices. Improper practices result in production of trashy and contaminated cotton. Excessive trash and contamination in cotton grown in north India have been a major cause of concern especially for spinning mills.

Government of India initiated Technology Mission on Cotton (TMC) in 2000 with a view to improve cotton productivity and its quality. Technology Misson on cotton was subcategorized into four mini mission modes namely I, II, III and IV. Mini Mission I and II pertained to varietal development, generation and transfer of technology. Mini Mission III and IV emphasised on development of market infrastructure and modernisation of ginning and pressing factories in order to reduce trash content and contamination level in cotton.

Table 1. Market yards developed and ginning and pressing factories modernised in north zone under TMC

State	Market yards developed	Ginning and pressing factories modernised
Punjab	19	11
Haryana	20	5
Rajasthan	14	0
North Zone	53	16
India	**250**	**859**

Source : CCI

A perusal of Table 1 indicates that 53 market yards were developed in north zone. There are around 400 working ginning and pressing factories in north zone but only 16 factories opted for modernisation. It is a matter of concern that despite government efforts, modernisation of ginning units could not take place in north zone.

Despite all efforts, trash content in north Indian cottons hovers around 4-5 per cent whereas modern textile machinery requires it to be less than 2 per cent. Since most of the trash and contamination occur during farm operations *viz.,* picking, storage and transportation and ginning process so a study was undertaken to assess the impact of appropriate on-farm and off-farm management practices on trash content and contamination in cotton.

MATERIALS AND METHODS

Twenty five Farmers from Neza Dela and Jhonpra villages in Sirsa district in Haryana were selected for the study under National Agricultural Innovation Project (NAIP). Various technological interventions were made during crop production and harvesting period. All the selected farmers were given off-farm and on-farm trainings in best management practices. They were made aware of types of contaminants found at mill level which are added during harvesting and post harvesting operations. They were supplied necessary picking aids like headgears, aprons, tarpaulins, bags for collecting seed cotton. Farmers were advised to pick damaged and stained *kapas* bolls separately from good fully opened bolls and collect in a separate pocket. Picked kapas was collected on a 20 x 20 ft tarpaulin in a corner of field to avoid contact with soil and other non lint material. The *kapas* was stored in neat and clean airy stores and transported to ginning factory in cotton cloth bags. All necessary steps were taken to avoid contamination of seedcotton with foreign matters. Two hundred eighty five quintals of seedcotton was ginned in a TMC modernised Sharda Cotton Factory at Sirsa following best management practices to get good quality lint. Before ginning, *kapas* was cleaned for any trash, contamination and kawdi cotton using automated precleaner. The ginned kapas was pressed into 63 standard sized bales (170 kg each) with identification number. Representative samples of sufficient quantity were drawn from each bale and tested for fibre properties on High Volume Instrument (MAG Expert 1201). Trash content in each bale was analysed by using Trash Analyser (MAG-SITRA Electronic Trash Separator). All the bales were tagged with corresponding fibre attributes and transported to spinning mill for further processing. Each and every bale was examined for contamination level at blow room stage in M/S Roshan Cotspin Limited at Mandi Killianwali in Punjab. All the 63 bales were converted into yarn at 24^s count. The yarn was further processed in autoconer and doubled on TFO for further end uses.

Table 2. Bale wise trash content data

Bale No.	Trash content (%)	Bale no.	Trash content (%)	Bale No.	Trash content (%)
1	1.95	22	2.11	43	1.77
2	1.89	23	2.01	44	2.08
3	2.07	24	1.93	45	2.04
4	1.79	25	1.96	46	1.96
5	1.94	26	2.00	47	2.21
6	1.88	27	1.84	48	1.95
7	1.99	28	1.89	49	1.99
8	2.09	29	1.98	50	2.00
9	2.11	30	1.89	51	1.95
10	2.17	31	2.08	52	2.18
11	1.99	32	1.91	53	1.96
12	1.73	33	2.00	54	2.01
13	1.88	34	2.10	55	1.95
14	1.74	35	1.94	56	2.04
15	2.05	36	1.90	57	1.81
16	2.16	37	2.02	58	1.95
17	1.90	38	1.90	59	1.91
18	1.89	39	2.00	60	1.88
19	2.06	40	2.06	61	1.79
20	1.91	41	1.89	62	1.98
21	1.99	42	1.96	63	2.01

RESULTS AND DISCUSSION

The intervention of clean cotton picking, storage and transportation resulted in high ginning outturn of 36 per cent against the normal range of 32-33 per cent. Clean picked cotton also facilitated increased ginning efficiency of 2.45 h/5 quintals against 3.00 h/5 quintals thus decreasing ginning cost. A perusal of the data in Table 2 clearly indicates that trash content level in all the pressed bales was found around 2 per cent against the normal range of 4-5 per cent in the region. Good management practices also resulted in negligible contamination in cotton lint. At blow room stage, contaminants like body hair, pouches, jute twine, plastics, pieces of stones etc. were not found. A negligible quantity of contaminants (95g out of 10202 kgs) was found. Absence of contaminants increased the cleaning efficiency and production efficiency of blow room and carding which impacted the efficiency of preparatory stage. More cleaned and good quality material in preparatory affected the working of ring frame, subsequently, increasing the speed of ring frame by 3 per cent which resulted in increased yarn production. The general appearance of yarn was observed on the standard sized black board and compared with ASTM Grades. The board was found on “A” Grade. Processing of yarn in Autoconer and doubling on TFO produced 0.2 per cent less Hard Waste due to very low breakages.

Fig. 1. Demonstaration of clean cotton picking

Fig. 2. Collection of *kapas* at farm

Fig. 3. Transportation of *kapas* to ginning factory

Fig. 4. Bales tagged with fibre properties

CONCLUSION

It may be concluded that clean cotton picking along with good post harvest practices can be effective tools to control trash content and contamination in cotton. Low trash and low contamination level in cotton lint will fetch good margin of profit to spinners as well as ginners which in turn will help farmers to fetch better price of their produce.

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Breeding potential of *Gossypium barbadense* L. introgressions into upland cotton

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Abstract : Cotton (*Gossypium* spp.) is one of the most important world's natural textile fibres crop. Amongst cultivated species of cotton, *G. barbadense* has superior extra-long and strong fibre than upland cotton. The unique fiber properties of *G. barbadense* make it an ideal genetic resource for providing new genetic variation useful for improving fiber quality in *G. hirsutum*. Attempts to incorporate genes from *G. barbadense* into upland cotton have generally not achieved stable introgression of the fibre properties. The problems associated with these attempts at introgression have been poor agronomic qualities of the progeny, distorted segregation, sterility, mote formation and limited recombination due to incompatibility between the genomes.

The most important aspect in interspecific introgression is to use valuable alien traits or genes of *G. barbadense*, such as fibre length, fineness and strength for improvement of upland cotton. In India, a remarkable success has been achieved in improvement of fibre quality, particularly fibre length and strength of cotton fibre. Breeding programmes in development of *G. barbadense* cultivars led to release of Sujata and Suvin which is significant breakthrough in fibre quality improvement. These varieties are capable of spinning 100 - 120 counts comparable to several Pima, Egyptian and Sudan types. Applications of correct methodology such as population improvement, recurrent backcrossing, advanced backcrossing and use of *G. barbadense* cotton chromosome substitution lines in breeding programmes will enable to improve fibre properties of upland cotton. Such methodological aspects and strategies shall be discussed.

Key words: Distorted segregation, *G. barbadense*, introgression, mote formation, pima cotton, sterility, substitution lines, transgressive segregants, upland cotton,

Cotton belongs to the *Gossypium* genus, which consists of approximately 45 diploid and 5 allotetraploid species. These species are grouped into nine genome types with the designations A, B, C, D, E, F, G, K, and AD (Fryxell 1979; Percival *et al.,* 1999; Wendel *et al.,* 2009). It is one of the most important world's natural textile fibres crop grown in more than 80 countries. Amongst the species, two cultivated species *G. hirsutum* and *G. barbadense* contribute to 95 per cent of the production of this natural fibre around the world. These species are crossable and each displays distinctive characteristics in their adaptability and fibre quality.

According to Bradow and Davidonis (2000), the perfect cotton fibers are those which are as white as snow, strong like steel, fine like silk and as elongated as wool. However, it is difficult to integrate these qualities favoured by cotton processors into a breeding strategy or to set them as quantitative objectives for cotton producers. Fibre quality can be described as a set of measurable fibre properties (length, fineness strength, uniformity and elongation) that improves the spinning performance during textile processing. Cotton fibre is the single cell elongation of the cotton seed (ovule) epidermis that is anatomically classified as a trichome which is composed of almost 89-100 per cent cellulose.

G. barbadense cultivars have longer, stronger and finer fibre than upland cultivars. The unique fiber properties of *G. barbadense* make it an ideal genetic resource for providing new genetic variation useful for improving fiber quality in *G. hirsutum*. Introgression is widely acknowledged as a potential source of valuable genetic variation, and growing effort is being invested in analysis of interspecific crosses conferring transgressive variation (Lacape *et al.,* (2005). Phylogenetic analyses of both nuclear and cytoplasmic DNA sequences indicate that *G. hirsutum* and *G. barbadense* are closely related (Small *et al.,* 1998, 1999) and these species cross easily to yield hybrids that show normal meiosis and produce fertile progeny.

Although *G. barbadense* and *G. hirsutum* share a common progenitor, the two species substantially differ, which has hindered the transfer of the superior fibre traits of *G. barbadense* to *G. hirsutum via* inter species hybridization. Attempts to incorporate genes from *G. barbadense* into upland cotton have generally not achieved stable introgression of the fibre properties. Associated with these attempts at introgression have been poor agronomic qualities of the progeny, distorted segregation, sterility, mote formation and limited recombination due to incompatibility between the genomes (Reinisch *et al.,* 1994). Segregation distortion (non-Mendelian inheritance) and restricted recombination are often found in the mosaic genomes of interspecific hybrid populations (Rick 1969; Paterson *et al.,* 1990;). Segregation distortion has previously been reported in interspecific populations of cotton (Yu *et al.,*, 2013). Dai *et al.,* (2016) found hybrid breakdown extensively in the interspecific F_2 population particularly on the reproductive traits because of the infertility and bare seeds.

Successes in interspecific hybridization have been surprisingly few and difficult. The uniqueness of the Acala cotton has been attributed to its unique breeding history in which germplasm from *G. barbadense* and a three species Triple Hybrid (ATH, *G. arboreum* × *G. thurberi* × *G. hirsutum*) has been introgressed into the Acala cotton (Smith and Cothren, 1999). Interspecific introgression has also contributed significantly to the development of high quality of Pee Dee germplasm lines (May, 2001). The Pee Dee germplasms involved multiple introgressions from the Triple Hybrid, *G. barbadense* and Acalas.

In India, a remarkable success has been achieved in improvement of fibre quality, particularly fibre length and strength of cotton fibre. MCU 5 is the first extra long stable variety of *G. hirsutum*. MCU 5 VT, MCU 9, MCU11, and Phule 388 are also other extra long stable varieties. Several *G. barbadense* cultivars have resulted in significant breakthrough in fibre quality improvement in India. The released varieties Sujata and Suvin capable of spinning 100 - 120 counts comparable to several Pima, Egyptian and Sudan types. Suvin is considered as one of the finest cotton produced in India and also a suitable substitute for Egyptian Giza 45. This is the distinct landmark in the cotton fibre quality enhancement in India. In addition, inter-specific (*G. hirsutum* × *G. barbadense*) hybrids Varalaxmi, DCH 32, HB 224; NHB 12, TCHB 123, Sruthi, Phule 388, DHB 915, DHB 1071, RHB 0711, RHB 0812 and New Bharat Kranthi have the high yield with good fibre quality. The interspecific *Bt* hybrids RCHB 708 *Bt* and MRC 6918 *Bt* also occupies some areas in South India. Gururajan and Manickam (2005) have reviewed the fibre quality improvement in extra-long staple *G. barbadense* cotton in different countries of the world.

Breeding strategies for utilizing potential of *Gossypium barbadense* L. introgressions into upland cotton : In interspecific *G. hirsutum* × *G. barbadense* crosses, segregants which are infertile or poorly productive are observed in early segregating generations. In order to obtain usable interspecific derivatives of *G. hirsutum* × *G. barbadense* crosses following conventional breeding and molecular breeding strategies are discussed.

- F_1 of *G. hirsutum* × G. *barbadense* backcrossed to *G. hirsutum* genotypes for several generations followed by selfing,
- Population improvement using intermating or recurrent selection and then develop homozygous intermediate *G. hirsutum* lines with *G. barbadense* type fiber quality,
- Advanced backcrossing (AB) followed by several generations of selfing to develop backcross inbred lines (BILs),
- To use *G. barbadense* cotton chromosome substitution lines (CSL) on upland cotton backgrounds to cross with upland cotton cultivars,
- Identification of quantitative trait loci (QTLs) and development of markers for marker assisted selection,
- To use stabilized introgressed lines as parents in producing mapping and breeding populations,
- To develop multiparent advanced generation intercross (MAGIC) population which involves intercrossing of multiple parents, forming a single large population is another form of next generation population which may provide enormous resources for future genetic breeding and
- To use multiple crosses (three-way, double crosses) for increasing the level of recombination.

Backcrossing : In interspecific *G. hirsutum* × *G. barbadense* crosses, segregants which are infertile or poorly productive and often encountered in early segrgegating or in recombinant inbred line (RIL) populations, are minimized through backcrossing. The chromosome segments transferred from *G. barbadense* to upland cotton are stabilized through several generations of backcrossing followed by selfing. Repeated backcrossing to one parent ensures the maintenance of the genetic balance of that species and permits the integration of a portion of the gene content of the other species without the risk of a genetic breakdown.

Jiang *et al.,* (2000) reported that in BC_3F_2 plants derived from 24 different BC_1 individuals of a cross between *Gossypium hirsutum* and *G. barbadense,* large and widespread deficiencies of donor (*G. barbadense*) chromatin were found, and seven independent chromosomal regions were entirely absent. This skewed chromatin transmission is best accounted for by multilocus epistatic interactions affecting chromatin transmission.

Park *et al.,* (2005) developed 183 recombinant inbred lines from the progeny of the *G. hirsutum* L cv. TM1 × *G. barbadense* L. cv. Pima 3-79 for genetic mapping of cotton fibre loci. Pang *et al.,*, (2007) hybridized Upland and Pima or Egyptian Giza and developed BC_2F_4 inbred lines which had Upland cotton plant type and morphological characteristics, showing no hybrid breakdown or weakness and performed very well in the field, showing high yield potential. Yu *et al.,* (2013) reported that backcross inbred lines (BILs) were developed through two generations of backcrossing followed by several generations of self pollination. Only limited chromosomal regions from the *G. barbadense* donor parent were transferred to the recurrent parent through backcrossing, and repeated self-pollination also minimized hybrid breakdown and stabilized the chromosome segments transferred from *G. barbadense* to upland cotton. Many BILs were found to have improved fiber quality in length, strength and micronaire than Upland cotton, some of which had similar lint yield to their recurrent upland parent, indicating introgression of desirable fiber quality genes from Pima to upland cotton.

Population improvement : The most efficient strategy in introgressing fiber quality genes from *G. barbadense* is to pyramid desirable fiber quality genes through population improvement using intermating or recurrent selection and then develop homozygous intermediate *G. hirsutum* lines with *G. barbadense* type fiber quality (Smith and Cothren, 1999)

Random mating, as one of several breeding approaches, has been used to successfully break linkage blocks in crops for multiple-trait improvements. Random mating requires a considerable expenditure of time and energy. If one starts with a large diverse group of parental lines, it offers an opportunity to break up adverse linkage blocks and to form new recombinations, some of which should be superior.

Random mating has previously been shown to reduce correlations between traits in cotton (Miller and Rawlings, 1967: Meredith, 1984: Meredith and Bridge, 1971). Random mating requires a considerable expenditure of time and energy. If one starts with a large diverse group of parental lines, it offers an opportunity to break up adverse linkage blocks and to form new recombinations, some of which should be superior. Jenkin *et al.,* (2008) reported that changes in correlations between traits among parents, C0, and C5 cycles show that after random mating, the C5 population has recombinations that should be useful for selection and cultivar development.

Advanced backcrossing (AB) : An adaptation of backcross QTL mapping is called the Advanced Backcross method (Tanksley and Nelson, 1996). It is especially useful for identifying beneficial QTL alleles in wild germplasm.

The advanced-backcross design creates populations with genomic compositions similar to those likely to result from interspecific hybridization in nature (Rieseberg *et al.,* 1996).

One strategy to minimize the problems is to use advanced backcrossing (AB) followed by several generations of selfing to develop backcross inbred lines (BILs) (Zamir, 2001).

A number of other investigations have reported using advanced backcrossing in interspecific populations prior to genotyping and phenotyping advanced generation (BC_1 to BC_3) individual plants within these populations (Lacape *et al.,*, 2005; Chee *et al.,*, 2005a, b; Draye *et al.,*, 2005). Nallathambi *et al.,* (2011) used backcross, modified back cross pedigree breeding method following marker-assisted selection to improve fibre strength of *G. hirsutum* by utilizing *G. barbadense* as donor parents. They obtained high productive progenies with high fibre strength that ranged from 30.0 t0 35.7 g/tex having more recurrent background in $BC1F_8$ generations. Zhang Jinfa (2011) developed introgressed lines with high yield potential and better fibre quality than upland cotton parents, indicating simultaneous introduction of desirable genes for yield and fibre quality. Backcross inbred lines (BIL) had improved fibre quality in fibre length, strength and micronaire than recurrent upland parent.

Chromosome substitution lines (CSL) : The development of chromosome substitution lines from *G. barbadense* (CS-B) opens a door for more efficient introgression of alleles from *G. barbadnese* into upland cotton. The *G. hirsutum* lines with *G. barbadense* fiber quality can then be further utilized to cross with elite upland cotton for further improvement.

Many individual chromosomes or chromosome arms from Pima cotton have been transferred into Upland cotton through monosomic or telosomic cytogenetic stocks, resulting in the development of 17 CSL in Upland cotton TM-1 background (Stelly *et al.,*, 2005). Genetic effects of Pima cotton chromosome A1, A2, A4, A6, D3 and D13 were reported earlier (Kohel *et al.,*, 1977; Ma and Kohel, 1983), while 13 CSL (B02-A2, 04-A4, 05sh-A5sh, 06-A6, 07-A7, 14sh-D2sh, 15sh-D1sh, 16-D7, 17-D3, 18-D13, 22Lo-D4Lo, 22sh-D4sh, and 25-D6) and their hybrids with several upland cotton cultivars have been recently tested for their effects on yield, yield components, fiber quality, and flower production (Saha *et al.,*, 2004, 2006; Jenkins *et al.,*, 2006, 2007; McCarty *et al.,*, 2006). Saha *et al.,* (2011) highlighted the importance of the epistasis in fibre quality traits and found higher fibre strength in substitution line crosses than parental lines. Li *et al.,* (2016) reported usefulness of chromosome segment substitution lines for improving yield and yield components in cotton.

The identification of QTLs and development of markers for marker assisted selection : The identification of QTLs and development of markers for marker assisted selection would be a great boon to the cotton breeder, providing greater precision in trait transfer, identification of desirable trait combinations, etc.

Molecular marker studies have identified alleles transferred between *G. barbadense* and *G. hirsutum* (Percy and Wendel 1990), suggesting that interspecific introgression has been an important source of selectable variation in the development of modern cotton cultivars. Permanent mapping populations from recombinant inbred lines (RILs) developed by single seeded descent (SSD) can facilitate gene mapping (Lu *et al.,*, 2004; Park *et al.,*, 2005; Frelichowski *et al.,*, 2006). For example, by crossing with TM-1, a stabilized introgression line NM 24016 (Cantrell and Davis, 2000) has yielded a number of RILs showing high fiber quality and acceptable agronomic properties (Percy *et al.,*, 2006). Even though many of the RILs have unacceptable yield or average fiber, the number of lines produced has increased the chance that one or two may have the right combination of yield and quality. Several RILs have been used in our heat tolerance/fiber quality breeding.

Many researchers have used the populations derived from *G. hirsutum* and *G. barbadense* to detect QTL related to agronomic traits, fiber quality traits (Chee *et al.,* 2005, Wang *et al.,* 2006, Chen *et al.,* 2008), and verticillium wilt resistance (Wu *et al.,* 2010, Wang *et al.,* 2008). A RIL population created from the introgressed parent NM 24016 and the upland TM-1 has demonstrated both the stability of the resulting recombinant inbred lines and the genetic variability that can be realized in such a population (Percy *et al.,*, 2006). In another example, no severe hybrid breakdown has been noted from a cross between Acala 1517-99 and Pima Phy 76 during consecutive selfing process. Lacape *et al.,* (2013) detected 166 QTLs covering 27 traits in derived recombinant inbred line population from an inter-specific cross between Gh and Gb.

Use of introgressed lines (ILs) : Introgrssed lines, which are homozygous and intermediate in phenotype, can serve as a bridge to avoid the hybrid breakdown and selective elimination of genes that occurs in interspecific segregating populations.

Attempts to produce high fiber quality lines through introgression have resulted in numerous stable breeding lines (Ma and Liu, 1982; Zhang *et al.,*, 1993; Cantrell and Davis, 2000; Liu *et al.,*, 2005), but only after many generations of backcrossing, selfing, and continuous pedigree selection.

Multiple crosses : Zeng *et al.,* (2010) reported that John Cotton (JC) cotton germplasm was developed from multiple crosses between *Gossypium hirsutum* L. and *G. barbadense* L. JC14, JC32, JC60, and JC65 were released by the USDA-ARS for their exceptional fiber quality or desirable combinations of lint yield and fiber properties. The prospect of combining fibre quality of *G. barbadense* var. Suvin with the high yield potential of *G. hirsutum* var. NH 615 was explored through interspecific hybridization (Palve *et al.,* 2017). They reported transgressive segregation for plant height and yield attributing traits like boll number in segrgating population of three-way crosses.

REFERENCES

Bradow, J. M. and Davidonis, G. H. 2000. Quantitation of fiber quality and the cotton production-processing interface: A physiologist's perspective. *J. Cotton Sci.* **4 :** 34–64.

Cantrell, R.G. and Davis, D.D. 2000. Registration of NM 24016, an interspecific-derived cotton genetic stock. *Crop Sci.* **40 :** 1208.

Chee, P. W., Draye, X., Jiang, C. X., Decanini, L. and Delmonte, T. A. 2005(a). Molecular dissection of phenotypic variation between *Gossypium hirsutum* and *Gossypium barbadense* (cotton) by a backcross-self approach: III. Fiber length. *Theor. Appl. Genet.* **111 :** 772-81.

Chee, P., Draye, X., Jiang, C. X., Decanini, L., Delmonte, T. A. and Bredhauer, R. 2005 (b). Molecular dissection of interspecific variation between *Gossypium hirsutum* and *Gossypium barbadense* (cotton) by a backcross self approach: I. Fiber elongation. *Theor. Appl. Genet.* **111 :** 757–63.

Chen, L., Zhang, Z. S. and Hu, M. C. 2008. Genetic linkage map construction and QTL mapping for yield and fiber quality in upland cotton (*Gossypium hirsutum* L.). Acta Agronomica Sinica. **34 :** 1199–1205.

Dai, B., Guo, H., Huang, C., Ahmed M. M. and Lin, Z. 2017. Identification and characterization of segregation distortion loci on cotton chromosome 18. *Frontiers Plant Science*. **7 :** 2037.

Draye, X., Chee, P., Jiang, C. X., Decanini, L., Delmonte, T.A., Bredhauer, R., Smith, C. W. and Paterson, A.H. 2005. Molecular dissection of interspecific variation between *Gossypium hirsutum* and *G. barbadense* (cotton) by a backcross-self approach: II. Fiber fineness. *Theor. Appl. Genet.* **111 :** 764-71.

Fryxell, P. A. 1979. Natural history of the cotton tribe (*Malvaceae*, tribe *Gossypieae*). Texas AandM University Press, College Station, p 245

Gururajan, K.N. and Manickam, S. 2005. Fibre quality improvement in Egyptian Cotton, Paper presented at the *National Seminar – SIMA – DCDRA*, Coimbatore.

Frelichowski, J.E., Palmer, M.B., Main, D., Tomkins, J.P., Cantrell, R.G., Stelly, D.M., Yu, J., Kohel, R.J. and Ulloa, M. 2006. Cotton genome mapping with new microsatellites from Acala 'Maxxa' BAC-ends. *Mol. Genet. Genomics* **275 :** 479-91.

Jiang, C. X., Peng, W. C., Xavier, D., Peter L. Morrell, Wayne Smith, C. and Andrew H. Paterson. 2000. Multilocus interactions restrict gene introgression in interspecific population of polyploidy *Gossypium* (Cotton). *Evolution* **54 :** 798-814.

Jenkins, J. N., McCarty, J. C., Jr., O. A. Gutierrez, R. W. Hayes, Bowman, D. T., Watson, C. E. and Jones. D. C. 2008. Registration of RMUP-C5, a Random Mated Population of Upland Cotton Germplasm. *Journal Plant Registrations*, **2 :** 239.

Jenkins J. N., McCarty, J. C., Wu, J. X., Saha, S., Gutierrez, O., Hayes, R., Stelly, D. M., 2007. Genetic effects of thirteen *Gossypium barbadense* L. chromosome substitution lines in topcrosses with upland cotton cultivars: I. Yield and yield components. *Crop Sci.* **46 :** 1169–78.

Jenkins J. N., McCarty, J. C., Wu, J. X., Saha, S., Gutierrez, O., Hayes, R., Stelly, D. M. 2007. Genetic effects of thirteen *Gossypium* *barbadense* L. chromosome substitution lines in topcrosses with upland cotton cultivars: II. Fiber quality traits. *Crop Sci.* **47 :** 561–70.

Lacape Jean-Marc , Gérard Gawrysiak, Tuong-Vi Cao, Christopher Viot, Danny Llewellyn, Shiming Liu, John Jacobs, David Becker, Paulo Augusto Vianna Barroso, José Henrique de Assunc¸ão, Oumarou Palaï , Sophie Georges, Janine Jean, Marc Giband. 2013. Mapping QTLs for traits related to phenology, morphology and yield components in an inter-specific Gossypium hirsutum × *G. barbadense* cotton RIL population. *Field Crops Research* **144 :** 256–67.

Lacape, J. M., Nguyen, T. B., Courtois, B., Belot, J. L., Giband, M., Gourlot, J. P., Gawryziak, G., Roques, S. and Hau, B. 2005. QTL analysis of cotton fiber quality using multiple *Gossypium hirsutum* × *Gossypium barbadense* backcross generations. *Crop Sci.* **45 :** 123-40.

Lacape, J. M. and Nguyen, T. B. 2005. Mapping quantitative trait loci associated with leaf and stem pubescence in cotton. *J. Hered.* **96 :** 441-44.

Li, X., Jin, X., Wang, H., Zhang X. and Lin, Z. 2016. Structure,evolution,and comparative genomics of tetraploid cotton based on a high-density genetic linkage map. *DNA Res.* **23 :** 283–93.

Liu, J. S., Yang, B. X., Gao, Z. Y., Yang, S. J., Zheng, F., Yan, Y. and Ban, Z. J. 2005. High fiber strength medium and long staple cottons developed by hybridization between Upland and Sea-island cotton. *China Cottons* **32 :** 12-14.

Lu, Y. Z., Zhang, J. F., Percy R. G. and Cantrell, R. G. 2004. An integrated SSR-STS-AFLP-SRAP genetic map using recombinant inbred line populations in tetraploid cottons. p1156-1161. *In* Proc. Beltwide Cotton Conf., San Antonio, TX. Jan. 5-9 2004**.** *Natl. Cotton* Counc. Am., Memphis, TN.

Ma, F. Z. and Liu, J. S. 1982. Genetic advances in economic traits of interspecific progenies between *Gossypium hirsutum* and *G. barbadense. J. China Agric. Univ.* **8 :** 23-32.

May, O. L. 2001. Registration of PD 94045 germplasm line of Upland cotton. *Crop Sci.* **41 :** 279-80.

McCarty J. C. Jr, Wu, J. X., Saha, S., Jenkins, J. N., Hayes, R. 2006. Effects of chromosome 5sh from *Gossypium barbadense* L. on flower production in *G. hirsutum* L. *Euphytica* **152 :** 99–107.

Miller, P. A., and Rawlings, J. O. 1967. Breakup of linkage blocks through intermating in a cotton breeding population. *Crop Sci.* **7 :** 199–204.

Meredith, W.R. 1984. Quantitative genetics. *In* R.J. Kohel and C.F. Lewis (ed.) Cotton. Agron. Monogr. 24. ASA, CSSA, and SSSA, Madison, WI., p. 131–50.

Meredith, W. R. and Bridge, R. R. 1971. Breakup of linkage blocks in cotton. *Crop Sci.* **11 :** 695–97.

Nallathambi Kannan, Selvakumar, P., Krishnamoorthy, R. , Raja, D., Bhuvaneshwari, M. , Subramanian V. and Ramasami, M. 2011. Introgression of high fibre strength trait to upland cotton using marker assisted selection . *WCRC - 6* Mumbai.

Palve S. M., Mandhyan P. K. and Kate, N. 2017. Genetic variability studies for quantitative traits between *Gossypium hirsutum* and *Gossypium barbadense* population developed by a three-way cross. *In 7th Asian Cotton Research and Development Network (ACRDN) Meeting*, Nagpur, India, pp 68.

Park, Y. H., Alabady, M. S., Ulloa, M., Sickler, B., Wilkins, T.A., Yu, J., Stelly, D. M., Kohel, R. J., El-Shihy, O. M. and Cantrell, R. G. 2005. Genetic mapping of new cotton fiber loci using EST-derived microsatellites in an interspecific recombinant inbred line cotton population. *Mol. Genet. Genomics* **274 :** 428-41.

Park, Y. H., Alabady, M. S., Ulloa, M., Sickler, B., Wilkins, T. A., Yu, J., Stelly, D. M., Kohel, R. J., El-Shihy, O. M. and Cantrell, R. G. 2005. Genetic mapping of new cotton fiber loci using EST-derived microsatellites in an interspecific recombinant inbred line cotton population. *Mol. Genet. Genomics* **274 :** 428-41.

Paterson, A. H., Deverna, J. W., Lanini, B. and Tanksley, S. D. 1990. Fine Mapping of Quantitative Trait Loci Using Selected Overlapping Recombinant Chromosomes, in an Interspecies Cross of Tomato. *Genetics* **124 :** 735-42.

Percy, R. G., Zhang, J. F. and Cantrell, R. G. 2006. Genetic variation for agronomic and fiber properties in an introgressed recombinant inbred population of cotton. *Crop Sci.* **46 :** 1311- 17.

Percival A. E., Wendel, J. F. and Stewart, J. M. 1999. Taxonomy and germplasm resources. *In*: Smith C. W. , J. T. Cothren (eds) Cotton: origin, history, technology, and production. Wiley, New York, pp 33–63.

Rinisch A. J., Dong, J. M., Brubaker, C., Stelly, D., Wendel, J. F. and Paterson, A. P. 1994. A detailed RFLP map of cotton (*Gossypium hirsutum* × *Gossypium barbadense*): chromosome organization and evolution in a disomic polyploid genome. *Genetics* **138 :** 829–47.

Rick, C. 1969. Controlled introgression of chromosomes of *Solanum pennellii* into *Lycopersicon esculentum:* segregation and recombination. Genetics **62 :** 753–68.

Reieseberg, L., Sinervo, B. R., Linder, Ungerer, M. and Arias, D. 1996. Role of gene interactions in hybrid speciation: evidence from ancient and experimental hybrids. *Science* **272 :** 741–45.

Saha S., Jenkins, J. N., Wu, J., McCarty Jr, J. C., Gutierrez, O. A., Stelly, D. M., Percy, R. G. and Raska, D. A. 2004. Effects of chromosome substitutions from *Gossyoium barbadense* L. 3-79 into *G. hirsutum* L. TM-1 on agronomic and fiber traits. *J. Cotton Sci.* **8 :** 162–69.

Saha S., Jenkins, J. N., Wu, J., McCarty Jr, J. C., Gutierrez, O. A., Percy, R. G., Cantrell R. G. and Stelly, D. M. 2006. Effects of chromosome specific introgression in Upland cotton on fiber and agronomic traits. *Genetics.* **172 :** 1927–38.

Saha S., Jenkins, J. N., Wu, J., McCarty Jr, J. C. and Stelly, D. M. 2008. Genetic analysis of agronomic and fiber traits using four interspecific chromosome substitution lines in cotton. *Plant Breed* **127 :** 612–18.

Saha S., Wu, J., Jenkins, J. N., McCarty Jr, J. C., Hayes, R. W. and Stelly, D. M. 2011. Delineation of interspecific epistasis on fiber quality traits in Gossypium hirsutum by ADAA analysis of intermated *G. barbadense* chromosome substitution lines. *Theor Appl Genet* **122 :** 1351–61.

Saha S., Wu, J., Jenkins, J. N., McCarty Jr, J. C. and Stelly, D. M. 2013. Interspecific chromosomal effects on agronomic traits in Gossypium hirsutum by AD analysis using intermated *G. barbadense* chromosome substitution lines. *Theor. Appl. Genet.* 126 : 109–111.

Small, R. L., Ryburn, J. A., Cronn, R. C., Seelanan, T. and Wendel, J. F. 1998. The tortoise and the hare: choosing between noncoding plastome and nuclear *Adh* sequences for phylogeny reconstruction in a recently diverged plant group. *Am. J. Bot.* **85 :** 1301–15.

Small, R. L., Ryburn, J. A. and Wendel, J. F. 1999. Low levels of nucleotide diversity at homoeologous *Adh* loci in allotetraploid cotton (*Gossypium* L.). *Mol. Biol. Evol.* **16 :** 491 501.

Smith, C. W. and Cothren, J. T. eds. 1999. Cotton: origin, history, technology, and production, New York: John Wiley and Sons, Inc.

Stelly, D. M., Saha, S. A., Raska, D. A., Jenkins, J. N., McCarty Jr., J. C. and Gutierrez, O. A. 2005. Registration of 17 germplasm lines of upland cotton (*Gossypium hirsutum*) cotton, each with a different pair of *G. barbadense* chromosomes or chromosome arms substituted for the respective *G. hirsutum* chromosome or chromosome arms. *Crop Sci.* 45 : 2663-65.

Tanksley, S. D. and Nelson, C. J. 1996. Advance backcross QTL analysis: a method for the simultaneous discovery and transfer of valuable QTLs from unadapted germplasm into elite breeding lines. *Theor. Appl. Genet.* **92 :** 191-203.

Wendel J. F., Brubaker, C., Alvarez, I., Cronn, R., Stewart, J. M. 2009. Evolution and natural history of the cotton genus. In: Paterson A. H. (eds), Genetics and genomics of cotton. Springer, New York, pp 3–22.

Wang, B. H., Guo, W. Z., Zhu, X. F., Wu, Y. T., Huang, N. T. and Zhang, T. Z. 2006. QTL mapping of fiber quality in an elite hybrid derived-RIL population of upland cotton. *Euphytica.* **152 :** 367–78.

Wang, H. M., Lin, Z. X., Zhang, X. L., Chen, W., Guo, X. P., Nie, Y. C. 2008. Mapping and quantitative trait loci analysis of verticillium wilt resistance genes in cotton. *J. Integr. Plant Biol.* **50 :** 174–82.

Wang P., Zhu, Y., Song, X., Cao, Z., Ding, Y., Liu, B., Zhu, X., Wang, S., Guo W. and Zhang, T. 2012. Inheritance of long staple fiber quality traits of *Gossypium barbadense* in *G. hirsutum* background using CSILs. *Theor. Appl. Genet.* **124 :** 1415–28.

Wu C. C., Jian, G. L., Wang, A. L., Liu, F., Zhang, X. L. and Song, G. L. 2010. Primary detection of QTL for verticillium wilt resistance in cotton. *Mol Plant Breeding.* **8 :** 680–86.

Xinhui Nie, Jianli Tu, Bin Wang, Xiaofeng Zhou, and Zhongxu Lin. 2015. A BIL Population Derived from *G. hirsutum* and *G. barbadense.* Provides a Resource for Cotton Genetics and Breeding. PLoS One. **10:** e0141064.

Yu J., Zhang, K., Li, S., Yu, S., Zhai H. and Wu, M. 2013. Mapping quantitative trait loci for lint yield and fiber quality across environments in a *Gossypium hirsutum* × *Gossypium barbadense* backcross inbred line population. *Theor. Appl. Genet.* **126:**275–87.

Yu J., Zhang, K., Li, S., Yu, S., Zhai, H., Wu, M., Li, X., Fan, S., Song, M., Yang, D., Li, Y. and Zhang, J. F. 2013. Mapping quantitative trait loci for lint yield and fiber quality across environments in a *Gossypium hirsutum* × *Gossypium barbadense* backcross inbred line population. *Theor. Appl. Genet.* **126:**275–87.

Zamir D. 2001. Improving plant breeding with exotic genetic libraries. *Nat. Rev. Genet.* **2 :** 983–89.

Zhang, J. F., Sun, J. Z., Liu, J. L. and Wu, Z. B. 1993. Identification of cotton varieties resistant to carmine spider mites and exploration of resistance mechanism. *Acta Phytophylacica Sinica* **20 :** 155-61.

Zhang J. 2011. Twenty-five years of introgression breeding through interspecific hybridization between Gossypium hirsutum and *Gossypium barbadense*. *Beltwide Cotton Conference*, Atlanta, Georgia, January 4-7, 2011.

Zeng L. Meredith W. R. and Campbell, B. T. 2010. Registration of four exotic germplasm lines derived from an introgressed population of cotton. *Journal Plant Registration.* **14 :** 240-43.

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Evaluation of newly developed *G. hirsutum* compact genotypes for high density planting system under irrigated condition

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ABSTRACT : Maharashtra is a major Cotton growing state contributing around 38 per cent of the area and 25 per cent of cotton production in India but low in productivity (398kg/ha). Plant density can be used to manipulate yield components. There is a scope for increasing the productivity with the compact and erect genotypes of cotton with synchronized and early boll maturity suitable for mechanical harvest. An experiment for initial evaluation of twenty compact genotypes of *G. hirsutum* along with two checks for high density was taken at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri during 2016-2017. The experiment was laid out in randomized block design with three replications. Two rows of 7.2 m length of each genotype with a spacing of 60 x 15cm were sown. Results were statistically significant for seed cotton yield and ranges from 3370kg/ha to 6193kg/ha. The only one genotype RHC HD-1420 (6193 kg/ha) showed significantly superior over the best check Phule Yamuna (4781kg/ha) at closer spacing for seed cotton yield. Whereas, five genotypes *viz.,* RHC HD-1312 (5623 kg/ha), RHC HD-1433 (5399 kg/ha), RHC HD-1446 (5336 kg/ha), RHC HD-1438 (5187 kg/ha) and RHC HD-1430 (5176 kg/ha) showed numerical higher yield over best check Phule Yamuna. Ginning outturn was ranged from 31.5 to 38.9 percent, the highest ginning percentage was recorded by the strain RHC-HD-1427 (38.9%) followed by RHC HD-1433 (38.0%), RHC HD-1412 (37.6%) and RHC HD-1420 and RHC-HD-1425 (36.0%). In conclusion, it is clearly visible that among the genotypes studied, the RHC-HD-1420 had significant seed cotton yield, zero monopodial branched, more sympodial branches, highest boll weight with early maturity and hence it would be more desirable for High Density Planting System (HDPS).

Key words : *G. hirsutum* compact genotype, HDPS

India has the largest area in the world under cotton at 11.700 mha and is the second largest producer in the world at 29.000 m bales. However, India's average cotton productivity is 540 kg lint yield/ha combining both irrigated and rainfed fields and this is low compared to other countries like China 1380, Brazil 1465 kg lint yield/ha, US as well as the world average yield of 926 kg lint yield/ha (Anonymous, 2016-2017).

The Ultra Narrow Rows system is popular in several countries like Brazil, China, Australia, Spain, Uzbekistan, Argentina, USA and Greece (Rossi *et al.,* 2004). The availability of compact genotypes, acceptance of weed and pest management technologies including transgenics, development of stripper harvesting machines and widespread application of growth regulators have made these high density cotton production systems successful in these countries. The obvious advantage of this system is earliness (Rossi *et al.,* 2004) since UNR needs less bolls / plant to achieve the same yield as conventional cotton and the crop does not have to maintain the late formed bolls to mature. The UNR cotton plants produce fewer bolls than conventionally planted cotton but retain a higher percentage of the total bolls in the first sympodial position and a lower percentage in the second position (Vories and Glover, 2006).The other advantages include better light interception, efficient leaf area development and early canopy closure which will shade out the weeds and reduce their competitiveness (Wright *et al.,* 2011). The early maturity in soils that do not support excessive vegetative growth (Jost and Cothern, 2001) can make this system ideal for shallow to medium soils under rainfed conditions, where conventional late maturity hybrids experience terminal drought. Therefore, the high density planting system (HDPS) is now being conceived as an alternate production system having a potential for improving the productivity and profitability, increasing input use efficiency, reducing input costs and minimizing the risks associated with the current cotton production system in India.

MATERIALS AND METHODS

During 2012-2013 work has initiated to develop the genotypes suitable for High Density Planting System (HDPS). Efforts were made to develop short (2-3Feet), zero monopodial, compact, early and synchronous maturing varieties with fruiting bodies close to the main stem. Twenty genotypes highly resembles to HDPS has been selected from germplasm as well as segregating population. For evaluation of these genotypes a field experiment was conducted at Cotton Improvement Project, MPKV, Rahuri during *kharif* 2016-2017 under irrigated condition. The topography of experimental field was fairly uniform, leveled and with a good drainage. The soil was deep black with rich in nutrients. The experiment was laid out in completely randomized block design with three replications. Two rows of 7.2 m length of each genotype with a spacing of 60 x 15cm were sown. The biometric observation on growth and yield attributes were recorded as per the standard procedure.

RESULTS AND DISCUSSION

Data on yield and yield attributes of twenty compact genotypes are presented in Table 1. The mean sum of squares due to treatment for all characters was highly significant except number of monopodia per plant. The genotype RHC HD 1420 recorded significantly higher seed cotton yield (6193 kg/ha) and lint yield (2230kg/ha) over the best check Phule Yamuna (4781kg/ha and 1590kg/ha, respectively). Likewise, this genotype gave significantly higher seed cotton yield per plant (75g) over the checks (52g/plant). Among the genotypes five genotypes *viz.*, RHC-HD 1430 (5176kg/ha and 1848kg/ha), RHC-HD 1433 (5399kg/ha and 2051kg/ha), RHC-HD 1438 (5187kg/ha and 1770kg/ha), RHC-HD 1446 (5336kg/ha and 1871kg/ha) and RHC-HD 1312

Table 1. Seed cotton yield, lint yield and ancillary characters of different entries tested in Station trial of compact genotypes conducted during *kharif 2016* at Cotton Project, MPKV, Rahuri.

Sr.	Entry	Yield (kg/ha)		Branches and bolls/plant (No)			Plant height (cm)	Av. boll wt. (g)	SCY / plant (g)	Days required for 50 No.%	
		Seed Cotton	Lint	Mono	Symp	Bolls				Flow.	Bursting
1	RHC-HD 1405	4728	1556	0.0	12.9	17	116	4.7	51	54	119
2	RHC HD 1406	4689	1616	0.0	11.7	13	105	**5.1**	40	53	**118***
3	RHC HD 1411	4191	1502	0.0	8.9	12	94	4.4	59	54	120
4	RHC HD 1412	4097	1542	0.0	12.2	15	104	4.1	46	53	119
5	RHC HD 1420	**6193***	**2230***	0.0	**15.1**	19	**127***	**5.3**	**75***	55	121
6	RHC HD 1425	4567	1643	0.1	11.1	14	98	3.7	58	54	120
7	RHC HD 1426	4555	1637	0.0	9.8	13	94	4.6	55	53	119
8	RHC-HD 1427	3370	1312	0.0	8.8	12	98	4.4	40	53	**118***
9	RHC-HD 1430	**5176**	**1848**	0.0	10.3	14	102	4.7	54	54	120
10	RHC-HD 1432	4289	1495	0.0	9.8	13	90	4.8	48	53	120
11	RHC-HD 1433	**5399**	**2051***	0.0	12.2	18	102	**5.2**	56	56	122
12	RHC-HD 1434	4517	1608	0.0	11.1	17	102	**5.1**	53	55	121
13	RHC HD 1436	4519	1502	0.0	11.0	14	98	**5.1**	47	55	121
14	RHC HD 1438	**5187**	**1770**	0.0	10.7	15	100	3.7	54	56	122
15	RHC HD 1446	**5336**	**1871**	0.1	**14.9**	**20**	**124***	3.7	60	56	122
16	RHC-HD 1312	**5623**	**1931**	0.1	**13.1**	**20**	112	5.0	**69***	56	123
17	RHC-HD 1314	4757	1504	0.1	**14.4**	19	116	4.2	48	56	121
18	RHC-HD 1333	3847	1311	0.1	10.2	13	100	4.4	40	54	120
19	RHC-HD 1501	4193	1420	0.0	13.9	18	110	**5.1**	41	53	119
20	RHC-HD 1502	4438	1462	0.0	**15.3**	**20**	**119***	**6.0***	40	54	120
21	Phule-688(c)	4680	1473	0.0	11.3	14	109	**5.0**	40	56	121
22	Phule Yamuna (c)	4781	1590	0.1	12.8	17	**118***	4.7	52	53	120
G. Mean		**4688**	**1630**	**-**	**11.9**	**16**	**106**	**4.7**	**52**	**54**	**120**
S.E. (kg/ha) ±		356.29	125.75	-	1.30	1.41	4.19	0.32	5.47	0.33	0.33
C.D. (p=0.05)		1016.86	358.89	*NS*	3.72	4.02	11.97	0.90	15.60	0.94	0.94
C.V. (%)		13.16	13.36	-	19.01	15.42	6.83	11.73	18.26	1.05	0.47

(5626kg/ha and 1931kg/ha) gave numerical higher seed cotton yield and lint yield over the check. The genotype RHC-HD 1433 gave significantly higher lint yield (2051kg/ha).

Among the genotypes RHC-HD 1502 recorded significantly superior average boll weight (6.0g) over the check (4.7g). Most of the genotypes have excellent boll size (>4.5cm) which shows positive increment in desirable direction. All the genotypes show synchronous maturity and earliness. But still more efforts required to develop extra early maturity *i.e.* 120-130DAS genotypes to escape the pink boll worm infestation. Looking to the sympodia per plant, non of the genotypes recorded significantly superior number over the check. However, RHC HD 1420, RHC HD 1446, RHC HD 1312 and RHC HD 1314 recorded numerical higher sympodia per plant.

Ginning percentage, lint index, seed index and fibre quality parameters of twenty genotypes tested in Station trial are presented in Table 2. The superiority of genotypes was varying among the characters. The genotype RHC HD 1427 was superior in ginning percentage while genotype RHC HD 1433 was superior in lint index. Likewise, the genotype RHC HD 1438 showed superior seed index (100

Table 2. Ginning percentage, lint index, seed index and fibre quality parameters of twenty genotypes tested in Station trial during *kharif 2016* at Cotton Project, MPKV, Rahuri.

Sr. No.	Entry	Ginning (%)	Lint Index	Seed Index Index	2.5 per cent	UR (%) S L	MIC	Tenacity 3.2 mm g/tex	Elon. (%)
1	RHC-HD 1405	32.9	4.4	9.1	**32.4**	48	4.2	22.8	5.3
2	RHC HD 1406	34.5	5.3	10.2	**31.7**	50	4.0	20.3	6.0
3	RHC HD 1411	35.8	5.9	10.6	29.2	52	4.4	20.5	6.4
4	RHC HD 1412	37.6	5.4	9.0	28.8	49	4.8	19.7	6.6
5	RHC HD 1420	36.0	5.5	9.8	28.3	52	**3.3**	19.7	**6.9**
6	RHC HD 1425	36.0	5.5	9.8	29.6	53	3.8	22.8	6.6
7	RHC HD 1426	35.9	6.1	10.9	29.9	53	4.4	21.0	5.9
8	RHC-HD 1427	**38.9**	5.7	8.9	29.7	50	4.9	20.0	5.9
9	RHC-HD 1430	35.7	5.7	10.2	30.9	52	4.4	20.8	5.9
10	RHC-HD 1432	34.9	5.5	10.3	28.7	53	3.9	22.4	5.9
11	RHC-HD 1433	38.0	**6.4**	10.4	29.9	53	4.0	22.7	5.9
12	RHC-HD 1434	35.6	6.1	11.1	29.4	53	4.3	22.1	5.9
13	RHC HD 1436	33.2	5.4	10.8	29.5	54	4.6	21.8	5.9
14	RHC HD 1438	34.1	6.0	**11.6**	30.7	54	4.4	21.6	5.9
15	RHC HD 1446	35.1	5.2	9.6	28.9	54	5.2	22.4	5.9
16	RHC-HD 1312	34.3	5.2	9.9	29.2	55	4.8	21.0	5.9
17	RHC-HD 1314	31.6	4.2	9.2	28.9	53	4.2	20.9	5.8
18	RHC-HD 1333	34.1	5.1	9.9	29.2	50	3.9	21.2	5.8
19	RHC-HD 1501	33.9	5.7	11.2	30.4	52	5.3	21.7	5.9
20	RHC-HD 1502	33.0	5.4	11.1	**31.7**	51	4.9	22.4	5.9
21	Phule-688(c)	31.5	4.8	10.5	28.3	**56**	4.4	23.3	6.0
22	Phule Yamuna (c)	33.3	4.0	8.1	28.5	54	3.8	**24.0**	6.0

seed weight).

The fibre quality parameters were estimated on ICC mode at CIRCOT, Mumbai. All the genotypes showed excellent fibre properties. Staple length ranged from 28.3mm (medium long) to 32.4mm (Long staple cotton) and tenacity ranged from 19.7g/tex to 24.0g/tex. Among the genotypes RHC-HD 1405 recorded highest staple length whereas, Phule Yamuna (Check) recorded highest tenacity i.e.24.0g/tex. The genotypes RHC-HD 1420 have fine micronaire (3.3).

Among the genotypes studied, the RHC-HD 1420 had significant seed cotton yield, zero monopodial branched, more sympodial branches, highest boll weight with early maturity and hence it would be more desirable for High Density Planting System. Data further indicated that, genotypes RHC-HD 1430, RHC-HD 1433, RHC-HD 1438, RHC-HD 1446 and RHC-HD 1312 responded favorably to HDPS. Silva *et al.* (2002) and Rossi *et al.*, (2007) observed significant interaction between plant density and genotype and recommended a density dependent selection of genotypes,

High density planting systems is a highly technical system and needs careful planning, timely planting, rigorous monitoring, and timely interventions. Several management related issues are yet to be resolved for development of technique. If this system clicks, it would be boom for cotton growing farmers particularly in Maharashtra region.

REFERENCES

Anonymous, 2016-2017. AICCIP Annual report 2016-2017, All India Coordinated Cotton Improvement Project, Coimbatore, Tamilnadu – 641 003.

Jost, P.H., and J.T. Cothren 2001. Phenotypic alterations and crop maturity diff erences in ultra-narrow row and conventionally spaced cotton - *Crop Science* **41 :** 1150–59.

Rossi, J., Novick, G., Murray, J., Landivar, J., Zhang, S., Baxevanos, D., Mateos, A., Kerby, T., Hake, K. and Krieg D 2004. Ultra Narrow Row Cotton: Global Perspective and Reduce Pesticide use. *Proceedings of the Technical Seminar of the 3rd Plenary Meeting of the ICAC: How to improve yields.* Mumbai, India. Nov 2004, pp. 7-11.

Rossi , J., Eva Braojos and Baxevanos, D. 2007. Varietal response to Ultra Narrow Row Cotton in Spain. *World Cotton Research Conference* 4 Sept 10-14, 2017. Lubbock Texas. http://wcrc.confex.com/wcrc/ 2007/ techprogram/P1772.

Silva, P. T., Macedo, F. G., Camacho, M. A., Santos, C, Santi, A., Krause, W. and Rambo, J. R. 2002. Spacing and plant density effect on reproductive development of herbaceous cotton. *Scientia Plena.* **8 :** 1-9.

Vories, E. D. and Glover, R. E. 2006. Comparison of Growth and Yield Components of Conventional and Ultranarrow Row Cotton - *The Jour. Cotton Sci.* **10 :** 235–43.

Wright, D. L., Marois, J. J., Sprenkel, R. K. and Rich J. R. 2011. Production of Ultra Narrow Row Cotton. University of Florida (UF), IFAS Extension. SSAGR- 83.

CROP PRODUCTION AND MECHANIZATION

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Effect of sowing dates, spacings and topping practices on growth and seed yield of sunnhemp (*Crotolaria juncea L.*)

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ABSTRACT : A field experiment was conducted during *kharif,* 2016 on medium black soil at Jute AINP Project, MPKV, Rahuri (MS) on medium black soil to evaluate the effect of sowing dates, spacings and topping management practices on growth and seed yield of sunnhemp (*Crotolaria juncea L.*). For this purpose twenty seven treatments combinations comprises three main plot treatments of sowing dates *viz.,* D_1- 25th MW, D_2- 27th MW, D_3- 29th MW, three sub plot treatments of spacing viz., S_1- 30 x 10 cm, S_2- 45 x 10 cm, S_3-60 x 10 cm and three sub sub plot treatments of topping viz., T_1- No topping, T_2 - 30 DAS, T_3 - 45 DAS. The results showed that, among the sowing dates, sowing date of 29th MW recorded significantly higher branches (24.37), basal diameter (1.25 cm), capsules/plant (90.27) and seed yield/plant (6.88 g). Similarly, higher growth and yield attributes ultimately resulted into higher seed yield of sowing date 29th MW (17.49 q/ha) as compared to 25th MW (16.28 q/ha) and 27th MW(16.69 q/ha). The sunnhemp crop sown at spacing 30 x 10 cm^2 recorded significantly higher seed yield (19.63 q/ha) than spacing 45x10 cm^2 (15.72 q/ha) and 60 x 10 cm^2 (14.11 q/ha). Topping at 30 DAS recorded significantly higher growth and yield attributes *viz.,* branches (23.05), basal diameter(1.19 cm), capsules/plant (83.17) and seed yield per plant (6.82 g) and seed yield (17.53 q/ha) than no topping(15.51 q/ha) and topping at 30 DAS (16.42) during period of experimentation (Table 1).Thus, results revealed that sowing of sunnhemp (*Crotolaria juncea L.*) during 29th MW, spacing 60 x 15 cm^2 and topping at 30 DAS were the beneficial for higher growth and yield attrbutes and seed yield and of sunnhemp in irrigated conditions.

Key words : Growth, seed yield, sowing dates, spacing, sunnhemp, topping

India is the largest producer of sunnhemp (*Crotalaria juncea* L.) fibre followed by Bangladesh and Brazil. India accounts for about 27 and 23 per cent worlds area and production respectively (Chaudhary, Babita., 2016). Seed is the critical input in any agricultural system for high yield. Quality of seed can be obtained only with improved agro-techniques. Abundant research has been done aiming at standardization of different factors for seed production in many crops but most of the agronomic practices have still not been standardized for seed production of sunnhemp. Spacing is also one of the major factors affecting seed yield of different crops. It influences growth rate and crop yield as a result of inter plant competition for different inputs needed for growth and development. The average yield of this crop is low due to imbalanced application of nutrients. Among the various factors affecting its production, phosphorus plays an important role in enhancing the production and productivity of the crop. Secondly, being a legume, it requires small quantity of nitrogen at initial stages to fulfill the nitrogen demand of seedling till *Rhizobia* are established on the roots.

For this purpose study was undertaken to study the effect of sowing dates, spacings and topping management practices on growth and seed yield of sunhemp (*Crotolaria juncea L.*).

MATERIALS AND METHODS

A field experiment was conducted during *kharif*, 2016 on medium black soil at Jute AINP Project, MPKV, Rahuri, Maharashtra (situated at lies between 19° 48' N and 19° 57' N latitude and 74° 32' E and 74° 19' E longitude) with twenty seven treatments combinations comprises three main plot treatments of sowing dates *viz.,* D_1- 25th MW, D_2- 27th MW, D_3- 29th MW, three sub plot treatments of spacing viz., S_1- 30 x 10 cm, S_2- 45 x 10 cm, S_3-60 x 10 cm and three sub-sub plot treatments of topping *viz.,* T_1- No topping, T_2 - 30 DAS, T_3 - 45 DAS. The experimental soil was vertisol in nature with low in available nitrogen (170.23 kg/ha), medium in available phosphorus (14.02 kg/ha) and high in available potassium (3866.01 kg/ha). The soil was moderately alkaline in reaction (pH 8.1) and moderate in Fe, Mn, Zn and Cu were 6.59, 9.51, 0.62 and 3.41 µg/g of soil. The field capacity, bulk density and permanent wilting point of the surface (0-15 cm) soil were 33.23 per cent on volume basis, 1.36 Mg^{-3} and 16.71 per cent, respectively. The average annual rainfall at Rahuri is 520 mm. Gross and net plot size was 5 x 4 m and 2.70 x 4.20 m. The cultivar of sunnhemp (SH 4) are sown, respectively. Fertilizer doses of 20, 40 and 40 kg/ha N, P_2O_5 and K_2O were applied at sowing time, respectively. Application of three irrigations, usual weed and pest control measures as per recommendations. As regards, for data collection on growth and yield attributing characters of five plants were selected at randomly from each plot. The crop was harvested and threshed as per treatment wise and seed yield were obtained from net plot was converted into q /ha.

RESULTS AND DISCUSSION

Effect of sowing dates : The results showed that, among the sowing dates, sowing date of 29th MW recorded significantly higher number of branches (24.37), basal diameter (1.25 cm), capsules/plant (90.27) and seed yield/plant (6.88 g). Similarly, higher growth and yield attributes ultimately resulted into higher seed yield of sowing date 29th MW (17.49 q/ha) as compared to 25th MW (16.28 q/ha) and 27th MW (16.69 q/ha). The sowing date of 29th MW was received less growth period and reduced vegetative growth but, it also converted into more reproductive parts (pods) as compared to 25th MW and 27th MW. Similar findings were reported by Kumar *et al.,* (2009) and Ulemale *et al.,* (2001).

Effect of spacings : The sunnhemp crop sown at spacing 30 x 10 cm^2 recorded significantly higher seed yield (19.63 q/ha) than spacing 45x10 cm^2 (15.72 q/ha) and 60 x 10 cm^2 (14.11 q/ha). This higher seed yield recorded due to higher plant population harvested more solar radiation and produced maximum photsynthates and beneficial to pod development. Similar results corroborated with Ulemale *et al.,* (2001) and Yaragoppa *et al.,* (2003).

Effect of toppings : It was observed that different topping management practices had significant effects on the growth and yield attributing parameters of sunnhemp (Table 1). Topping at 30 DAS recorded significantly higher growth and yield attributes *viz.,* number of branches (23.05), basal diameter (1.19 cm), capsules/plant (83.17) and seed yield/plant (6.82 g) and seed yield (17.53 q/ha) than no topping(15.51 q/ha) and topping at 30 DAS (16.42) during period of experimentation (Table 1). Earlier topping at 30 DAS is more beneficial for early removal of apical portion of the plant checked the vertical growth from early growing stage. It is also helpful to increase the growth attributes and yield of sunhemp. Similar results also corroborated with the results of Dripathi *et al.,* (2013) and Das *et al.,* (2014)..

Thus, results revealed that sowing of sunnhemp (*Crotolaria juncea L.*) during 29th MW, spacing 60 x 15 cm^2 and topping at 30 DAS were the beneficial for higher growth, yield attributes

Table 1. Growth and yield attributes sunnhemp as influenced by different treatments

Treatment	Branches/ plant	Basal diameter (cm)	Capsule/ plant	Seed yield/plant (g)	Seed yield (q/ha)
A. Sowing dates					
D_1- 23rd June (25th MW)	18.67	1.12	68.17	6.23	16.28
D_2- 7th July (27th MW)	20.51	1.16	78.44	6.62	16.69
D_3- 21st July (29th MW)	24.37	1.25	90.27	6.88	17.49
SEm +	0.64	0.02	1.22	0.06	0.25
CD (p=0.05)	2.52	0.06	4.80	0.22	N.S.
B. spacings (cm)					
S_1- 30 x 10	15.84	1.11	61.33	5.35	19.63
S_2- 45 x 10	19.76	1.13	72.34	6.36	15.72
S_3- 60 x 10	23.16	1.19	86.25	7.56	14.11
SE m +	0.64	0.01	1.30	0.04	0.236
C.D. (p=0.05)	1.974	0.03	4.01	0.13	0.728
C. Topping (DAS)					
T_1- No topping	17.06	1.09	64.01	5.99	15.51
T_2 - 30	23.05	1.19	83.17	6.82	17.53
T_3 - 45	18.66	1.14	72.73	6.46	16.42
SE m +	0.485	0.01	1.307	0.082	0.296
C.D. (p=0.05)	1.390	0.03	3.748	0.236	0.849
D. Interaction : DXS	N.S.	N.S.	N.S.	N.S.	Sig.
DXT	N.S.	N.S.	N.S.	N.S.	N.S.
SXT	N.S.	N.S.	N.S.	N.S.	Sig.
DXSXT	N.S.	N.S.	N.S.	Sig	N.S.
General mean	**19.59**	**1.14**	**73.31**	**6.42**	**16.49**

and seed yield and of sunnhemp in irrigated conditions.

Interaction effects : The interaction effect between sowing dates, spacings and toppings were found to be significant, but in case of seed yield of sunhemp were found to be significant incombined effect of sowing dates with spacings and spacing with topping treatments.

REFERENCES

Chaudhary, Babita 2016. Traditional cultivation of sunnhemp (*Crotolaria juncea*) in eastern India. *Indian J. Agric. Sci.* **86** : 369-72

Das, H., Poddar, P., Haque, S., Pati, S., Poddar, R. and Kundu, C. K. 2014. seed yield and economics of white Juite as influenced by different dates of sowing, spacing and topping schedule in Terai region of West Bengal. *Int. J. Farm Sci.* **4 :** 51-58.

Kumar, C.J., S.M. Hiremath, B.M. Chittapur and V.P. Chimmad, 2005. Effect of sowing time and fertilizer levels on seed production of sunnhemp in northern transitional zone of Karnataka. *Karnataka J. Agric. Sci.,* **18** : 594-98.

Tripathi, M.K., Chaudhary, B., Singh, S.R. and Bhandari, H.R. 2013. Growth and yield of sunhemp (*Crotalaria juncea* L) as influenced by spacing and topping practices. *African J. Agric. Res.* **8 :** 3744-49.

Ulemale, R. B., D. G. Giri and R. S. Shivankar, 2001. Effect of sowing date, row spacing and phosphate level on biomass studies in sunnhemp. *J. Maharashtra Agric. Univ.,* **26** : 323-25.

Yaragoppa, S.D., B.K. Desai, A.S. Halepyati and B. T. Pujari, 2003. Influence of plant densities and phophorus management on growth and seed yield of *Sesbania aculeata* (Wills.) Poir. *Karnataka J. Agric. Sci.,* **16** : 297-99.

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Effect of agro techniques on yield components and seed yield of jute (*Corchorus olitorius*)

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ABSTRACT : A field experiment was carried out for *kharif,* 2015 at Jute and Allied Fibre crops, MPKV, Rahuri (MS) to find out the optimum sowing time, spacing along with topping practices in yield components and seed yield of Jute (*Corchorus olitorius*). The three dates of sowing D_1- 24^{th} MW (16^{th} June), D_2- 26^{th} MW(30^{th} June) and D_3- 28^{th} MW (15^{th} July), four spacings (S_1-45 x 10 cm, S_2-45 x 15 cm, S_3-60 x 15 cm and S_4-60 x 30 cm and three topping management techniques (T_1-No Topping, T_2- 30 DAS and T_3- 45 DAS) were laid out in split split plot design with three replications. The results stated that the crop sown in 24^{th} MW was significantly recorded highest growth and yield attributes. It is also resulted into higher jute seed yield (25.80, q/ ha) of jute as compared to 26^{th} MW (23.06, q/ ha) and 28^{th} MW (17.61, q/ ha) and it was 19.44 per cent higher than 26^{th} MW and 37.15 per cent higher than 28^{th} MW during the *kharif,* 2015. Crop sown at spacing 60 x 15 cm was recorded significantly highest seed yield (25.90 q/ha) than rest of all treatments. Topping at 45 DAS (T_2) exhibited superior performance with regard to all growth and yield parameters *viz.,* branches/plant (20.28), pods/plant (123.93) and seed yield (17.88 q/ha) than over no topping and topping at 30 DAS. Sowing of jute (*C olitorius*) during 24^{th} MW week (16^{th} June) with optimum spacing of 60 x 15 cm and topping at 45 DAS is recommended for higher growth and seed yield under irrigated conditions.

Key words : Growth attributes, jute, seed yield, sowing, spacings, toppings

Jute, one of the most important commercial crops of eastern Indian states of West Bengal, Assam, Bihar, Orissa and eastern Uttar Pradesh is an important foreign exchange earner and is supporting nearly 7 million small and marginal families, industrial employees and trade. Quality of seeds can be obtained only with improved agro techniques. Abundant research has been done aiming at standardization of different factors for seed production in many crops but most of the agronomic practices have still not been standardized for seed crop of Jute. At present jute seed crop particularly *Corchorus olitorius* varieties were grown mainly in Andhra Pradesh, Maharashtra and Gujarat. Non availability of quality jute seed to the farmers at a lower price and proper time is one of the major constraints faced by jute farmers. To minimize the hindrances towards getting higher jute fibre production with uniform productivity across the growing zones, these issues are to be readily addressed for standardization of quality jute seed production technology. Date of sowing is one of the major factors affecting seed yield of different crops. Spacing influences growth rate and crop yield as a result of inter-plant competition for different inputs needed for growth and development (Tripathi *et al.*, 2013). Thus investigation on spacing arrangements becomes mandatory for understanding the mechanism of yield enhancement. Apical topping breaks the apical dominance and induces development of lateral branches thereby increasing the site for pod and capsule development. The practice of topping has proved to be effective in increasing the yield levels of different crops (Sajjan *et al.,* 2002; Singh *et al.*, 2011). Very meager information is available on interactive effect of different sowing dates, spacings along with topping management practices on seed production of jute and allied fibre crops. Keeping these in view, the present investigation was carried out to study the effect of sowing dates, spacings and topping techniques on growth and seed yield of jute (*Corchorus olitorius*).

MATERIALS AND METHODS

The three dates of sowing D_1- 24th MW (16th June), D_2- 26th MW(30th June) and D_3- 28th MW (15th July), four spacings (S_1-45 x 10 cm, S_2-45 x 15 cm, S_3-60 x 15 cm and S_4-60 x 30 cm) and three topping management practices (T_1-No Topping, T_1- 30 DAS and T_2- 45 DAS) were laid out in split-split plot design and replicated thrice. The experimental soil was vertisol in nature with low in available nitrogen (172.23 kg/ha), medium in available phosphorus (15.02 kg/ha) and high in available potassium (426.0 kg/ha). The soil was moderately alkaline in reaction (pH 8.2). The electrical conductivity, organic carbon and $CaCO_3$ were 0.19 dSm^{-1}, 0.56 and 4.59 per cent, respectively. Fertilizer doses of 60, 30 and 30 kg/ha N, P_2O_5 and K_2O were applied respectively. N was applied in two equal split doses one as basal dose and another top dressed at 30 DAS when hand weeding was done. Application of three irrigations, usual weed and pest control measures as per recommendations.

RESULTS AND DISCUSSION

Sowing dates : The crop sown in 24th MW (D_1-16th June) was significantly recorded highest plant height (247.28 cm) as well as number of branches (21.58) plant^{-1} and similarly, the higher growth attributes were reflected in higher yield attributes *viz.,* basal diameter/plant (2.32 cm) and pods/plant (130.50) during this year. Sowing date of 24th MW was resulted into significantly higher jute seed yield (25.80, q ha^{-1}) as compared to 26th MW (23.06 q ha^{-1}) and 28th MW (17.61 q/ha) and it was 19.44 per cent higher than 26th MW and 37.15 per cent higher than 28th MW during the *kharif,* 2015 (Table 1). Similar results were registered by Mishra *et al.*,1997 and Das *et al.,* 2014.

Spacings : The jute crop sown at different spacings as influenced by different significant differences. The crop sown at spacing 60 cm x 15 cm was recorded significantly the highest seed yield (25.90 q/ha) than spacing of 45 x 30 cm (24.86 q/ha), 45 x 15 cm (24.64 q/ha) and 60 x15 cm (22.32 q/ha). Similar results were recorded by growth and yield attributes of jute crop (Table 1). Similar results corroborated with the results of Mishra and Naik (1997).

Toppings : Topping at 45 DAS (T_2)

Table 1. Effect of sowing date, spacing and topping management on jute seed yield

Treatments	Plant height (cm)	Branches/ plant	Basal diameter (cm)	Pods/ plant	Seed yield (q/ha)
Sowing date					
24^{th} MW	**247.28**	**21.58**	**2.32**	**130.50**	**25.80**
26^{th} MW	194.23	16.06	1.63	101.38	23.06
28^{th} MW	201.40	14.81	1.73	87.42	17.61
SE+	2.31	0.44	0.020	3.03	0.33
CD (p=0.05)	9.09	1.72	0.078	11.91	1.30
Spacing (cm)					
45 x 15	219.81	14.41	1.88	94.04	24.64
45 x 30	219.33	21.83	1.96	126.06	24.86
60 x 15	223.98	18.67	1.86	112.41	25.90
60 x 30	221.09	20.37	2.19	131.26	22.32
SE+	2.74	0.35	0.027	2.27	0.34
CD (p=0.05)	NS	1.03	0.082	6.74	1.01
Topping (DAS)					
1. No topping	240.40	17.43	1.90	106.31	23.29
2. 30	202.15	18.75	2.03	117.58	24.58
3. 45	220.61	20.28	1.98	123.93	25.41
SE+	1.74	0.39	0.019	1.43	0.32
CD (p=0.05)	4.76	1.10	0.055	4.07	0.92

exhibited superior performance with regard to all the growth and yield parameters viz., branches/plant (20.28), pods/plant (123.93). This might due to be topping at 30 DAS promoted much vegetative growth but better reproductive growth was obtained with topping at 45 DAS. Topping at 45 DAS registered significantly higher seed yield (17.88 q/ha) than over no topping and topping at 30 DAS. Earlier topping ie topping at 30 DAS had harmful effect on plant height but rendered beneficial effect in terms of other growth parameters like basal diameter/ plant. This could be because of the fact that in 30 DAS is early removal of apical portion of the plant checked the vertical growth and reduced growth and yield attributes as compared to the topping at 45 DAS (Table 1). Similar results recorded by Sajjan *et al.,* (2002) and Tripathi *et al.,* (2013).

Sowing of jute (*C olitorius*) during 24^{th} MW week (8-16^{th} June) with optimum spacing of 60 x 15 cm and topping at 45 DAS is recommended for higher growth attributes and seed yield under irrigated conditions.

REFERENCES

Das, H., Poddar, P., Haque, S., Pati, S., Poddar, R. and Kundu, C. K. 2014. seed yield and economics of white Jute as influenced by different dates of sowing, spacing and topping schedule in Terai region of West Bengal. *Int. J. Farm Sci.* **4** : 51-58.

Mishra, G.C. and Nayak, S.C., 1997. Effect of sowing date and row spacing on seed production of jute (*Corchorus species*) genotypes with and without clipping. *Indian J. Agron.* **42 :** 531-34.

Sajjan, A.S., Shekaragouda, M. and Badanu, V. P. 2002. Influence of apical pinching and pod picking on growth and seed yield of okra. *Karnataka J. Agric. Sci.***15 :** 367-72.

Singh, F., Kumar, R., Kumar, P. and Pal, S. 2011. Effect of irrigation, fertility and topping on Indian mustard (*Brassica juncea*). *Progressive Agriculture* **11 :** 477- 78.

Tripathi, M.K., Chaudhary, B., Singh, S.R. and Bhandari, H.R. 2013. Growth and yield of sunhemp (*Crotalaria juncea* L) as influenced by spacing and topping practices. *African J. Agric. Res.* **8 :** 3744-49.

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Weed management in irrigated *Bt* cotton (*Gossypium hirsutum* L.)

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ABSTRACT : A field experiment was conducted for two consecutive *kharif* season of the year 2014 and 2015 at research farm of AICRP-Weed Management, AAU, Anand to study the integrated weed management in cotton under irrigated condition. Application of pendimethalin 1000 g/ha PE *fb* twice hand weeding at 20 and 50 DAS and pyrithiobac-sodium + quizalofop-p-ethyl (62.5+50 g/ha) PoE *fb* directed spray of glyphosate 2000 g/ha at 60 DAS recorded significantly lower weed dry biomass as well as higher seed cotton yield and benefit cost ratio as compared to rest of the treatments. Moreover, the weed control efficiency of these treatments proved to be 90 and 86 per cent, respectively.

Key words : Herbicides, integrated weed management, seed cotton yield, weed density

India is the leading country in terms of area under cotton in the world. Gujarat, Maharashtra and Telangana are the major cotton growing states contributing around 70 per cent of the area and 67 per cent of cotton production in India. Cotton crop is the main *kharif* crop in irrigated middle-western plain of Gujarat. It covers around 27.61 lakh ha area which is next to Maharashtra in India (Anon., 2015-2016). Losses in seed cotton yield due to presence of weeds is maximum. Weeds not only compete with the crop for nutrients, light, moisture, space and heat energy but, also harbor insects and disease organism thus, reducing the growth and yield of cotton due to weed competition (Papamichail *et al.*, 2002). Cotton generally needs weed management in early stages of growth, weed control in cotton from sowing to 8 weeks after sowing may increase the seed cotton yield from 30-40 percent (Jarwar *et al.,* 2005).

Weed infestation in cotton has been reported to offer severe competition and causing yield reduction to the extent of 74 per cent. According to Zhang (2003) manual measures for weed control without herbicide application is the most labour intensive and impractical method in modern agricultural production system. Under such circumstances, herbicides have remained the principal tool and foundation of most effective weed control programmes (Norsworthy *et al.*, 2012). Yadav and Singh (2005) suggested the integrated use of various methods of weed control resulted significant increase in yield of crop. The chemical weed control suppresses the weeds at early stage of cotton and enables the cotton plant to grow vigorously.

Generally, pre emergence herbicides are not as effective against all weeds whereas, post-emergence herbicides can control weeds but it needs proper time and skill. The combination of pre and post emergence herbicides is required to be integrated for effective weed control to increase seed cotton yield. Therefore, the present study was undertaken to determine the efficacy of different herbicides as pre and post-emergence, for controlling the weeds and their effect on seed cotton yield and economics of cotton.

MATERIALS AND METHODS

A field experiment was conducted at research farm of AICRP- Weed Management, Anand Agricultural University, Anand (Gujarat) during the *kharif*, 2014-2015 and 2015-2016. The soil of the experimental field was sandy loam in texture with pH of 8.10 and EC of 0.34 dS/m. The organic carbon, available nitrogen, phosphorus and potash of the soil were 0.46 per cent (low), 240.57 kg/ha (low), 15.54 kg/ha (medium) and 233.29 kg/ha (medium), respectively. The experiment was comprised of ten treatments *viz.* pendimethalin 1000 g/ha PE *fb* HW at 20 & 50 DAS, pendimethalin 1000 g/ ha PE *fb* pyrithiobac-sodium 62.5 g/ha PoE, pendimethalin 1000 g/ha PE *fb* pyrithiobac + quizalofop-p-ethyl (62.5 + 50 g/ha) PoE, pyrithiobac-sodium + quizalofop-p-ethyl (62.5 + 50 g/ha) PoE, pyrithiobac + quizalofop (62.5 + 50 g/ha) PoE *fb* manual weeding 50 DAS, pyrithiobac + quizalofop (62.5 + 50 g/ha) PoE *fb* directed spray of paraquat 600 g/ha at 60 DAS, pyrithiobac + quizalofop (62.5 + 50 g/ha) PoE *fb* directed spray of glyphosate 2000 g/ha at 60 DAS, pendimethalin 1000 g/ha PE *fb* glyphosate directed spray 2000 g/ha at 45 DAS, mechanical weeding (20, 40 and 60 DAS) and Weedy check. Experiment was laid out in randomized complete block design with three replications.

The *Bt* cotton (GCH 8) was sown keeping the seed rate of 2.5 kg/ha with 120 cm row to row and 45 cm plant to plant distance. The crop was fertilized with 280 kg N/ha supplied through urea only. One fourth quantity of nitrogen (70 kg/ha) was applied as a basal and remaining quantity of nitrogen applied at different growth stages of cotton *viz.* square formation, flowering and boll formation stages as top dressing in three equal splits. The pre-emergence herbicides were applied to soil on next day of sowing, while post-emergence herbicide spray was done at 20-25 DAS based on soil moisture condition as per the treatments. The weed density and dry weight of weeds were recorded at 90 DAS. Weed control efficiency (WCE) was calculated on the basis of formulae suggested by Mani *et al.*, (1973). BCR value was also worked out by considering the prevailing market price on the basis of pooled seed cotton and stalk yields.

RESULTS AND DISCUSSION

Effect on weeds : The predominant weeds identified in the experimental site among the monocot weeds were *Eleusine indica, Commelina benghalensis, Eragrostis major, Dactyloctenium aegyptium, Digitaria sanguinalis and Cyperus iria* and among dicot weeds were *Digera arvensis, Phyllanthus niruri, Euphorbia hirta, Oldenlandia umbellate and Boerhavia diffusa.* Grassy weeds were predominated (72.1%) followed by broad leaved weeds (27.9) in the experimental field of cotton. *Eleusine indica* and *Digera arvensis* were found to be more dominant weed species among the grassy and broad leaved weeds, respectively.

Table 1. Weed density and biomass as influenced by integrated weed management practices at 90 DAS in cotton

Treatment	Weed density (no./m^2)			Weed dry biomass (g/m^2)		
	Monocot weed	Dicot weed	**Total weed**	Monocot weed	Dicot weed	**Total weed**
Pendimethalin 1000 g/ha PE *fb* HW at 20 and 50 DAS	5.11(25.4)	8.15(69.7)	**9.66(95.0)**	6.21(43.1)	4.64(22.6)	**8.04(65.7)**
Pendimethalin 1000 g/ha PE *fb* pyrithiobac-sodium 62.5 g/ha PoE	5.98(35.0)	3.93(14.7)	**7.11(49.7)**	15.8(267)	9.01(85.7)	**18.2(352)**
Pendimethalin 1000 g/ha PE *fb* pyrithiobac + quizalofop-p-ethyl (62.5 + 50 g/ha) PoE	5.66(31.5)	4.37(18.8)	**7.10(50.3)**	14.6(230)	8.44(76.1)	**16.8(306)**
Pyrithiobac-sodium + quizalofop-p-ethyl (62.5 + 50 g/ha) PoE	8.42(70.0)	6.32(46.0)	**10.7(116)**	14.3(240)	13.6(186)	**20.3(426)**
Pyrithiobac + quizalofop (62.5 + 50 g/ha) PoE *fb* manual weeding 50 DAS	6.24(39.2)	7.11(57.7)	**9.76(96.8)**	6.11(36.9)	5.82(37.2)	**8.57(74.2)**
Pyrithiobac + quizalofop (62.5 + 50 g/ha) PoE *fb* 600 g/ha at 60 DAS directed spray of paraquat	5.88(34.2)	6.06(36.0)	**8.41(70.2)**	10.4(121)	7.21(51.8)	**12.8(173)**
Pyrithiobac + quizalofop (62.5 + 50 g/ha) PoE *fb* directed spray of glyphosate 2000 g/ha at 60 DAS	5.08(29.4)	2.59(5.90)	**5.68(35.2)**	7.69(66.8)	4.44(19.6)	**9.00(86.4)**
Pendimethalin 1000 g/ha PE *fb* glyphosate directed spray 2000 g/ha at 45 DAS	5.31(27.4)	5.24(29.0)	**7.45(56.4)**	13.5(183)	7.58(57.9)	**15.5(241)**
Mechanical weeding (20, 40 and 60 DAS)	7.07(50.7)	6.43(47.0)	**9.57(97.7)**	10.5(110)	4.22(20.7)	**11.4d(131)**
Weedy check	7.58(57.2)	4.67(22.0)	**8.90(79.2)**	18.1(358)	16.3(295)	**25.6(653)**
S.Em. ± LSD (P=0.05) CV (%)	0.82NS8.0	1.59NS11.0	**1.14NS6.1**	3.51NS7.3	1.765.6412.6	**2.026.455.8**
Y x T S. Em. ± LSD (p=0.05)	0.290.83	0.351.00	**0.300.86**	0.491.41	0.591.7	**0.491.4**

Note: Data subjected to Ö(X+1) transformation.

Table 2. Yield and economics of cotton as influenced by integrated weed management practices

Treatment	Seed cotton yield (t/ha)	Stalk yield (t/ha)	Gross return ($x10^3$ Rs/ha)	Additional cost over control ($x10^3$ Rs/ha)	Cost of cultivation ($x10^3$ Rs/ha)	Net return ($x10^3$ Rs/ha)	B:C ratio	WCE at 90 DAS (%)	Weed index (%)
Pendimethalin 1000 g/ha PE *fb* HW at 20 and 50 DAS	3.30	5.66	140.9	8.13	58.25	82.71	2.42	90	0
Pendimethalin 1000 g/ha PE *fb* pyrithiobac-sodium 62.5 g/ha PoE	2.29	4.42	98.31	4.95	55.08	43.23	1.78	44	31
Pendimethalin 1000 g/ha PE *fb* pyrithiobac + quizalofop-p-ethyl (62.5 + 50 g/ha) PoE	2.25	4.82	97.07	6.55	56.68	40.39	1.71	52	32
Pyrithiobac-sodium + quizalofop-p-ethyl (62.5 + 50 g/ha) PoE	1.71	3.51	73.62	4.12	54.25	19.37	1.36	33	48
Pyrithiobac + quizalofop (62.5 + 50 g/ha) 50 DAS PoE *fb* manual weeding	2.73	4.55	116.4	6.10	57.09	59.39	2.04	88	17
Pyrithiobac + quizalofop (62.5 + 50 g/ha) PoE *fb* directed spray of paraquat 600 g/ha at 60 DAS	2.90	5.27	124.1	5.80	55.92	68.25	2.22	72	12
Pyrithiobac + quizalofop (62.5 + 50 g/ha) PoE *fb* directed spray of glyphosate 2000 g/ha at 60 DAS	3.08	5.36	131.6	6.38	56.51	75.13	2.33	86	7
Pendimethalin 1000 g/ha PE *fb* glyphosate directed spray 2000 g/ha at 45 DAS	2.19	4.42	94.21	4.70	54.82	39.39	1.72	62	34
Mechanical weeding (20, 40 and 60 DAS)	2.78	5.01	118.9	6.00	56.13	62.86	2.12	79	16
Weedy check	0.81	1.80	35.01	0.0	50.13	-15.12	0.70	-	76
S.Em.	0.16	0.27							
±LSD (p=0.05)	0.54	0.87							
CV (%)	8.3	9.8	-	-	-	-	-	-	-
Y x T S. Em. ±	114	-							
LSD (p=0.05)	329	-	-	-	-	-	-		

All the weed control treatments caused remarkable reduction in monocot, dicot and total weed density and weed dry matter production when compared with weedy check (Table 1). The weed density in terms of monocot, dicot and total weeds at 90 DAS was found to be non-significant due to different weed management practices. Through the marginally lower number of monocot, dicot as well as total weeds were recorded under application of pyrithiobac + quizalofop (62.5 + 50 g/ha) PoE *fb* directed spray of glyphosate 2000 g/ha 60 DAS followed by pendimethalin 1000 g/ha PE *fb* twice hand weeding ay 20 and 50 DAS. However, minimum weed dry biomass of dicot and total weeds were also registered under directed application of pendimethalin 1000 g/ha PE *fb* HW at 20 and 50 DAS followed by pyrithiobac + quizalofop (62.5 + 50 g/ha) PoE *fb* directed spray of glyphosate 2000 g/ha at 60 DAS. The reduction in weed dry weight under said treatments might be due to pendimethalin act as both pre emergence and as early post emergence that inhibited the cell division and root and shoot growth of the weeds hence, prevented weeds from emerging, particularly during the crucial development phase of the crop. The results are in accordance with the finding of Gnanavel and Babu (2008) and Chinnusamy and Chinnagounder (2013). The highest weed dry biomass of monocot (18.1 g/m^2), dicot (16.3 g/m^2) and total weed (25.6 g/m^2) were recorded under weedy check treatment (Table 1).

Effect on crop : All the weed management practices significantly increased the seed cotton and stalk yield/ha (Table 2) over unweeded. Treatment of pendimethalin 1000 g/ha PE *fb* hand weeding carried out at 20 and 50 DAS, pyrithiobac sodium + quizalofop-p-ethyl (62.5 + 50 g/ha) PoE *fb* directed spray of glyphosate 2000 g/ha at 60 DAS, pyrithiobac-sodium + quizalofop-p-ethyl (62.5 + 50 g/ha) PoE *fb* directed spray of paraquat 600 g/ha and mechanical weeding (20, 40 and 60 DAS) remain at par with each other and recorded significantly higher seed cotton yield as compared to rest of the weed management practices. This may be due to suppression of weed competition by integrated weed management treatments offering efficient and prolonged weed control leading to higher seed cotton yield. Gnanavel and Babu (2008) observed that application of pendimethalin at lower dose in conjunction with hand weeding provided significantly higher seed cotton yields than application of herbicides alone at higher doses. Similarly, Ali *et al.,* (2005) reported that seed cotton yield increase to the tune of 199.4 per cent under application of pendimethalin in combination with inter culturing and hand weeding. Among the herbicidal treatments, desired seed cotton yield was not achieved in case of pyrithiobac sodium + quizalofop-p-ethyl (62.5 + 50 g/ha) PoE. Similar line of results was also noticed for stalk yield. More than 79 per cent weed control efficiency was recorded in pendimethalin 1000 g/ha PE *fb* hand weeding carried out at 20 and 50 DAS, pyrithiobac sodium + quizalofop-p-ethyl (62.5 + 50 g/ha) PoE *fb* manual weeding at 50 DAS, pyrithiobac sodium + quizalofop-p-ethyl (62.5 + 50 g/ha) PoE *fb* directed spray of glyphosate 2000 g/ha at 60 DAS and mechanical weeding (20, 40 and 60 DAS). Chinnusamy and Chinnagounder (2013) concluded that hand weeding twice at 25 and 45 DAS or pre emergence application of pendimethalin 1.0 kg/ha *fb* hand weeding at 45 DAS achieved higher weed control efficiency and seed cotton yield of transgenic cotton with better economic returns.

Economics : Economics of the various treatments showed that pre emergence application of pendimethalin 1000 g/ha PE *fb* HW at 20 and 50 DAS recorded maximum gross, net return and B:C ratio of Rs. 140900/ha, Rs. 827100/ha and 2.42, respectively followed by pyrithiobac + quizalofop (62.5 + 50 g/ha) PoE *fb* directed spray of glyphosate 2000 g/ha at 60 DAS which recorded the values of Rs. 131600/ha, Rs. 75130/ha and 2.33, respectively (Table 2). Weedy check recorded minimum gross and net return as well as benefit cost ration as compared to other treatments.

Pre emergence application of pendimethalin 1000 g/ha *fb* hand weeding at 20 and 50 DAS and pyrithiobac + quizalofop (62.5 + 50 g/ha) PoE *fb* directed spray of glyphosate 2000 g/ha was found effective for controlling weeds and increased seed cotton yield and net return with higher cost benefit ration as compared to rest of the treatments.

REFERENCES

Ali, H., Muhammad, D. and Abid, S.A. 2005. Weed control practices in cotton (*Gossypium hirsutum L.*) planted on bed and furrow. *Pakistan Jour. Weed Sci. Res.* **11**: 43-48.

Anonymous, 2015. Annual report of ICAR-All India Coordinated Research Project on Cotton.

Chinnusamy, Nithya and Chinnagounder. 2013. Evaluation of weed control efficacy and seed cotton yield in transgenic cotton. *Indian Jour. App. Res.* **3** : 2-13.

Gnanavel, I. and Babu, S. 2008. Integrated weed management in Irrigated hybrid cotton. *Agri. Sci. Dig.* **28** : 93-96.

Jarwar, A.D., Baloch, G.M., Memon, M.A. and Rajput, L.S. 2005. Efficacy of pre and post-emergence herbicides in cotton. *Pakistan Jour. Weed Sci. Res.* **11** : 141-45.

Mani, V.S., Gautam, K.C. and Bhagvandas 1973. Chemical weed control in sunflower. *Proc. 3rd All India Weed Control Seminar*, Hisar, p. 48.

Norsworthy, J.K., Ward, S.M., Shaw, D.R., Llewellyn, R.S., Nichols, R.L., Webster, T.M., Bradley, K.W., Frisvold, G., Powles, S.B., Burgos, N.R., Witt, W.W. and Barrett, M. 2012. Reducing the risks of herbicide resistance: best management practices and recommendations. *Weed Sci.* **60 :** 31-62.

Papamichail, D., Eleftherohoriunus, I., Froud-Williams, R. and Gravanis, F. 2002. Critical periods of weed competition in cotton in Greece. *Phytoparasitica* **30** : 1-7.

Yadav, V.K. and Singh, S.P. 2005. Losses due to weeds and response to pendimethalin and fluchloralin in varieties of summer sown *Vigna radiata. Ann. Plant Protection Science* **13 :** 354-457.

Zhang, Z. 2003. Development of chemical weed control and integrated weed management in China. *Weed Biology Manage* **4**: 197-203.

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Response of different weed control practices in mesta (Roselle)

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ABSTRACT : A Field experiment was carried out for *kharif* season of 2016 at Jute and Allied Fibre crops, MPKV, Rahuri (MS) in medium black soil to study the different weed control practices in Mesta (roselle) along with weed smoothering intercrops like groundnut, blackgram and clusterbean. This experiment comparises seven treatments *viz.,* T_1: Pretilachlor (50%) EC 900 ml/ha (pre emergence) + one hand weeding (15 DAE), T_2: Nail weeder -1st at 5-6 DAE (at field capacity) and 2nd at 10 DAE + one hand weeding with in row at 15 DAE, T_3: Mesta+ groundnut (1:1),T_4: Mesta+ clusterbean (1:1),T_5: Mesta+ blackgram(1:1),T_6: Hand weeding Twice (15 and 21 DAE) and T_7: Unweeded control with randomized block design and replicated thrice. The results indicated that, among the chemical and cultural practices of weed control, the application of pretilachlor (50%) EC 900 ml /ha, at 45-48 h of sowing with irrigation + one hand weeding (15 DAE) recorded the lowest weed count (5.91), dry matter (4.13 g) and maximum weed contol efficency (56.96 %) at 30 DAS than rest of the treatments of mesta and it's intercrops. The growing of mesta + groundnut intercrop recorded significantly higher fibre equivalent yield (2.53 t/ha) than rest of the treatments. The application of pretilachlor (50%) EC 900 ml /ha, at 45-48 h of sowing with irrigation + one hand weeding (15 DAE) also recorded higher fibre yield (1.61 t/ha) than rest of all treatments except intercrops like mesta + groundnut, mesta + cluster bean and mesta + black gram . The maximum yield and yield attributes of mesta + groundnut recorded maximum B:C ratio (2.07) than rest of the treatments. Intercropping of mesta + groundnut (1:1) recorded higher fibre yield and economic returns under irrigated condition. The application of herbicide pretilachlor (50%) EC is exhibited lower weed count, weed dry weight and higher weed control efficiency at 30 DAS in mesta.

Key words *:* Fibre equivalent yield, growth, intercrops, mesta, weed control, yield

Roselle (*Hibiscus* sp.) is one of the most important fibre crops grown in india. Roselle fibre is used for making ropes, twines,carpet backing etc. Roselle, *Hibiscus sabdariffa* (L) and *Hibiscus Cannabinus* (Kenaf) are the two species of Mesta. In india 90 per cent of the total mesta areas is under *Hibiscus sabdariffa*. The productivity of mesta crop is low due to crop invested at early growth stages and later, it is not control properly to any weedicides. For in this study, weed control involves utilizing all methods available and combining them in an integrated weed management system; but considering the present day labour scarcity and their higher wages for cultural and mechanical weed control practices and economics of Mesta cultivation is quite disturbed. Hence emphasis should be given to adopt the intercropping and chemical weed control like pretilachlor which is helpful for to control weeds and increases net returns per rupees invested in Mesta (Chaudhary, *et al.,* 2009). For this purpose study was undertaken to find out the effect of chemical and cultural practices in controlling weeds of Mesta (Roselle).

MATERIALS AND METHODS

A Field experiment was carried out for *kharif* 2016 at Jute and Allied Fibre crops, MPKV, Rahuri (MS), with seven treatments combinations *viz.,* T_1: Pretilachlor (50%) EC 900 ml /ha (pre emergence) + one hand weeding (15 DAE), T_2: Nail weeder -1st at 5-6 DAE (at field capacity)and 2nd at 10 DAE + one hand weeding with in row at 15DAE, T_3: Mesta+ groundnut (1:1),T_4: Mesta+ clusterbean (1:1),T_5: Mesta+ blackgram(1:1),T_6: Hand weeding Twice (15 and 21 DAE) and T_7: Unweeded control with randomized block design and replicated thrice. The experimental soil was vertisol in nature with low in available nitrogen (170.23 kg/ha), medium in available phosphorus (14.02 kg/ha) and high in available potassium (3866.01 kg/ ha). The soil was moderately alkaline in reaction (pH 8.1). Gross and net plot size was 5 x 4 m and 2.70 x 4.20 m. Component crops in between Mesta rows and Mesta spacing at 45 cm row-row, respectively. The cultivar of Mesta (AMV 5) and intercrops like groundnut (Phule Unnati), clusterbean (Phule gawar) and black gram (TAU 1) were sown, respectively. Fertilizer doses of 40, 20 and 20 kg/ha N, P_2O_5 and K_2O were applied respectively. N was applied in three equal split doses one as basal dose and another top dressed at 21 and 35 DAS. Application of three irrigations, usual weed and pest control measures as per recommendations.

RESULTS AND DISCUSSION

The results indicated that, among the chemical and cultural practices of weed control, the application of pretilachlor (50%) EC 900 ml / ha, at 45-48 h of sowing with irrigation + one hand weeding (15 DAE) recorded the lowest weed count (5.91), dry matter (4.13 g) and maximum weed contol efficency (56.96 %) at 30 DAS than rest of the treatments of Mesta and it's intercrops (Table 1). As a results of restricted cell division, growth of the emerging weed seedling is prevented and death due to lack of food reserves. On the contrary, sole Mesta with vacant inter row space at initial stage might have invited more number of weeds. These findings are in harmony with those of Chaudhary *et al.,* (2009) and Bhoi *et. al.,* (2010).

The growing of Mesta + groundnut intercrop recorded significantly higher fibre yield and intercrop yield (1.98 and 0.93 t/ha) as compered to the Mesta + cluster bean (1.15 and 0.83 t/ha) and Mesta + black gram (1.54 and 0.43 t/ha) . This is resulted into the increase fibre equivalent yield of Mesta (2.53 t/ha) than rest of the treatments. Secondly Mesta + black gram recorded the higher fibre equivalent yield (2.06 t/ha). The application of pretilachlor (50%) EC 900 ml /ha, at 45-48 h of sowing with irrigation + one hand weeding (15 DAE) also

Table 1. Weed count, weed dry weight and weed control efficiency as influenced by different treatments

Treatment	Weed count (no./m^2)	Weed dry weight (g/m^2)	Weed control efficiency (%)	Fibre yield (t/ha)	Intercrop yield (t/ha)	Fibre equivalent yield (t/ha)	Cost of cultivation (x 10^3 Rs./ha)	B:C ratio
T_1 - Pretilachlor + 1 HW (15 DAE)	5.91* (34.66)	4.13(16.69)	56.96	1.61	—	1.61	44.80	1.79
T_2 - Nail weeder (5,10 DAE) + 1 HW 15 DAE	6.82(46.38)	4.76(22.34)	50.41	1.38	—	1.38	45.77	1.51
T_3 - Mesta+ groundnut(1:1)	7.70(58.92)	5.37(28.34)	44.13	1.98	0.93	2.53	61.16	2.07
T_4 - Mesta+ clusterbean(1:1)	8.68(75.26)	6.04(36.18)	37.23	1.15	0.83	1.74	64.62	1.34
T_5 - Mesta+ blackgram 1:1)	8.27(68.19)	5.76(32.82)	40.01	1.54	0.43	2.06	55.28	1.86
T_6 - Hand weeding twice (15 and 21DAE)	6.90(47.56)	4.81(22.86)	49.90	1.17	—	1.17	47.50	1.23
T_7 - Unweeded control	13.34(177.11)	9.62(92.18)	—	0.83	—	0.83	41.07	1.01
LSD(p=0.05)	16.47	0.79	7.76	0.22	—	0.24	—	0.27

*Actual values are given in parenthesis which was transferred by root square transformation at 30 DAS. Price rate (Rs/q): Mesta Rs.5000/q; Groundnut pod-Rs.3300/q;Clusterbean-Rs-3500/q; Black gram Rs.6000/q (2016) .

recorded higher fibre yield (1.61 t/ha) than rest of all treatments except intercrops like Mesta + groundnut, Mesta + cluster bean and Mesta + black gram . The lowest fibre yield (0.83 t/ha) was recorded in unweeded control treatment due to higher weed count (13.34/m^2) and weed dry weight (9.62 g) at 30 DAS. The maximum yield and yield attributes of Mesta + groundnut recorded maximum B:C ratio (2.07) than rest of the treatments (Table 1) due to additional benefits of intercrop like groundnut and black gram which has smothering effect of weeds and also increases more nitrate reductase activities in root which is beneficial for base crop and legume having peg formation and pod development stage. These findings are analogous to those of Prachand et *al.,* (2014) and Mathukia *et al.,* (2015).

Intercropping of Mesta + groundnut (1:1) recorded higher fibre yield and economic returns under irrigated condition. The application of herbicide pretilachlor (50%) EC is exhibited lower weed count, weed dry weight and higher weed control efficiency at 30 DAS in Mesta.

REFERENCES

Bhoi, S.K., Lakpale, R., Jangre, A. and Mishra, S. 2010. Studies on the effect of weed control methods on growth and yield attribute of hybrid cotton. *Res. J. Agric. Sci.* **1** : 434-37

Chaudhary, P. P., Barman, K. K. and Varshney, J. G. 2009. Photolysis of pretilachlor on soil surface. *Indian J. Weed Sci.* **41 :** 87-89.

Mathukia, R. K., Mathukia, P. R. and Polara, A. M. 2015. Intercropping and weed management in pearlmillet (*Pennisetum glaucum*) under rainfed condition. *Agric. Sci. Digest*, **35** : 138-41.

Smita, Prachand, Kubde, K. J. and Bankar, Sujata 2014. Effect of chemical weed control on weed parameters, growth, Yield attributes, yield and economics in soybean (*Glycine max* L.). *American-Eurasian J. Agric. Environ. Sci.,* **14** : 698-701.

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Critical period of crop weed competition in cotton under rainfed condition

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Cotton (*Gossypium hirsutum* L.) the 'white gold' or 'money spinner' enjoys a predominant position amongst all cash crops in India as well as in Gujarat. Cotton occupies the prime in India constituting more than 70 per cent of the total fibre consumption in the textile sector. Cotton being a wide spaced and relatively slow growing crop during its initial stages, is subjected to severe weed menace. Cotton crop has a wide adaptability under rainfed as well as irrigated condition. Weed competition during initial period of growing reduces yield drastically as well as deteriorated the quality of lint yield. So it is necessary to find out critical crop-weed competition period for cotton crop for maximizing yield and reducing cost on weed management practices. Very scare information is available in this regards especially under rainfed condition of south Gujarat. Hence, this experiment was planned with the objectives of to find out the critical period of crop-weed competition for cotton crop under rainfed condition.

MATERIALS AND METHODS

A field experiment was conducted at College Farm, College of Agriculture, Navsari Agricultural University, Bharuch during *kharif* season in three consecutive years (2013-2014, 2014-2015 and 2015-2016) to study "Critical period of crop weed competition in cotton under rainfed condition". The eight treatments *viz.*, T_1-Weed free up to 20 DAS, T_2-Weed free up to 40 DAS, T_3-Weed free up to 60 DAS, T_4-Weed free up to 80 DAS, T_5-Weed free up to 100 DAS, T_6-Weed free up to 120 DAS, T_7-Weed free up to harvest, T_8-Weedy up to 20 DAS, T_9-Weedy up to 40 DAS, T_{10}-Weedy up to 60 DAS, T_{11}-Weedy up to 80 DAS, T_{12}-Weedy up to 100 DAS, T_{13}-Weedy up to 120 DAS and T_{14}-Weedy up to harvest were evoluted with three replications in a randomized block design (RBD). The cotton var. G.Cot.Hy. 8 (BG II) was sown with spacing of 120 x 45 cm during second week of July. The crop was fertilized with recommended dose of 180-0-0 kg NPK/ha in three equal splits at basal, 30 and 50 DAS. All the data obtained from cotton crop for consecutive three years were statistically analyzed using the *f* test. The net realization was calculated by deducting the total cost of cultivation from the gross realization for each treatment.

RESULTS AND DISCUSSION

The predominant weed species observed in experimental plot were *Cyperus rotundus* L. (Sedge); *Echinochloa colonum* link, *Brachiaria* sp., *Eragrosits major*, *Cynodon dactylon* L., *Cloris*

Table 1. Total weed population as affected by different treatments (Pooled data of three years).

Tr. No.	Treatments	Total weed population (DAS) 20	40	60	80	100	120	At harvest
T_1	Weed free up to 20 DAS	1.00 (0.00)	4.37 (18.10)	7.40 (53.70)	9.03 (80.60)	9.32 (85.80)	9.61 (91.30)	9.73 (93.70)
T_2	Weed free up to 40 DAS	1.00 (0.00)	1.00 (0.00)	4.81 (22.10)	7.27 (51.90)	8.64 (73.60)	9.34 (86.20)	9.61 (91.30)
T_3	Weed free up to 60 DAS	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	4.56 (19.80)	6.77 (44.90)	8.43 (70.00)	8.90 (78.20)
T_4	Weed free up to 80 DAS	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	2.98 (7.90)	4.35 (17.90)	6.20 (37.40)	6.83 (45.60)
T_5	Weed free up to 100 DAS	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	3.91 (14.30)	5.50 (29.30)
T_6	Weed free up to 120 DAS	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	3.92 (14.40)
T_7	Weed free up to harvest	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
T_8	Weedy up to 20 DAS	5.99 (34.90)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
T_9	Weedy up to 40 DAS	6.00 (35.00)	7.36 (53.20)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
T_{10}	Weedy up to 60 DAS	5.87 (33.40)	7.53 (55.70)	9.06 (81.10)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
T_{11}	Weedy up to 80 DAS	5.81 (32.80)	7.47 (54.80)	9.33 (86.10)	9.64 (92.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
T_{12}	Weedy up to 100 DAS	5.82 (32.90)	7.09 (49.30)	9.28 (85.10)	9.85 (96.10)	9.96 (98.30)	1.00 (0.00)	1.00 (0.00)
T_{13}	Weedy up to 120 DAS	5.97 (34.60)	7.36 (53.10)	9.41 (87.60)	9.79 (94.80)	9.93 (97.70)	10.03 (99.60)	1.00 (0.00)
T_{14}	Weedy up to harvest	6.05 (35.60)	7.36 (53.20)	9.28 (85.10)	9.68 (92.70)	9.88 (96.60)	10.05 (100.00)	10.16 (102.30)
	SEm ±	0.13	0.11	0.13	0.20	0.11	0.10	0.10
	CD (p=0.05)	0.38	0.32	0.36	0.58	0.31	0.28	0.29
	CV (%)	13.24	9.64	8.90	7.34	7.70	6.93	7.45

Note: Data in parenthesis indicates actual value and outside parenthesis indicates ($\sqrt{X + 1}$) transformed value

Table 2: Dry weight of weed (g/m^2) as affected by different treatments (Pooled data of three years).

Tr. No.	Treatments	Dry weight of weeds (g/m^2) (DAS) 20		40		60		80		100		120		At harvest	
T_1	Weed free up to 20 DAS	1.00	(0.00)	2.93	(7.60)	6.80	(45.20)	9.55	(90.20)	11.75	(137.10)	13.01	(168.20)	13.68	(186.10)
T_2	Weed free up to 40 DAS	1.00	(0.00)	1.00	(0.00)	3.18	(9.10)	7.17	(50.40)	9.25	(84.60)	11.90	(140.60)	12.70	(160.30)
T_3	Weed free up to 60 DAS	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	3.15	(8.90)	6.63	(43.00)	8.56	(72.30)	11.32	(127.20)
T_4	Weed free up to 80 DAS	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	2.83	(7.00)	4.93	(23.30)	7.96	(62.30)
T_5	Weed free up to 100 DAS	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	2.70	(6.30)	4.22	(16.80)
T_6	Weed free up to 120 DAS	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	2.59	(5.70)
T_7	Weed free up to harvest	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)
T_8	Weedy up to 20 DAS	3.86	(13.90)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)
T_9	Weedy up to 40 DAS	3.96	(14.70)	6.75	(44.60)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)
T_{10}	Weedy up to 60 DAS	3.73	(12.90)	6.76	(44.70)	10.26	(104.30)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)
T_{11}	Weedy up to 80 DAS	3.73	(12.90)	6.73	(44.30)	10.39	(106.90)	12.83	(163.60)	1.00	(0.00)	1.00	(0.00)	1.00	(0.00)
T_{12}	Weedy up to 100 DAS	3.74	(13.00)	6.57	(42.10)	10.54	(110.10)	12.58	(157.30)	13.10	(170.70)	1.00	(0.00)	1.00	(0.00)
T_{13}	Weedy up to 120 DAS	3.78	(13.30)	6.73	(44.30)	10.62	(111.70)	12.83	(163.70)	13.45	(180.00)	14.22	(201.10)	1.00	(0.00)
T_{14}	Weedy up to harvest	3.99	(14.90)	6.69	(43.70)	10.62	(111.80)	12.51	(155.60)	13.22	(173.70)	14.17	(199.90)	14.66	(213.80)
	SEm ±	0.08		0.11		0.14		0.12		0.16		0.16		0.15	
	CD (p=0.05)	0.21		0.32		0.39		0.35		0.45		0.45		0.44	

Note: Data in parenthesis indicates actual value and outside parenthesis indicates ($\sqrt{X + 1}$) transformed value

Table 3. Growth parameters and yield attributes of cotton as affected by different treatments (Pooled data of three years).

Tr. No.	Treatments	Plant height at harvest	Mono-podial bran-ches/ plant	Sym-podial bran-ches/ plant	Boll weight (g)	Boll/ plant	Seed cotton yield/ plant (g)	Seed cotton yield (kg/ha)	Weed comp-etition index (%)	Cost of culti-vation (₹/ha)	Gross reali-zation (₹/ha)	Net reali-zation (₹/ha)	BCR
T_1	Weed free up to 20 DAS	77.5	1.00	7.6	3.23	8.6	28.0	385	67.0	30459	21150	-9309	-0.31
T_2	Weed free up to 40 DAS	100.5	1.27	14.7	3.25	15.5	51.3	693	40.6	32939	38100	5161	0.16
T_3	Weed free up to 60 DAS	107.0	1.64	20.0	3.14	20.7	66.0	898	23.0	35419	49417	13998	0.40
T_4	Weed free up to 80 DAS	121.2	1.96	24.6	3.20	25.4	82.3	1127	3.4	37199	61973	24774	0.67
T_5	Weed free up to 100 DAS	124.1	2.04	24.6	3.29	25.5	85.0	1142	2.1	38979	62809	23830	0.61
T_6	Weed free up to 120 DAS	127.9	2.04	24.6	3.32	25.4	85.4	1156	0.9	39869	63594	23725	0.60
T_7	Weed free up to harvest	128.2	2.13	25.6	3.24	26.4	86.7	1166	0.0	40759	64140	23381	0.57
T_8	Weedy up to 20 DAS	111.9	1.76	23.0	3.29	23.7	78.9	1073	8.0	39869	59036	19167	0.48
T_9	Weedy up to 40 DAS	94.4	1.27	13.7	3.21	14.5	47.0	648	44.4	37389	35636	-1753	-0.05
T_{10}	Weedy up to 60 DAS	85.5	1.17	8.3	3.20	9.1	29.3	402	65.5	35609	22131	-13478	-0.38
T_{11}	Weedy up to 80 DAS	75.8	1.09	7.8	3.19	8.5	27.6	378	67.6	34019	20773	-13246	-0.39
T_{12}	Weedy up to 100 DAS	74.8	1.11	7.1	3.20	7.9	25.3	346	70.4	33129	19012	-14117	-0.43
T_{13}	Weedy up to 120 DAS	74.4	0.96	6.3	3.19	7.0	22.3	307	73.7	31349	16875	-14474	-0.46
T_{14}	Weedy upto harvest	73.9	0.87	6.0	3.18	6.8	21.8	299	74.4	26009	16422	-9587	-0.37
	SEm ±	3.4	0.08	1.6	0.05	2.5	8.9	106.2					
	CD (P=0.05)	9.5	0.23	4.7	NS	7.4	25.9	308.7					
	CV (%)	10.8	17.5	18.3	5.03	17.9	17.2	16.5					

infata, *Dinebra retroflexa* and *Dactylactenium aegyptium* (Monocots); and *Alternenthera sessilis* L., *Digera arvensis* Forsk , *Portulaca oleracea* L., *Phyllanthus moderaspatenia* L., *Eclipta alba* (L.) Hassk, *Euphorbia hirta* L., *Centella asiatica* Urb., *Melilotus indica* (L.) All., *Convolvulus arvensis* L., *Physalis minima* L. and *Corchorus acutangulus* L. (Dicots).

During the life span of cotton, total weed population and dry weight of weed was found least in the treatment T_7 *i.e.* Weed free up to harvest followed by the weed free up to 120 DAS (T_6), weed free up to 100 DAS (T_5), weedy up to 20 DAS (T_8) and weed free up to 80 DAS (T_4). Significantly higher plant height (128.2 cm), monopodial branches/plant (2.13), sympodial branches/plant (25.6), bolls/plant (26.4), seed cotton yield (1166 kg/ha) were recorded under the treatment T_7-Weed free up to harvest which was found statistically *at par* with the treatments T_4-Weed free up to 80 DAS, T_5- Weed free up to 100 DAS, T_6 - Weed free up to 120 DAS and T_8-Weedy up to 20 DAS. The lowest weed competition index (0.9 %) were recorded in treatment T_6 (weed free upto 120 DAS) followed by the treatment T_5 (weed free up 100 DAS), T_4 (weed free up 80 DAS) and T_8 (weedy up to 20 DAS). This could be due to lower weed population which provided congenial condition for better growth and development of the cotton crop. Similar findings were also reported by Ayyadurai and Poonguzhalan (2011). The highest net realization of ₹ 24774/ha was obtained in treatment of weed free upto 80 DAS (T_4) with BCR value of 0.67 followed by T_5 (weed free upto 100 DAS), T_6 (weed free upto 120 DAS), T_7 (weed free upto harvest), T_8 (weedy upto 20 DAS) and T_3 (weed free upto 60 DAS) among different treatments of critical period of crop weed competition in cotton.

CONCLUSION

From the foregoing discussion, it can be concluded that 20 to 80 days after sowing of cotton found as a critical period of crop weed competition for getting lower weed competition index and higher profitable seed cotton yield under rainfed condition.

REFERENCES

Ayyadurai, P. and Poonguzhalan, R. 2011. Critical period of crop weed competition in zero-till cotton. *Indian J. Weed Sci.*, **43 :** 228-30.

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Ascertaining impact of sowing dates, levels of pre sowing irrigation and application time of first post sowing irrigation on growth and yield parameters of American cotton in south western Punjab

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ABSTRACT : Field experiment was conducted to ascertain the impact of sowing dates, levels of pre sowing irrigation and application time of first post sowing irrigation on growth and yield parameters of American cotton. The experiment was replicated thrice with combination of two sowing dates (April 30; timely and May 30; late) and two levels (shallow and heavy) of pre sowing irrigation (PSI) in main and four levels of application of first post sowing irrigation (POSI) applied at 3,4,5 or 6 weeks after sowing (WAS) in sub plots of split plot design. The crop sown on April 30 (3492 kg/ha) recorded significantly better seed cotton yield (SCY) over the crop sown on May 30 (2541 kg/ha) due to statistically higher plant population and better yield attributes like boll number and boll weight. Significant reduction in plant population under late sowing was due to seedling burning/mortality owing to prevalent higher temperature and was a prime reason for low yield. Delayed sowing also resulted in less vigorous plants than timely sown crop which was evident from significant reduction in plant height and other growth parameters. Heavy PSI (3295 kg/ha) resulted in significantly higher SCY by 20.3 per cent over the shallow irrigation (2738 kg/ha). Among timing of first POSI, cotton crop receiving irrigation at 6 WAS recorded significantly least SCY (2609 kg/ha), whereas all other levels were at par. Date of sowing was found to be the major governing factor for yield as there was maximum decline (37.4 %) in SCY which was indicative of significance of changed and relatively unsuitable climatic and biotic conditions under late sowing. This was followed by levels of PSI (20.3 %) and application timing of first POSI, where reduction in SCY was 2.5-24.8 per cent (6 WAS) over 3-5 WAS. This study identified late sowing to be prime factor for low productivity at Farmers field where cotton sowing is often dragged due to reasons like delayed harvesting/threshing of *rabi* crops and/or unavailability of canal water for PSI. Timely sowing and assured release of canal water supply for irrigation (pre and post sowing) hold the key for success of cotton crop in South-Western Punjab and has potential to enhance productivity even higher than world average.

Key words: Post sowing irrigation (POSI), pre sowing irrigation (PSI), seed cotton yield (SCY), weeks after sowing (WAS)

Cotton is a thermophilic and semi-xerophyte forced annual plant and varied temperature and water regimes are required at different growth stages. India has highest acreage under cotton in the world but with an exceptional low productivity of only 560 kg /ha, owing to the limits of different agro-climatic situations, as against the world average of 788 kg/ha (Anonymous, 2016). Despite significant growth in production, productivity and quality of Indian cotton during the last 50 years, it is way below the average world productivity and far below the general quality requirements. Cotton-Wheat is a dominant cropping system in semi-arid region of southwestern Punjab which covers 11 per cent of the total cultivated area (4.6 m ha). In Punjab, cotton was grown on 0.34 million hectares with total production 0.39 million bales having a low productivity level of 197 kg lint/ ha during 2015 which is merely 25 per cent of the global average of 788 kg/ha (Anonymous, 2017). Southwestern Punjab is characterized with arid climate, poor rainfall (40 cm annually), brackish underground water and poor soil fertility. Here, canal water is the sole source of irrigation for crops and its availability during the recommended sowing time (*i. e.* April-mid May) is often meager because of ongoing repair work required for safe water flow during upcoming *kharif* season. (Singh *et al.,* 2013). As a result, timely sowing of cotton is severely affected. In this region, sowing of cotton is staggered from April to first week of June, depending upon the surface water supply from canal as the ground water is unfit for irrigation (Singh *et al.,* 2002).Consequently, crop sown after PSI with brackish underground water results in poor emergence owing to high sensitivity of germinating cotton seed to accumulated salts in the soil. The situation becomes worse when young cotton seedlings are further exposed to continuously rising temperature often exceeding 40°C and this result in high seedling mortality due to scorching and burning. Ultimately poor plant stand of the less vigorous crop results in huge reduction in SCY. The late sown cotton crop has a fate to bear dry and hot weather during initial stages of seedling growth besides stunted growth as well as doubtful plant survival. The situation is further aggravated when first post sowing irrigation is delayed beyond 40 DAS due to non availability of canal water and thus leads to partial drought like situation. Under such situations, risk of sucking pest infestation is always on a higher side as evident by incidence of sucking pests like whitefly which is increasing since last couple of years and has been more pronounced on relatively weaker and smaller plants. Complete failure of cotton crop in Punjab during infamous year 2015 was primarily an amalgam of above said problems. Jack (2011) also quoted poor plant population stand, non uniform sowing dates, subdued and injudicious input use, endemic and bursts of insect build up and weed crop competitions in cotton as main constraints which need to be addressed seriously. Horst *et al.,* (2005) also identified the need for better irrigation timings adjustment because traditional irrigation results in small soil moisture deficits at time of irrigation that lead to high percolation and runoff volumes. Thus, in addition to improving irrigation systems, there is also a need to establish adequate irrigation scheduling for cotton (Cholpankulov *et al.,* 2008). Moreover, growth and total duration of cotton is linearly related to water availability because of semi xerophytic and indeterminate forced annual plant characteristics (Rao *et al.,* 2016). There is little doubt that timely and adequate supply of water is necessary for better yield realization in cotton (Chauhan and Bhunia ,2010) but the sole purpose of irrigation is to keep crop water status at a level that maximizes solar radiation harvesting (Aujla *et al.,* 2005).

Keeping view of above mentioned issues, an investigation was planned to find out reasons for low productivity at farmers fields by evaluating the yield realization as well as losses under different dates of sowing besides effect of pre and post sowing irrigation scheduling on cotton growth and yield attributes. Identification of reasons behind the productivity decline in the cotton crop and way out for possible solutions can be greatly helpful in reviving the cotton acreage as well as productivity. Accordingly, cotton growers need to be acquainted with improved production practices so as to get sustained yield and improve profit margins by scientific adoption. Therefore, a field experiment was conducted to ascertain the impact of sowing dates, levels of pre-sowing irrigation and application time of first post-sowing irrigation and their interactive effect on growth and yield parameters of American cotton in south western Punjab.

MATERIALS AND METHODS

The experiment was conducted at Research Farm of Punjab Agricultural University, Regional Research Station, Faridkot, India, during the *kharif* 2016. PAU, Regional Research Station, Faridkot (30°40'Nand 74°44'E) typically represents Zone IV (South western zone) of Punjab situated at 200 m above MSL. Geologically, the farm area forms a part of the Indo-Gangetic alluvial plains. The area is characterized as semi arid (dry). Rainfall is monsoonal in nature of which approximately 70–80 per cent is received during the months of July, August and September. Mean monthly maximum air temperature (28.6-40.5°C), minimum air temperature (10.6-28.3°C), maximum (59-87%) and minimum relative humidity (23-71 %) varied significantly during crop growth period starting from April to November, 2016. A maximum temperature of 40.5°C was recorded in May which was indicative of its being the hottest month (Fig.1). The total rainfall during the cropping season was 38.5 cm. The soil of the experimental field was sandy loam, slightly high in pH (8.1), normal EC (0.65), medium in OC (0.57), medium in available P (15.8 kg/ha) but high in available K (473 kg/ha). The experiment was laid in split plot design with combination of two sowing dates (April 30; timely and May 30; late) and two levels (shallow and heavy) of pre sowing irrigation (PSI) in main plots and four levels of timing of first post sowing irrigation (POSI) scheduling (*i.e.* after 3rd, 4th, 5th and 6th week of sowing) in sub plots. The recommended fertilizer level *i.e.* 75 kg N and 30 kg P_2O_5/ha was applied, of which phosphorus was applied as basal dose by uniform broadcasting at the time of field preparation before sowing while N was applied in three equal splits at 40, 75 and 90 DAS. Sowing was done by maintaining a recommended planting geometry of 67.5 cm between rows and 75 cm for plant to plant using *Bt* cotton Cv. RCH650 BGII. Heavy PSI was given by making strong bunds around designated plots each measuring 24 sq m whereas shallow irrigation was given to rest of plots as being practiced by farmers. On an average, about 10 minutes were required for shallow (60-70 mm) PSI of each plot while heavy PSI (100 mm) for each plot took 14 minutes. All other production as well as protection practices were adopted as per the recommendations of Punjab Agricultural University. Data on various growth and yield attributes were recorded from 5 randomly selected plants in each treatment plot. SCY (kg/ha) was recorded from whole plot. The data were analyzed statistically as per the standard procedure.

RESULTS AND DISCUSSION

Effect of pre sowing irrigation (PSI) : The data presented in Table 1 revealed that cotton crop performed better under heavy PSI as compared to shallow by exhibiting higher growth as well as yield attributes. Significantly higher plant height under heavy PSI (131.8 cm) indicated vigorous growth than the shallow (125.0 cm). Although number of monopods per plant remained at par but sympods were statistically better under heavy PSI. Higher SCY owing to better yield attributing characters such as bolls per plant (68.0) and boll weight (3.68g)was observed under heavy PSI (3295 kg/ha) than under shallow conditions (2738 kg/ha). Significantly better plant survival (17276/ha) as compared to shallow irrigation (15586/ha) was another major reason for higher yield of crop sown after heavy PSI as there was least seedling burning and mortality. Consequently, reduced final plant population under shallow irrigation was a due to higher burning/mortality of seedlings which ultimately contributed to reduced yield attributes and lower SCY.

Effect of date of sowing : Significantly improved vegetative parameters like plant height, monopods and sympods prompted timely

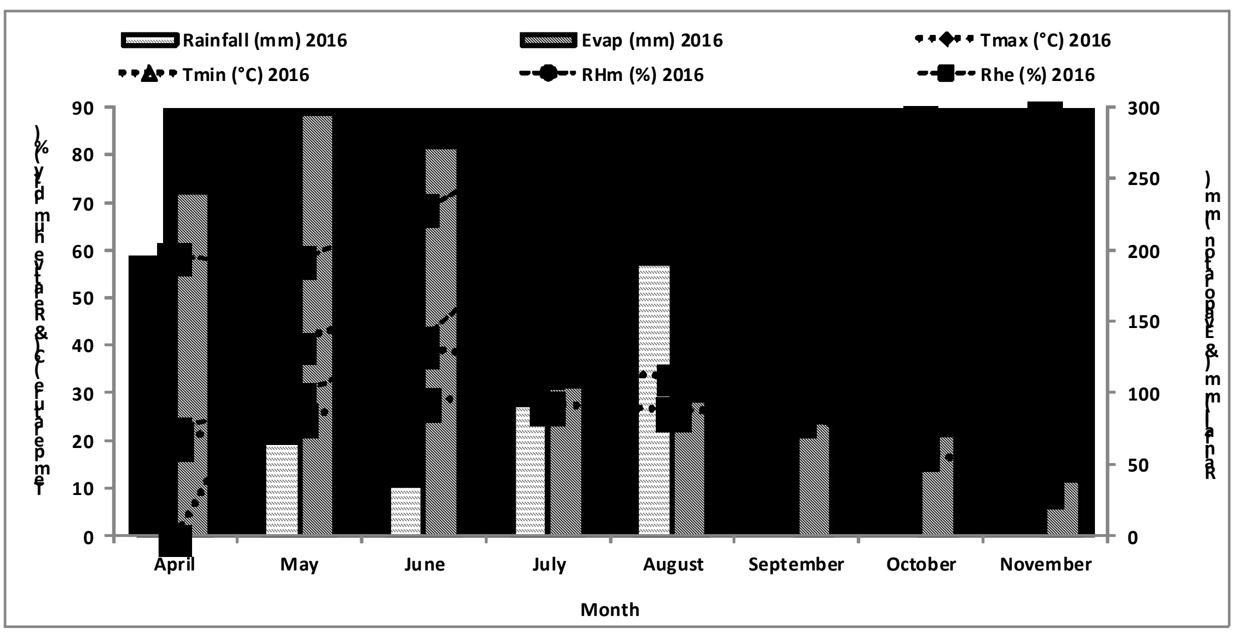

Fig. 1. Prevailing weather conditions of the experimental site during crop season 2016

sown cotton crop on April 30 for transformation into more bolls/plant and statistically higher boll weight (Table 1). The growth parameters such as plant height (145.8 cm) and number of monopods (2.5) as well as sympods/plant (25.0) were significantly higher under the timely sown than the late sown crop. Significantly higher number of bolls per plant (71.5) , improved boll weight (3.73g) and better final plant population under April sown crop ultimately contributed to better SCY. Cotton crop sown on April 30 (3492 kg/ha) recorded 37.4 per cent significantly better SCY over the crop sown on May 30 (2541 kg/ha). Jalota *et. al.,* (2008) reported higher SCY in timely sown (April) than the late sown crop (after mid-May) and reduction in the period necessary for full boll growth and maturity and less favorable conditions for boll maturity to be reasons for such response (Nawar *et al.,* 1986 and Soomro *et al.,* 2014). Severe seedling burning and mortality owing to higher temperature during seedling stage was the main reason behind the lower plant stand (14645/ha) under late sown crop.

Effect of timing of first post sowing irrigation (POSI) : Among timing of first POSI, highest SCY of 3257 kg/ha was recorded when cotton was irrigated at 4 WAS, though it was *at par* with 3 WAS (3175kg/ha) and 5 WAS (3024 kg/ha).However, cotton receiving first irrigation at 6 weeks after sowing (WAS) recorded significantly least SCY (2609 kg/ha).This indicated that too early as well as later irrigation than the optimum time (4 WAS) had a negative effect on the yield performance. Though, delay from 4 to 5 weeks could not bring significant

Table 1. Growth, yield and yield contributing characters of American cotton under different treatments

Treatments	Plant height (cm)	Mono-pods/ plant	Sym-pods/ plant	Boll weight (g)	Bolls/ plant	Seed cotton yield (kg/ha)	Stick weight (q/ha)	Plant stand/ ha
Pre-sowing Irrigation (PSI)								
Heavy	131.8	2.5	20.7	3.68	68.0	3295	159.6	17276
Shallow	125.0	2.1	18.3	3.41	59.9	2738	127.9	15586
CD (p=0.05)	2.4	NS	1.2	0.25	3.2	309	206	274
CV (%)	15.6	12.4	4.9	5.6	4.1	8.2	11.5	-
Date of sowing								
April 30	145.8	2.5	25.0	3.73	71.5	3492	170.6	18217
May 30	111.0	2.1	14.0	3.36	56.4	2541	116.9	14645
CD (p=0.05)	13.8	0.3	2.1	0.23	3.9	265	202	261
CV (%)	13.4	18.9	13.6	7.98	7.6	10.9	17.6	-
Timing of first post sowing irrigation (POSI)								
3 WAS	125.6	2.6	20.3	3.62	65.9	3175	151.9	16916
4 WAS	131.7	2.4	20.7	3.65	66.3	3257	155.3	16622
5 WAS	129.7	2.2	19.2	3.48	65.4	3024	145.0	16314
6 WAS	126.6	2.0	17.8	3.44	58.3	2609	122.7	15873
CD (p=0.05)	NS	0.3	2.0	NS	4.4	355	143	406
CV (%)	7.3	14.4	12.2	6.4	8.1	13.9	11.8	-

WAS : weeks after sowing

reduction in yield but thereafter decline was significant. Significant reduction in bolls per plant (58.3) was prime reason for statistically least SCY for crop applied with irrigation at 6 WAS. Non significant differences among irrigation applied at 3,4 or 5 WAS level are also supported by Jalota *et al.,* (2008) with the contention that water stress at early stages of cotton stimulates the deeper penetration of rooting system, which can exploit more volume of the soil to withstand the water stress during mid season and may increase seed cotton yield. The favorable effect of water stress resulting from delayed first irrigation on cotton seed yield has been observed by a number of researchers (Buttar *et al.,* 2007; Guinn and Mauney, 1984).

CONCLUSION :

Our studies stated that in south-western Punjab conditions, POSI after 5 WAS significantly reduced the SCY and probably significant reduction in plant population along with their reduced yield attributes were among the primary reasons for such reduction. A temperature range of 38-40^{o}C prevalent during month of May and June resulted into severe scorching and burning followed by mortality of seedlings leading to significant reduction of plant stand under all three conditions *viz.*, shallow PSI, late sown crop on May 30 as well as crop receiving delayed application of POSI at 6 WAS. However, maximum reduction was observed in late sown cotton crop on May 30 after shallow PSI and receiving first POSI at biggest gap of 6 WAS. In this case, young saplings remained under high temperature stress starting from their emergence due to lack of inadequate soil moisture in root zone and it was further aggravated with their encounter with severe heat exceeding >38 ^{o}C coupled with low relative humidity during June month. It can be stated that the date of sowing is the major governing factor for yield in south-western Punjab as there was maximum decline (37.4 %) in SCY which was indicative of significance of changed and relatively unsuitable biotic/climatic conditions under late sowing. This was followed by depth of pre sowing irrigation , where 20.3 per cent reduction in yield was recorded under shallow PSI than deep PSI and timing of first POSI where reduction in SCY was in the range of 2.5-24.8 per cent (6 WAS) over 3-5 WAS. Our study established date of sowing to be the major reason behind the low yield at farmer fields where crop sowing is often dragged due to reasons like unavailability of canal water for PSI or delayed wheat harvesting/threshing. Conclusively it should be assured to release ample canal water immediately by April end so that farmers may apply a heavy PSI besides application of first POSI around 4-5 WAS. There was no advantage of early POSI at 3WAS to a timely sown crop after heavy PSI. However, growth and yield of late sown crop with shallow or sub optimal soil moisture levels would be worst affected if first irrigation is applied at 6 WAS.

REFERENCES

Anonymous, 2016. All India co-ordinated research project on cotton-Annual Report (2016-17) *http://aiccip.cicr.org.in/main_aiccip_reports.html.*

Anonymous, 2017. Package and practice for *Kharif* crops. Punjab Agricultural University, Ludhiana. ISSN 2278-3725.

Barradas, G. and Lopez-Bellido, R.J. 2009. Genotype and planting date effects on cotton growth and production under South Portugal conditions. III-Boll set percentage, boll location, yield and lint quality. *J. Food. Agric. Environ.* **7 :** 322-28.

Aujla, M.S., Thind, H.S., and Buttar, G.S 2005. Cotton yield and water use efficiency at various levels of water and N through drip irrigation under two methods of planting. *Agric Water Manage* **71:** 167-79.

Buttar, G.S., Thind, H.S., Aujla, M.S., Singh, C.J., Saini, K.S. 2007. Effect of timing of first and last irrigation on the yield and water use efficiency in cotton. *Agric. Water Manage.* **89 :** 236-42.

Chauhan, R.P.S., and Bhunia, S.R 2010. Effect of sulphur and irrigation on productivity of American cotton . *J Cotton Res Dev* **24 :** 64-66.

Cholpankulov E. D., Inchenkova, O. P., Paredes, P. and Pereira, L. S. 2008. Cotton irrigation scheduling in central Asia: Model calibration and validation with consideration of groundwater contribution. *Irri. Drain.* **57 :** 516-32.

Guinn, G., Mauney, J.R 1984. Fruiting of cotton. I. Effects of moisture status on flowering. *Agron. J.* **76 :** 90-94.

Horst, M.G., Shamutalov, Gonçalves, J.M., Pereira, L.S 2005. Assessment of furrow irrigation improvements and water saving in cotton irrigation. *www.cawater-info.net/library/eng/copernicus/pdf/14_horst_et_al.pdf.*

Jack, K 2011. "Market Ineciences and the Adoption of Agricultural Technologies in Developing Countries," ATAI. 1, 3.

Jalota S.K., Buttar, G.S., Sood, Anil, Chahal, G.B.S., Ray, S.S. and Panigrahy, S. 2008. Effects of sowing date, tillage and residue management on productivity of cotton (*Gossypium hirsutum* L.)–wheat (*Triticum aestivum* L.) system in northwest India. *Soil and Till. Res.* **99:** 76-83.

Nawar, A.I., Kassem, A.A., Bishr, M.A. and Khadr, F.H. 1986. Sowing cotton after berseem and relay cropping with onions. *Egypt. Soc. Crop Sci.* **2 :** 299-308.

Rao, I.M., Miles, J.W., Stephen, E., Beebe, S.E., and Horst, W.J 2016. Root adaptations to soils with low fertility and aluminum toxicity. *Ann Bot 118: doi:10.1093/aob/mcw073.*

Singh, K., Singh, H., Singh, K., and Rathore, P. 2013. Effect of transplanting and seedling age on growth, yield attributes and seed cotton yield of *Bt* cotton (ý*Gossypium hirsutum*). *Indian J Agric Sci.* **83:** 508-13.

Singh, C.J., Aujla, M.S., Saini, K.S., Buttar, G.S., Brar, J.S 2002. Conjunctive use of fresh and salty water in cotton and wheat in south-western Punjab. In: *"Proceeding 17th World Congress Soil Science"*, August 12–14, pp. 1-7.

Soomro, A.W., Panhwar, F.H., Channa, A.R., Ahsan, M.Z., Majidano, M.S., Khaskheli, F.I. and Sial, K.B. 2014. Effects of sowing time on yield, got and fiber traits of upland cotton Gossypium hirsutum L.). *Int. J. Scient. Eng. Res.*, **5 :** 194-98.

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Status of cotton cultivation in Meghalaya

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The diverse soil types in Meghalaya support various agricultural crops including cotton. Cotton, Mesta and jute are the three important fibre crops cultivated in the state and exclusively grown in Garo Hills districts of Meghalaya. However, among these fibre crops, cotton has the highest area (>7000 ha) under cultivation and is grown exclusively in the Garo Hills districts. However, very few people know that Meghalaya is a cotton producing state. Nonetheless, cotton is traditionally grown in Garo Hills and is spun into different fabric in the state and the country. The cotton grown in Garo Hills is also known as *Comilla* cotton because during the pre-independence period cotton trade flourished from the Garo Hills through the markets of Comilla district of Bangladesh. This International trade may have stopped, but sale of cotton from Garo Hills is on the rise with a shortage of cotton throughout India. Garo Hills cotton is finding excellent markets and these are being produced into sarees and other garments for women like salwar suits, lehenga choli and others. The Garo Hills cotton belongs to the *Gossypium arboretum* and has a good market as short staple cotton. Such types of cotton are also used for mixing with wool. The other varieties produces in the state are *Gossypium hirsutum*, *Gossypium barbadense* and *Gossypium harbaceum*. Meghalaya cotton is known for its softness and durability. The cotton area and production in the state not getting popularity due to various reasons, like poor seed and other critical input supply, lack of awareness among the farming community, sound scientific package of production etc. Furthermore, Assam Comilla cotton is traded much below the MSP mainly because of absence of procurement centres of cotton by Cotton Corporation of India in north eastern states (CCI 2011). Hence, now it is economical to procure such type of cotton from Meghalaya and transport and gin at central India with lower price to that of *Bt* and hybrid cotton. Assam Comilla cotton cultivation can be encouraged with incentives which can lead to better employment generation and increase in farm income.

Status of cotton in Meghalaya : The optimum sowing and harvesting time of cotton in Garo hills area of Meghalya is July-August and November-December, respectively. The average annual area and production cotton in Meghalaya during 2014-2015 was 7512 ha 5887 bales, respectively (Fig.1). In last 10 years the average annual change in area, production and productivity was -10 ha and 210 bales, respectively which indicates that although there was a mark decrease in area, the production has however increased. Singh *et al.,* (2003) reported that cotton germplasm material in

Meghalaya displayed considerable variability in desirable traits, namely, average seed-cotton yield per plant (24–82 g), boll weight (4.9–7.3 g), ginning outturn (37–46%), mean halo length (18–22 mm) and resistance to various diseases and pests. The important variability in different races of *G. arboreum* included big, long boll types with high boll weight, high ginning outturn, higher seed number/ locule/capsule, high seed-cotton retention and resistance to disease and pests in the race *cernuum* from *jhum* in parts of the Garo Hills of Meghalaya.

Cotton cultivation in slash and burn system of Meghalaya : *G. arboreum* var. LD 230 and RG-8 grown commercially in the Meghalaya under slash and burn system. Jhum cultivation is unaffected by *Bt* hybrid cotton invasion. Sowing of cotton generally done by dibbling under slash and burn system. The dibbling and planting of seeds is mainly done by female famers. In this system the male farmers generally adopted the broadcasting method of cotton seed sowing. While dibbling the seeds, the woman walk over the field with a digging stick or bill-hook in hand, make a hole in the ground, sow a few seeds and cover it over with earth by pressing it down with her toe. In the mixed cropping cotton is cultivated with soil enriching crops. A combination of cotton and ground nuts or cotton and pigeon pea as mixed crops is very popular in Garo Hills. This practice has many direct and indirect advantages. These crops harvest at different periods, thereby providing the tribes with varied food for nearly six to nine months in a year.

Future perspective of cotton in Meghalaya : Land cultivation in Meghalaya is classified into two different patterns—settled/ semi-intensive farming on the permanent in valley areas and shifting cultivation on the hills slopes. In the hill areas, shifting cultivation

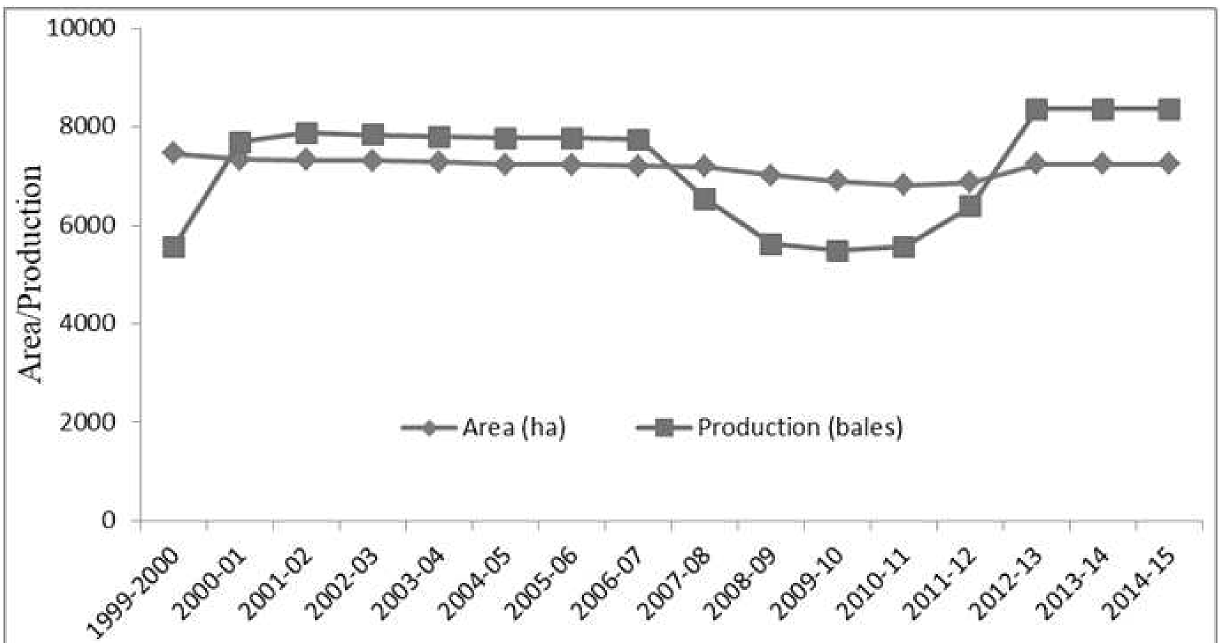

Fig.1 Area and production of cotton in Meghalaya

requires a large amount of land but it supports only a small number of populations. Hence, the cotton will be the good alternative crop to the jhumias in the state. Similarly, boundary and intercrop cultivation of cotton can also hold a good promise in the state. Meghalaya condition is very conducive for organic farming and cotton- an ideal candidate for organic farming, being semi-xerophyte plant cotton a forced annual with indeterminate growth habit. Its ability to put forth repeated flushes in response to pest pressures and moisture/nutrient supply is advantageous to minimize yield losses under organic conditions. Due to its long duration, ample of time is available for assimilating mineralized end products made available from slowly available organic sources. Its ability to absorb foliar applied nutrient formulations is higher than many other crops. These natural physiological mechanisms make cotton a forerunner for organic farming. Use of chemicals at such scale causes a lot of hazards to man, *i.e.,* environmental pollution, soil health, and agro- www.cicr.org.in 3 ecology and poor profitability in cotton farming. This has basically prompted the demand or organically cultivated eco-friendly or ‘green’ cotton. Cotton based farming system is the key component of agricultural production system

REFERENCE

CCI. 2011-2012. Minimum support prices for fair average quality for Cotton season. http://www.cotcorp.gov.in/msppri ce.aspx

Singh, V.V., Mohan, Punit, Kulkarni, V.N., Baitule, S.J., Pathak, B.R. 2003. Exploration within India for collection of cotton species germplasm. *Plant Genetic Resources Newsletter* **136 :** 40–46.

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Impact of minimum support prices (MSP) on cotton farming in India

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ABSTRACT : In the present study, farmers' awareness of minimum support price (MSP) and influence of MSP on production of cotton has been analysed. Data from National Sample Survey Office, 70th round dataand Ministry of Agriculture were used for the study. The results indicated that only 20.4 and 22.6 per cent of farmers in India are aware of MSP of cotton grown by them in kharif and kharif long duration season, respectively. Therefore, there is need to increase the awareness among the cotton growing farmers in all cotton growing states to increase the bargaining power for their produce. The results also revealed that there was higher growth in area and production (*i.e.* 4.16 and 5.95 per cent, respectively) and MSP of medium and long staple cotton (*i.e.* 9.37 and 8.66 per cent, respectively) in period II (2005-2006 to 2015-2016).Therefore, MSP is one among the factors to impact production of cotton in India. The major reason given by farmers for not selling their produce directly to procurement agency is that procurement agency / local purchaser are not available to procure and also there is delay in payments. Thus, there is need to set up additional procurement centres in major growing areas with improved infrastructure and finance facilities.

Keywords : Awareness, cost, growth, MSP, procurement

Cotton popularly known as "White Gold" is a major commercial crop and has a global significance which is grown for its lint and seed. India is the largest producer of cotton in the world accounting for about 27 per cent of the world cotton production. The major cotton growing states in India are Gujarat, Maharashtra, Andhra Pradesh, Telangana, Haryana, Karnataka, etc. It is important for the government to protect the interest of cotton growers and increase in the production by assuring better price of their produce.Therefore, Minimum Support Price (MSP) is a component of Agricultural Price Policy in India to ensure agricultural producers against any sharp fall in prices. The major objective of MSP is to avoid farmer from distress sale of their produce.

In India, there have been many concerns of awareness and regarding effective operation of minimum support price (MSP). Few studies have pointed out that MSP has led to regional imparity in incomes and effective in states where procurement is carried (Ali *et al.*, 2012). In this study, MSP is treated as a safety net and an attempt has been made to analyse the awareness of MSP among cotton growers in India and major producing states. Also, we explore the major reasons of farmers for not selling produce to procurement agency (Cotton Corporation of India). The study also tries toestablish possible relationship of MSP and production and MSP and costs for understanding the performance of MSP in cotton.

MATERIALS AND METHODS

In this study, the data pertaining to farmers’ awareness of MSP in cotton has been collected from ‘Situational Assessment Survey of Farmers’ (National Sample Survey Office 70thround). The data were collected for the *kharif* (July – December 2012), and *kharif* long duration season (January – May 2013) in two separate visits and pertain to the year 2012-2013. The secondary data on production of cotton and Minimum Support Prices (MSP) has been collected for the period1994-95 to 2015-16 from Ministry of Agriculture and Farmers’ Welfare. The whole period was divided into period I – before introduction of *Bt* cotton (1994-1995 to 2004-2005) and Period II after adoption of *Bt* cotton (2005-2006 to 2015-2016). The details regarding cost of production in cotton and procurement of cotton were collected from official secondary sources.

Growth rate analysis

The compound growth rates in area, production, productivity, and cost of production and MSP of cotton in India were estimated by using the following exponential growth function of the form:

$Y = ab^t u_t$

Where, Y = Area, production, productivity and MSP of cotton

a = intercept

b = regression coefficient

t = time variable

The equation was estimated by transforming in to log form as follows;

log y = log a + t log b + log Ut

Then, the per cent compound growth rate (g) was calculated by using the relationship

r = {antilog of (logb)-1} x 100

RESULTS AND DISCUSSION

The compound growth rates of area, production, productivity and MSP of cotton in India for the period 1994-1995 to 2015-2016 were computed. The Table1 revealed that, there was considerable change in area, production and productivity of cotton in India from 1994-1995 to 2015-2016. In overall period, the area increased from 78.71 to 122.92 lakh ha with 1.98 per cent growth, production increased from 118.88 to 300.05 lakh bales with 6.87 per cent growth and productivity increased with 4.79 per cent. The negative growth rates were found in area and production of cotton during period I. But, there was tremendous growth in period II with 4.16, 5.95 and 1.73 per cent growth in area, production and productivity of cotton, respectively.The reason for increase in production in period II can be attributed to increase in adoption of *Bt* cotton varieties, improved technology and other factors like crop protection *i.e.* insect-pest and disease management and adequate price support mechanism.

The growth in MSP of cotton leads to increase in market price, if not produce is procured by government at the announced MSP. This protects interest among cotton growers and influences increase in area and production of cotton. The growth in MSP of medium and long staple cotton for period I was 5.68 and 4.94 per cent, respectively .In the period II, the MSP’s of

Table 1. Growth in area, production and productivity of cotton for period 1994-1995 to 2015-2016

Years	Area (lakh ha)	Production (lakh bales) (1 Bale=170kg)	Productivity (kg/ha)
1994-1995	78.71	118.88	257
1995-1996	90.35	128.61	242
1996-1997	91.21	142.31	265
1997-1998	88.68	108.51	208
1998-1999	93.42	122.87	224
1999-2000	87.10	115.30	225
2000-2001	85.34	95.20	190
2001-2002	91.32	99.97	186
2002-2003	76.70	86.24	191
2003-2004	75.98	137.29	307
2004-2005	87.87	164.28	318
2005-2006	86.77	184.99	362
2006-2007	91.45	226.32	421
2007-2008	94.14	258.84	467
2008-2009	94.07	222.76	403
2009-2010	101.32	240.22	403
2010-2011	112.35	330.00	499
2011-2012	121.78	352.00	491
2012-2013	119.77	342.20	486
2013-2014	119.60	359.02	510
2014-2015	128.46	348.05	461
2015-2016	122.92	300.05	415
CGR (%)			
Period I: 1994-1995 to 2004-2005	**-0.63**	**-0.04**	**0.59**
Period II: 2005-2006 to 2015-2016	**4.16**	**5.95**	**1.73**
Overall: 1994-1995 to 2015-2016	**1.98**	**6.87**	**4.79**

medium staple and long staple cotton seen growth of 9.37 and 8.66 per cent, respectively (Table 2). The highest growth in area, production and productivity of cotton were also found during period II. Therefore, we can say that MSP is one among the factors to impact area and production of cotton. The change in MSP over the previous year was highest during the year 2008-2009 and 2012-2013 with (38.89 and 47.78) and (28.57 and 18.18) per cent for medium and long staple cotton. The overall growth of MSP for the period 1994-1995 to 2015-2016 was 6.15 and 5.92 per cent in medium and long staple cotton, respectively.

The determinants of MSP are demand and supply, cost of production, domestic price, international price, inter-crop price parity and likely implications of MSP on that product. But, cost of production is an important factor in fixing

Table 2. Growth in minimum support prices (MSP)of cotton for the period 1994-1995 to 2015-2016

Years	Medium Staple		Long Staple	
	MSP (Rs/Q)	% Change	MSP (Rs/Q)	% Change
1994-1995	1000	10.00	1200	14.29
1995-1996	1150	15.00	1350	12.5
1996-1997	1180	2.61	1380	2.22
1997-1998	1330	12.71	1530	10.87
1998-1999	1440	8.27	1650	7.84
1999-2000	1575	9.38	1775	7.58
2000-2001	1625	3.17	1825	2.82
2001-2002	1675	3.08	1875	2.74
2002-2003	1675	0	1875	0
2003-2004	1725	2.99	1925	2.67
2004-2005	1760	2.03	1960	1.82
2005-2006	1760	0	1980	1.02
2006-2007	1770	0.57	1990	0.51
2007-2008	1800	1.69	2030	2.01
2008-2009	2500	38.89	3000	47.78
2009-2010	2500	0	3000	0
2010-2011	2500	0	3000	0
2011-2012	2800	12	3300	10
2012-2013	3600	28.57	3900	18.18
2013-2014	3700	2.78	4000	2.56
2014-2015	3750	1.35	4050	1.25
2015-2016	3800	1.33	4100	1.23
CGR(%)				
Period I: 1994-1995 to 2004-2005	**5.68**		**4.94**	
Period II: 2005-2006 to 2015-2016	**9.37**		**8.66**	
Overall: 1994-1995 to 2015-2016	**6.15**		**5.92**	

Table 3. Relationship between cost of production and minimum support price (MSP) in cotton

Years	Cost of production–C2(Rs/Q)	Staple medium MSP (Rs/Q)	Length long MSP (Rs/Q)
2007-2008	2110	2030	1800
2008-2009	2088	3000	2500
2009-2010	2111	3000	2500
2010-2011	2129	3000	2500
2011-2012	2528	3300	2800
2012-2013	2772	3900	3600
2013-2014	3533	4000	3700
2014-2015	3480	4050	3750
2015-2016	3767	4100	3800
CGR (%) 2007-2008 to 2015-2016	8.95	7.88	9.33

the MSP. Hence, relationship between MSP and cost of production in cotton has been analysed for the period 2007-2008 to 2015-2016. Table 3 revealed that growth in cost of production of cotton for the period is 8.95 per cent, whereas growth in MSP of medium staple and long staple has found 7.88 and 9.33 per cent, respectively. The cost of production and MSP had increased at almost the same rate. Thus, we can conclude that growth in MSP of cotton has been influenced by cost of production.

Table 4. Comparison of different cost concepts andMSP in cotton for 2017-2018

Particulars	A2	A2+FL	C2	C3
Cost (Rs/Q)	2622	3276	4376	4814
MSP (Rs/Q) – **Long staple**		4320		
MSP>Cost (%)	64.76	31.87	-1.28	-10.26
MSP (Rs/Q) – **Medium staple**		4020		
MSP>Cost (%)	53.32	22.71	-8.14	-16.49

Table 4 accompanied with details of all-India weighted average A2, A2+FL, C2 and C3 production costs for cotton, as projected by the CACP and announced MSP of cotton for the year 2017-2018 kharif season. A2 costs basically cover all paid out expenses, both in cash and kind incurred by the farmers. A2+FL cost covers actual paid out expenses plus an imputed value of family labour. C2 costs are comprehensive, accounting for A2+FL cost plus the rentals and interest foregone on owned land and fixed capital assets respectively. Lastly, C3 covers C2 cost plus 10 per cent of C2 as managerial cost. The announced MSP of cotton is found 50 per cent more than A2 cost and 20 per cent more than A2+FL cost of production. It's worse with regard to C2 and C3 cost, where the announced MSP is lesser than these costs. Thus, there is need to clarity of the cost concept considered for fixing

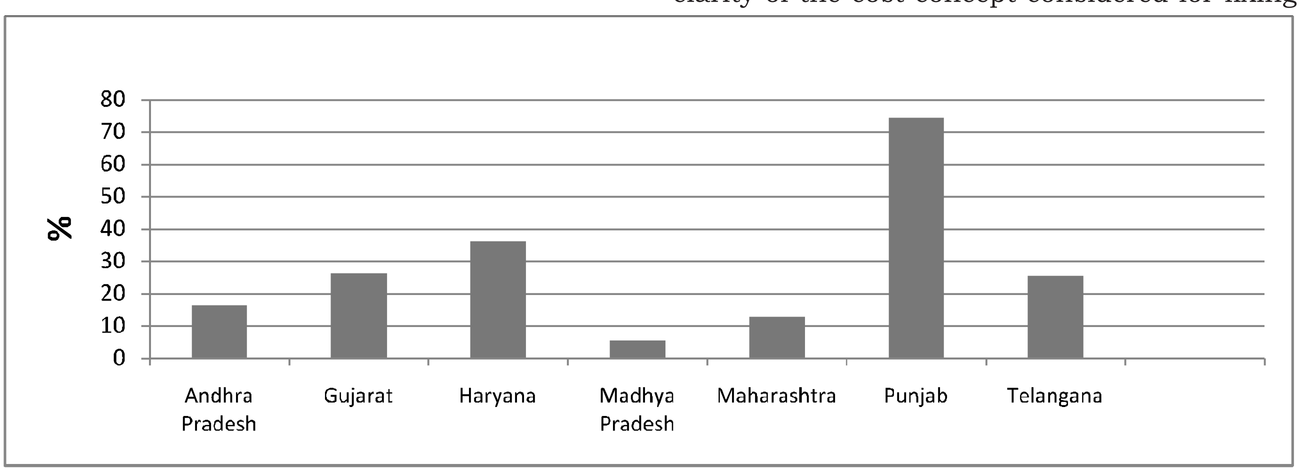

Fig 1. Farmers' awareness about MSP of cotton in major cotton growing states

Table 5. State wise procurement of cotton under MSP by Cotton Corporation of India (CCI) (In 000' Bales)

Years	Andhra Pradesh	Gujarat	Haryana	Madhya Pradesh	Maharashtra	Punjab	Telangana	Others	India
2005-2006	350.1 (27.95)	293.2 (23.41)	4.4(0.35)	118.3(9.45)	295.2 (23.57)	52.4 (4.18)	-	138.9 (11.09)	1252.5(100.00)
2006-2007	527.6 (44.77)	-	-	89.8(7.62)	539.8(45.80)	-	-	21.3(1.81)	1178.5 (100.00)
2007-2008	218.7 (97.94)	-	-	-	-	-	-	4.6(2.06)	223.3 (100.00)
2008-2009	3275.8 (36.66)	1236.1 (13.83)	255.3 (2.86)	736.5 (8.24)	1997.1 (22.35)	255.3 (2.86)	-	1178.7 (13.19)	8934.8 (100.00)
2009-2010	445.6 (76.75)	0.2(0.03)	21.8 (3.75)	-	0.5(0.09)	21.8 (3.75)	-	90.7 (15.62)	580.6 (100.00)
2010-2011	-	-	-	-	-	-	-	0.2 (100.00)	0.2 (100.00)
2011-2012	7.6(98.70)	-	-	-	-		-	0.1 (1.30)	7.7 (100.00)
2012-2013	2174.9 (95.11)	-	-	3.6(0.16)	41.6(1.82)	-	-	66.6 (2.91)	2286.7 (100.00)
2013-2014	40.8(100.00)	-	-	-	-	-	-	-	40.8(100.00)
2014-2015	1755.6 (20.19)	666.5 (7.66)	79.9 (0.92)	281.9 (3.24)	1763.1 (20.28)	79.9 (0.92)	3690.9 (42.44)	378 (4.35)	8695.8 (100.00)
2015-2016	40.0 (4.74)	51.5 (6.10)	-	29.0 (3.43)	116.8 (13.83)	-	595.2 (70.48)	12(1.42)	844.5 (100.00)

(Figures in parenthesis are percentages to total)

*Up to 2013-2014, procurement in Andhra Pradesh includes Telangana region of MSP.

The major procurement agency of cotton in India is Cotton Corporation of India (CCI). As and when cotton prices touch the level of MSP, CCI resorts to immediate market intervention and involves in purchase at MSP. In the year 2014-2015 and 2015-2016, the cotton procured in India is 8695.8 and 844.5 thousand bales, respectively. The major procuring activity of cotton was found in states of Telangana + Andhra Pradesh, Maharashtra and Gujarat (Table 5). In the absence of MSP operations, CCI undertakes viable commercial operations at its own risk, for supply of cotton to mills in the domestic market. The purchases of cotton under commercial operations are also made through auctions conducted by the APMCs in the notified market yards.

Table 6 represents the percentage of farmers who were aware of MSP and involved in sale of cotton grown by them to the procurement agency. The awareness stood at 20.4 per cent and 22.6 per cent for *kharif* and *kharif* long duration, respectively. So we can say that less than 25 per cent farmers aware of MSP of cotton grown in India. Out of the farmers' who are aware of MSP of cotton, only 34.32 per cent and 37.17 per cent of farmers sold produce to procuring agency in kharif and kharif long duration, respectively. State-wise figures on farmers' knowledge reveals that 74.5 per cent farmers in Punjab and 36.2 per cent of farmers in Haryana were aware of MSP of cotton (Fig.1). The high awareness of Punjab and Haryana farmers is because, the procuring activity of food grains in these states are high and simultaneously, they knew of MSP of cotton. Knowledge of MSP of cotton in major procuring states Telangana + Andhra Pradesh, Maharashtra and Gujarat was found just inbetween 12-27 per cent. Thus, there is need to increase the awareness among the cotton growing farmers in all cotton growing states to increase the bargaining power in selling the produce and to avoid the distress sale.

Out of proportion of farmers who were aware of MSP of cotton, 65.68 and 62.83 per cent offarmers in kharif and kharif long duration, respectively have not sold the produce to procurement agency (Table 7). The function of

Table 6. Farmers' knowledge of minimum support prices in cotton in India

Particulars		*Kharif* (July-Dec.)	*Kharif* long duration (Jan.-May)
Sample size		2114	425
Aware	Number	431	96
	Percentage	20.4	22.6
Sold to Procurement agency(Out of aware)	Number	148	36
	Percentage	34.32	37.17
Not aware	Number	1683	329
	Percentage	79.6	77.4

Table 7. Reasons quoted by farmers for not selling to procurement agency

Particulars	*Kharif* (July-Dec.)	*Kharif* long duration (Jan.-May)
Percentage of farmers not selling to procurement agencies	65.68	62.83
Reason		
Procurement agency not available	25.37	17.61
No local purchaser	13.43	14.08
Poor quality of crop	2.98	1.41
Crop pre pledged	0.75	0
Received better prices	24.63	33.80
Others	32.84	33.10
Total	**100.00**	**100.00**

MSP is to set the floor price, and if farmers have received a better price than MSP, then it is considered as fine reason. Only 24.63 and 33.80 per cent of farmers reported that they had received a better price in the market. The major reason given by farmers for not selling the produce to procurement agencyis that no procurement agency / local purchaser area available (38.80, 31.69 %) to procure the produce at MSP. Thus, there is need to set up additional procurement centres in major growing areas with improved infrastructure facilities. Then, 32.84 and 33.10 per cent of farmers in *kharif* and *kharif* long duration, respectively reported that they have not sold to procurement agency because of other reasons. The other reason may include a delay in payments of money by procurement agency. A study by NITI Aayog (2016) reported lag of nearly 1 month between procurement and payment in more than 50 per cent of cases. The payment on same day for the procured produce encouragesthe farmers to improve their production and create more marketable surplus.

CONCLUSION

The highest growth in area, production and productivity of cotton was found in period II (2005-2006 to 2015-2016) with 4.16, 5.95 and 1.73 per cent, respectively. Also, MSP's of medium staple and long staple cotton seen highest growth in period IIwith 9.37 and 8.66 per cent, respectively. Hence, we can say that MSP is one among the factors to impact production of cotton in India. Cost of production is said to be the major determinant of MSP. Both cost of production and MSP of cotton had increased at almost at the same rate over the period. The announced MSP of cotton in the year 2017-2018 *kharif* is found 50 per cent more than A2 cost and 20 per cent more than A2+FL cost of production. It was worse with regard to C2 and C3 cost, where the announced MSP is lesser than these costs. Thus, there is need to clarity of the cost concept considered for fixing of MSP.The major procuring activity of cotton was found in states of Telangana + Andhra Pradesh, Maharashtra and Gujarat.

In India, less than 25 per cent farmers aware of MSP of cotton grown in India. Out of the farmers' who are aware of MSP of cotton, only 34.32 per cent and 37.17 per cent of farmers sold produce to procuring agency in kharif and kharif long duration, respectively.Knowledge of MSP of cotton in high procuring states was found just in between 12-27 per cent. Therefore, there is need to increase the awareness among the cotton growing farmers in all cotton growing states to increase the bargaining power in selling the produce and to avoid the distress sale.The major reason given by farmers for not selling the produce to procurement agency is that no procurement agency / local purchaser are available to procure and delay in payments. Thus, there is need to set up additional procurement centres in major growing areas with improved infrastructure facilities. Also, payment to the beneficiaries is tried to be made on same day.

REFERENCES

Aditya, K.S., Subash, S.P., Praveen, K.V., Nityashree, M.L., Bhuvana, N. and Sharma, A.(2017). Awareness about Minimum Support Price and Its Impact on Diversification Decision of Farmers in

India.*Asia Pacific Policy Studies*, **4** : 514-526.

Ali, S.Z., Sindhu, R.S. and Vatta, K. 2012. The Effectiveness of Minimum Support Price Policy for Paddy in India with a Case Study of Punjab.*Agri Eco Res Rev*, **25** : 231-42.

Kadasiddappa, M., Soumya, B., Prashanth, P. and Sachin, H.M. 2013. A Historical Prospective for Minimum Support Price of Agricultural Crops, *Kisan World,***40**(12).

NSSO (National Sample Survey Office) 2015. Situation Assessment Survey of Agricultural Households: January-December 2013. NSS 70th Round (unit level data). Ministry of Statistics and Programme Implementation (MOSPI), Government of India.

Ramachandra, V. A., Basana, R. T., Salunke, R. and Ravusaheb, M. 2011. Growth in Area, Production and Productivity of Major Crops in Karnataka.*International Journal of Agri Eco Stat,* **4** : 117-23

Tripathi, A.K. 2013. Agricultural Price Policy, Output, and Farm Profitability – Examining Linkages during Post reform Period in India.*Asian Jour Agri Dev*, **10** : 91-111.

www.indiastat.com. Agriculture prices, Minimum Support Prices,Datanet India.

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Recommended technology is boon or bane for cotton crop in Punjab

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ABSTRACT : Cotton is a highly sensitive crop and its productivity always remained volatile over the period of time. Huge loss of cotton crop had been observed in Punjab due to menace of whitefly during 2015 and Punjab government had to spent Rs.735 crore as compensation. During field surveys, the various factors that came into limelight were late sowing, growing un-recommended *Bt* hybrids, under dose of recommended fertilizers, spray of un-recommended pesticides, etc. To revive cotton crop in the state, an extensive campaign was carried out by Punjab Agricultural University and Department of Agriculture during 2016. To assess the performance of recommended technology at farmer's field an economic study was carried out on 100 farmers selected from 7 blocks of cotton belt of the state. The study revealed that during 2015 only 81.15 per cent area of selected farmers followed the recommended time of sowing which subsequently increased to 95.58 per cent during 2016. Similarly 15.3 per cent increase in adoption of recommended *Bt* hybrids was reported in 2016 over 2015 *i.e.* 70.7 per cent to 86.1 per cent, respectively. The data suggested that only 40 and zero per cent of selected farmers followed the recommended dose of nitrogen and potassium nitrate (KNO_3) fertilizers in 2015, whereas this level increased to 67 per cent and 50 per cent, respectively after campaign during 2016. Further as per the use of recommended insecticides is concerned, the investigation reported that only 23 per cent of the farmers used up to 6 recommended insecticides during 2015 which increased to 91 per cent in 2016. So present study gives a clear indication that campaign to revive the cotton crop in Punjab played an important role and increased the cotton yield from 195 kg/ha in 2015-16 to 756 kg/ha during 2016-17, which is a record production all the time in the country. The study further revealed that the recommended technology played a vital role in uplifting of cotton yield and proved as a boon for the cotton growers of Punjab.

Key words : Cotton, Recommended technology, fertilizers, yield

Cotton *i.e. Gossypium* species (L.), an important *kharif* crop popularly known as "White Gold" is an extensively studied crop and is the chief source of natural fibre worldwide (Riaz *et al.*, 2013). The crop is of great economic importance as it plays a vital role in agricultural and industrial development and enables to earn foreign exchange through export of its raw materials as well as finished products (Tuteja, 2014). Further *Bt* cotton adoption has increased aggregate employment, poverty reduction and rural development in India (Subramanian, 2009). Cotton productivity is influenced by many abiotic and biotic factors. Abiotic factors are mainly concerned with environment whereas biotic factors are related with insect-pest and diseases. During the whole growing period of the crop, attack of 1326 insect pests has been estimated, which results in heavy quantitative and qualitative losses to the crop (Manjunath, 2004). For the control of the insect pests, farmers depend on the use of chemical control (Arif *et al.*, 2007) leading to increase in cost of production, reducing the population of natural enemies of the pest, development of pesticide resistant races of the pest and environmental pollution. One of the most hopeful ways to improve cotton productivity and quality is to grow resistant varieties, which is very efficient, inexpensive, economical and environment friendly approach (Pedigo, 1989). Host plant resistance acts as an effective tool for controlling the insect pests by enabling the plant to avoid, tolerate or recover from insect pest attack (Pedigo, 1996). Over the years, many *Bt* and non *Bt* varieties and hybrids of cotton have been introduced. These commercialized transgenic *Bt* cotton cultivars though resistant to bollworm attack but are highly vulnerable to sucking insect pests (Kranthi *et al.*, 2005). Among sucking pests, whitefly (*Bemisia tabaci* Genn. Homoptera: Aleyrodidae) plays an important role by sucking a large amount of plant juices (Oleveira *et al.*, 2001). It also causes indirect loss by secreting honeydew, closing respiratory pores, enhancing growth of sooty mold fungus and reducing the process of photosynthesis. Most importantly, it acts as a vector of some dangerous plant viruses, which are acquired and transmitted between plants through this insect. Cotton is a highly sensitive crop and its productivity always remained volatile over the period of time. Huge loss of cotton crop had been observed in Punjab due to menace of whitefly during 2015 and Punjab government had to spent Rs.735 crore as compensation. So the present study was carried out to investigate the potential of recommended technology at farmers field of south western region of Punjab.

MATERIALS AND METHODS

Survey sample : The survey was conducted in 7 blocks of Bathinda, the central district of cotton belt of Punjab, for two consecutive years *i.e.* 2015-2016 and 2016-2017. In this study, a sample of 100 farmers was selected in 2015 whereas 80 farmers were formed in the year 2016. To evaluate the potential of recommended technology in cotton field *viz.,* date of sowing, growing of recommended or unrecommended *Bt* hybrids, application of recommended dose of fertilizers, spray of recommended or unrecommended pesticides, etc. The survey sample has been elaborated in the following Table:

DATA RECORDING

Area sown: During survey a window of four time of sowing was framed to observe the interest of farmers for this practice during both the years. First window was kept from 16-30 April, subsequently, 1-15 May, 16-31 May and 1-15 June was kept as 2nd ,3rd and 4th window. In this study, area sown under recommended hybrids and *desi* varieties along with un-recommended hybrids are also taken into consideration.

Fertilizer application: Four important nutrients viz., nitrogen, phosphorous, potash

Table 1. Sample detail of the study during 2015-2016 and 2016-2017

S.No	2015-2016			2016-2017		
	Block	Villages	Farmers	Block	Villages	Farmers
1	Bathinda	3	19	Bathinda	8	44
2	Bhucho	3	9	Bhucho	3	11
3	Rampura	6	8	Rampura	2	5
4	Maur	3	9	Maur	1	5
5	Talwandi Sabo	3	12	Talwandi Sabo	4	10
6	Goniana	2	7	Goniana	1	5
7	Sangat	8	16	Sangat	9	20
		28	**80**		**28**	**100**

(KNO3) and zinc were evaluated at different doses the details of which are given below:

Spray of micronutrients and insecticides: Three to four sprays of potassium nitrate @ 2 kg/ac are recommended for cotton crop by Punjab Agricultural University, Ludhiana. To investigate the spray schedule of potassium nitrate, 1 to 5 sprays were taken into consideration. Besides micronutrient sprays, the number of spray carried out throughout the season was also recorded. To record the number of insecticides spray, ten categories from 0 to more than 8 were used.

Crop damage: On visual observation, the crop damage was assessed. This data includes the complete damage caused due to weather as well as insect pests and diseases.

Table 2. Fertilizer application format by the sample cotton farmers

Nitrogen quantity (kg/ac)	Phosphorus quantity (kg/ac)	Potash quantity (kg/ac)	Zinc quantity (kg/ac)
0-15	Nil	Nil	Nil
15-30	5-10	1-10	1-5
30-45	10-15	10-20	**5-10***
45-60*	15-20	**20-30***	>10
60-75	**20-25***	30-40	Total
>75	25-30	41-50	
Total	Total	Total	

*range includes recommended dose of fertilizers.

Statistical analysis : The data recorded was subjected to analysis with CPCS1 software developed by Department of Mathematics and Statistics, Punjab Agricultural University, Ludhiana. The mean and per cent value was calculated for finding the significance of the recorded data. The equation for the average or mean is:

Average (X) = “x/N

Where (X) is the mean

“x is the sum of farmers in particular categories.

N is the number of farmers.

RESULTS AND DISCUSSION

Area sown: The results of the study revealed that most of the sampled farmers sown the cotton cultivars during recommended time period and only 82.5 ac were sown in the third window *i.e.* 16-31 May during 2015. Another major constraint observed during 2015 survey that maximum (82 per cent) area was under un-recommended hybrids / genotypes and only 18 per cent area was under recommended hybrids.

No farmer from the selected sample opted for the cultivation of *desi* cotton varieties / hybrids. During 2016, an extensive campaign was conducted that changed the whole scenario. Maximum area was sown during recommended time of sowing *i.e.* in first two windows (16 April to 15 May) and total area under recommended hybrids also increased from 18 to 70.66 per cent (Table 3) in 2016. So from this study it can be concluded that if the farmers follow recommended time of sowing and grow recommended *Bt* hybrids the productivity can be increased many folds.

Recommended dose of fertilizers: The data presented in Table 4 showed 9 per cent increase in the farmers number who had opted the recommended dose of nitrogen to cotton crop during 2016 (59%) over the previous year 2015 (50%). On the other side, the recommended dose of phosphorous was applied by 29 per cent of the farmers during 2016 as compared to 35 per cent in 2015. Similar observations were recorded in the used dose of potash. This shows that following the recommended package of practices by the selected farmers resulted in fetching good yield and less crop damage by the insect pests and diseases. One interesting fact came into light that selected farmer also opted the use of Zn to their soils and 1.25 per cent increase in the adoption of recommended level of zinc was noticed in this study.

Per cent reduction in insecticides spray: In this study, a schedule of 0 to more than 8 insecticides was followed. During 2015, it was recorded that most of the selected farmers applied six (10 %), seven (13%), eight (15%) and more than eight (29%) sprays of different un-recommended insecticides to cotton crop (Table

Table 3. Area in acres under recommended, *desi* and un-recommended cotton genotypes during different sowing periods.

Variety / hybrids	16-30 April		1-15 May		16-31 May		1-15 June		Per cent area	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Recommended hybrids / varieties from SAU	3	75.25	76	123.5	0	10.25	0	3	**18**	**70.66**
Desi varieties	0	16	0	5.5	0	0	0	0	**0**	**7.17**
Unrecommended hybrids/ genotypes	0	16	276.25	50.5	82.5	0	0	0	**82**	**22.17**

Table 4. Per cent of farmer's follow recommended dose of fertilizer in cotton

Nitrogen (kg/ac)	2015	2016	Phosphorous (kg/ac)	2015	2016	Potash (kg/ac)	2015	2016	Zn (kg/ac)	2015	2016
0-15	1.25	1	Nil	10	20	Nil	**70**	**85**	**Nil**	80	82
15-30	8.75	10	5-10	3.75	10	10-20	3.75	0	5-10	10	4
30-45	5	18	10-15	42.5	36	20-30	1.25	0	**10-15**	**8.75**	**10**
45-60	**50**	**59**	15-20	3.75	3	20-30	20	9	15-20	1.25	4
60-75	22.5	12	**20-25***	**35**	**29**	30-40	1.25	1			
>75	12.5	0	25-30	5	2	41-50	3.75	5			

5). After the campaign during 2016 the selected farmers gave only four sprays (41 %) and five sprays (33%) of recommended insecticides. So, this study concluded that if the farmers monitor his cotton crop regularly and sprayed the recommended insecticides at economic threshold level, the number of sprays can decrease significantly.

Spray of potassium nitrate (KNO_3): As per recommendation 3 to 4 sprays of potassium nitrate at flowering stage in cotton are must to enhance its yield. During 2015, 85 per cent farmers not used this recommendation whereas five per cent farmers gave one spray and 10 per cent opted only two sprays during flowering stage. After campaign during 2016, this percentage increased and 43 per cent farmers gave three sprays during flowering stage and 4 per cent applied four sprays of potassium nitrate (Table 6) Another interesting observation came into light that only 19 per cent farmers didn't use any spray of KNO_3 where as this percentage was as high as 85 during 2015.

Table 5. Per cent reduction in number of insecticide/ pesticides sprays during 2015 and 2016.

No. of spray	2015	2016
0	0	0
1	0	0
2	0	3
3	2	8
4	**5**	**41**
5	**6**	**33**
6	10	8
7	13	5
8	15	2
>8	29	0

Table 6. Per cent increase in number of sprays of potassium nitrate by the sample farmers

Number of spray	2015	2016
0	**85**	**19**
1	5	12
2	10	22
3	**0**	**43**
4	**0**	**4**
5	0	0

Table 7. Crop damage due to various factors viz, insect pests, diseases and climate.

Extent of damage (%)	2015	2016
Up to 25	4	92.5
25-50	13	6.25
50-75	8	1.25
>75	75	0

Crop damage: In this study on the basis of visible damage to cotton crop, four categories for extent of damage were kept. The damage to cotton crop recorded in this study was the gross damage caused due to insect pests attack, disease incidence and climatic conditions. During 2015, maximum (75 %) damage was recorded in which more than 75 per cent cotton crop was badly affected (Table 7). Only 4 per cent farmers had managed the insect pests and diseases during 2015. After the campaign in 2016, the farmers became more vigilant and aware regarding insect pests and diseases attack and they managed the same well in time. So, during 2016, 92.5 per cent farmers had their cotton crop in a very good condition and none of the farmers faced more than 75 per cent loss to his cotton crop.

CONCLUSIONS

From this study it can be concluded that the recommended technology for the cotton crop in the state has the potential to achieve a record level of production with the available resources. Though abiotic factors highly target the sensitivity of the crop but the biotic stress can be easily managed by the proven technology. The adoption of recommended technology improves the production as well as economics from the cotton crop (Gandhi *et al* 2006 and Qaim *et al.,* 2006. Thus, if the farmers remain vigilant from the insect pests attack, monitor their fields regularly, use recommended dose of fertilizers and insecticides then a significant level of production can be assured.

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REFERENCES

Arif , M.J., Abbas, G., Saeed S. 2007. Cotton in danger, Dawn*, The Internet Edition*, March 24th 2007. pp:4

Ashok,K.R, Uma, K, Prahadeeswaran,M, Jeyanti, H. 2012. Economic and Environmental Impact of *Bt* Cotton in India, *Ind, Jour. Agri. Eco.* **67**.

Gandhi, V.P, Namboodiri, N.V. 2009. The Adoption and Economics of *Bt* cotton in India, IIM Institutional Repsitory at hhttp://hdl.handle.net/11718/187

Kranthi, K.R., Kranthi, S., Ramesh, K., Nagrare, V.S., Barik, S. 2005. Advances in cotton IPM (Technical Bulletin). *Central Institute for Cotton Research* Post Bag No. Shankar Nagar, PO, Nagpur (MS), India.

Manjunath, T.M. 2004. *Bt* cotton in India. In: the technology wins as the controversy wanes. Available at *www.monsanto.co.uk/newsukshowlib.html?wid+8478*.

Oliveira, M.R.V, Henneberry, T.J., Anderson, P. 2001. History, current and collaborative research projects for *Bemisia tabaci. Crop Protection*, **20 :** 709-23.

Pedigo, I.P, 1989. *Entomology and Pest Management*. Prentice Hall of India (Pvt.) Ltd. New Delhi-110001, pp: 413.

Pedigo, L.P. 1996. Plant resistance to insects. *In*: *Entomology and Pest Management*. Prentice hall of India Private Limited, New Delhi, pp: 413-24.

Qaim, M., Subramanian, A., Naik Gopal, David, Z, 2006. Adoption of *Bt* Cotton and Impact variability: insights from India, *Applied Economic Prospective and Policy,* **28 :** 48-58

Riaz, M., Naveed, M., Farooq, J., Farooq, A., Mahmood, A, Rafiq, Ch. M, Nadeem M., Sadiq A. 2013. AMMI analysis for stability, adaptability and GE interaction studies in cotton (*Gossypium hirsutum* L.). *J. Anim. Plant Sci.*, **23 :** 865-71.

Subramanian, A., Qaim, M. 2009. The Impact of *Bt* Cotton on poor households in rural India, *The journal of development Studies (online), http://doi.org/10.1080/295.311*

Tuteja, O.P.2014. Studies on heterosis for yield and fibre quality traits in GMS hybrids of upland cotton (*Gossypium hirsutum* L.). *J.cotton Res. Dev.* **28 :** 1-6.

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Interaction effect of genotypes and time of sowing on crop productivity and leaf reddening in *Bt* cotton

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ABSTRACT: Delay in sowing in the Indian subcontinent often may result in leaf reddening in cotton due to early exposure to limiting factors depending on resilience of cultivars and their production potential. The field experiments, therefore, conducted at College of Agriculture Farm, Raichur during *kharif* 2014-15 and 2015-16 to study the interaction between cultivars and planting time revealed significantly higher leaf area (78.1 dm^2 $plant^{-1}$), LAI (1.45 at final picking), monopodial and sympodial count (2.86 and 31.9 $plant^{-1}$, respectively), nodes on main stem (35.3), GDD (2084 to 2093 ^{0}days), lower boll shedding (11.4 and 11.8 at 90 and 135 DAS, respectively), lower leaf anthocyanin (0.017, 0.043, 0.067 and 0.092 at 90, 105, 120 and 135 DAS, respectively), no reddening up to 105 DAS, maximum (62.8) boll count, highest productivity efficiency (0.48 kg/ha $dm^{-2}day^{-1}$), seed cotton yield (4173 kg/ha) and gross and net income (Rs.2,31,498 and Rs.1,87,119/-, respectively) with early sowing in June in more so with cv. Bindas compared to delayed sowings with same or different cultivars.

Key words: *Bt* cotton, leaf reddening, growth and yield attributes

Green Revolution and succeeding many other technology led revolutions in agriculture from later part of 20th century helped to enhance productivity to cope up with the burgeoning population and industrial demands in the country. Cotton (*Gossypium* spp.), 'the king of fibers' also popularly known as 'the white gold' enjoys a pre-eminent position amongst cash crops in the world and in India as well. It is the nature's most precious gift to the mankind, contributed by the genus *Gossypium* to clothe the people all over the world. Four out of the 50 recognized *Gossypium* species in the world viz., *G. arboreum*, *G. herbaceum*, *G. hirsutum* and *G. barbadense* are cultivated for natural fibre, and India is the only country in the world where all the four species and some of their hybrid derivatives are commercially grown. Today over hundreds of *Bt* cultivars are cultivated and the production has increased from a meagre 2.79 million bales (170 kg lint $bale^{-1}$) in 1947-48 to an all time record of 35.10 million bales during 2016-17 (CAB, 2016). There is great discontent in different quarters with the cultivars as some varieties are becoming vulnerable to boll worm (mostly due to spurious seed/F2 seed) and/or to many physiological disorders and, hence, yield below par (Venkateshwaralu, 2002) besides producing poor quality fibre as reported in Maharashtra and Gujarat (Hebbar and Mayee, 2011). In this context, the present investigation on interaction effect of genotypes and time of sowing on crop productivity and leaf reddening in cotton was planned and executed during the growing seasons of 2014 and 2015 under irrigation.

MATERIALS AND METHODS

Investigations were carried out at Agricultural College Farm, University of Agricultural Sciences, Raichur, Karnataka under deep black soil under irrigation. The experiment was laid out using Split plot design consisting of five main plot treatments (sowing date: D_1- Second fortnight of June, D_2- First fortnight of July, D_3- Second fortnight of July, D_4- First fortnight of August, and D_5- Second fortnight of August) and four sub plot treatments (cotton cultivars: G_1- Bindas, G_2- Bunny-Bt, G_3- ATM and G_4- Dr. Brent). The recommended dose of fertilizers 150: 75:75 kg/haN, P_2O_5 and K_2O were applied during both the years. The data were subjected to statistical analysis (Gomez and Gomez, 1984) and means were compared using Duncan's Multiple Range Test (DMRT) using SPSS 16.0 version at P = 0.05.

RESULT AND DISCUSSION

Across genotypes early sowing during II fortnight of June performed better and progressive delay in planting resulted in linear decrease in growth and yield attributes, while among cultivars averaged across planting time, cv. Bindas fared better followed by ATM (Table 1). Among the treatment combinations, all the cultivars sown during II fortnight of June fared similarly and cv. Bindas (D_1G_1) recorded numerically higher values (Table 2). Higher leaf area per plant was recorded with early planted crop sown during second fortnight of June (78.1 at last picking) (D_1G_1) while lower leaf area was recorded with last sowing (D_5G_{1-4}) irrespective of the cultivars sued. Consequently higher LAI indices (1.45 at last picking) occurred with II fortnight June with cv. Bindas (D_1G_1) whereas cv. Dr. Brent sown last (D_5G_4) had lower indices (0.57 at final picking) among all. In case of monopodials, sympodials and nodes on main stem initially the differences were more but with time the differences decreased and cv. Bindas sown during II fortnight of June (D_1G_1) recorded more number of monopodials, sympodials and nodes on main stem (2.86, 31.9 and 35.3 at last picking, respectively,) while last sown crop irrespective of cultivars recorded lower values among all.

Cotton cultivars sown during II fortnight of June in combination with cv. Bindas (D_1G_1) had numerically lower boll shedding (12.9 and 11.8 at 90 and 135 DAS, respectively on pooled basis) among all consequent upon significantly lower anthocyanin contents (0.092 at 135 DAS on pooled basis) in other words lower intensity of reddening particularly with cv. Bindas (D_1G_1) and other cultivars were at par. Sowing time and genotypes also revealed significant differences in growing degree days (GDD) wherein the maximum number of GDD accrued at each stage and overall (total GDD ranged from 2084 to 2093) with first sown crop during II fortnight of June irrespective of cultivars (D_1G_{1-4}), while last sown crop irrespective of cultivars (D_5G_{1-4}), recorded lower GDD count (Total GDD ranged from 1462 to 1472) among all.

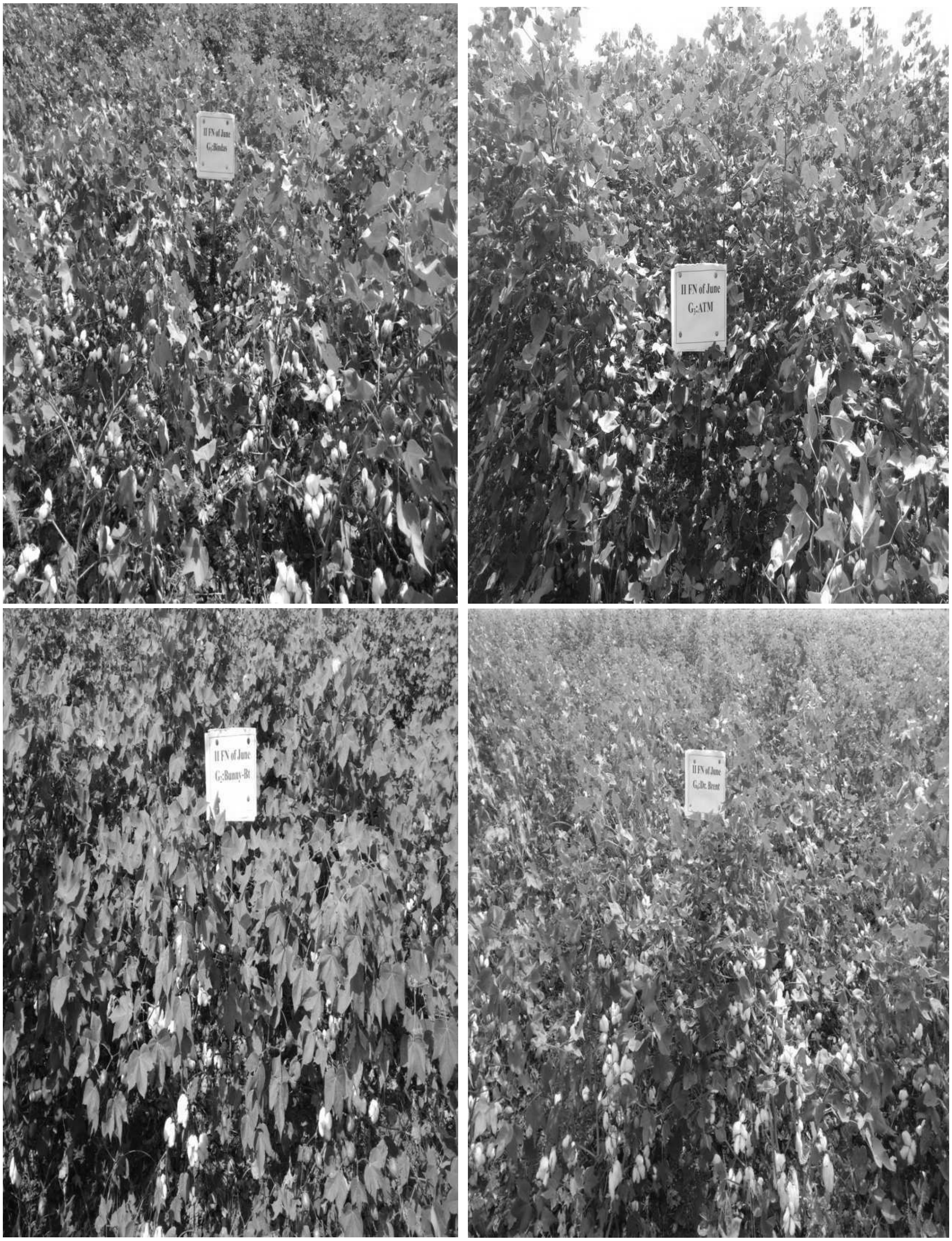

Plate 1. Photograph showing the difference between II fortnights of June sowing with different genotypes at 135 DAS

Plate 2. Photograph showing the difference between II fortnight of July sowing with different genotypes at 135 DAS

Plate 3. Photograph showing II fortnight of June and July sowing with genotype Bindas

Table 1. Main effects of time of planting and genotypes on leaf area per plant (dm^2 $plant^{-1}$), LAI, monopodials, nodes and sympodials per plant, boll shedding (%), leaf anthocyanin content (mg g^{-1} fresh weight), leaf reddening index, growing degree days (GDD), productivity efficiency (kg $ha^{-1}dm^{-2}day^{-1}$), seed cotton yield (kg ha^{-1}) and net returns (Rs.ha) (Pooled two years)

Treatments	Leaf area	LAI	Monop-odials	Symp-odials	Nodes	Boll shedding	Antho-cyanin	Leaf reddenin	GDD	Yield	Net returns
Plant time											
D_1	76.6^{a}	1.42^{a}	2.5^{a}	28.7^{a}	33.0^{a}	12.4^{e}	0.102^{d}	1.01^{e}	2089^{a}	3837^{a}	$1,69,389^{a}$
D_2	65.7^{b}	1.22^{b}	0.8^{b}	24.9^{b}	29.4^{b}	14.9^{d}	0.220^{c}	1.37^{d}	1847^{b}	3392^{b}	$1,47,195^{b}$
D_3	56.7^{c}	1.05^{c}	1.6^{c}	20.8^{c}	26.2^{c}	18.2^{c}	0.252^{b}	1.67^{c}	1744^{c}	2711^{c}	$1,10,476^{c}$
D_4	45.9^{d}	0.85^{d}	1.3^{d}	19.3^{c}	21.0^{d}	22.8^{b}	0.268^{a}	1.99^{b}	1558^{d}	2015^{d}	$72,404^{d}$
D_5	32.3^{e}	0.60^{e}	1.2^{e}	12.8^{d}	16.5^{e}	27.7^{a}	0.284^{a}	2.32^{a}	1466^{e}	982^{e}	$17,337^{e}$
S.Em±	**1.3**	**0.01**	**0.02**	**0.67**	**0.39**	**0.4**	**0.007**	**0.05**	**6.3**	**71**	**2,918**
Genotypes											
G_1	58.3^{a}	1.08^{a}	1.8^{a}	23.4^{a}	26.2^{a}	17.2^{d}	0.198^{b}	1.42^{c}	1750^{a}	2873^{a}	$1,18,544^{a}$
G_2	54.0^{b}	1.00^{b}	1.6^{b}	19.6^{c}	24.3^{c}	21.3^{a}	0.252^{a}	1.81^{a}	1736^{b}	2280^{d}	$87,355^{d}$
G_3	55.9^{b}	1.03^{b}	1.6^{b}	21.8^{b}	25.6^{b}	18.5^{c}	0.207^{b}	1.67^{b}	1738^{b}	2673^{c}	$1,08,011^{b}$
G_4	53.7^{b}	1.00^{b}	1.6^{b}	19.9^{c}	24.7^{cb}	19.9^{b}	0.244^{a}	1.79^{a}	1738^{b}	2517^{b}	$99,529^{c}$
S.Em±	**1.2**	**0.01**	**0.03**	**0.65**	**0.39**	**0.2**	**0.002**	**0.04**	**6.0**	**43**	**1,990**

*Means with same letters do not differ significantly under DMRT

Main plot treatments: Time of planting (D)

D_1: Second fortnight of June
D_2: First fortnight of July
D_3: Second fortnight of July
D_4: First fortnight of August
D_5: Second fortnight of August

Sub plot treatments: Genotypes (G)

G_1: Bindas
G_2: Bunny-*Bt*
G_3: ATM
G_4: Dr. Brent

Seed cotton yield ranged from 841 to 4173 kg/ha due different treatment combinations and revealed significant differences. Average of last sown crop was less than one-quarter of first sown crop. Overall, II fortnight of June with cv. Bindas (D_1G_1) resulted in maximum seed cotton yield (4173 kg/ha); cv. ATM sown simultaneously (D_1G_3) was next best (3784 kg/ha), while other cultivars (G_2 and G_4) were at par. Cv. Bindas sown during I fortnight of July (D_2G_1) was also on par with the latter cultivars. Whereas, significantly lower seed cotton yield (841, 856 and 946, respectively) was observed with the second fortnight of August with cvs. Dr Brent, Bunny *Bt* and ATM (D_5G_{2-4}). Cv. Bindas was superior to others even during last sowing (D_5G_1) (1286 kg/ha on pooled basis).

In all, among early sowing during II fortnight of June (D_1G_1) recorded significantly higher net return with cv. Bindas (D_1G_1) (Rs.1, 87,119/-); other cultivars sown simultaneously were at par and stood next in order. Thereafter, net returns decreased with considerably low values with the last sowing during II fortnight of August irrespective of cultivars used except cv. Bindas (the returns ranged from Rs. 9,837/- to Rs. 15,438) which fared well even during last sowing (Rs. 33,422/-). Overall, cv, Bindas sown during II fortnight June (D_1G_1) performed better followed by cv. ATM sown simultaneously and cv. Bindas sown during I fortnight of July was at par. The, delayed planting would lead to yield

Table 2. Interaction effect influenced by time of planting and genotypes on leaf area per plant (dm^{2} plant^{-1}), LAI, monopodials, nodes and sympodials per plant, boll shedding (%), leaf anthocyanin content (mg g^{-1} fresh weight), leaf reddening index, growing degree days (GDD), productivity efficiency (kg ha^{-1}dm^{-2}day^{-1}), seed cotton yield (kg ha^{-1}) and net returns (Rs.ha) (Pooled two years)

Treatments	Leaf area	LAI	Monop-odials	Symp-odials	Nodes	Boll shedding	Antho-cyanin	Leaf reddenin	GDD	Yield	Net returns
D x G											
D_1G_1	78.1^{a}	1.45^{a}	2.8^{a}	31.9^{a}	35.3^{a}	11.8^{m}	0.092^{j}	0.86^{j}	2084^{a}	4173^{a}	1,87,117^{a}
D_1G_2	75.6^{a}	1.40^{a}	2.4^{c}	25.7^{cd}	31.5^{bc}	13.0^{lm}	0.108^{j}	1.04^{ji}	2084^{a}	3692^{cb}	1,61,925^{b}
D_1G_3	77.4^{a}	1.43^{a}	2.2^{d}	29.5^{b}	33.5^{da}	12.4^{lm}	0.102^{j}	1.13^{hi}	2093^{a}	3784^{b}	1,66,606^{b}
D_1G_4	75.4^{a}	1.40^{a}	2.6^{b}	27.8^{cb}	32.8^{bc}	12.4^{lm}	0.107^{j}	1.00^{ji}	2093^{a}	3695^{cb}	1,61,907^{b}
D_2G_1	69.4^{b}	1.29^{b}	2.0^{e}	26.7^{cd}	30.0^{de}	13.7^{lk}	0.190^{i}	1.37^{hgf}	1850^{b}	3595^{c}	1,57,950^{b}
D_2G_2	64.0^{cd}	1.19^{cd}	1.8^{f}	24.5^{ed}	28.3^{fe}	16.1^{ji}	0.249^{efg}	1.30^{hj}	1843^{b}	3335^{d}	1,44,152^{c}
D_2G_3	66.1^{cb}	1.22^{cb}	1.8^{f}	25.2^{ed}	28.5^{e}	14.8^{jk}	0.205^{hi}	1.38^{hfg}	1848^{b}	3364^{d}	1,45,671^{c}
D_2G_4	63.4^{cb}	1.17^{cd}	1.6^{g}	24.8^{ed}	28.9^{e}	15.0^{jk}	0.235^{fg}	1.43^{fg}	1847^{b}	3276^{d}	1,41,007^{dc}
D_3G_1	60.1^{de}	1.11^{bc}	1.8^{f}	22.9^{ef}	28.0^{fe}	16.5^{i}	0.222^{hg}	1.42^{fg}	1748^{c}	3113^{e}	1,31,746^{d}
D_3G_2	55.0^{e}	1.02^{f}	1.6^{g}	18.8^{ghi}	26.8^{h}	20.7^{gf}	0.285^{dc}	1.95^{cd}	1739^{c}	1810^{h}	62,687^{g}
D_3G_3	56.6^{e}	1.05^{ef}	1.6^{g}	20.9^{gf}	26.9^{fg}	17.2^{i}	0.228^{hfg}	1.58^{ef}	1744^{c}	3205^{ed}	1,36,658^{dc}
D_3G_4	55.1^{e}	1.02^{f}	1.4^{h}	20.1^{gh}	25.3^{hg}	18.6^{h}	0.272^{ed}	1.74^{ed}	1744^{c}	2718^{f}	1,10,811^{e}
D_4G_1	48.8^{f}	0.90^{g}	1.4^{h}	21.6^{gf}	22.1^{i}	20.1^{g}	0.237^{fg}	1.49^{efg}	1594^{d}	2202^{g}	82,485^{f}
D_4G_2	44.6^{f}	0.83^{g}	1.2^{i}	17.9^{hi}	20.9^{i}	25.2^{d}	0.302^{b-e}	2.17^{cb}	1545^{d}	1728^{h}	57,363^{g}
D_4G_3	46.3^{f}	0.86^{g}	1.4^{h}	19.8^{ghi}	21.2^{i}	21.5^{f}	0.244^{efg}	2.07^{cb}	1545^{d}	2073^{g}	75,684^{f}
D_4G_4	44.0^{f}	0.81^{g}	1.2^{i}	17.4^{i}	19.8^{i}	24.5^{ed}	0.290^{bdc}	2.25^{b}	1545^{d}	2058^{g}	74,084^{f}
D_5G_1	35.0^{g}	0.65^{h}	1.2^{i}	13.8^{j}	16.9^{j}	23.7^{e}	0.249^{efg}	1.95^{cd}	1472^{e}	1286^{i}	33,422^{h}
D_5G_2	30.7^{g}	0.57^{h}	1.2^{i}	11.6^{k}	16.1^{j}	31.6^{a}	0.319^{a}	2.60^{a}	1467^{e}	856^{j}	10,650^{i}
D_5G_3	32.9^{g}	0.61^{h}	1.2^{i}	13.5^{kj}	16.7^{j}	26.6^{c}	0.254^{ef}	2.17^{cb}	1462^{e}	946^{j}	15,438^{i}
D_5G_4	30.8^{g}	0.57^{h}	1.2^{i}	10.9^{k}	16.0^{j}	29.0^{b}	0.316^{ba}	2.56^{a}	1462^{e}	841^{j}	9,837^{i}
S.Em±	**2.6**	**0.01**	**0.06**	**1.42**	**1.45**	**0.5**	**0.008**	**0.10**	**13.6**	**113**	**4,833**

*Means with same letters do not differ significantly under DMRT

Main plot treatments: Time of planting (D)

D_1: Second fortnight of June
D_2: First fortnight of July
D_3: Second fortnight of July
D_4: First fortnight of August
D_5: Second fortnight of August

Sub plot treatments: Genotypes (G)

G_1: Bindas
G_2: Bunny-*Bt*
G_3: ATM
G_4: Dr. Brent

reduction which could not compensated by any other production practices (Pyati, 2016). Lower lint yield with late sowing could be probably due to shortened fruiting period and delayed maturity compared to early sowing (Bangee *et al.*, 2004). In case of late sowing flowering initiates late in the season when temperature is low that probably affected radiation use efficiency which might have limited crop growth, while early sowing provided favourable temperature and water supply contributing towards boll development and boll filling that probably resulted in higher yield (Yates *et al.*, 2010).

REFERENCES

Bange, M., Brown, E. Caton, J. and Roche, R., 2004. Sowing time, variety and temperature effects on crop growth and development in the Hillston region. 11th Australian cotton conference proceedings. Gold cost convention Exhibition Centre, Broadbeach Queensland.

Cotton Advisory Board (CAB), 2016-17.

Elayan, E. D., Sohair, Abdalla, A. M. A. and Abdel Gawad, 2015. Effect of delaying planting date on yield, fiber and yarn quality properties in some cultivars and promising crosses of Egyptian cotton. *American-Eurasian J. Agric. Environ. Sci.*, **15 :** 754-63.

Gomez, K. A. and Gomez, A. A., 1984. *Statistical Procedure for Agricultural Research,* John Willey and Sons, New York (USA).p. 680.

Hebbar, K. B. and Mayee, C. D., 2011. Para wilt/ sudden wilt of cotton – a perspective on the cause and its management under field condition. *Curr. Sci.*, **100 :** 1654-62.

Pyati, P. S., 2016. Response of *Bt* cotton (*Gossypium hirsutum* L.) to method and time of planting, nutrient omission and SSNM in TBP command. *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci., Raichur, Karnataka.

Venkateshwaralu, K., 2002. The Hindu, December 30, 2002.

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Cotton for productivity and leaf reddening as influenced by nutrition management for targeted yield

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ABSTRACT : Performance of three yield targets (M_{1-3}:3, 4 and 5 t ha^{-1}) and four nutrient practices (S_1- Vermicompost @ 2.5 tha^{-1} in seed line, S_2- S_1+$MgSO_4$ 10 $kgha^{-1}$ in seed line, S_3- S_1+$MgSO_4$ 25 $kgha^{-1}$ in seed line, S_4- $MgSO_4$ 25 kg ha^{-1} in seed line + foliar nutrition of 1%, and control-RDF with recommended practice $MgSO_4$ +19:19:19 + 1% KNO_3 (thrice each)) was assessed using a Spilt plot design during *kharif* 2014-15 and 2015-16 at College of Agriculture Farm, Raichur on medium black soil. SSNM for yield targets of 5 t ha^{-1} and supplementary nutrition of $MgSO_4$ both to soil and to foliage and foliar application of major nutrients (19:19:19 and KNO_3) recorded significantly higher plant height (158 cm), count of monopodials (3.0) sympodials (27.5), nodes on main stem (37.8) at final picking, good opened bolls (61.1 to 61.9), total developed bolls (66.2 - 66.9), lower leaf anthocyanin (0.048 at 135 DAS, respectively on pooled basis), lower LRI indices (1.10 at 135 DAS, respectively), higher productivity efficiency (0.52 during first year), seed cotton yield (5349 kg ha^{-1}) and net returns (Rs.2,45,120/-) over other yield targets and recommended practices.

Key words: *Bt* cotton, SSNM, Yield target, Supplement nutrition

Cotton (*Gossypium* spp.), the prime vegetable fibre crop, enjoys a pre-eminent position amongst cash crops in the world and in India as well. Today, the Bt technology has revolutionized production and the country has witnessed quantum jump in production hailed as next best to Green Revolution. The crop is cultivated in 10.50 m ha with a production of 35.10 million bales of seed cotton (2016-2017), and the country is very close in production to China ranking first in the world. Average productivity of cotton in India, however, is low (568 kg lint ha^{-1}) when compared to the world average (725 kg lint ha^{-1}) (CAB, 2016) or the leading producers namely, Australia (1781 kg ha^{-1}), China (1719 kg ha^{-1}), Brazil (1522 kg ha^{-1}), the USA (974 kg ha^{-1}) and Pakistan (699 kg ha^{-1}). Of late, however, there is gradual decline in productivity in the region for varied reasons (Venkateshwaralu, 2002) besides poor quality fibre reported in Maharashtra and Gujarat (Hebbar and Mayee, 2011). The principle cause of reddening is nitrogen and magnesium deficiencies triggered by lower nutrient availability and /or crop uptake determined by inclement climate and/or poor soil (Sathyanarayanrao, *et al.*, 2014; Honnali and Chittapur, 2017) which are critical when set targets are particularly high, hence, the investigation.

MATERIALS AND METHODS

Investigations on cotton for higher productivity and leaf reddening as influenced by nutrition management for targeted yield was carried out at Agricultural College Farm, University of Agricultural Sciences, Raichur, Karnataka during growing seasons 2014-15 and 2015-16 under irrigation. The experiment consisted of three main plot treatments (Yield targets: M_1 - SSNM for targeted yield of 3 t ha^{-1}, M_2 - SSNM for targeted yield of 4 t ha^{-1}, and M_3 - SSNM for targeted yield of 5 t ha^{-1} seed cotton) and four sub plot treatments (nutrient supplementation to manage leaf reddening malady: S_1 - Vermicompost @ 2.5 t ha^{-1} in seed line, S_2 - S_1 + MgSO4 10 kg ha^{-1} in seed line, S_3 - S_1 + MgSO4 25 kg ha^{-1} in seed line and S_4 - MgSO4 25 kg ha^{-1} in seed line + foliar nutrition of 1% MgSO4 +19:19:19 + 1% KNO_3) alongwith recommended fertilizer practices (RDF) as outside control for comparison laid out using Split plot design with three replication under irrigation (Table 1). For the yield targets fertilizers were applied based on the soil test and crop requirement as per SSNM (IPNI). In control the recommended doses of fertilizers were applied (150 kg N, 75 kg P_2O_5 and 75 kg K ha^{-1}). Foliar spray was done during flowering, boll development and boll bursting stage.

The data were subjected to statistical analysis (Gomez and Gomez (1984). The level of significance used in ‘F’ and‘t’ test was P = 0.05. Means were compared using Duncan’s Multiple Range Test (DMRT) using SPSS 16.0 version.

RESULTS AND DISCUSSION

Pooled data revealed that SSNM for yield targets of 5 t ha^{-1} and supplementary nutrition of $MgSO_4$ both to soil and to foliage and foliar application of major nutrients (19:19:19 and KNO_3) (M_3S_4) resulted in taller plants at final picking (158 cm). Other treatment combinations influences except M_3S_2 and M_3S_3 were not comparable with $M_3S_{4,}$ however, they were intermediary and overlapping with each other and $M_1S_1$with 3 t ha^{-1} target and vermicompost alone to soil had lower plant height amongst all (132 cm). Monopodials per plant (3.0), sympodials per plant (27.5) and nodes on main stem (37.8) were also higher with SSNM for yield targets of 5 t ha^{-1} and supplementary nutrition of $MgSO_4$ both to soil and to foliage and foliar application of major nutrients (19:19:19 and KNO_3) (M_3S_4) while, 3 t ha^{-1} yield target in combination with application of vermicompost alone (M_1S_1) recorded lower number of monopodial, sympodials

Table 1. Soil test value, ratings, nutrient requirement to achieve the target and adjusted nutrients for the I Experiment during 2014-15 and 2015-16

YieldTargets	Soil test value ($N:P_2O_5:K_2O$ kg ha^{-1}) 2014-15	2015-16	Nutrient requirement ($N:P_2O_5:K_2O$ kg ha^{-1})*	Final applied ($N:P_2O_5:K_2O$ kg ha^{-1})
3 t ha^{-1}	168:72:184	198:74:208	192:84:114	240 : 63 :114
4 t ha^{-1}	168:72:184	198:74:208	256:112:152	316 :84 :152
5 t ha^{-1}	168:72:184	198:74:208	320:140:190	400 : 105 : 190

*Nutrient requirement to achieve the yield targets according to International Plant Nutrition Institute (*www.IPNI.com*).

Plate 1. Photograph showing the difference between 5 t ha^{-1} yield targets with leaf reddening management practices at 135 DAS

Plate 2. Photograph showing the difference between M_3S_4 and M_1S_1 at harvest

and nodes on main stem and it was on par with the yield target receiving extra application of 10 kg ha^{-1} $MgSO_4$ in seed line (M_1S_2).

Leaf anthocyanin content varied significantly due to SSNM based major nutrients application for varied yield targets and supplementary nutrition for leaf reddening control, overall LRM practices had little impact in association with SSNM levels and hence was comparable within the yield target particularly with advancement in age. Of the treatment combinations, SSNM for yield target of 5 t ha^{-1} and supplementary nutrition of $MgSO_4$ both to soil and foliage and foliar application of major nutrients (M_3S_4) resulted in lower anthocyanin contents (0.048 mg g^{-1} fresh weight at 135 DAS, respectively on pooled basis); with decreasing yield targets leaf anthocyanin contents increased significantly while, the maximum leaf anthocyanin (0.037, 0.057, 0.079 and 0.108 at 90, 105, 120 and at 135 DAS, respectively on pooled basis) among all was observed with lower target of 3 t ha^{-1} coupled with vermicompost application (M_1S_1). In case of leaf reddening indices 5 t ha^{-1} yield target coupled with application of $MgSO_4$ both to soil and to foliage and foliar application of major nutrients (M_3S_4) resulted in significantly lower indices throughout (1.10 at 135 DAS, respectively pooled basis), whereas the higher reddening indices were recorded with lowering of nutrition in commensuration with lower yield targets; 3 t ha^{-1} coupled with vermicompost alone (M_1S_1) had higher indices (2.02 at 135 DAS respectively on pooled basis) throughout among all.

Significantly highest good opened bolls per plant (61.9) and also total bolls per (66.9) were recorded with M_3S_4 over other treatment combinations. Interaction effects due to SSNM levels and LRM practices also differed significantly during both the years and on pooled basis. Similar to main effects of LRM practices, variations within the same yield target (M_{1-3}) were rather narrow and overlapping either with low (S_1) or high yielding (S_4) treatment while on pooled basis there occurred more clarity wherein the maximum seed cotton yield (5349 on pooled basis) was obtained with SSNM for 5 t ha^{-1} yield target coupled with soil application of $MgSO_4$ combined with foliar application of 1% each of $MgSO_4$, 19:19:19 and KNO_3 (thrice each) at flowering, boll development and boll bursting (M_3S_4); similar was the trend with other yield targets while significantly lower seed cotton yield (3401 on pooled basis) was observed with 3 t ha^{-1} yield target coupled with vermicompost application (M_1S_1); all other treatment combinations fared better except M_1S_2. Further, interactions due to SSNM and nutrient supplementation for leaf reddening influenced productivity efficiency significantly, during both the years and on pooled basis as well. Overall, SSNM for yield target of 5 t ha^{-1} and supplementary nutrition of $MgSO_4$ both to soil and to foliage and foliar application of major nutrients (19:19:19 and KNO_3) (M_3S_4) resulted in higher net returns (Rs.2,45,120/-) closely followed by the same yield target but with vermicompost and $MgSO_4$ 25 kg ha^{-1} as basal application (M_3S_3) (Rs.2,42,092/-) which was on par but still there occurred a difference of rupees 3,038-/ between them; yet former combination faring better. M_1S_1 with 3 t ha^{-1} target and vermicompost alone to soil had lower net returns amongst all (Rs.1,47,634/-). SSNM basically takes care of plant requirement for a set yield

Table 2. Plant height (cm), monopodials, sympodials, nodes on main stem, anthocyanin content in leaves (mg g^{-1} fresh weight), leaf reddening index, good opened bolls, total bolls, seed cotton yield (kg ha^{-1}) and net returns (Rs ha^{-1}) as influenced by SSNM based yield targets and nutrition for leaf reddening management

Treatments	Plant height	Monop-odials	Symp-odilas	Nodes	Antho-cyanin	Leaf reddening	Good bolls	Total bolls	Cotton yield	Net returns
Main plots										
M_1	136^{c}	2.16^{c}	23.1^{c}	26.2^{c}	0.102^{a}	1.56^{a}	43.3^{c}	54.5^{c}	3482^{c}	150858^{c}
M_2	149^{b}	2.37^{b}	25.9^{b}	28.1^{b}	0.076^{b}	1.22^{b}	52.9^{b}	60.6^{b}	4494^{b}	202404^{b}
M_3	156^{a}	2.83^{a}	29.1^{a}	33.8^{s}	0.056^{c}	1.10^{b}	61.2^{a}	66.4^{a}	5246^{a}	241224^{a}
S.Em±	0.9	0.03	0.4	0.4	0.001	0.05	0.40	0.70	76.9	657
Sub plots										
S_1	142^{c}	2.23^{c}	23.9^{c}	27.3^{c}	0.084^{a}	1.52^{a}	52.5^{a}	61.4^{a}	4318^{b}	194744^{cb}
S_2	146^{bc}	2.41^{b}	25.1^{c}	28.2^{c}	0.081^{a}	1.30^{b}	52.7^{a}	60.9^{b}	4384^{a}	197355^{b}
S_3	148^{ba}	2.60^{a}	26.7^{b}	29.9^{b}	0.077^{ba}	1.29^{b}	52.9^{a}	60.7^{a}	4434^{a}	198916^{b}
S_4	152^{a}	2.57^{a}	28.4^{a}	32.1^{a}	0.071^{a}	1.07^{c}	53.1^{a}	60.3^{ba}	4495^{a}	201632^{a}
S.Em±	0.9	0.06	0.5	0.6	0.001	0.05	0.30	0.30	40.6	1041
M x S										
M_1S_1	132^{i}	2.0^{g}	21.1^{g}	24.8^{f}	0.108^{a}	2.02^{a}	43.0^{c}	54.8^{d}	3401^{i}	147634^{g}
M_1S_2	135^{ih}	2.03^{g}	22.3^{fg}	25.5^{f}	0.105^{a}	1.58^{b}	43.7^{c}	55.3^{d}	3452^{hi}	149611^{g}
M_1S_3	138^{igh}	2.23^{fe}	23.7^{fe}	26.6^{fe}	0.101^{a}	1.54^{cb}	43.8^{c}	55.1^{d}	3509^{hg}	151645^{gf}
M_1S_4	141^{fgh}	2.37^{de}	25.2^{de}	28.0^{e}	0.093^{ba}	1.12^{ed}	44.3^{c}	54.4^{d}	3568^{g}	154540^{f}
M_2S_1	145^{feg}	2.17^{gf}	23.9^{fe}	26.5^{fe}	0.080^{bc}	1.35^{cbd}	53.3^{b}	62.6^{b}	4407^{f}	199222^{e}
M_2S_2	147^{fed}	2.40^{dce}	25.3^{de}	27.0^{fe}	0.077^{c}	1.27^{ced}	53.1^{b}	61.1^{cb}	4487^{e}	202145^{ed}
M_2S_3	149^{edc}	2.57^{c}	26.3^{dc}	28.6^{de}	0.076^{c}	1.29^{cebd}	53.2^{b}	60.1^{c}	4517^{ed}	203011^{ed}
M_2S_4	153^{bcd}	2.33^{fe}	28.2^{bc}	30.5^{dc}	0.072^{dc}	0.99^{e}	52.9^{b}	59.4^{c}	4568^{d}	205236^{d}
M_3S_1	151^{b-e}	2.53^{dc}	26.8^{dc}	30.8^{dc}	0.063^{dce}	1.21^{ed}	61.1^{a}	67.2^{a}	5148^{c}	237376^{c}
M_3S_2	155^{bac}	2.80^{b}	27.6^{dc}	32.1^{c}	0.060^{de}	1.06^{ed}	61.7^{a}	66.7^{a}	5212^{cb}	240308^{bc}
M_3S_3	158^{ab}	3.0^{a}	30.1^{ba}	34.4^{b}	0.055^{e}	1.05^{ed}	62.0^{a}	66.9^{a}	5275^{b}	242092^{ba}
M_3S_4	161^{a}	2.0^{g}	32.3	37.8^{a}	0.048^{e}	1.10^{ed}	61.9^{a}	66.4^{a}	5349^{a}	245120^{a}
S.Em±	1.7	0.1	0.9	1.0	0.001	0.09	0.60	0.70	86.9	1695
Control	126	1.90	18.5	21.0	0.110	2.10	43.2	55.0	2836	119577
S.Em±	3.3	0.1	1.0	0.5	0.003	0.06	1.6	0.70	162.6	1890
C.D. 0.05	9.4	0.30	2.7	1.4	0.009	0.19	4.7	2.1	474.5	5517

*Means with same letters do not differ significantly under DMRT

Note: DAS – Days after sowing, SSNM- Site Specific Nutrient Management

Main treatments: Yield Target (M)

M_1- SSNM for targeted yield of 3 tha^{-1}

M_2 - SSNM for targeted yield of 4 tha^{-1}

M_3- SSNM for targeted yield of 5 tha^{-1}

Control-RDF with recommended practice

Sub treatments: Leaf reddening management (S)

$\mathbf{S_1}$- Vermicompost @ 2.5 tha^{-1} in seed line

$\mathbf{S_2}$- S_1+$MgSO_4$ 10 $kgha^{-1}$ in seed line

$\mathbf{S_3}$- S_1+$MgSO_4$ 25 $kgha^{-1}$ in seed line

$\mathbf{S_4}$- $MgSO_4$ 25 kg ha^{-1} in seed line + foliar nutrition of 1% $MgSO_4$ +19:19:19 + 1% KNO_3 (thrice each)

target considering soil supply and fertilizer contribution. Besides, supply of 25 kg ha^{-1} $MgSO_4$ and foliar supplementation through 1 per cent spray of $MgSO_4$, 19:19:19 and KNO_3 thrice, LRM package, helped to alleviate leaf reddening and its consequent negative impact on yield. Foliar application of KNO_3 which is a source of both N and K, is highly beneficial in increasing the seed cotton yield (Brar *et al.*, 2008 Rajendran *et al.* (2010) and Hosmath (2011).

REFERENCES

Brar, M. S., Gill, M. S., Sekhan, K. S., Sidhu, B. S., Sharma, P. and Singh, A., 2009. Effect of soil and foliar application of nutrients on yield and nutrient concentration in *Bt* cotton. *J. Res., Punjab Agric. Univ.,* **45 :** 126-31.

Hebbar, K. B. and Mayee, C. D., 2011. Para wilt/ sudden wilt of cotton – a perspective on the cause and its management under field condition. *Curr. Sci.*, **100 :** 1654-62.

Honnali, S. N. and Chittapur, B. M., 2017. Higher productivity and sustainability in cotton (*Gossypium hirsutum*) through management of leaf reddening by foliar nutrition. *J. Cotton Res. Develop.,* **31** : 232-37.

Hosmath, J. A., 2011. Evaluation of *Bt* cotton genotypes and nutrient management to control leaf reddening. *Ph. D. Thesis*, Univ. Agric. Sci., Dharwad, Karnataka (India).

Rajendran, K., Mohamed, M. A. and Vaiyapuri, K., 2010. Influence on growth, yield attributes and yield of *Bt* cotton by soil and foliar application of nutrients. *Madras Agric. J.,* **98 :** 67-68.

Sathyanarayanarao, Gante, V. K., Chittapur, B. M., Ajaykumar, M. Y. and Honnali, S.N., 2014. Management of leaf reddening in *Bt*-Cotton. *Proceedings of ZREAC and ZREFC Meet*, held at UAS Raichur, 2-4 June 2014, pp. 55.

Venkateshwaralu, K., 2002. The Hindu, December 30, 2002.

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Integrated weed management in rainfed *Bt* cotton in vertisols

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ABSTRACT : A field experiment was conducted during *kharif* 2014-2015 and 2015-2016 in rainfed vertisols of Regional Agricultural Research Station, Lam to study the integrated weed management practices in *bt* cotton to reduce the cost of cultivation and get higher yield. The experiment was laid out with thirteen treatments in randomized block design with three replications. The post emergence treatments were imposed at 2-4 weed leaf stage. Cotton being a long duration crop one intercultural operation was done at 60 DAS in all the treatments except for weedy check. The results of the study revealed that weed density and weed dry matter recorded at 45 and 60 days after sowing were influenced by the different treatments. Lowest weed control efficiency was recorded in the T_1 Pendimethalin @ 1.0 kg a.i/ha as Pre E and maximum was recorded in T_{11} Glyphosate @ 1.0kg a.i/ha as directed spray at 45 DAS among the different chemical control treatments. The remaining pre E and post E weedicides alone or in combination were *on a par* with each other. The bolls/plant were significantly superior in weed free treatment and lowest in weedy check. Among the different chemical treatments lowest number of bolls/plant were recorded in (T_1 Pendimethalin @ 1.0 kg a.i/ha as Pre E). The maximum number of bolls were recorded in T_{12} weed free check and lowest were recorded in T_{13} weedy check and rest of the treatments were on par with each other. Highest seed cotton yield was recorded in weed free check (T_{12} weed free check) and lowest seed cotton yield was recorded in T_{13} weedy check. The weedicides tested did not show any negative impact on lint index, seed index and ginning outturn.

Bt cotton is mostly grown under rainfed situation in the state of Andhra Pradesh. *Bt* cotton is high yielding and responsive to higher levels of inputs and is grown under intensive cropping system, promote luxurious growth of weeds which grow more quickly than cotton and compete strongly for soil moisture, nutrients, light and space. The vagaries of monsoon and availability of labour during the critical periods (depending on the type of weeds the critical period of weed competition in cotton could be up to 40-60 days after sowing), weeding is not possible and weed competition leads to yield reduction and loss in the quality of produce. The yield reduction due to uncontrolled weed infestation was reported from 50-85 per cent (Joshi, 1997) and 70-97 per cent (Kumar *et al.,* 1989, Dadari and Kuchinda, 2004). Indiscriminate use of herbicides leads to rsistance development. Non availability of labour during critical periods, relatively longer duration of cotton crop and emphasis towards cleaner cotton fibre makes weed management as one of the critical production intervention and integration of efficient, economical and environmentally safe viable weed management is to be developed. Hence there is a need to study the performance of bt cotton with pre and post emergence herbicides.

MATERIALS AND METHODS

The field experiment was conducted at Regional Agricultural Research Station, Lam, Guntur during *kharif* 2014-2015 and 2015-2016 to study the integrated weed management practices in *bt* cotton to reduce the cost of cultivation and get higher yield in randomized block design with thirteen treatments and three replications. The soil of the experimental site is clay loam in texture, slightly alkaline with pH 7.8, low in available organic carbon (0.38 %), low in available nitrogen (188 kg/ha), medium in available phosphorus (28 kg/ha) and high in available potassium (856 kg/ha). The treatments The thirteen treatments tested were T_1 Pendimethalin @ 1.0 kg a.i/ha as Pre E ,T_2 Quizalofopethyl 50 g a.i/ha, T_3 T_1 *fb* PoE Quizalofop ethyl 50g a.i/ha ,T_4 Pyrithiobac Sodium @ 62.5g a.i/ha, T_5 T_1 *fb* PoE pyrithiobac Sodium @ 62.5g a.i/ha, T_6 Pyrithiobac Sodium @ 62.5g a.i/ha + Quizalofopethyl 50g a.i/ha as PoE, T_7 T_1 *fb* PoE Pyrithiobac Sodium @ 62.5g a.i/ha + Quizalofopethyl 50g a.i/ha, T_8 Propaquizafop 10 Ec @ 62.5 g ai/ha as PoE, T_9 T_1 *fb* PoE Propaquizafop 10 Ec @ 62.5 g ai/ha, T_{10} T_1 *fb* PoE Propaquizafop 10 Ec @ 62.5 g ai/ha + Pyrithiobac Sodium @ 62.5g a.i/ha,T_{11} Glyphosate @ 1.0kg a.i/ha as directed spray at 45 DAS, T_{12} Weed Free check, T_{13} Weedy check. The post emergence treatments were imposed at 2-4 weed leaf stage. Cotton being a long duration crop one intercultural operation was done at 60 DAS in all the treatments except for weedy check. Weed density and weed dry matter was recorded at 45 days after sowing and 60 days after sowing. Recommended cultural practices and plant protection were followed through out the crop growing season. The data were analysed statistically by adopting the standard procedures described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The dominant species of weed flora in the experimental site was *Cyprus rotundus ,Cynodon spp ,Commalina bengalensis, Corchorus acutangulus, Amaranthus viridis, Abutilon indicum Phyllanthus niruri, Celosia argentia, Trianthema spp Sida sp* etc. Among all the weed control treatments at 45 DAS and 60 DAS the lowest number of weeds as well as weed dry weight was recorded in the weed free check. Among the different pre and post emergence chemicals tested at 45 DAS the weed count and weed dry weight was lowest in T_{10}, T_7 and T_6 treatments. At 60 DAS lowest weed count and weed dry weight was recorded in T_{11}. All the herbicides and cultural operation treatments decreased significantly the weed density than weedy check. The weed control efficiency was maximum in the treatments where pre and post emergence herbicides were used.(Table1).Most of the growth and yield attributes were affected remarkably due to different weed management treatments (Table 2). The bolls/plant were significantly superior in weed free treatment and lowest in weedy check. Among the different chemical treatments lowest boll/plant were recorded in (T_1) and rest of the treatments were *on a par* with

Table 1. Weed density as influenced by the weed management practices in *Bt.*cotton

Treatments	Weed count at 45 DAS (m^{-2})	Weed dry weight at 45 DAS (g/m)	WCE	Weed count at 60 DAS (m^{-2})	Weed dry weight at 60 DAS (g/m)	WCE
T_1: Pendimethalin @ 1.0 kg a.i/ha as Pre E+ IC	65.65	203.7	5.64	74.5	265.3	6.8
T_2: Quizalofopethyl 50 g a.i/ha, + IC	32.6	138	37.65	50.05	206.45	41.1
T_3: Pendimethalin 1.0kg a.i/ha *fb* PoE Quizalofopethyl 50g a.i/+ IC	31.5	133.8	39.55	45.7	165.75	43.09
T_4: Pyrithiobac Sodium @ 62.5g a.i/ha PoE+ IC	28.85	108.2	49.35	33.65	122.4	56.85
T_5: Pendimethalin 1.0kg a.i/ha *fb* Pyrithiobac Sodium @ 62.5g a.i/ha PoE + IC	25.6	100.9	52.9	37	115.5	59.29
T_6 : Pyrithiobac Sodium @ 62.5g a.i/ha + Quizalofopethyl 50g a.i/ha 20-30 DAS + IC	23.5	95.5	55.35	29.95	117.15	58.38
T_7: Pendimithaline@ 1.0 kg a.i/ha as Pre E *fb* Pyrithiobac Sodium @ 62.5g a.i/ha + Quizalofopethyl 50g a.i/ha+ IC	21.3	91.7	56.9	28	97.4	65.82
T_8: Propaquizafop 10 Ec @ 62.5 g ai/ha + IC	32.35	146.2	33.45	49.25	164.55	44.13
T_9: Pendimithaline@ 1.0 kg a.i/ha as Pre E *fb* Propaquizafop 10 Ec @ 62.5 g ai/ha+ IC	30.15	134.9	59.05	45.55	160.5	45.10
T_{10}: Pendimithaline@ 1.0 kg a.i/ha as Pre E *fb* Propaquizafop 10 Ec @ 62.5 g ai/ha + Pyrithiobac Sodium @ 62.5g a.i/ha+ IC	25.25	95.4	55.05	26.85	94.9	66.72
T_{11} : Glyphosate @ 1.0 kg a.i/ha as directed spray at 45 DAS	62.4	200		5.7	2.5	99
T_{12} : Weed Free check	6.15	10		4.25	1.5	
T_{13} : Weedy check	69.35	216.3		82	285.55	
SEm+	2.3	10.8		2.1	12.5	
CD (p=0.05)	6.9	28.5		5.4	31.2	

Table 2. Growth, yield attributes, yield and quality of *Bt.*cotton influenced by the weed management practices

Treatments	Plant height (cm)	Mon/ plant	Sym/ plant	Bolls/ plant (g)	Boll weight	Seed index	Lint index	GOT (%) yield	Seed cotton (kg/ha)
T_1: Pendimethalin @ 1.0 kg a.i/ha as Pre E+ IC	171.0	2.1	20.4	38.2	4.8	10.5	5.9	36.1	2838
T_2: Quizalofopethyl 50 g a.i/ha, + IC	171.0	2.3	21.7	45.4	5.3	10.6	5.7	35.2	3497
T_3: Pendimethalin 1.0kg a.i/ha *fb* PoE Quizalofopethyl 50g a.i/+ IC	182.5	2.0	20.1	45.4	4.9	10.4	5.7	35.5	3521
T_4: Pyrithiobac Sodium @ 62.5g a.i/ha PoE+ IC	172.5	1.9	20.5	42.4	5.1	10.7	5.5	33.6	3431
T_5: Pendimethalin 1.0kg a.i/ha *fb* Pyrithiobac Sodium @ 62.5g a.i/ha PoE + IC	168.5	1.9	21.1	43.2	4.9	10.4	5.6	35.1	3399
T_6 : Pyrithiobac Sodium @ 62.5g a.i/ha + Quizalofopethyl 50g a.i/ha 20-30 DAS + IC	170.5	1.8	20.7	44.2	5.1	10.3	5.5	36.9	3392
T_7: Pendimithaline@ 1.0 kg a.i/ha as Pre E *fb* Pyrithiobac Sodium @ 62.5g a.i/ha + Quizalofopethyl 50g a.i/ha+ IC	175.0	2.0	22.0	44.4	5.0	10.6	5.4	33.4	3464
T_8: Propaquizafop 10 Ec @ 62.5 g ai/ha + IC	170.0	2.3	21.4	45.3	5.0	10.3	5.6	35.1	3454
T_9: Pendimithaline@ 1.0 kg a.i/ha as Pre E *fb* Propaquizafop 10 Ec @ 62.5 g ai/ha+ IC	171.0	2.0	22.2	45.9	4.9	10.6	5.8	35.5	3464
T_{10}: Pendimithaline@ 1.0 kg a.i/ha as Pre E *fb* Propaquizafop 10 Ec @ 62.5 g ai/ha + Pyrithiobac Sodium @ 62.5g a.i/ha+ IC	174.5	2.0	22.5	46.0	5.1	10.6	5.7	34.8	3547
T_{11}: Glyphosate @ 1.0 kg a.i/ha as directed spray at 45 DAS	171.5	1.6	20.3	43.8	5.4	10.9	6.2	37.0	3503
T_{12}: Weed Free check	175.0	1.8	19.8	43.8	5.5	10.5	5.6	34.8	4133
T_{13}: Weedy check	178.0	2.3	20.8	42.0	5.1	9.9	5.7	36.4	2072
SEm+	6.9	0.3	1.3	1.7	0.2	0.5	0.3	1.6	184
CD (p=0.05)	NS	NS	NS	4.7	NS	NS	NS	NS	559

each other. Highest seed cotton yield was recorded in weed free check (T_{12}) and lowest seed cotton yield was recorded in weedy check. The other treatments recorded significantly superior yield over T_1 and were *on par* with each other. No differences were recorded with boll weight, seed index lint index and ginning out turn. The higher yield under the integrated weed management practices may be attributed to better weed control and reduce crop weed competition in early growth stage, ultimately increase the cotton yield.

REFERENCES

Dadari, S.A. and Kuchinda, N.C. 2004. Evaluation of some pre – and post-emergence weed control measures on rain-fed cotton *(Gossypium hirsutum* L) in Nigerian savannah – *Crop Protection,* **23 :** 457-61.

Gomez, A.K. and Gomez, A.A. 1984. Statistical procedures for Agricultural Research. International Rice Research Institute Book. International Science Publication. John Wiley and Sons, Singapore.

Joshi, M. 1997. Hybrid Cotton in India, Kalyani Publishers, Ludhiana, p.191.

Kumar, V., Yoyock, J.Y. and Ogunlela, V.B. 1989. Cotton production in Nigeria. Retrospect and prospect. African Cotton Research Conference, Institute for Agricultural Research, ABU, Zaria, pp.461-478.

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Socio technological analysis, adoption determinants and impact of drip irrigation : Empirical results of extension research

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ABSTRACT : Drip irrigation is one of the proven technology for water conservation in India. Despite of several initiatives by central and state government research institute as well as by developmental departments, still the technology adoption rate is 15-20 per cent. Since cotton is a row crop, the applicability of drip irrigation is beyond doubt and already several research studies across India have confirmed the effectiveness of drip irrigation in cotton cultivation. Even though there are lot of studies carried out about the effectiveness of drip irrigation but fewer studies have been carried out to study the Socio-economic impact of drip irrigation among famers in cotton cultivation in India. This paper reviews the socio-economic impact of drip irrigation in different crop in particular emphasis with cotton crop. This paper analyses 1) the social dynamics exists among the drip and non-drip farmers, 2) What are all the socio economic impact of drip irrigation, 3) To enumerate the constraints involved in drip irrigation. As per the social dynamics is concern, most of the studies revealed that the drip farmers were in better position in different social indicators *viz.,* social value, social norms, social status and group dynamics etc. Socio economic impact is concern, drip irrigation brought out several direct and indirect socio-monitory benefits to the farmers. Farmers using the drip system not only for the first crop but also they adjust the cropping pattern and geometry in such a way that it can be utilized for the following crop as well and it ensure the zero tillage and reduce the field operation cost. The review on constraints shows that the initial investment is higher in spite of Government's subsidy. This is because of the difference in per acre calculation by government agency and actual field cost which calculated by the private companies. Further, the procedure involved to get the subsidy also is cumbersome and involve some bias. If the technology is properly understood by the different stakeholders, then it may have another 50 per cent scope for adoption by farmers in India. Hence, ground water availability and over all water availability in majority of the states are already in grey and red zone area.

Drip irrigation is one of the proven technologies for water conservation in all most all the crops. The present status of drip irrigation revealed that only 7.73 million hectares is covered by the technology in India, as compared to a potential of 69.5 million hectares as per the estimate in 2015 (Karpagam, *et al.,* 2017). Even though it has tremendous advantages, its development in India is slow as compared to other developing countries (Kumar and Singh, 2002). Despite of several initiatives by central and state government research institute as well as by developmental departments, still the technology adoption rate is around 10-15 per cent only. 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 per cent of the total irrigated area in India. (Karpagam, 2012). Cotton is one of the important candidate crop for drip irrigation. Sankaranarayanan, *et al.,* (2011) found that the factors such as longer duration, suitability of growing environment, early sowing, flexible drip system, higher economic return, higher fertilizer use efficiency, enhancement of seed cotton yield, suitability to light soil and enhancement of fiber quality were responsible for why cotton is the candidate crop for drip irrigation. There are several aspects which determined the adoption of drip irrigation; among them social dynamics is very important one. Even though there are lot of studies carried out about the effectiveness of drip irrigation but fewer studies have been carried out to study the Socio-economic impact of drip irrigation among famers in cotton cultivation in India. This paper reviews the socio economic impact of drip irrigation in different crop in particular emphasis with cotton crop. This paper analyses 1) the social dynamics exists among the drip and non-drip farmers, 2) What are all the socio economic impact of drip irrigation, 3) To enumerate the constraints involved in drip irrigation.

Social dynamics exists among the drip and non drip farmers : Social-dynamics may be conceptualized as the extent to which the existence of selected social indicators at given point of time. Different researchers studied the social dynamics of drip and non drip irrigated farmers in different dimensions in different crops. Arunachalam (2002) proposed the Empowerment Index, based on the sum of individual scores of the farm women. Based on the perceived empowerment level index score, farm women were classified into low, medium and high levels of perceived empowerment. Sakunthalai (2004) has developed women empowerment index with the following sub components: decision making behaviour, social participation, economic independence, market intelligence, political participation, extension participation, information seeking behaviour, practicing science based technologies,

Table 1. Social-dynamics index for drip and non-drip users

S.No	Indicator wise social dynamics index	Drip users	Non drip users
1	Social value index	0.76	0.67
2	Social status index	0.77	0.64
3	Social process index	0.81	0.59
4	Stratification index	0.82	0.85
5	Social solidarity index	0.80	0.58
6	Group dynamic index	0.82	0.63
7	Leadership behaviour index	0.64	0.56
8	Social problem index	0.64	0.69
	Mean index	**0.76**	**0.65**

leadership quality, awards won and maintenance of health status. Karpagam (2012) reported that moderate to high level of perceived social-dynamics existed among majority (65% and 22.5%) of total drip users. Among three categories of drip users, sugarcane and onion growers had higher moderate level of social dynamics (67.50% each) compared to leaf banana growers (60.00%). Sugarcane cultivation needs active cooperation and interaction with various stake holders such as sugar factories, input dealers and fellow farmers which lead to high existence of social dynamics among them. Onion is a short duration crop and highly sensitive to price fluctuation. This forced them to take timely decision at various stages, such as storage and marketing by consultations with fellow farmers, input dealers and commission agents. Due to increased interactions, social dynamics indicators played significant role among these two categories of respondents. Moreover, installation of drip itself needs frequent contact with various agencies, which may also contribute for higher social dynamics among three categories of drip users in general.

Further, social dynamic itself is influenced by several sub indicators such as social value, social status, social process, social stratification, social solidarity, group dynamics, leadership behavior and social problems. In cotton cultivation also, these indicators play a major role in determining the social dynamic of the drip and non drip farmers. Karpagam (2013) studied the different indicators of Social dynamics and the study revealed that existence of mean social dynamics index was found more (0.76) among sugarcane drip users compared with non drip users (0.65) (Table.1). The indicators such as social value, status, process, solidarity, group dynamics and leadership behaviour have been observed more among sugarcane drip users. In case of non drip users, social stratification (0.85) and social problem (0.69) were dominated. The research analysis concluded that sugarcane drip users were strong in developmental oriented indicators whereas non drip users established more stratification among them which has led to strong social problem too.

Socio economic impact of drip irrigation : Sivanappan (1991) identified that in drip irrigation the water saving was about 50 to 70 per cent and the yield increase by 10 to 100 per cent for various crops; the main advantage of drip irrigation being increased water use efficiency, higher yield, decreased tillage, high quality produce, higher fertilizer efficiency and less weed growth. Manimekalai and Thirunavukkarasu (1999) reported that water saving is 50 to 70 per cent and the yield increase is 60 to 70 per cent for different crops under drip irrigation. Karpagam (2010) clearly indicated that 24.98 per cent yield efficiency was obtained due to adoption of drip irrigation in sugarcane cultivation. The possible reason might be that drip irrigation in sugarcane favors most yield attributes *viz*., more number of millable canes, taller canes, increased cane weight etc. which obviously leads for more yield. These findings are in compliance with the findings of Patil (1990), Sivanappan (1991) and Pawar *et al.,* (2000) who reported that drip irrigation resulted in increased yield in grape, sugarcane and banana respectively. As per the income is concerned 23.58 per cent efficiency could be obtained under drip irrigation condition. The finding is in consistency with Patil (1990) who reported increased income under drip irrigated condition. Higher efficiency percentage (40.64) was observed in case of water used. Hence drip irrigation mainly saves the water and it obviously lead for higher water use efficiency. The similar findings are reported by Kannaiyan (2001), Sivanappan (2002), Sivanappan (2003) and Krishnaraj (2004). In case of labour use efficiency, 10.49 per cent of efficiency was observed due to adoption of drip irrigation. It is because of that majority respondents reported that due to adoption of drip irrigation, weed population (Sivanappan 2003) and pest attack was reduced marginally which also resulted in reduction of labour usage. Further, they reported that minimal tillage practices were sufficient due to adoption of drip irrigation since soil become more pulverized (Sivanappan 1991). Next to water use efficiency, input use efficiency was observed more (34.88) under drip irrigated condition. Due to efficient input management plan, the input use efficiency was observed. Further more drip irrigation may reduce the need of inputs such as fertilizer, pesticide and weedicide. The findings were in accordance with Sivanappan (1991) and Sivanappan (2003). Apart from that drip irrigation reduced the energy consumption as well. Energy use efficiency was observed as 11.74 per cent under drip irrigated condition. Similar findings were observed by Nagarajan (2001). Namara (2007) reported that use of micro irrigation in the cultivation of banana, cotton and groundnut is both technically and economically viable.

Constraints in drip irrigation: Karpagam (2012) reported that high investment cost despite subsidy was the main constraint faced by the drip users (mean score-73.75). For one acre drip installation, farmers could get around Rs.11,500 as subsidy and rest of the amount (Rs. 20,000-25,000) is to be arranged by farmers through any soft loan or from their own savings. This could be the reason for high investment cost as the foremost constraint. Similar constraint was reported by Nandal *et al.* (1991), Rangarajan (1992) and Krishnaraj (2004) in their studies. Inadequate subsidy is the next major constraint reported by many researchers in the drip irrigation. It was learnt from various sources that subsidy provided by Government is not exactly in the total cost incurred by the farmers. For subsidy calculation the cost of drip installation during the year 1993 was taken as the base year in Government of India guidelines. It was reported by many researchers viz., Kandaswamy (1990), Puranik *et al.* (1992) and Nikhade (1993). Clogging of emitters is the next leading technical constraint identified by many researchers. Even though, acid treatment was recommended for clogging of emitters. The possible reason might be that majority respondents installed low cost filters to reduce higher initial investment cost whereas, high cost and advanced filtering system was installed by very few. Furthermore, regular maintenance of the system is found to be poor by the farmers. Similar constraint was observed by Kandaswamy (1990), Prichard (1991), Mahendran (1993) and Krishnaraj (2004).

REFERENCES

Kandasamy, P. 1990. Drip Irrigation Need for More Scientific Research for Large Scale Adoption. *Kisson World*, **17 :** 31-32.

Kannaiyan, S. 2001. Micro irrigation and fertigation for sustainable crop production. *Kissan World*, **28 :** 23-27.

Karpagam, C. 2012. Identifying the factors of Social-dynamics among drip users – a socio-technological enquiry. *Ind. Res. Jour. Ext. Edu.* **12 :** 112-15.

Karpagam, C. and Sankaranarayanan, K. 2017. Status of drip irrigation for cotton in Punjab and Haryana- A field level enquiry. *Cotton Innovate,* CICR Online News letter. (Under Press).

Karpagam, C., Ravichandran, V., Murali, P., Putira Prathap., D and Rajula Shanthy. T. 2013. Influence of profile characteristics on Social-Dynamics among sugarcane drip users and non drip users – A farm level enquiry. *Sugar Tech* (Oct-Dec 2013). **15 :** 349-53.

Karpagam, C., Ravikumar Theodore, Ravichandran, V and P.Murali. 2010. Impact of drip irrigation in sugarcane – A field level enquiry. *Cooperative Sugar.* **42 :** 51-53.

Krishnaraj, A. 2004. Awareness - knowledge, extent of adoption and consequential efects of water management / conservation practices. *Unpub. M.Sc. (Ag.) Thesis*, TNAU, Coimbatore.

Kumar, A and A.K. Singh 2002. Improving nutrient and water use efficiency through fertigation, *Jour. Water Manag.* **10 :** 42-48.

Mahendran, K. (1993) An economic appraisal of drip irrigation system in coimbatore district of Tamil Nadu. Unpub. *M.Sc. (Ag.) Thesis.* TNAU, Coimbatore.

Nagarajan, S.S. 2001. Tissue culture and drip in banana. *Kissan World*. 23-24.

Namara, R.R., Nager, R.k and Upadhyay, B. 2007. Economic, adoption determinants and impacts of micro irrigation technologies: empirical results from India. *Irri. Sci.* 25 : 283-97.

Nandal, U.K., Banerjee, M. K. and Arora, S.K. 1991. Drip irrigation: new approach in vegetable farming. *National Bank News Review*. 38-39.

Nikhade, P. 1993. Drip irrigation some constraints. *Rural India,* **56 :** 6-8.

Patil, S.M. 1990. Drip irrigation very successful in grapes too, *Kisan World*, **38 :** 28-29.

Pawar, D.D., Dhonde, M.B., Bhoi P.G. and Shmde, S.H. 2000. Ecological fertility of drip irrigation for sugarcane. *Kissan World*, **27 :** 31.

Prichard, T.L. 1991. How to keep drip lines and emitters clay free. *Agri Business World Wide,* **11 :** 8-12.

Puranik, R.P., Khonde S.R. and Ganorkar, P.L. 1992. Constraints in adoption of drip irrigation system. *Indian Journal of Extension Education*, **28 :** 1-2.

Rangarajan, C. 1992. Better water management. *Kissan World,* **19 :** 30-32.

Sankanarayanan, K., Nalayini P., Sabesh M., Usha Rani S., Nachane R.P and Gopalakrishnan N. 2011. Low cost drip- cost effective and precision irrigation tool in Bt cotton. CICR Publication. Technical Bulletin No. 1/2011.

Sivanappan, R.K. 1991. Technology, economic aspects of drip and sprinkler irrigation for various crops and soils. *Kissan World*. May 1991. 23-26.

Sivanappan, R.K. 2002. Micro irrigation means future. *Kissan World*. Apr. **02 :** 38-41.

Sivanappan, R.K. 2003. Increasing the productivity of cotton through drip irrigation. *Kissan World.* Nov. 2003. pp. 40-41.

CROP PROTECTION AND BIOSAFETY

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Development of Alternaria leaf spot in cotton as influenced by weather parameters

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ABSTRACT: The effect of weather factors on the development of Alternaria leaf spot in *Bt* Cotton hybrid Jadoo BG II was investigated during *kharif* 2013-2016. Multiple regression analysis of pooled data, using Excel programme revealed significant negative correlation of minimum temperature and morning relative humidity; positive correlation of maximum temperature and evening relative humidity with per cent disease index (PDI). In prediction model (1) for every one per cent increase in maximum temperature and evening relative humidity, there was corresponding increase of 3.59 and 0.74, respectively, in PDI of Alternaria leaf spot. Similarly, for one percent decrease of minimum temperature and morning relative humidity, PDI decreased by 3.70 and 2.51, respectively. Further evaporation showed positive influence while rainy days and sun shine hours exhibited negative effect on the progress of Alternaria leaf spot. In prediction model (2) for every one per cent increase in evaporation PDI increased by 3.95, while for one percent decrease of rainy days and sun shine hours PDI decreased by 4.05 and 1.88, respectively. Thus, temperature, rainy days, relative humidity, evaporation and sun shine hours are the critical parameters contributing to the development of Alternaria leaf spot in cotton.

Key words **:** Alternaria leaf spot, cotton, weather parameters

Cotton is an important commercial crop in India with a production of 351 lakh bales of 170 kg lint in 2016-2017 from an area of 105 lakh ha with a productivity of 568 kg/ha, which is far behind the leading countries. Andhra Pradesh stood 6th in area (4.49 lakh ha) but 8th in production (13.10 lakh bales) and 2nd in productivity (719 kg/ha) during 2016-2017 (Anonymous, 2017). Cotton crop is affected by fungal, bacterial and viral diseases. In India, foliar diseases have been estimated to cause yield losses up to 20 to 30 per cent. Alternaria leaf spot/blight is an economically important disease in Andhra Pradesh causing losses to the tune of 38.23% in cotton variety LRA 5166 (Bhattiprolu and Prasada Rao, 2009) and 33.43 per cent in variety Jayadhar (Chattannavar *et al.*, 2010). Understanding the influence of weather factors on host stage and disease development is prerequisite to strategically manage the disease. Hence an experiment was conducted to assess the progress of Alternaria leaf spot in relation to environmental factors along with phenological stage of the crop.

MATERIALS AND METHODS

The effect of weather factors on the development of Alternaria leaf spot in susceptible *Bt* Cotton hybrid Jadoo BG II was investigated during *kharif* 2013-2016 at Regional Agricultural Research Station, Lam, Guntur. The crop was raised in a bulk plot of 150 $m^{2.}$ Alternaria leaf spot was scored on 0 to 4scale (Sheo Raj, 1988) at weekly intervals on randomly labeled plants up to the end of the January and expressed as Percent Disease Index (PDI) using Wheeler's formula: PDI = Sum of numerical ratings X 100/ Total Number of leaves scored x maximum disease grade. Meteorological data (maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, rain fall, rainy days, sunshine hours, evaporation and wind speed) was recorded daily from sowing onwards and weekly means were calculated while rainfall during the standard meteorological week was totaled. Correlation between progress of Alternaria leaf spot severity and weather factors was calculated and multiple regression equations for the pooled data were derived using Excel programme.

RESULTS AND DISCUSSION

Pooled data revealed that Alternaria leaf spot appeared during 36^{th} meteorological week at vegetative stage and reached its peak during the 44^{th} meteorological week at boll development stage (Fig. 1). Significant negative correlation of PDI was observed with rain fall and rainy days. Multiple regression analysis using Excel programme showed significant negative correlation of minimum temperature and morning relative humidity; positive correlation of maximum temperature and evening relative humidity with PDI. In prediction model (1) for every one per cent increase in maximum temperature and evening relative humidity, there was corresponding increase of 3.59 and 0.74, respectively, in PDI of Alternaria leaf spot. Similarly for one percent decrease of minimum temperature and morning relative humidity, PDI decreased by 3.70 and 2.51, respectively (Table 1). Further, evaporation showed positive influence while rainy days and sun shine hours exhibited negative effect on the progress of Alternaria leaf spot. In prediction model (2) for every one per cent increase in evaporation, PDI increased by 3.95 while for one percent decrease of rainy days and sun shine hours PDI decreased by 4.05 and 1.88, respectively. Rainy days and rainfall individually showed partial influence on the disease progress. Thus, maximum, minimum temperatures, morning and evening relative humidity, rainy days, sun shine hours and evaporation are the critical parameters contributing to the development of Alternaria leaf spot in cotton.

These results are in conformity with earlier reports. Hosagoudar (2012) reported that maximum, minimum temperatures, RH (morning and evening) and rainy days significantly influenced the intensity of Alternaria leaf spot in cotton. Temperature regime of 20 - 30°C with prolonged high humidity (>80%) and frequent rains favoured *A. macrospora* infection and disease development in cotton (Johnson *et al.*, 2013). Minimum

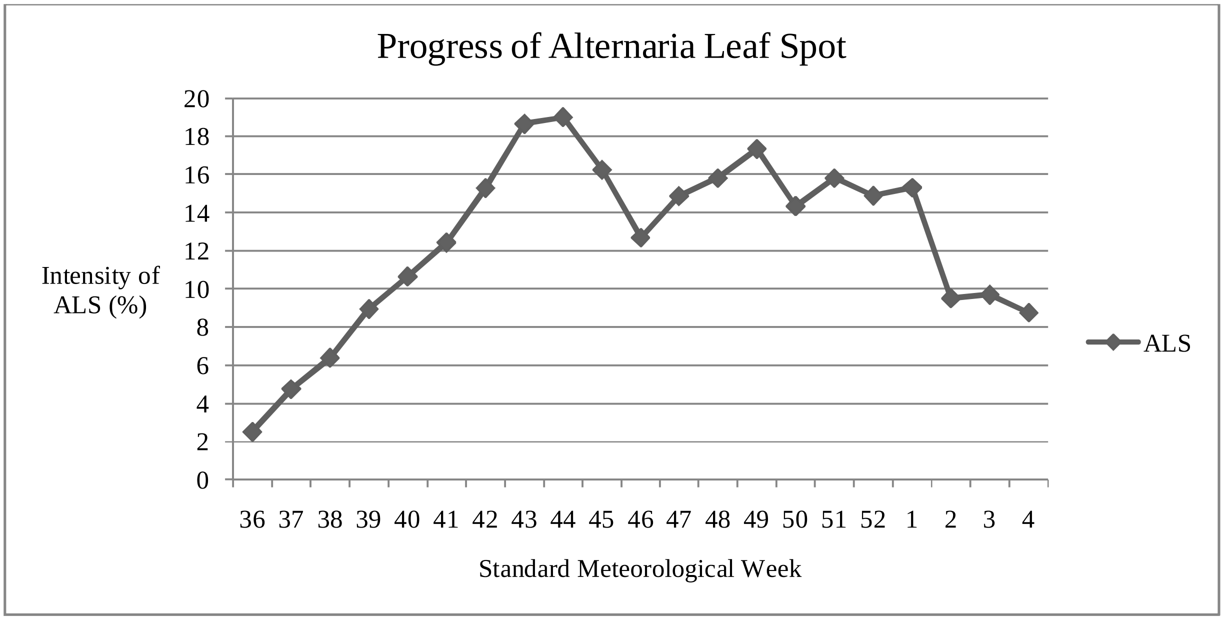

Fig 1. Progress of Alternaria leaf spot (Pooled data of 2013-2016)

Table 1. Regression Equations developed for Alternaria leaf spot at Guntur (Pooled data of 2013-2016)

S. No.	Multiple Regression Equation	Coefficient of determination (R^2)
1	Y = 151.11 + 3.59 max T** - 3.709 min T** - 2.51 RH I* + 0.74 RH II*	0.7475
2	Y = 10.36 - 4.05 RD** - 1.88 S* + 3.95 E**	0.7173
3	Y = 3.61 - 2.45 RD** + 2.83 E**	0.6185
4	Y = 10.55 - 3.09 W* + 3.38 E**	0.3952
5	Y = 15.32 - 2.05 RD**	0.3206
6	Y = 15.09 - 0.09 RF*	0.2230

**Significant at 1%; * Significant at 5%

Y = PDI of Alternaria leaf spot; Max T = Maximum Temperature; Min T = Minimum Temperature; RH I = Morning Humidity; RH II = Evening Relative Humidity; RD = Rainy Days; S = Sun Shine Hours; E = Evaporation; W = Wind Speed and RF = Rainfall

temperature and afternoon relative humidity were found critical to forecast the Alternaria blight disease in cotton genotypes (Venkatesh *et al.*, 2013). Singh and Ratnoo (2013) observed that 28.8-31°C and 86-93 per cent RH were conducive for Alternaria leaf spot (*A. gossypina* and recorded negative correlation of PDI with minimum temperature and positive correlation with maximum RH. Significant negative correlation of PDI with maximum, minimum temperatures and positive correlation with morning RH and sun shine hours was recorded in cotton variety, Narasimha (Venkatesh *et al.*, 2016).

Based on the present study cotton farmers are advised to take up preventive and/ or protective measures with recommended fungicides like propiconazole 0.1 per cent under the favourable temperature and humidity for the progress of Alternaria leaf spot.

REFERENCES

Hosagoudar G. N. 2012. Epidemiology and management of leaf spot of cotton caused by *Alternaria* spp. *Ph. D. Thesis*, University of Agricultural Sciences, Dharwad.

Johnson, I., Ramjegathesh, R., Karthikeyan, M. and Chidambaram, P. 2013. Epidemiology of grey mildew and *Alternaria* blight of cotton. *Arch. Phytopath. Plant Prot.* **46 :** 2216-23

Singh Sumer and Ratnoo R. S. 2013. Effect of different weather parameters on progress of alternaria leaf spot (*Alternaria gossypina*) of cotton. *Jour. Plant Dise. Sci.* **8 :** 221-24.

Venkatesh, H., Rajput, R. B., Chattannavar, S. N. and Hiremath, J. R. 2013. Weather based forecasting of Alternaria blight disease on cotton at Dharwad. *Jour.Agromet.* **15** (Special Issue-II): 20-24.

Venkatesh, I., Bhattiprolu, S. L., Krishna Prasadji, J. and Ramachandra Rao, G. 2016. Influence of weather parameters on the development of Alternaria leaf spot in cotton crop. *J. Cotton Res. Dev.* **30** : 127-30.

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Plant parasitic nematodes associated with cotton in Haryana and their population dynamics in cotton-wheat cropping system

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ABSTRACT : Cotton is an important crop of Haryana cultivated in about five lakh (0.5 million) ha. Population dynamics of major plant parasitic nematodes was studied in cotton-wheat cropping system. Cereal cyst nematode (*Heterodera avenae*), stunt nematode (*Tylenchorhynchus* species), lesion nematode (*Pratylenchus* species), spiral nematode (*Helicotylenchus* sp), lance nematode (*Hoplolaimus indicus*), needle nematode (*Longidorus pisi*), root knot nematode (*Meloidogyne incognita*) and reniform nematode (*Rotylenchulus reniformis*) were the major nematodes recorded in this cropping system. *Aphelenchus avenae*, *Ditylenchus* sp., *Hemicriconemoides* sp and predatory nematodes *Seinura* sp. and *Fictor composticola* were the other nematodes present in the samples. In general, populations of *M. incognita*, and *R. reniformis Helicotylenchus* sp., *Hoplolaimus* sp., were higher on cotton than wheat but *Tylenchorhynchus* species, and *Pratylenchus* species (*P. thornei, P.mulchandi* & *P.zeae*), were more on wheat crop. Association of high population of nematodes like *Pratylenchus* species, *Hoplolaimus indicus, Helicotylenchus* sp and *Tylenchorhynchus* species with cotton necessitates further studies.

Key words : cotton, cotton-wheat cropping system, plant parasitic nematodes, population dynamics.

Cotton is an important industrial crop grown for fibre and other byproducts (Banu, 2010). In Haryana, it is cultivated in Southern part of the state having light textured soil. During 2016-2017, it covered 4.98 lakh ha area with a production of 20.0 lakh bales, in the state (Anonymous, 2016). Its production is challenged by several biotic factors like insects, diseases and nematodes. With the introduction of *Bt* cotton in the state, whitefly, mealy bug, and root knot nematode problem have increased. Nematodes belonging to 16 genera have been found associated with cotton in India (Banu, 2010). The disease incidence and severity have been reported to increase in presence of nematode (Starr *et al.*, 1989; Patel *et al.* 2004).

Root- knot and reniform nematodes are considered economically important to cotton crop, throughout world. In India, these two nematode spp cause 7.63 per cent loss in cotton (Jain *et al.*, 2007). Das and Gaur (2009) reported *Rotylenchulus reniformis* in 30 per cent samples of cotton in Haryana. Root knot nematode is a prevalent pest of cotton in India including Haryana (Walia *et al.*, 2016).

In Haryana, Cereal cyst nematode (*Heterodera avenae*), is a serious pest of wheat, more so in late sown crop which is taken after cotton (Kanwar *et al.*, 2011). To avoid late sowing of wheat in the cotton wheat system, relay cropping of wheat is also practiced by farmers (Kanwar, 2017). Annual yield loss caused by plant parasitic nematodes, on world basis, was estimated to be 10.7 per cent (Sasser and Freckman, 1987). In India, avoidable yield loss due to nematodes, using nematicides was estimated to be 8-10 % under field conditions (Narkhedar *et al.*, 2005). Present paper reports the nematode species associated with cotton and their population dynamics in cotton –wheat system, in Haryana.

MATERIALS AND METHODS

Population behavior of plant parasitic nematodes in cotton wheat cropping system was studied in Haryana during 2004-2005 to 2014-2015. Soil samples were taken from cotton in August-Sept, and from following wheat crop,in March-April. In 2004-2005 and 2005-2006, samples were taken thrice *i.e.* Sept, Dec. (cotton) and March (wheat); and in 2009 samples were collected from wheat in February. Three sub-samples of 200 cc soil from each composite sample were processed for extraction of nematodes by Schindler's (1961) method and population density was determined. For nematode identification, samples were processed to glycerol by slow method. Counting was done by dilution method under stereomicroscope. Data was presented for selected years as the trend was similar for nematode population behaviour.

RESULTS AND DISCUSSION

In 2004-2005, populations of *Helicotylenchus*, *Hoplolaimus, Longidorus*, and Criconematids were more on cotton than wheat but Stunt nematode increased on wheat (Fig.1). In 2007-2008, in field I, which was under wheat in the preceding year, cyst population increased three times i.e. from 12 to 36 /200 cc soil. Population of *Tylenchorynchus* sp. first increased

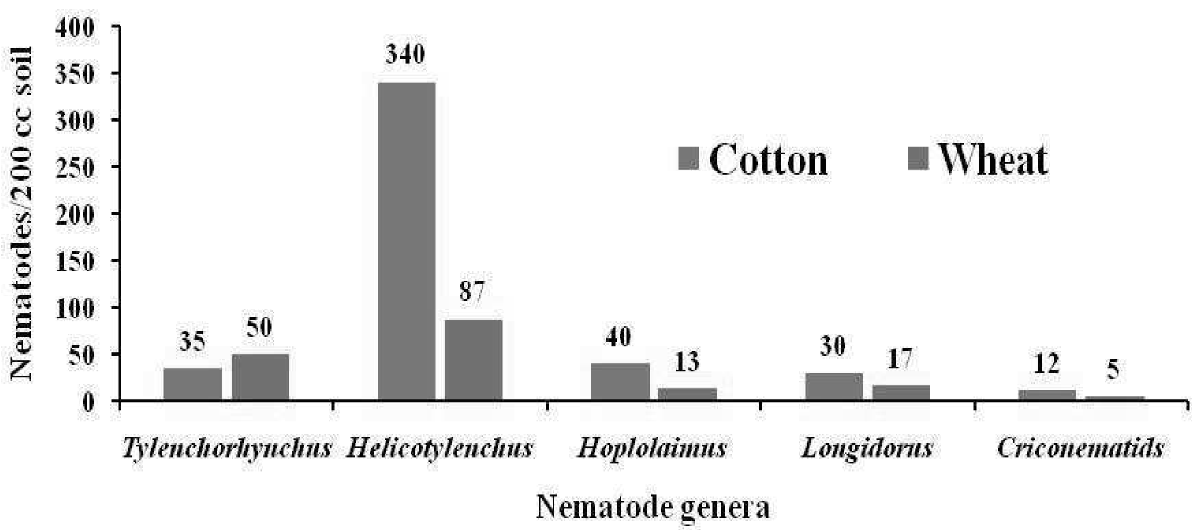

Fig .1. Populations of plant parasitic nematodes in cotton–wheat system (2004-05)

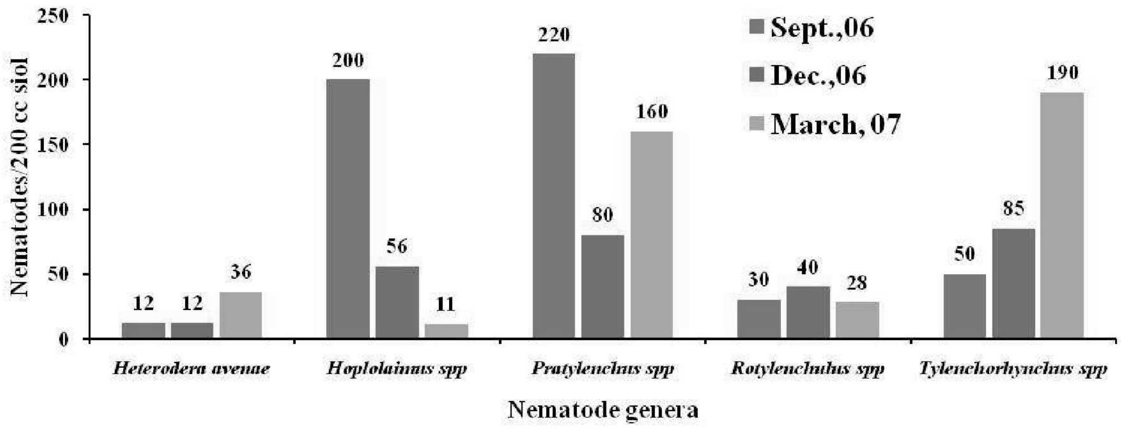

Fig. 2. Population of plant parasitic nematodes under cotton-wheat system (2006-07)

on cotton from 50 to 85in Dec. and 190 on wheat in March but *Hoplolaimus indicus* declined from 210 to 11. Population of *Pratylenchus* sp was high (220) in Sept on cotton which declined to 80 in Dec but showed an increase on wheat in March (Fig.2). Large numbers of this nematode (200/ 5g roots) were recovered from wheat roots also. *R. reniformis* population remained almost similar in Sept and March with a slightly higher number (40) in Dec. This nematode did not seem to parasitize wheat as no egg masses or larval stages of it were observed on wheat roots.

In 2008-2009, Populations of *H. avenae* increased in all the four fields after growing wheat. Populations of *Hoplolaimus* were more on cotton than wheat, whereas those of stunt

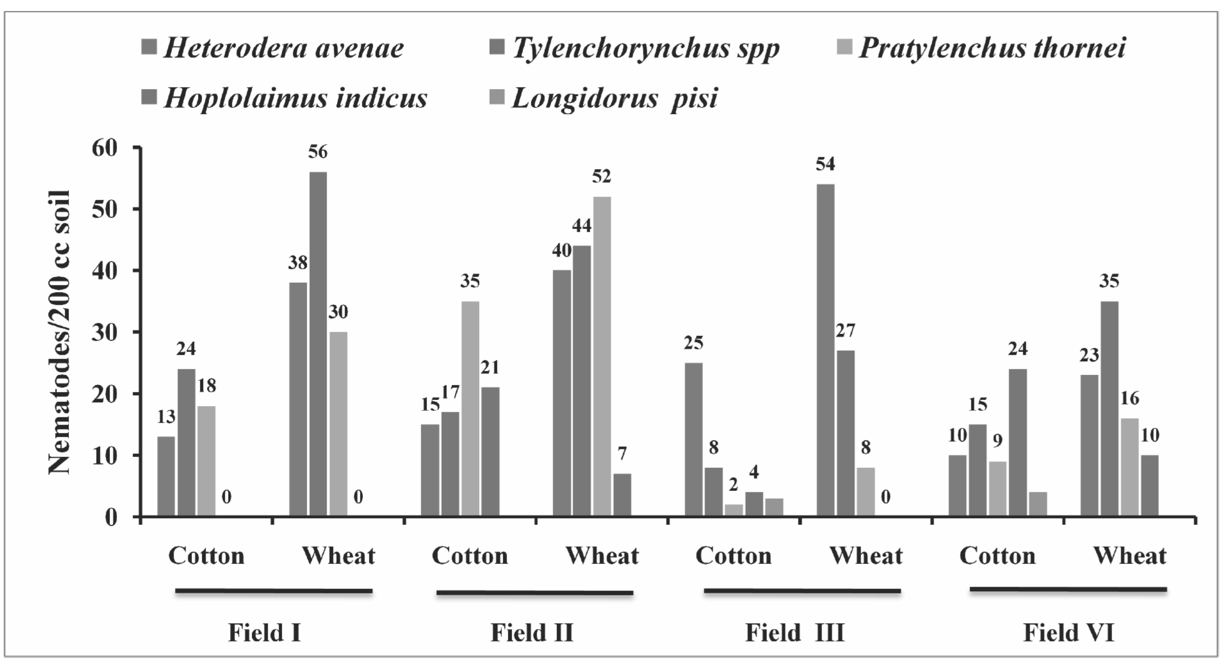

Fig. 3. Populations of major plant parasitic nematodes in cotton –wheat system (2008-09)

nematode (*Tylenchorynchus* sp.) and lesion nematode (*Pratylenchus* sp.) were more on wheat than cotton in all the fields. In two fields (III and IV), *Longidorus pisi* was also present in low numbers but it was not deteced in samples taken from wheat crop (Fig 3).

In 2010-11, *H. avenae* was not present in samples of villages Bheriyan and Kaimri in Hisar. The fields of cotton-wheat from Badopal (Fatehabad) having cysts of *H. avenae*, when sampled in wheat season during February 2011, showed presence of only a few white females and males in soil although roots had symptoms of 'Molya'. Most of the population was inside the roots by this time. Reniform nematode was found in the sample of cotton from Kaimri and in one sample from Badopal. In wheat season, it was reported only in Badopal's sample where it reduced on wheat from 50 to 30/200 cc soil.Other nematodes found in samples were-root lesion (*P. thornei*, *P. mulchandi* and *P. zeae*), stunt, needle, lance, and spiral nematodes. A high population of free living nematodes (>200/ 200 cc soil) was recorded on cotton in the samples (data not presented).

The populations of important plant parasitic nematodes recorded in 2011-2012, are given in Table 1. In all the fields, except III at Badopal, mustard was the preceding crop in *rab*i season. In cotton season, samples from all the fields except IV had partially filled and floating cysts but field no. III had 5 full cysts as well. In samples from field III and V, less cysts were recovered because the wheat crop was late and nematode was still in developmental stage in the roots. In samples of Badopal and Khara kheri, *R. reniformis* and *Meloidogyne* larvae were found in cotton season but not from wheat crop.

In 2013-2014, as revealed from the data (Table 2) cyst nematode was present in four fields and its population increased in all fields on wheat. Stunt nematode and lance nematodes were present in four and three fields, respectively; and their populations increased on

Table 1. Population dynamics of major plant parasitic nematodes in cotton wheat rotation in 2011-2012

Field.no./village	Rotation/ crop	Nematodes / 200 cc soil					
		HA cysts	HL	TR	PL	HT	Other
I Khairampur	Cotton	5PF	210	-	120	20	10 LD
	Wheat	20	80	-	150	28	2 LD
II Khairampur	Cotton	20PF	10	30	20	10	-
	Wheat	13	56	112	70	28	-
III Badopal	Cotton	5+ 15PF	-	-	-	20	200RR
	Wheat	3WF	-	-	-	8	-
IV Dharnia	Cotton	-	-	20	100	-	-
	Wheat	4	-	40	30	-	-
V Kharakheri	Cotton	10PF	10	80	-	-	30 RKJ2
	Wheat	7	-	20	-	-	-

HA = *Heterodera avena* , WF = white female, ; HT= Helicotylenchus, LD= LongidorusTR = *Tylenchorynchus* , HL = *Hoplolaimus*, PL = *Pratylenchus*, RR= *Rotylenchulus reniformis*PF = floating , partially filled /empty cysts. RKJ2= second stage larvae of root knot nematode. -= not detectedSampling date field no. I, II: cotton 26/9/11; wheat: 25/ 4/12 at crop harvest; field no. III, IV, V, cotton: 27/9/12 and wheat 9/4/12 (standing crops).

wheat. Root lesion nematode was present in three fields; and in wheat season its population increased in two fields but reduced in one field. Reniform and spiral nematodes were found in two fields in cotton season but they were not recorded in wheat crop. Four individuals of *Longidorus* sp also found in Kumhariya on cotton.

It is revealed from the data in Table 3 that in 2014-2015, cyst nematode was present in all the four fields and its population increased from 2.5 to 5 times on wheat depending on initial population. Population of lance nematode was higher on cotton and it decreased on wheat; in one field its number was low on cotton which was not detected on wheat. Population of stunt nematode (*Tylenchorynchus* sp.) was found higher on wheat in all the fields. Root lesion nematode was present in two fields and in wheat season its population decreased in both fields probably because wheat was not its preferred host.

Table 2. Population dynamics of major plant parasitic nematodes in cotton –wheat system in 2013-2014

Field no.	Crop/ Rotation	Nematodes /200 cc soil						
		HA	HL	TR	PL	HT	RR	Other
I Dharnia	Cotton	13	24	15	20	-	40	-
	Wheat	40	4	44	53	-	-	-
II Dharnia	Cotton	7	56	15	-	8		-
	Wheat	22	7	20	-	-	-	-
III Khairampur	Cotton	-	80	-	120	-	300	-
	Wheat	-	5	-	10	-	-	-
IV Agroha	Cotton	15	-	10	14	4	-	-
	Wheat	46	-	18	20	-	-	-
V Kumhariya	Cotton	6	-	40	-	-	-	4 LD
	Wheat	30	-	50	-	-	-	-

HA = cysts of *Heterodera avenae* ; HL = *Hoplolaimus* sp., TR = *Tylenchorynchus* sp., PL = *Pratylenchus* sp., HT = *Helicotylenchus* sp. , RR = *Rotylenchulus reniformis*, LD = *Longidorus* sp. , - = not detected

Cereal cyst nematode (*Heterodera avenae*), stunt nematode (*Tylenchorhynchus* species), lesion nematode (*Pratylenchus* species), spiral nematode (*Helicotylenchus* sp.), lance nematode (*Hoplolaimus indicus*), needle nematode (*Longidorus pisi*), root knot nematode (*Meloidogyne incognita*) and reniform nematode (*Rotylenchulus reniformis*) were the major nematodes recorded in this cropping system. The other nematodes recorded in the samples were: *Aphelenchus avenae*, *Ditylenchus* sp., *Hemicriconemoides* sp. and predatory nematodes *Fictor composticola* and *Seinura* sp. Maximum number of *H.avenae* cysts (64/200 cc soil) were recorded in a Khairampur in 2007-2008 on wheat. Maximum populations of *Pratylenchus* species (220) and *H. indicus* (210) were recorded on cotton in samples of village Khairampur in 2006-2007 and 2007-2008, respectively. The highest population of *Helicotylenchus* sp.(340)on cotton was recorded in 2004-2005 and that of *Tylenchorhynchus* species (300 on cotton and 445 on wheat) in village Dharnia in 2009-2010.

Population of *H.avenae* increased to varying levels on wheat depending on its initial population in cotton. In general, populations of

Table 3. Population dynamics of major plant parasitic nematodes in cotton –wheat system in 2014-15

Field no./ village	Crop / Rotation	Nematodes /200 cc soil				
		HA cysts	HL	TR	PL	FL
I Badopal	Cotton	8	88	70	60	200
	Wheat	40	60	125	50	120
II Agroha	Cotton	12	16	100	-	60
	Wheat	37	10	160	-	40
III Kharakheri	Cotton	20	2	200	20	330
	Wheat	50	-	240	12	280
IV Kumhariya	Cotton	6	30	80	-	140
	Wheat	28	20	110	-	100

HA = *Heteroderaavenae* ; HL = *Hoplolaimus* sp., TR = *Tylenchorynchus* sp., PL = *Pratylenchus* sp., FL= free living , - = not detected

Helicotylenchus sp, *Hoplolaimus* sp, *L. pisi, M. incognita*, and *R. reniformis* were higher on cotton than wheat but *Tylenchorhynchus* species, and *Pratylenchus* species (*P. thornei, P.mulchandi* & *P.zeae*), were more on wheat crop. Root- knot and reniform nematodes were not recorded in wheat season except in one field at village Badopal where they seem to survive on weeds.

Tylenchorynchus sp and *Pratylenchus* spp feed on both the crops while *H. avenae* remains dormant during *kharif* (April- October). Populations of *Hoplolaimus, Helicotylenchus*, were more on cotton than wheat. *M. incognita*, *R. reniformis* and *L. pisi* were found in some fields occasionally on cotton but not recorded in wheat crop. High populations of *R. reniformis*, *Hoplolaimus* and *L. pisi* on cotton and *Tylenchorynchus* spp., *Pratylenchus* spp needs attention on both crops. High populations of *H. indicus*, *Tylenchorhynchus* species, and *Pratylenchus* species in cotton warrants further studies on their host parasitic relations, loss estimation and interaction with other pathogens in cotton. *R.reniformis* was found in soil samples of Kaimiri and Badopal having high clay contents as also reported by Robinson *et al.,* (1987).

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REFERENCES

Anonoymus, 2016. Cotcorp.gov.in / current cotton scenario

Banu, J.G. 2010. Nematode infestations in cotton. In Nematode Infestations Part II: Industrial Crops (eds. M .R. Khan and M.S. Jairajpuri), National Academy of Sciences, India, Allahabad pp 256-88

Das, D.K. and Gaur, H.S. 2009. Distribution and abundance of Rotylenchulus reniformis in cotton growing areas in North India. *Ind. Jour. Nem.,* **39 :** 98-103.

Jain, R.K, Mathur, K.N. and Singh, R.V. 2007. Estimation of losses due to plant parasitic nematodes on different crops in India. *Ind. Jour. Nem.,* **37 :** 219-21.

Kanwar, R.S., Nandal, S.N., Paruthi, I.J. and Bajaj, H.K. 2011. Status of *Heterodera avenae* Woll. and losses caused by it in wheat in Haryana state of India. *Haryana agric. Univ. J. Res.* **41:** 21-23.

Kanwar, R.S. 2017. Effect of relay cropping of wheat in cotton on Cereal Cyst Nematode, Heterodera avenae. In *"National Symposium on Climate Smart Agriculture for Mematode Management"*. CCARI, Ela,Goa 11-13 Jan, 2017, p78-79.

Narkhedar , N.G. Lavhe, N.V. and Sheo Raj. 2005. Avoidable losses in cotton due to plant parasitic nematodes.paper presented in *"National Symposium on Recent Advances and Research Priorities in Indian Nematology"*, 9-10 Dec, 2005, IARI, New Delhi.

Robinson, A.F., Heald, C. M., Flanagan, S.I., Thames W.H. and Amador, J. 1987. Geographical distribution of *Rotylenchulus reniformis, Meloidogyne incognita Tylenchulus semipenitrans* in the lower Rio Grande Valley as related to soil texture and land use. *Ann. App. Bio.,* **I :** 20-25.

Schindler, A. F. 1961. A simple substitute for Baermann funnel. *Plant Dis. Rep.* **45 :** 747-48.

Sasser, J.N. and Freckman, D.W. 1987. A world perspective of Nematology. In : Vistas on Nematology (eds. J.A.Veech, and D.W. Dickson), Soc. of Nematologists, Hyatsville, USA,7-14.

Walia, R.K., Kumar, V. and Kumar,P. 2016. Major Nematode Problems Crop Losses and Technologies Generated for their Management. P.C. Cell, LBS Building, ICAR-IARI, New Delhi pp 34.

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Bt cotton cultivation: Strategies adopted for management of whitefly

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Abstract : Cotton is grown in mainly in Sirsa, Fatehabad, Hisar, Bhiwani and Jind district of Haryana. The major loss in cotton yield was recorded in Haryana in all districts during *kharif* 2015 due to the attack of whitefly, *Bamisia tabaci.* Incidence of pest was so severe that farmers fails to harvest seed cotton mere 2-3 qt/ha. The scientists of KVK Hisar as well CCS HAU Hisar conducted survey to find out the reasons for crop loss. The major reason is attack of whitefly resurgence and it is the resultant of indiscriment use of non-recommended pesticides and planting of inferior hybrid seed as well delay sowing. KVK Hisar proposed action plan for whitefly control including early and timely sowing of *Bt* cotton crop before 10th May, growing of selected recommended and tolerant hybrid of *Bt* cotton, promotion of *desi* cotton instead of *Bt* cotton, proper fertilization and timely irrigation, weed control, conservation of bio-agent using strip cropping, use of *neem* based formulation only as preventive measure and potassium nitrate (%) twice at flowing at 20 days interval. About 148 frontline demonstrations and on farm trails were conducted during 2014-2015, 2015-2016 and 2017-2018. Yield was very low during *kharif* 2015 and average yield was only 12.8 to15.5 q/ha in KVK conducted trails, where as yield increase in *kharif* 2016 and 2017 22.5 and 23.8 q/ha respectively in potassium nitrate spray trails. In case of university recommended practices including initial two *neem* based spraying at ETL bases, yield was 23.2 and 26.5 qts ha.$^{-1}$/ha *kharif* 2015 in farmers and recommended practices trials, respectively. Per acre net returns over total cost and net returns over variable cost were higher in Hisar (Rs. 10147 and Rs. 20087) as compared to Bhiwani (Rs. 8139 and Rs. 18674) during 2013-2014.

Cotton is the backbone of textile industry, which consumes 59 per cent of the country's total fibre production. It accounts for 34 per cent of the country's export and fetches about Rs.50, 000 crores annually to the exchequer. Along with the industry, which it sustains, it touches the country's economy at several points including employment and export earnings. India annually cultivates more than eleven million ha, the largest in the world. In fact, one out of every four ha of land under cotton in the world is in India. Around 6 to 6.5 million farmers grow the crop in about 10 States (Punjab, Haryana, Rajasthan, Gujarat, Madhya Pradesh, Maharashtra, Andhra Pradesh, Telangana, Karnataka and Tamil Nadu). Around 60 million people are estimated to depend on it one way or the other to make out their living Cotton is an International crop grown by about 80 countries across the world. On an average, cotton is planted in an area of 329.49 lakh ha. India is at top with 1st rank by contribution of 33.23 per cent in total area of the world. China is at 2nd position by contributing 16.02 per cent. The countries of

USA, Pakistan, Uzbekistan and Brazil rank 3 rd, 4th, 5th and 6th by contribution of 11.27 per cent, 9.01 per cent, 4.06 per cent and 3.09 per cent respectively. Of the total area in the world, about 76 per cent is contributed by the countries of India, China, USA, Pakistan, Uzbekistan and Brazil. During the period in the table above, the highest coverage under cotton was 361.63 lakh ha in 2011-2012 whereas the lowest was 303.02 lakh ha in 2009-2010. The highest contribution was of China (28.30%), followed by India (22.67%), USA (13.59 per cent), Pakistan (8.14%), Brazil (5.95%) and Uzbekistan (3.93%) (Anonymous 2017).

At the national level, Gujarat (25.7%) followed by Maharashtra (22.5%) of central cotton growing zone, and Andhra Pradesh (21.62%) of the south zone are the leading cotton producing States [Anonymous2014].

In northern India, Punjab, Haryana and Rajasthan grow cotton across an area of 5.05, 5.66 and 3.03 m ha with a production and productivity of 18.5, 20.0 and 12.9, and 706.9, 690.8 and 785.4 kg lint/ha, respectively [Anonymous2014 a].

In Haryana, cultivation of cotton is on 6.39 lakh ha with production of 22.00 lakh bales and average yield of 665 kg/ha (Anonymous, 2015)

Although the introduction of *Bt* cotton hybrids into the northern states since 2005 has significantly reduced the bollworm infestations and led to an increase in production, the potential yield (800 kg lint/ha) possible with straight varieties under ideal irrigation and management conditions could not be attained due to the problems of flooding, water logging and salinity in certain areas besides harsh climate with high temperature (40–45C) [Gopalakrishnan *et al.,* 2007].

The low productivity of cotton is ascribed to many factors, but the most serious is the intensity of insect pests damage. The insect pests spectrum of cotton is quite complex and as many as 1326 species of insect pests have been listed on this crop throughout the world. However, ravages in cotton production are because of major insect pests like (whitefly, *Bemisia tabaci* (*Gennadius*), leafhopper, *Amrasca biguttula biguttula* (Ishida), mealybug, *Phenacoccus solenopsis* (Tinsley), thrips, *Thrips tabaci* (Lindeman), aphid, *Apis gossypii* (Glover), American bollworm, *Helicoverpa armigera* (Hubner), pink bollworm, *Pectinophora gossypiella* (Saunders) and spotted bollworms, *Earias vittella* (Fabricius), *Earias insulana* (Boisduval) and Tobacco caterpillar *Spodoptera litura* (Fabricius) responsible for reduction in yield and also adversely affect the quality of lint and seed.

Amongst the sap sucking insects pests damaging this crop, whitefly, *B. tabaci* (Hemiptera: Aleyrodidae), a highly polyphagous insect-pest, has become serious, causing heavy losses during certain years. High population of the pest has the potential to remove significant amounts of phloem sap resulting in the reduction of plant vigour. Damage by this pest is caused in two ways: (a) the vitality of the plant is lowered through the loss of cell sap, and (b) normal photosynthesis is interfered with the growth of sooty mould on the honeydew excreted by the insect. Due to sooty mould growth reduces the quality and marketability of harvested products. Honeydew falling on open bolls makes the lint sticky which creates problems during ginning (Hendrix *et al.,* 1995).

Leaf hoppers (earlier referred as jassids), *A. biguttula biguttula* (Ishida), thrips, *Thrips tabaci* indeman and whiteflies, *B. tabaci* Gennadius are the important sap feeders of cotton which reduce assimilates of the crop through their feeding injury. Cotton leaf curl virus disease is also transmitted by the whiteflies in the north zone. The extent of avoidable loss was estimated to vary between 3.2 and 16.2 per cent in Punjab [Dhawan *et al.,* 2008, Kumar and Stanley 2006] due to sap feeders. Majority of the *Bt* cotton hybrids are susceptible to whiteflies and the leafhoppers [Kranthi *et al.,* 2011 and Kranthi 2015] and both the insects have developed resistance to neonicotinoids (imidacloprid, thiamethoxam, and acetamiprid) due to their continuous exposure over 14–15 years [Kranthi K (2015] to these insecticides.

Transgenic cotton is now a handy tool to ward-off bollworm menace. Plenty of *Bt* cotton hybrids developed by different agencies have entered in the market in cotton growing countries. Cotton cultivars generally referred as Bollgard I (BG I) contains only one gene (Cry1Ac) which offers protection against lepidopteran pests and known to be effective against *H. armigera, E. vittella* and *P. gossypiella* in India and later on two genes *viz.,* Cry1Ac + Cry2Ab (referred as Bollgard-II) considered to be more effective concept came in. Bollgard II (BG II) provides season long control key of cotton boll worms and also helps in delaying the resistance development in boll worms.

In India, hybrid cotton carrying Cry1Ac gene was approved for commercial cultivation in March 2002 and thence has been able to reduce the use of chemical insecticides, thereby lowering the risks pertaining to environment hazards, human health and production costs. The introduction of *Bt* cotton in India is likely to prove useful in the management of the bollworm, *H. armigera* with reduced dependence on pesticides (Kranthi *et al.,* 2005). In 2006, three new events were approved for incorporation in *Bt* hybrids in India. These events were, Bollgard II event, event I71, having modified Cry1Ac gene and event GFM having Cry1Ab and Cry1Ac genes.

In India, 21 per cent of insecticides are used on cotton currently, a reduction of 25 per cent over the pre *Bt* cotton period [Kranthi *et al.,* 2011]. Despite widespread adoption of genetically modified crops in many countries, heated controversies about their advantages and disadvantages continue. Especially for developing countries, there are concerns that genetically modified crops fail to benefit smallholder farmers and contribute to social and economic hardship. Many economic studies contradict this view, but most of them look at short term impacts only, so that uncertainty about longer term effects prevails. Findings show that *Bt* cotton adoption has caused sizeable socioeconomic benefits for smallholder farm households in India. The technology has increased cotton yields and profits by 24 per cent and 50 per cent, respectively (Kathage and Qaim 2012). The initial reduction of pesticide use registered as a consequence of *Bt* cotton cultivation shifted towards an increase in insecticide use against the sucking pests owing to increased incidence of sap feeders [Kranthi 2012].

Dahiya *et al.,* 2013 have reported variable associations of leafhopper and whitefly in *Bt* cotton hybrids with climatic factors like temperature and humidity during different cropping seasons, and suggested that the resistance levels of hybrids to these pests play an equally important role in their population build up. Since the widespread use of synthetic pesticides against plant pests from the middle of last century, the crop protection community has been searching for guiding principles, capable of responding both to the needs of agricultural production and the constraints imposed by a sustainable development of the planet (Lewis *et al.,* 1997).

Chemical control rapidly revealed its limitations, as well as its possibilities, and alternative solutions to pest management problems have been recommended since at least the 1960s. A new strategy was developed under the rubric 'integrated control', envisaging the employment of a range of different control measures, constrained by their compatibility and the requirement for minimising noxious effects on the wider environment. As much for socio-economic as for ecological reasons, from here comes a re-examination of farming systems traditionally practiced, via an innovative agro-ecological approach (Dalgaard *et al.,* 2003).

Cost of production in Hisar and Bhiwani district : Dass *et al.,* (2014) conducted survey in Hisar and Bhiwani districts of Haryana on randomly sample of 80 *Bt* cotton growers from 4 randomly selected villages was taken. Per acre cost of production in Hisar district came out to be Rs. 25911 as compared to Rs. 25432 in Bhiwani. Per ac net returns over total cost and net returns over variable cost were higher in Hisar (Rs. 10147 and Rs. 20087) as compared to Bhiwani (Rs. 8139 and Rs. 18674). Per q cost of production in Hisar and Bhiwani was observed as Rs. 3112 and Rs. 3303, respectively as compared to Per q price of Rs. 4250 and Rs. 4230 realized by the respondents of Bhiwani and Hisar districts, respectively.

Major crops in Hisar : District Hisar is located in the western bulge of the State, almost compact shaped Hisar district is bounded by Fatehabad district in the north west, by Jind district in the north east, a small portion is touched by Rohtak district in the south eastern part. In the south Bhiwani district makes boundary with the district. To its south west lies Rajasthan state. The crops grown in the district are divided into two main categories viz. *kharif* and *rabi*, locally called as sawani and sadhi. The former is the summer season harvest and the latter the winter season harvest. Any crop which does not strictly fall within these two harvests is known as a *zaid* crop and its harvest is called the *zaid kharif* or *zaid rabi*, according to the harvest with which it is assessed. *Toria* (an oilseed) is cultivated as *zaid kharif* and vegetables, melon and green fodder as *zaid* rabi. The major *kharif* crops of the district include *bajra*, paddy and cotton while the minor ones are *kharif* pulses. The major rabi crops are wheat, gram, barley, vegetables and sugarcane and oilseeds while minor ones are *rabi* vegetables and pulses.

Major loss in *kharif* 2015 and reasons behind crop failure in 2015-2016 : In Haryana cotton is grown in majorly in Sirsa, Fatehabad, Hisar, Bhiwani and Jind district. The major loss in cotton yield was recorded in Haryana in all district during *kharif* 2015 due to the attack of whitefly, *B. tabaci*. Incidence of pest was so

Front line demonstrations and on farm trial conducted by KVK Hisar during *kharif,* 2016 and 2017:

***kharif,* 2015**

Crop/ enterprise	Farming situation	Problem diagnosed	Title of OFT	No. of trials*	Technology assessed	*Production/ unit	Net Return (Profit) in Rs. / unit	BC Ratio
Cotton (*kharif* 2015)	Irrigated	Resurgence of White fly	Integrated approach for management of sucking pestsin Bt cotton	3	1. Farmer Practices (Excessive use of insecticides) 2. Foliar spray : 1st Rogor 30EC @ 300ml/ac, 2nd spray Imidacloprid 17.5 SL @ 40ml/ac 3. Yellow sticky traps and foliar spray with 1st Neemicidine; 2nd Neemicidine @1 l/ac	12.8	8700	1.1

***Kharif,* 2016**

Name of trial	Technology demonstrated	Demons-tration	Area (ha)	Production (q/ha)	Net return (Rs)	BC ratio
Foliar spray of KNO3 as supplementation of nutrition in Bt cotton	Two foliar spray of pot nitrate at 15 days interval at flowering	20	8	22.5	47500	1.6

Name of trial	Technology demonstrated	Demons-tration	Production (q/ha)	Net return (Rs)	BC ratio
Ecofriendly management of white fly in cotton	1. Farmer practices (Excessive use of pesticides) 2. HAU Hisar Recommendation First two spray of Neemicidine @1 l/ac at weekly interval on ETL basis	25	23.2 26.5	50300 63500	1.7 1.8

***kharif*, 2017**

Name of trial	Technology demonstrated	Demons-tration	Area (ha)	Production (q/ha)	Net return (Rs)	BC ratio
Quantitative Impact of foliar spray of KNO3 as in Bt cotton	Two Foliar spray of pot nitrate at 15 days interval at flowering	100	40	23.8	48700	1.6

severe that farmers fails to harvest seed cotton mere 2-3 q/ha. The scientists of KVK hisar as well CCS HAU Hisar conducted survey to find out the reasons behind crop failure. The major reasons behind is attack of whitefly resurgence. The whitefly resurgence was due to indiscrement use of non recommended pesticides and inferior variety seed as well delay sowing.

Strategies adopted by Krishi Vigyan Kendra to resolve the whitefly menace in *kharif* 2016 and *Kharif*, 2017 : From the experience of past year CCS HAU Hisar evolved a state level strategies in collaboration with KVKs of state to face the future threat of devastating whitefly in state. KVK Hisar themselves proposed action plan for this which includes:

- Early and timely sowing of *Bt* cotton crop before 10th may
- Growing of selected recomended and tolerant varieties of *Bt*.
- Promotion of *desi* cotton instead of bt cotton.
- Proper fertilization and to timely irrigation
- Destruction of collateral host of pests
- Conservation of bioagent using strip cropping
- Use of *neem* based formulation only.
- Spraying of pottassium nitrate (%) twice at flowing at 20 days interval

REFERENCES

AICCIP, 2011. All India Coordinated Cotton Improvement Project. Annual Report 2010–11, Central Institute for Cotton Research, Regional Station, Coimbatore, pp. 1–5.

Anonymous, 2014. Agricultural research data book. http://iasri. res.in/agridata/14data/HOME_14.HTML.

Anonymous, 2015. Cotton Advisory Board: Current cotton scenario (2014a). http://cotcorp.gov.in/current-cotton.aspx.

Anonymous, 2015. Anonymous, 2015. All India coordinated Research Project on Cotton. Annual Rep., 2014-2015, CICR, Coimbatore, India, pp. 1-5.

Anonymous, 2017. Status Paper of Indian Cotton. Directorate of Cotton Development Government of India Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers Welfare (DAC and FW) pp 1-182.

AICCIP, 2017. All India Coordinated Cotton Improvement Project. Annual Report 2010–11, Central Institute for Cotton Research, Regional Station, Coimbatore, pp. 1–5.

Arun, Janu and Dahiya, K. K. 2017. Influence of weather parameters on population of whitefly, Bemisia tabaci in American cotton (Gossypium hirsutum). *Jour. Ento. Zoo. Studies* **5 :** 649-54

Balasubramanian, A. and Muralibhaskaran, R.K. 2000. Intluence of organic amendment and inorganic fertilizer on the incidence of sucking pest of cotton. *Madras Agri. Jour.* **87 :** 359-61.

Dahiya, K, Kumar, D. and Chander, S. 2013. Influence of abiotic factors on leafhopper and whitefly population build up in *Bt* cotton hybrids. *Indian J Entomol* **75 :** 194–98.

Dalgaard, T., Hutchings N.J., Porter J.R. 2003. Agroecology, scaling and interdisciplinarity. *Agr. Ecosyst. Environ.* **100 :** 39–51.

Devi Dass, Virender Singh, Khatkar, R. K., Jogender Singh, Baljit Singh, Parminder Singh 2014. Economic analysis of *Bt* cotton production in Haryana. *J. Cotton Res. Deve.* **28 :** 167-69.

Dhawan, A., Sharma, M., Jindal, V., Kumar, R. 2008. Estimation of losses due to insect pests in *Bt* cotton. *Indian J Ecol* **35 :** 77–81

Gopalakrishnan, N., Manickam, S. and Prakash, A. H. 2007. Prospects of cotton in different zones of India. Central Institute for Cotton Research, Regional Station, Coimbatore. http://www.cicr.org.in/ pdf/ELS/ general3.pdf. Accessed 01 June 2016

Guerena, M. and Sullivan P. 2003. Organic cotton production.www.attra.ncat.org

Hendrix, D. L., Steele, T. L. and Perkins, H. H. 1995. *Bemisia*: Honeydew and cotton. In: Gerling, D. and Mayer, R.T. (ed) *Bemisia*: 1995. Taxonomy, Biology, Damage, Control and Management. Pp.189-199.Intercept, U.K.

Kathage, J. and Qaim, M. 2012. Economic impacts and impact dynamics of *Bt* (Bacillus thuringiensis) cotton in India. Proceedings of national academics of sciences of the united state of America. 109(29) 11652–11656, doi: 10.1073/pnas.1203647109

Kavitha, G., Ram, P. and Saini, R. K. 2003. Arthropod predatory fauna and its population dynamics in cotton in Haryana. *J. Cotton Res. Dev.* **17 :** 167–71.

Kavitha, G., Ram, P. and Saini, R. K. 2003. Arthropod predatory fauna and its population dynamics in cotton in Haryana. *J. Cotton Res. Dev.* **17 :** 167–71.

Kranthi, S., Kranthi, K.R., Rishi, Kumar, Dharajothi, Udiker, S.S., Prasad Rao G.M.V., Zanwar, P.R., Nagrare, V.N., Naik, C.B., Singh, V., Ramamurthy, V.V., Monga, D. 2011. Emerging and key insect pests on *Bt* cotton-their identification, taxonomy, genetic diversity and management. *Book of papers. World Cotton Research Conference-5,* Mumbai, India, 7–11 November 2011 (Excel India Publishers), pp 281–286

Kranthi, K. 2012. *Bt*-cotton question and answer (Indian Society for Cotton Improvement). Central Institute for Cotton Research, Nagpur, p 71

Kranthi, K. 2015. Whitefly—the black story. Cotton statistics and news **23 :** 1–4.

Kranthi, K. 2015. Technologies are breaking down—what next? Cotton statistics and news 19: 1-4. http://cicr.org.in/pdf/Kranthi_art/Technologies_break_down.pdf.

Kumar, K. and Stanley, S. 2006. Comparative efficacy of transgenic *Bt* and non transgenic cotton against insect pest of cotton in Tamil Nadu, India. *Resist Pest Manag Newsl* **15 :** 38–43

Lewis, W.J., van Lenteren J.C., Phatak S.C., Tumlinson J.H. III 1997. A total system approach to sustainable pest management. *Proc. Nat. Acad. Sci.* (USA) **94 :** 12243–248.

Patel. H.M. 2001. Ilabitat manipulation in Hy. Cotton-l 0 and evaluation of subsequent arthropod natural enemies on insect pests. *Ph.D. Thesis* submitted to Gujarat Agricultural University. Anand.

Patel, H. M., 2001. Habitat manipulation in Hybrid cotton-10 and evaluation of subsequent arthropod natural enemies on insect pests. *Ph. D. Thesis,* Gujarat Agric. Univ., Sardar Krushinagar (India).

Panse, V.G., Sukhatme, P.V. 1995. Statistical methods for Agricultural workers, ICAR: New Delhi, 1995, 15.

Rajendran, T. P, Venugopalan. V. and Taehalkar. P. P. 2000. Organic cotton farming in India. eICR technical bulletin No.1/2000.Central Institute of Cotton Research. Nagpur. PP: 1-39.

Ramcsh. P.. Mohan Singh and Subba Rao, A. 2005. Organic fanning: Its relevance to the Indian context. *Curro Sci.* **88 :** 561-68.

Roomi, 2014. Population dynamics of different insect pests and arthropods natural enemies on various *Bt* cotton gene events, *M.Sc. Thesis*, CCS Haryana Agricultural University, Hisar, 2014, 85.

Shalaby, F. F., Kares, E.A. and Ibrahim, A.A. 1983. Effect of intercropping maize in cotton fields on the attractiveness of predaceous insects. *Ann. Agric. Sci .* **22 :** 109-22.

Sharma, P. D., Jat, K. L. and Takar, B. 2004. Population dynamics of insect pest on American cotton in Haryana. *J. Cotton Res. Dev.* **18 :** 104–06.

Yadav, D.N. Mathew, K.L. and Jha, A. (2001 and 02). In *Situ* conservation of arthropod natural enemies of crop pests. *GA U Res. J..* **27 :** 24-29.

Wille, J .M. 1951. Biological control of certain cotton insects and application of new organic insecticides in Peru. *J. Econ.Ent.* **44 :** 13-18.

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Determination of relative toxicity of insecticides on larval stages of green lacewing, *Chrysoperla zastrowi sillemi* (Esben-Petersen)

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ABSTRACT : Laboratory studies were conducted on the toxicity of imidacloprid 17.8 SL, acetamiprid 20 SP, thiamethoxam 25 WG, profenofos 50 EC, triazophos 40 EC and thiodicarb 75 WP on 2nd instar larvae of *Chrysoperla zastrowi sillemi* by diet contamination method. Each insecticides were evaluated with six concentrations. Observations were made on the per cent larval mortality at 24 and 48 hrs after treatment (HAT). Moribund grubs were counted as dead. The results showed that the profenofos and acetamiprid was found to be highly toxic to 2nd instar larvae of *C. zastrowi sillemi*. Based on the LC_{50} values (ppm) the descending order of toxicity was profenofos (12) > acetamiprid (21) > thiamethoxam (33) > triazophos (40) > imidacloprid (88) > thiodicarb (396). Thiodicarb proved to be safest whereas, imidacloprid was safe and exhibited slight harmful effect at high concentration. Among the three neonicotinods, imidacloprid was less toxic to *C. zastrowi sillemi.*

Key words: *Chrysoperla zastrowi sillemi*, insecticides, LC_{50}, relative toxicity

The green lacewing, *Chrysoperla zastrowi sillemi* (Esben Petersen) is a promising polyphagous predators, feeding on jassids, psyllids, aphids, coccids and mites. It is widely distributed and easily amenable to mass multiplication under laboratory conditions. Effectiveness of *Chrysoperla* sp as biological control agent had been demonstrated in field crops, orchards and in green houses. Natural occurrence of *Chrysoperla* sp in field is rare due to frequent use of non-selective agrochemicals (Nasreen *et al.,* 2005). The impact of synthetic pesticides on beneficial arthropods and the human health risks posed by exposure to these chemicals are issues of growing concern. To mitigate these adverse effects, choice of selective insecticide, dosage, or timing of insecticide application can be a viable option. Biological control and selective insecticides proved to be compatible tactics in Integrated Pest Management (IPM) programs (Galvan *et al.,* 2005). With this background, the present study was aimed to determine the relative toxicity of insecticides against green lace wing *C. zastrowi sillemi.*

MATERIALS AND METHODS

The eggs of *C. zastrowi sillemi* obtained from Department of Agricultural Entomology, TNAU, Coimbatore, served as a nucleus culture. Commercial formulations of imidacloprid 17.8 SL, acetamiprid 20 SP, thiamethoxam 25 WG, profenofos 50 EC, triazophos 40 EC, thiodicarb 75 WP were evaluated with six concentrations on 2nd instar larvae of *C. zastrowi sillemi* by diet contamination method (Table 1). The different concentrations of insecticides were used for surface treatment of petrdishes. Thereafter apterous female aphids, *Aphis craccivora* were released in to the surface treated petridish. The counted numbers of larvae of *C. zastrowi sillemi* were allowed to feed the treated aphids and once they complete feeding, untreated aphids were provided until pupation. The untreated check was maintained as control by spraying the aphids with distilled water. The treatments were replicated five times. Observations were made on the per cent larval mortality at at 24 and 48 hrs after treatment (HAT). Moribund grubs were counted as dead. Data were analyzed through POLO PLUS (Probit and Logit Analysis) Statistical Analysis Software version 2.

RESULTS AND DISCUSSION

The results showed that the profenofos and acetamiprid was found to be highly toxic to 2nd instar larvae of *C. zastrowi sillemi*. Based on the LC_{50} values (ppm) the descending order of toxicity was profenofos (12) > acetamiprid (21) > thiamethoxam (33) > triazophos (40) > imidacloprid 17.8 SL (88) > thiodicarb (396). Thiodicarb proved to be safest whereas, imidacloprid was safe and exhibited slight harmful effect at high concentration. Among the three neonicotinods, imidacloprid was less toxic. This is in accordance with the findings of Preetha *et al.,* 2009 and Shankarganesh *et al.*, 2016 where recommended dose of imidacloprid was found to be toxic to larvae of *C. zastrowi sillemi*.

REFERENCES

Nasreen, A., Mustafa, G. and Ashfaq, M. 2005. Mortality of *Chrysoperla carnea* (Stephens) (Neuroptera; Chrysopidae) after exposure to some insecticides laboratory studies. *South Pacific Studies*, **26** : 1-6.

Galvan, T.L., Koch, R.L. and Hutchison, W.D. 2005. Toxicity of commonly used insecticides in sweet corn and soybean to multi coloured Asian lady beetle (Coleoptera: Coccinellidae). *Jour Eco Ent*, **98** : 780-89

Preetha, G., Stanley, J., Manoharan, T., Chandrasekaran, S. and Kuttalam, S. 2009. Toxicity of imidacloprid and diafenthiuron to *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) in the laboratory conditions. *Jour Plant Prot Res*, **49** : 290-96.

Shankarganesh, K., Naveen, N. C. and Bishwajeet Paul 2016. Effect of Insecticides on Different Stages of Predatory Green Lacewing, *Chrysoperla zastrowi sillemi* (Esben. Petersen), *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences,* DOI 10.1007/s40011-016-0719-x.

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Induced tolerance in *Bt* cotton against sucking insect pests

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Cotton, *Gossypium hirsutum* L. (Family: Malvaceae), is one of the most important commercial fibre crops in the world. Production of cotton is limited by biotic and abiotic stresses of which the biotic factors like insect pests are the real bottleneck. As many as 1326 insect pests have been reported to attack cotton at various stages of crop growth across the globe (Hargreaves, 1948). However, in India the number is limited to 130 species (Agarwal *et al.,* 1984).

Bt cotton has developed high levels of resistance to several commonly used insecticides. Therefore, there is a need to search for alternative methods of pest control to reduce the over dependence on insecticides and to conserve biodiversity. It is in this context host plant resistance, which is economic and environmental friendly, assumes a vital role in integrated pest management. Although many plant hormones act as elicitors of induced resistance, the most important and widely used phytohormones are jasmonic acid (JA) and salicylic acid (SA). Hence, to know the effect of induced tolerance to the sucking insect pests of *Bt* cotton , this study was undertaken.

MATERIALS AND METHODS

The untreated seeds of *Bt* cotton hybrid (MRC 7351) were raised in main field with a spacing of 90 x 60cm by following recommended agronomic practices prescribed by university. Similarly the cotton crop was raised in pots(size 2'x2'x2')for undertaking the laboratory studies wherein, when the seedlings were 15 days old treatment were imposed so as to induce tolerance and after leaving a grace period of 15 days the known number of leaf hopper and aphids were placed in the caged potted plants. Subsequently the observations on plant height and monopodial branches were recorded at 30 days after spraying. Further along with these parameters the, sympodial branches and number of squares/plant were recorded at 60 days. Later biochemical parameters *viz.*, phenols, total and reducing sugars were estimated by standard procedures and chlorophyll content was recorded with the SPAD chlorophyll meter in treated and untreated plants on 30 and 60 days old crop . All the research data generated were analysed statistically by following DMRT (Gomez and Gomez,1984)

RESULTS AND DISCUSSIUON

Effect of growth regulators and nutrients on growth and yield parameters of *Bt* cotton under glass house conditions

Growth parameters : At 30 days after spraying, there was a significant increase in the plant height in the plants treated with jasmonic and salicylic acid as compared to other treatments. This may be due to the fact that these growth regulators have their primary function of enhancing the plant growth which might have increased the plant height even after sustaining the pest population pressure . Similar effect of these treatments was also noticed during 60 days of spraying wherein the plant height was highest(73.00 cm) in jasmonic acid which was on par with SA, N:P:K and KNO_3. However the lowest plant height was recorded in the untreated control (63.67 cm) (Table 1). Further, when observations were extended to monopodial branches there was no significant effect among treatments. Whereas, a significant difference in the number of monopodial branches was recorded at 60 days of spraying. The least number of monopodial branches was recorded in the plants treated with jasmonic (1.17)and salicylic acid(1.33). This indicates that the there was transformation of the vegetative growth into the reproductive growth of the plants which may be due to the low population of the sucking pests in the plants treated with jasmonic and salicylic acid. The maximum number of monopodial branches was recorded in the plants that did not receive any of the treatments.

Yield parameters : Maximum number of sympodial branches was recorded in the plants treated with jasmonic acid which had recorded 9.33 sympodial branches/plant which was on par with salicylic acid followed by potassium during 60days of observation. These results were in line with the findings of Shaikh and Patel (2012) and Mahmoud (2013) who reported that potassium was responsible for reducing the sucking pests and also increased the fruit yield in brinjal. The lowest number of sympodial branches was recorded in the untreated control. Similar to the above parameters at 60 days after spraying, there was an increase in the number of squares in the plants treated with jasmonic acid (31.67/

Table 1. Effect of growth regulators and nutrients on growth and yield parameters of *Bt* cotton under glass house conditions

Treatments	Dosage/	30 DAS		60 DAS				Yield
		Growth parameters		Growth parameters		Yield parameters		(g/
	lit of water	Plant height (cm)	Mono-podial branches/ plant	Plant height (cm)	Mono podial branches/ plant	Sym-podial branches/ plant	Number of fruiting bodies/ plant	plant)
T1: N:P:K (19:19:19)	4g	32.00^{b}	1.33	71.67^{ab}	1.27^{bc}	7.60^{b}	26.00^{c}	136.90
T2: JA	1 mM	43.00^{a}	1.17	73.00^{a}	1.00^{a}	9.33^{a}	31.67^{a}	150.00
T3: SA	1 mM	40.33^{a}	1.63	72.00^{ab}	1.17^{ab}	9.03^{a}	30.33^{ab}	145.00
T4: KNO_3	5 g	34.00^{b}	1.63	71.33^{ab}	1.30^{bc}	7.93^{b}	27.33^{bc}	137.67
T5: $CaNO_3$	15 g	33.00^{b}	1.33	66.33^{bc}	1.36^{cd}	6.93^{bc}	25.00^{c}	130.33
T6: Bio 20	5 ml	31.33^{b}	1.17	66.33^{bc}	1.26^{bc}	7.20^{bc}	24.67^{c}	130.17
T7: Vermiwash	1:10	31.00^{b}	1.27	65.67^{cd}	1.40^{cd}	7.23^{b}	25.00^{cd}	128.17
T8: *P.fluorescens*	4 g	33.33^{b}	1.17	66.67^{bc}	1.33^{cd}	6.17^{cd}	24.00^{c}	133.33
T9: Untreated control	-	29.67^{b}	1.20	63.67^{d}	1.50^{d}	5.37^{d}	20.67^{d}	120.00
CV (%)	7.42	8.54	5.21	5.17	8.22	8.75	4.19	
S.Em (±)	1.46	0.06	2.07	0.06	0.35	1.32	3.25	
CD (p=0.05)	4.34	NS	6.14	0.18	1.05	4.07	9.67	

DAS: Days after spraying

Table 2. Effect of growth regulators and nutrients on growth and yield parameters of *Bt* cotton under field conditions

Treatments	Dosage/ lit of water	30 DAS Growth parameters Plant height (cm)	30 DAS Growth parameters Mono-podial branches/ plant	60 DAS Growth parameters Plant height (cm)	60 DAS Growth parameters Mono podial branches/ plant	60 DAS Yield parameters Sym-podial branches/ plant	60 DAS Yield parameters Number of fruiting bodies/ plant	Yield (g/ plant)
T1: N:P:K (19:19:19)	4 g	37.83^{bc}	2.67	83.33^{ab}	1.83^{ab}	8.00^{ab}	30.67^{a}	24.29
T2: JA	1 mM	46.83^{a}	2.53	90.33^{a}	1.33^{a}	9.50^{a}	34.33^{a}	26.85
T3: SA	1 mM	44.33^{ab}	2.50	85.33^{ab}	1.67^{b}	8.93^{ab}	33.00^{a}	25.92
T4: KNO_3	5 g	38.00^{bc}	2.57	81.00^{ab}	1.83^{bc}	8.77^{ab}	32.67^{a}	24.99
T5: $CaNO_3$	15 g	35.67^{c}	2.40	76.33^{bc}	1.90^{c}	7.53^{b}	25.33^{b}	23.40
T6: Bio 20	5 ml	35.33^{c}	2.70	71.67^{bc}	1.92^{bc}	7.30^{b}	25.33^{b}	23.32
T7: Vermiwash	1:10	34.00^{c}	2.60	70.33^{cd}	1.73^{bc}	7.23^{bc}	25.00^{bc}	22.60
T8*: P. fluorescens*	4 g	35.50^{c}	2.63	75.00^{bc}	1.74^{bc}	7.20^{bc}	25.33^{b}	23.37
T9: Untreated Control	-	30.33^{c}	2.43	63.33^{d}	1.90^{c}	5.50^{c}	20.00^{c}	20.48
CV (%)	12.80	12.65	10.33	11.08	14.02	10.38	11.16	
S.Em (±)	2.77	0.21	4.61	0.06	0.62	1.67	2.24	
CD (p=0.05)	8.31	NS	13.82	0.18	1.89	5.02	4.68	

DAS: Days after spraying

plant) which was *on par* with salicylic acid. This indicates that jasmonic acid and salicylic acid, apart from inducing defense responses in plants they are also involved in enhancing the vegetative and reproductive growth in cotton plants. These results were in line with the findings of Thaler (1999) who reported that exogenous application of jasmonic acid resulted in increased yield in tomatoes. The lowest number of squares per plant was recorded in the untreated plants. The highest yield was recorded in the plants treated with jasmonic acid (150 g/ plant) which was followed by salicylic acid (145.00 g/ plant).These results indicate that additional application of growth regulators like jasmonic acid and salicylic acid have an positive impact on increasing the yields in cotton apart from reducing the population of sucking insect pests.

Effect of growth regulators and nutrients on biochemical parameters in *Bt* cotton Total and reducing sugars : Highest amount of total sugars was recorded in the treatment jasmonic acid (5.87 mg/g) which was followed by salicylic acid (5.64 mg/g) under field conditions (Table 2). These results indicated that higher the amount of total sugars in the cotton leaves treated with jasmonic acid may be the reason for the low population of sucking pests. Even at 60 days after spraying the highest amount of reducing sugars was recorded in the plants treated with jasmonic acid which confers that the application of the growth regulators may induce tolerance to sucking pests without affecting the growth and yield of the plant.

Total phenols : The phenol content in the leaves at 30 days after spraying varied from 2.01 to 5.45 mg per gram. The highest amount of phenol was recorded in the leaves treated with jasmonic acid with 5.45 mg per gram which was followed by salicylic acid with 5.05 mg/g of phenols in cotton leaves. Phenols are known to act as defense metabolites in plant immune system; hence these results indicate that the low population coupled with good yield may be due to the defense mechanism offered by these plant secondary metabolites. Similar trend was noticed when phenolic content was estimated at 60 days after spraying. These results are in line with Thaler (1999).

Tannins : Present investigations indicated that higher amount of tannins were recorded in the plants treated with salicylic acid which had recorded 3.51 mg/g of cotton leaves at 60 days after spraying. Even jasmonic acid had recorded 3.43 mg/g of tannins in cotton leaves. It is evident from the results of present investigation that tannins also aid the plants to combat against the insect pests.

Chlorophyll : Highest amount of chlorophyll was recorded in the plants treated with jasmonic acid which was due to less injury by the sucking pests to cotton leaves, hence the leaves were greener and healthier thereby recorded more chlorophyll content which contributed towards more photosynthetic ability in plants apart from acting as defensive functions in plant metabolism. These results are in line with the findings of Vicent and Plasencia (2011), who reported the crucial role of SA in the regulation of physiological and biochemical processes in the entire life span of the plant.

CONCLUSION

It is concluded from the studies that exogenous application of JA and SA and other growth promoter will increase the health of the plant with enhanced growth which improved plant metabolic activity which ultimately had impacted on increased growth (plant height, more number of leaves and monopodial branches) yield parameters *viz.*,number of flowers ,squares and yield. The induced tolerance is an added advantage to the plants which not only sustain the pest pressure but also yields more compared to normal application of nutrients.

REFERENCES

Agarwal, R. A., Gupta, G. P. and Garg, D. O., 1984, *Cotton pest management in India*.Research publications, Azadnagar, Delhi. 1-191.

Hargreaves, H., 1948, List of recorded cotton insects of the world, Commonwealth Institute of Entomology., London. 50.

Mahmoud, M. F., 2013, Induced plant resistance as a pest management tactic on piercing sucking insects of sesame crop. *Arthropods*., **2 :** 137-49.

Shaikh, A. and Patel, J., 2012, Effect of different levels of potash on incidence of sucking pests in brinjal. *J. AGRES*, **1 :** 298-304.

Thaler, J. S., 1999, Induced resistance in agricultural crops: Effects of jasmonic acid on herbivory and yield in tomato plants. *Environ. Entomol.*, **28 :** 30-37

Vicent M. R. S. and Plasencia. J., 2011, Salicylic acid beyond defence: Its role in plant growth and development. *J. Exp. Bot.*, 3321-38.

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Variability of *Alternaria* spp associated with leaf blight of cotton in India

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ABSTRACT : Leaf blight of cotton caused by *Alternaria* spp is an important disease and the samples were collected during the survey for the study of morphological and molecular variability. The study of variability with respect to morphological characters revealed that out of 25 isolates of *Alternaria* spp, 18 showed complete resemblance with *Alternaria macrospora* and remaining seven isolates resembled to *Alternaria alternata*. The conidial size varied from 42.43 x17.69 ìm in Garag to 76.20x13.20 ìm Tadakod isolates. As per structural description of *A. macrospora* by Ellis, 18 isolates showed complete resemblance with *Alternaria macrospora* and remaining 7 isolates resembles to *Alternaria alternata* morphologically. In molecular variability study, DNA sequences of twenty five isolates were compared using the bioinformatics tool of the National Centre for Bioinformatics (NCBI) blast programme. PCR amplification of *Alternaria* spp with conserved primers ITS1 and ITS4 that yielded an approximately 560 bp rDNA amplicon product. Based on sequence comparison, the sequences of eighteen isolates were confirmed as *Alternaria macrospora* and seven as *Alternaria alternate* and accordingly phylogenetic trees were constructed. The present investigation revealed that there is greater morphological and molecular variability among the different isolates of *Alternaria* sp. It also showed that the genetic variation among the pathogen from different cotton growing areas of India.

Cotton known as the *'King of Fibre'* and called as *'White Gold'* and is the most vital crop of commerce to many countries including India having largest cotton area of 10.5 million hectares with a production of 33.4 million bales and productivity of 568 kg/ha568. Karnataka state has an area of 4.64 lakh hectares and a production of 19.9 lakh bales bales with productivity of 769 kg/ha (Anonymous, 2017). The low productivity of cotton in Karnataka is attributed to many factors, one of which is the losses due to diseases. Among all the foliar diseases, Alternaria leaf spot disease has the prime importance. Conidiophores of *Alternaria macrospora* Zimm. arise singly or in groups. They are erect, simple straight or flexuous, cylindrical or tapering towards the apex and septate. They are pale brown in colour, 4-9 ìm thick and up to 180 ìm in length. Conidia are solitary or in chains of two, straight or curved, obclavate or with the body of the conidium ellipsoidal, tapering to a narrow beak and equal in length or up to twice as long as body. They are reddish brown in colour with four to nine transverse septa and several longitudinal septa (Ellis, 1971). Several attempts are made to classify *Alternaria* genera, several redescriptions and revised criteria of these genera resulted in a growing number of new species. Results of a lifetime study on *Alternaria* taxonomy based upon morphological characteristics were summarised by Simmons (2007), in which 275 *Alternaria* species were recognised. Though, several cotton varieties and hybrids are being released from time to time, none of them has shown absolute resistance to this disease. This indicates the existence of variability among the isolates of this pathogen. Therefore, the present study was undertaken to understand the different aspects of *Alternaria* spp with respect to its morphological and molecular variability.

MATERIALS AND METHODS

Leaf blight infected by *Alternaria* spp. Cotton leaves with typical dark brown, circular to irregular spots were collected from different cotton growing areas and were isolated from these infected leaves by standard tissue isolation technique in the laboratory. The single spore isolation of *Alternaria* spp was carried out by following the standard procedure. Ten milli litre of clear, filtered two per cent water agar was poured into sterile petriplates and allowed to solidify. The dilute spore suspension was prepared in sterilized distilled water from 15 days old culture. One milli litre of such suspension was spread uniformly on agar plate. These plates were incubated at 27 ± 1°C for 12 hrs. Then such plates were examined under microscope to locate single isolated and germinated conidium and marked with ink on the surface of the plates. The growing hyphal tip portion was transferred to PDA slants with the help of cork borer under aseptic conditions and incubated at 27 ± 1°C. These culture tubes were used for further studies. The pure culture of the fungus was obtained after ten to fifteen days of inoculation which showed whitish growth at initial stage turning later to ash grey colour.

Pathogenicity : In order to confirm pathogenicity, cotton seeds of hybrid Bunny *Bt,* were surface sterilized with 0.1 per cent sodium hypochlorite and sown in earthen pots containing sterilized soil. They were allowed to grow for a month. Prior to inoculation, the plants were exposed to 95 per cent humidity for 24 hours. Thereafter, they were inoculated with spore suspension of (5.4 x 10^6 spores/ ml) the fungus, by using atomizer. After inoculation, the plants were exposed in the same conditions for 24 hours. Suitable control plants were maintained by spraying of sterile distilled water. After fifteen days of inoculation, the leaves exhibited initial symptoms of infection. Small, dull to dark brown, circular or irregularly shaped spots varying in diameter from 0.5 to 10 mm were observed. They developed concentric rings and presented a target board appearance which is better defined on the upper surface. The spots coalesced and occupied larger area of the leaf. The isolates were re-isolated and the morphological character of the re isolated organisms were compared with the original culture. Hence, it was confirmed that different *Alternaria* spp were involved in the causation of leaf blight disease in cotton. The fungus was sub cultured on Potato Dextrose Agar (PDA) slants and allowed to grow at 27 ± 1°C for 15 days. These slants were then preserved in the refrigerator at 5°C and sub-cultured once in two months. This pure culture was used for further studies. Morphological characters such as length and width of conidia, number of horizontal and vertical septa and beak length were measured under 40x using DIC (Differential Image Contrast) microscope and the pathogen was cultured on Potato Dextrose Agar.

Molecular variability of different isolates : For molecular variability study among different isolates so collected, the mycelium collected from the cultures of *Alternaria* spp after 5 days of incubation was used for DNA isolation. Total genomic DNA from fungal isolates were extracted by following Hi media kit protocol. DNA of the isolates were isolated by using Himedia kit method protocol. Internal Transcribed Spacer (ITS) was used to detect the variation among the ten isolates of *Alternaria* spp. collected from different districts of northern Karnataka. ITS1 and ITS4 Universal, *Alternaria macrospora* and *Alternaria alternata* specific primers obtained from Operon technologies, M/s Bangalore Genie, were used to determine molecular variability between the isolates. Polymerase Chain Reaction (PCR) amplification was done using Universal fungus ITS and Alternaria specific primers.

ITS-1-5' TCC GTA GGT GAA CCT GCG G 3'

ITS-4 -5' TCC TCC GCT TAT TGA TAT GC 3' ,

Size of amplified product = 560 bp

Then the amplified PCR product was sent for sequencing to Chromous Biotech Pvt limited Bengaluru. PCR amplification of rDNA sequences for *Alternaria* spp was conducted in ml reaction volumes using following primers and the reaction mixture mentioned below.

The PCR protocol was standardized to amplify rDNA sequences from a strain each of *Alternaria* spp. infecting cultivated species of *Bt*

Primers

Organism	Primer code	Sequence	Size of amplified product
Universal fungus ITS	ITS1	5' TCC GTA GGT GAA CCT GCG G 3'	560 bp
	ITS4	5' TCC TCC GCT TAT TGA TAT GC 3'	
Alternaria macrospora	AmF	5' CGGTACTACTGTCATCTTCG 3'	442bp
	AmR	5' CTTACGGTACCTGAGTTGAC 3'	
Alternaria alternata	Aa F2	5' TGCAATCAGCGTCAGTAACAAAT 3'	380 bp
	Aa F3	5' ATGGATGCTAGACCTTTGCTGAT 3'	

PCR programme for amplification of 16S rDNA

Step	Universal fungus ITS		*Alternaria macrospora*		*Alternaria alternata*	
	Temp (°C)	Duration (min)	Temp (°C)	Duration (min)	Temp (°C)	Duration (min)
Initial denaturation	94	4	94	5	94	2
Denaturation	94	1	94	1	94	30 sec
Annealing	55	1	55	3	55	30 sec
Extension	72	1	72	2	72	30 sec
Final extension	72	20	72	10	72	5
Hold	4	30	4	30	4	30
Number of cycles:DenaturationAnnealing Extension			35	30	35	

cotton. Negative controls were used to test for false priming and amplification. A 10 ml PCR amplification product for each of the *Alternaria* species was visualized on a 1 per cent agarose gel and viewed under UV light following staining with ethidium bromide.

RESULTS AND DISCUSSION

The morphological characters of the pathogen was studied and the morphological study of causal organism revealed that, the conidia of different isolates were septated by 1-3 vertical and 1-5 horizontal septa. Isolate A_5, A_8, A_{14}, A_{15}, A_{16} showed maximum horizontal septa and isolates A_3 and A_{16} showed maximum vertical septa. A_7 showed maximum size of the conidia and least shown by A_4 and highest beak length by isolate A_8 and least length by $A_{20.}$ Table 1 showed that, conidia of different isolates were septated by 1-3 vertical and 1-5 horizontal septa. The isolates, A_5, A_8 , A_{14} , A_{15} and A_{16} showed maximum horizontal septa of 5 whereas, minimum horizontal septa (1) was observed in the isolates, A_{16} and A_{17}. The isolates, A_3 showed maximum of 3 vertical septa and isolates, A_1, A_2 , A_4, A_5, A_7, A_8, A_{10}, A_{17}, A_{19} and A_{20} showed minimum of 1vertical septa. The isolates, A_7, A_{11} and A_8 showed maximum size of 76.20x13.20 ìm, 74.36x17.40 ìm and 73.89x 15.69ìm, respectively. The least size of the conidia (42.43 x17.69 ìm) was observed in isolate, A_4. By comparing with *A. macrospora* as per structural figure described by Ellis (1971) revealed that out of 25 isolates, 18 isolates showed complete resemblance with *Alternaria macrospora* and remaining 7 isolates resembles to *Alternaria alternata* morphologically which is in accordance with the findings of Anil (2013) who reported that out of their 12 isolates, only four showed complete resemblance with *A. macrospora*, morphologically. Similarly Jadhav *et al.*, (2011) and Ramegowda (2007) observed diversity in cultural and morphological characteristics such as growth rate, type of growth, colony colour and sporulation among different isolates of *Alternaria* spp., in cotton.

The PCR protocol was standardized to amplify rDNA sequences from a strain each of

Table 1. Morphological variability of different isolates of *Alternaria* spp

Isolates	Size of conidia (ìm) (Length x Breadth	Septation Vertical	Hrizontal	Beak length (ìm)
A_1	46.85 x16.70	1	3	14.88
A_2	50.83 x28.07	1	4	21.81
A_3	61.98 x30.08	3	4	17.40
A_4	42.43 x17.69	1	3	23.45
A_5	57.71 x 14.67	1	5	22.45
A_6	56.52x 12.33	2	4	21.46
A_7	76.20x13.20	1	4	23.28
A_8	73.89x 15.69	1	5	28.64
A_9	44.75x11.44	2	4	19.84
A_{10}	48.36x11.96	1	4	16.41
A_{11}	74.36x17.40	2	3	21.39
A_{12}	69.25x16.32	2	4	23.30
A_{13}	72.73x12.05	2	4	26.03
A_{14}	44.73x17.39	2	5	21.35
A_{15}	57.35x13.78	2	5	21.34
A_{16}	65.56x 16.34	3	5	24.35
A_{17}	62.36x18.61	1	3	23.25
A_{18}	63.58x19.31	2	2	24.01
A_{19}	48.07x14.91	1	1	20.90
A_{20}	59.05x20.52	1	1	11.79

A-1=Khangaon A-2=Badrinal A-3=Dharwad
A-4=Garag A-5=Budrakati A-6=Tadkoad
A-7=Bailhongal A-8=Yargatti A-9=Saundatti
A-10=Arabhavi A-11=Gokak A-12=Sankeshwar
A-13=Khalghatgi A-14=Munnavali A-15=Kuloli
A-16=Shaktinagar A-17 = Mantralaya
A-18=Agasinkoppa A-19 = Yadwad A-20 = Chiknasbi

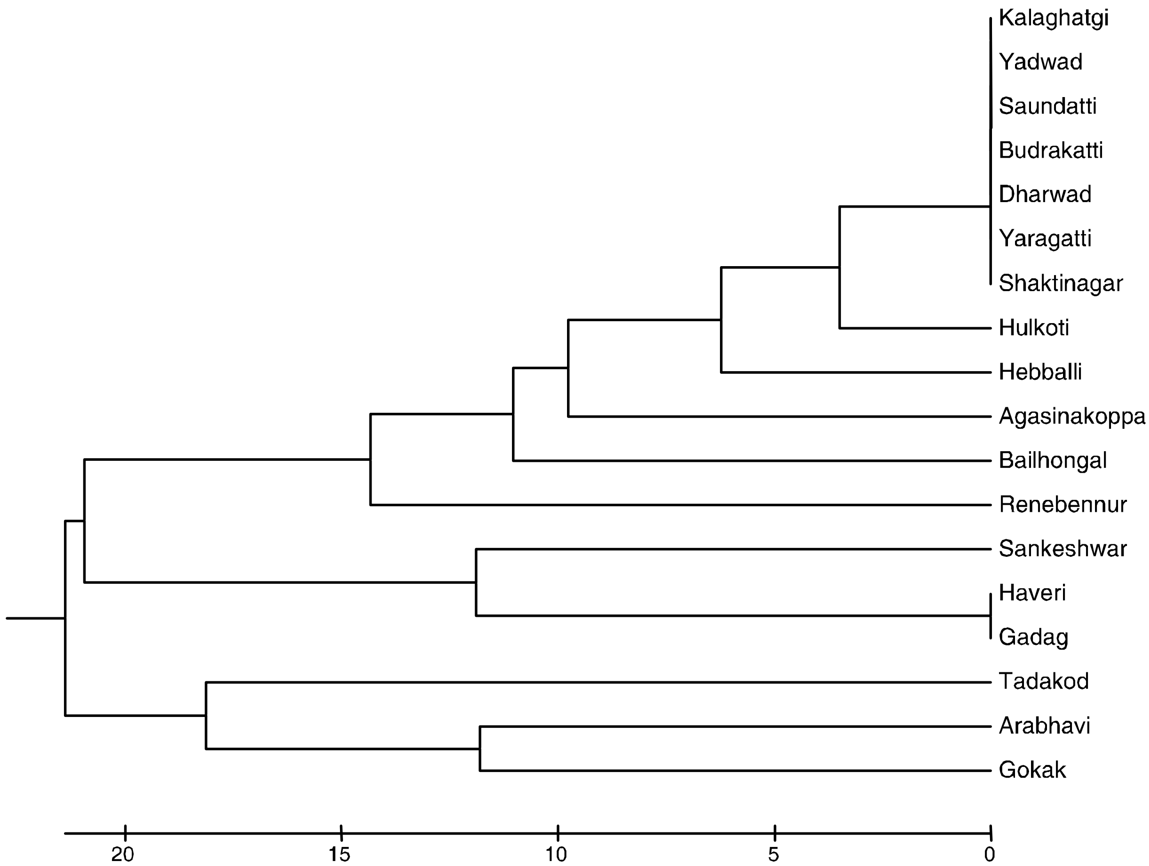

Fig 1. Phylogenetic tree for *Alternaria macrospora* of different isolates
There was 3 major clusters among 18 different isolates of *A macrospora* indicated that there may be existence of variability in *A macrospora* with respect to races or species level

Alternaria spp infecting cultivated species of *Bt* cotton. Negative controls were used to test for false priming and amplification. A 10 ml PCR amplification product for each of the *Alternaria* species was visualized on a 1 per cent agarose gel and viewed under UV light following staining with ethidium bromide.

The DNA sequences of twenty five isolates were compared using the bioinformatics tool of the National Centre for Bioinformatics (NCBI) blast programme. Based on sequence comparison, the identification of *Alternaria* spp isolates was confirmed and all the sequences of isolates were confirmed as eighteen isolates *Alternaria macrospora,* and seven as *Alternaria alternata* and accordingly phylogenetic trees were constructed (Fig. 1 and 2). Polymerase chain reaction (PCR) based molecular markers are useful tools for detecting genetic variation within populations of phytopathogens. PCR amplification of *Alternaria* spp with conserved primers ITS1 and ITS4 yielded an approx. 560 bp rDNA amplicon product. Based on sequence comparison, the identification of *Alternaria* spp isolates were confirmed and all the sequences of isolates were confirmed as eighteen *Alternaria macrospora* and seven *Alternaria alternata.*

The study revealed that there is greater

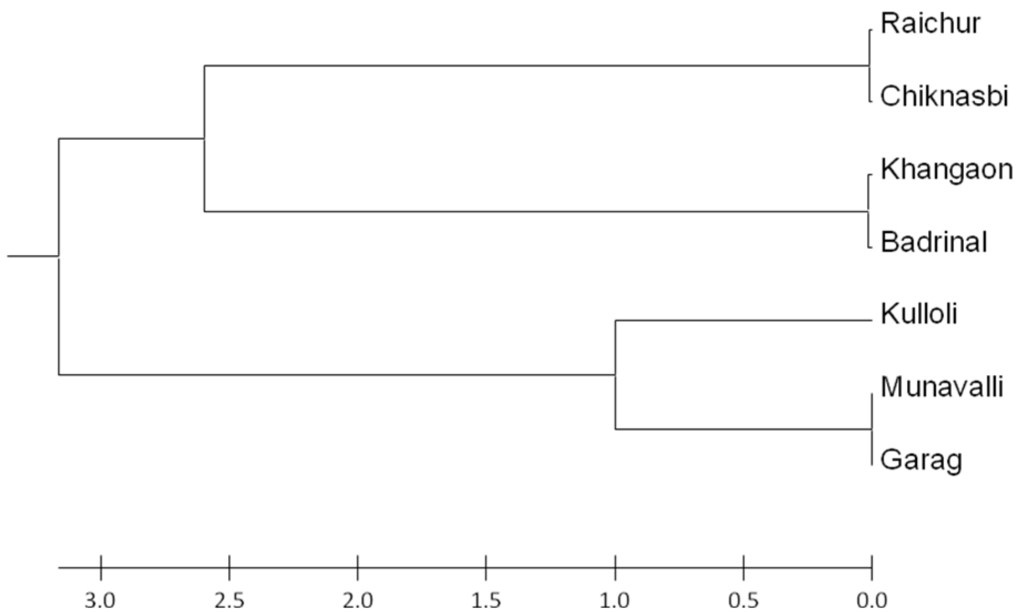

Fig. 2. Phylogenetic tree for Alternaria alternata of different isolates

There was 3 major clusters among 7 different isolates of *A alternata* indicated that there may be existence of variability in *A alternata* with respect to races or species level.

molecular variability among the different isolates of Alternaria sp. It also shows that the genetic variation among the pathogen varies from location to location. Findings of this experiment are in agreement with the results of Jadhav *et al.*, (2011) who conducted molecular variability test among different isolates of Alternaria macrospora and found that all the primers showed the polymorphism in the range of 64-92 per cent; however maximum polymorphism was observed by OPB 9 primer. Finally, involvement of *Alternaria* spp in causation of leaf blight disease was confirmed through pathogenicity test. The phylogenetic tree representation showed that, among 18 isolates of *A.macrospora*, there is variation in different cluster of isolates indicted that there may be variability with respect to races or species level. There was 3 major clusters among 18 different isolates of *A macrospora* indicated that there may be existence of variability in *A macrospora* with respect to races or species level (Fig.1). Similar variability was observed in 7 isolates of *A. alternate*. There was 3 major clusters among 7 different isolates of *A alternata* indicated that there may be existence of variability in *A. alternata* with respect to races or species level (Fig. 2).

Finally observed that *A.macrospora* is the major species of *Alternaria* causing leaf blight in cotton and in some cases there may be involvement of *A. alternata* causing leaf blight. This is in agrrement with findings of Sangeeta *et al.*, (2016) who conducted molecular variability test among different isolates of Alternaria spp causing leaf blight in cotton. The primer pAmac however, was not specific to *A. macrospora* of cotton but supported amplification of the rDNA fragment from several species of *Alternaria* (Kadam, 2005). Molecular techniques, if not alone, can be used in conjunction with classical methods where the latter approaches can at least narrow pathogen diagnosis to genus level. Once genus is narrowed by morphology, symptomatology, host-specificity, *etc.*, then PCR can be used to differentiate species. The outcome of the result finds the way for the exact cause or species involved and also the existence of pathogenic variability among isolates of different locations.

REFERENCES

Anil, G. H., 2013. Studies on leaf blight of Bt cotton caused by *Alternaria* spp. *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad, Karnataka (India).

Anonymous, 2017. “Annual Report” All India Coordinated Cotton Improvement Project (AICCIP). 2016-17.

Ellis, M. B., 1971, *Dematiaceous Hypomycetes*, Commonwealth Mycological Institute, Kew, Surrey, England, pp. 495-496.

Jadhav, B. M., Perane, R. R., Kale, A. A. and Pawar N. B., 2011. Morphological, pathological and molecular variability among Alternaria macrospora isolates causing leaf blight of cotton. *Indian Phytopath.*, **64** : 152-56.

Kadam, B. P. 2005. Characterization of molecular variability among some species of *Alternaria* that cause economically important diseases of crop plants and development of molecular diagnostic tools. *M. Sc. (Agri.) Thesis,* Univ. Maharashtra Agriculture University Parbhani(India).

Ramegowda, G., 2007. Disease scenario in *Bt* cotton with special reference to Alternaria leaf spot. *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad, Karnataka (India).

Sangeetha, K.D, Ashtaputre, S.A and Rao, M.S.L. 2016. Studies on morphological and cultural variability of *Alternaria* spp isolates causing leaf blight of cotton. *The Bioscan,* **11** : 755-57.

Simmons, E.G. 2007. *Alternaria*: An Identification Manual. *CBS Biodiversity Series* **6**: 775pp

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Efficacy of IPM modules against major pests of cotton

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ABSTRACT : Field experiments were carried out at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra during the season of 2011 to 2015 with cotton hybrid Phule 492 to study the efficacy of different IPM modules against major pests of cotton. After confirmation of efficacy of module, the validation of module was carried out on farmers field during 2016-2017. The investigations revealed that IPM module-III proved to be the most effective with lowest incidence of sucking pests 12.86, 5.34, 12.46 and 10.34 aphids, jassids, thrips and whitefly/3 leaves, respectively. While the infestation of american, spotted and pink bollworms on green bolls were of 5.43, 8.13 and 27.50, respectively. Lower incidence of pests in module III revealed the effectiveness of thiamethoxam seed treatment, application of NSKE, sowing of separate line of cowpea, maize and setaria, use of pheromone traps, release of *T.chilonis,* spraying of HaNPV, bird perches and use of yellow sticky traps for whitefly. Thus, supplementing imidacloprid with thiamethoxam as seed treatment, planting maize and cowpea as ecofeast crops enhanced the effectiveness, which has reflected in lower incidence of pests in IPM module III. In farmers practice, where thiamethoxam and bioagents did not form part of the module had more incidence of pests. The infestation of bollworms in case of open boll damage and locule damage in open boll was in the range of 7.66 to 37.95 and 7.13 to 32.68 per cent, respectively, observed in all modules evaluated. The maximum average seed cotton yield of 17.21 q/ha was found in the same module during 2011 to 2015 as against 12.58 q/ha in farmers practice. This showed that the IPM treatments gave 26.90 per cent higher yield as compared to farmers practice. The studies also showed that net return was also higher in this module as compared to other modules. The maximum net realization was obtained from IPM module III followed by IPM module I and II. The ICBR was, however, the highest in IPM module III followed by IPM module I and II. Thus, all the IPM modules proved more effective and economical against cotton pests than the insecticide module *i.e.* farmers practice giving higher ICBR and promoted activities of natural enemies of insect pests. From this study, it could be concluded that judicious use of pesticides along with seed treatment and other IPM strategies kept the pests population below the economic threshold level besides giving higher level of productivity. These IPM modules had also shown higher activity of natural enemies over farmers practice.

Key words : Cotton, cotton pests, IPM, modules, natural enemies

Cotton crop is an important cash crop and cultivated over an area of 118.81 lakh hectares. with a production of 352lakh bales. Cotton crop is attacked by 1326 species of insects at different stages. Among them 16 species are of major importance resulting in an annual loss of 50-60 per cent of total production (Anonymous, 2017). Generally the farmers rely on chemicals, for the control of cotton pests. This crop is known to consume about 55 per cent of toxic insecticides used in India. It is now an established fact that injudicious use of pesticides leads to several hazards such as development of resistance to insecticides. Destruction of natural enemies, alarming quantities of toxic residues of pesticides in food, water, soil etc. result in the serious problems of biological magnificence of pesticides through food chain. It felt imperative to minimize the environmental risks due to chemical insecticides, various IPM component *viz.*, fertilizer application, resistant varieties, seed treatments, trap crops, pheromone traps, bioagents, biopesticides, botanicals, neem products and insecticides with novel mode of action have been found effective against cotton pests. Previously IPM modules (Balakrishnan *et al.*, 2010; Swamy *et al.*, 2010) was available leafhopper, *Amrasca devastans* (Distant) (Murugesan and Kavitha, 2008; Murugesan and Kavitha, 2009) stem weevil and root rot complex (Vimala *et al.*, 2009), *Phenococcus solenopsis* and *Paracoccus marginatus* (Gulsar Banu *et al.,* 2010).

Keeping in view the need to incorporate effective eco friendly measures in the IPM programmes for cotton crop pests, the present investigation was undertaken in western Maharashtra region to formulate IPM module for non *Bt* cotton hybrids for the management of sucking pests and bollworms on cotton Hybrid RHH 492.

MATERIALS AND METHODS

The field trials were conducted at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra during five consecutive *Kharif* seasons of 2011 to 2015 with cotton hybrid Phule 492. Treatments were laid out in completely randomized design with 10 repetitions. Each IPM Block was arranged in 0.2 hectare area. The observations on incidence of sucking pests *viz.,* aphids, jassids, thrips and whitefly alongwith their natural enemies were recorded at 5 randomly selected spots in all modules at 45, 60 and 75 DAS. At each spot, 5 plants were randomly selected and tagged for recording the observations. The incidence of spotted bollworm (*Earias vitella*), american bollworm (*H.armigera*), pink bollworm (*Pectinophora gossypiella*), square damage (45, 60 and 75 DAS), green boll and locule damage (90, 105 and 120 DAS) on five tagged plants was recorded and per cent damage was worked out. Pheromone traps were installed in all modules to monitor population of adults of bollworms. At harvest, open boll damage & locule damage in open bolls and data on yields of cotton (q/ha) was worked out in each module and economics was computed considering the market price of various inputs and seed cotton. The following four IPM modules were tested for its efficacy:

IPM module: M-I

1 Seed treatment with thiamethoxam 30% FS @ 10 ml/kg seed.

2 Border one row of maize and between two maize plants, one plant of cowpea and at every 10th row of cotton alternate line of maize and cowpea.

3 Application of neem oil @ 2.5 l/ha at 45 DAS.

4 Use of pheromone traps @ 5/ha for *E.vittella* and *H.armigera* at 50 DAS.

5 Release of *Chelonus blackburni* @ 2000 adults/ha at 55 DAS.

6 Application of *Ha*NPV @ 500 LE/ha at 75 DAS.

7 Installation of pheromone traps @ 5/ha for *P.gossypiella* at 80 DAS.

8 Release of *Trichogrammatoidea bactrae* @ 1.5 lacs/ha at 90 DAS.

9 Use of yellow sticky traps @ 10/ha for whitefly monitoring at 95 DAS.

10 Spraying profenophos 50 EC @ 1000 ml/ha at 100 DAS.

11 Application of *Lecanicillium lecanii* @ 2 kg/ha at 105 DAS.

12 Spraying lambda cyhalothrin 5SC @ 500ml/ha at 120 DAS.

IPM module: M-II

1 Seed treatment with thiamethoxam (30%) FS @ 10 ml/kg seed.

2 Border one row of jowar and between two jowar plants, one plant of cowpea and at every 10th row of cotton alternate line of jowar and cowpea.

3 Application of (5%) NSKE at 45 DAS.

4 Use of pheromone traps @ 5/ha for *E.vittella* and *H.armigera* at 50 DAS.

5 Release of *Trichogramma chilonis* @ 1.5 lacs/ha (10 cards/ha) at 55 DAS.

6 Application of *Ha*NPV @ 500 LE/ha at 75 DAS.

7 Installation of pheromone traps @ 5/ha for *P.gossypiella* at 80 DAS.

8 Release of *Trichogrammatoidea bactrae* @ 1.5 lacs/ha at 90 DAS

9 Use of yellow sticky traps @ 10/ha for whitefly monitoring at 95 DAS.

10 Spraying indoxacarb 14.5 SC @ 500ml/ha at 100 DAS.

11 Application of *Lecanicillium lecanii* @ 2 kg/ha at 105 DAS.

12 Spraying emammectin benzoate 5SG @ 200g/ha at 120 DAS onwards.

IPM module: M-III

1 Seed treatment with thiamethoxam 30% FS @ 10 ml/kg seed.

2 Planting one row of maize and cowpea alternate at one meter distance around the field as border crop and at every 9th row of cotton alternate line of maize, cowpea and setaria.

3 Application of (5%) NSKE at 30 and 45 DAS.

4 Use of pheromone traps @ 5/ha each for monitoring of *E.vittella* and *H.armigera* at 45 DAS.

5 Release of *Trichogramma chilonis* @ 2 lacs/ha (10 cards/ha) at 60 DAS.

6 Application of *Ha*NPV @ 500 LE/ha at 75 DAS.

7 Installation of 'T' shaped bird perches @ 25/ha at 80 DAS.

8 Installation of pheromone traps @ 5/ha for monitoring of *P.gossypiella* at 85 DAS.

9 Spraying of profenophos 50 per cent EC @ 20 ml/10 liters of water at 90 DAS.

10 Use of yellow sticky traps @ 10/ha for whitefly monitoring at 100 DAS.

11 Spraying of triazophos 40%EC @ 20 ml/10 liters of water at 105 DAS.

12 Spraying of lambda cyhalothrin 5%SC @ 10 ml/10 liters of water at 120 DAS.

IPM module: M-IV Farmer's practice

1 Seed treatment with imidacloprid 70 WS @ 9 ml/kg of seed.

2 Application of acephate 75 SP @ 500 g/ha at 30 DAS.

3 Application of imidacloprid 17.8 Sl @ 200 ml/ha at 45 DAS.

4 Application of profenophos 50 EC @ 1000 ml/ha at 60 DAS.

5 Application of deltamethrin 2.5 EC @ 200 ml/ha at 75 DAS.

6 Application of acetamiprid 20 SP @ 100 g/ha at 90 DAS.

7 Spraying indoxacarb 14.5 SC @ 500 ml/ha 105 DAS.

8 Spraying lambda cyhalothrin 5 SC @ 500 ml/ha 120 DAS.

9 Spraying triazophos 40 EC @ 1000 ml/ha at 130 DAS

RESULTS AND DISCUSSION

A. Impact of IPM technology on the incidence: The data presented in table 1revealed that all three modules were significantly superior over farmers practice. The mean incidence of sucking pests was lower in module III and I as compared to module II. Among three modules, module III had recorded significantly lower population of 17.23, 6.72, 14.44 and 13.09 aphids, jassids, thrips and whitefly/3 leaves, respectively. The open boll damage and locule damage in all modules was in the range of 11.72 to 37.51 and 11.01 to 32.10 per cent, respectively. Lower incidence of pests in non *Bt* IPM module-III & I revealed the effectiveness of seed treatment with thiamethoxam, planting of ecofeast crops, application of (5%) NSKE in early stage of crop growth, installation of pheromone traps, release of *Trichogramma chilonis*, spraying of HaNPV, installation of bird perches and use of yellow sticky traps for whitefly with application of profenophos, trizophos and lambda cyhalothrin has reflected in lower incidence of pests in IPM module III over farmers practice. Thus, supplementing imidacloprid with thiamethoxam as seed treatment, planting ecofeast crops, application of (5%) NSKE in early stage of crop growth, installation of pheromone traps, release of *Trichogramma chilonis*, spraying of HaNPV, installation of bird perches and use of yellow sticky traps for whitefly enhanced the effectiveness, which has reflected in lower incidence of pests in IPM module III. In farmers practice, where thiamethoxam and bioagents did not form part of the module had more incidence of pests. For sucking pest management, planting of ecofeast crops and application of (5%) NSKE in early stage of crop growth and use of yellow sticky traps for whitefly in later stage of crop growth; while for bollworm control, installation of pheromone traps and bird perches, release of *Trichogramma chilonis*, spraying of HaNPV proved more effective combactant as compared to sole insecticide sprayings in farmers practice. Bharpoda *et al.,* (2000) also observed that the IPMmodules proved significantly effective by managing the

Table 1. Incidence of various pests in different IPM modules adopted in non *Bt* cotton (w.e.f 2011 to 2015).

Sr. No.	Particulars	Sucking pests/3 leaves				Predators/ plant	Larvae/5 plant		PBW larvae/ 20 GBs	(%)Square damage	% infestation on green bolls			(%) damage in open bolls	(%) locule damage in open bolls
		Aphids	Jassids	Thrips	Whitefly		ABW	SBW			ABW	SBW	PBW		
1.00	Module I	20.26	7.64	17.50	15.09	7.46	2.34	2.58	6.51	5.98	2.40	3.48	11.34	14.64	13.90
		(4.56)*	(2.85)	(4.24)	(3.95)	(3.59)	(1.68)	(1.75)	(2.34)	(14.15)**	(8.92)	(10.75)	(19.68)	(22.50)	(21.89)
2.00	Module II	29.27	8.84	20.58	16.00	5.63	2.57	3.08	8.02	7.61	3.23	4.96	15.01	19.84	18.93
		(5.46)	(3.06)	(4.59)	(4.06)	(3.90)	(1.75)	(1.89)	(2.52)	(16.02)	(10.35)	(12.87)	(22.79)	(26.45)	(25.79)
3.00	Module III	17.23	6.72	14.44	13.09	8.43	2.04	2.25	4.72	5.80	2.35	3.48	8.77	11.72	11.01
		(4.21)	(2.69)	(3.87)	(3.69)	(3.41)	(1.59)	(1.66)	(2.22)	(13.93)	(8.82)	(10.76)	(17.22)	(20.02)	(19.38)
4.00	Module IV	45.17	13.13	35.49	25.54	3.54	3.80	4.40	13.60	12.89	5.20	7.41	25.48	37.51	32.10
		(6.76)	(3.69)	(6.00)	(5.10)	(4.93)	(2.07)	(2.21)	(3.07)	(21.04)	(13.18)	(15.80)	(30.31)	(37.77)	(34.51)
	SE ±	0.23	0.09	0.18	0.10	0.11	0.02	0.04	0.14	0.25	0.26	0.34	0.43	1.42	1.79
	CD (p=0.05)	0.70	0.23	0.54	0.32	0.34	0.07	0.13	0.40	0.75	0.77	1.03	1.29	4.27	5.38
	CV (%)	11.60	11.32	12.12	11.74	13.92	10.67	11.90	11.89	10.15	11.55	9.12	12.18	11.67	13.67

Table 2. Economic viability of different IPM modules in non *Bt* cotton (w.e.f 2011 to 2015).

SN	Particulars	Yield q/ ha	Cotton Rate/q	Gross return (Rs/ha)	Cost of treatment (Rs/ha)	Cost of cultivation (Rs/ha)	Total cost of IPM	Net returns (Rs./ha)	Net profit (Rs./ha)	CBR	ICBR
1.	Module I	16.29	4120	67094	5835	32800	38635	28459	15568	1.75	2.72
2.	Module II	15.30	4120	63015	7120	32800	39920	23095	10204	1.59	1.46
3.	Module III	17.17	4120	70646	7449	32800	40249	30398	17507	1.77	2.42
4.	Module IV	13.04	4120	53702	8012	32800	40812	12891	0	1.33	0.00
	SE ±	0.29	—	—	—	—	—	—	—	—	—
	CD (p=0.05)	0.87	—	—	—	—	—	—	—	—	—
	CV (%)	12.56	—	—	—	—	—	—	—	—	—

Table 3. Economic viability of different IPM modules in non *Bt* cotton (w.e.f 2011 to 2015).

S	Particulars	Yield q /ha						CBR						ICBR					
		2011	2012	2013	2014	2015	**Av**	2011	2012	2013	2014	2015	**Av**	2011	2012	2013	2014	2015	**Av**
1	Module I	19.52	17.56	16.14	12.87	15.37	**16.29**	2.10	1.97	1.89	1.27	1.52	**1.75**	3.38	3.19	2.88	1.96	2.21	**2.72**
2	Module II	18.14	16.32	15.41	11.93	14.68	**15.30**	1.90	1.78	1.75	1.14	1.40	**1.59**	1.74	1.64	1.69	0.95	1.28	**1.46**
3	Module III	20.93	18.85	16.39	14.06	15.61	**17.17**	2.17	2.04	1.84	1.33	1.47	**1.77**	3.28	3.11	2.23	1.86	1.61	**2.42**
4	Module IV	15.49	13.93	13.03	10.33	12.41	**13.04**	1.59	1.49	1.45	0.96	1.15	**1.33**	0.00	0.00	0.00	0.00	0.00	**0.00**

population of bollworms and sucking pests on Cotton Hybrid 4.

B. Impact of IPM technology on the seed cotton yield and economic returns : Seed cotton yield recorded in module III was 17.17 q/ ha that was significantly higher over module I, II and IV (Table 2). This showed that the IPM treatments gave 31.67 per cent higher yield as compared to farmer's practice (Module IV), where no IPM technology had been undertaken. The data presented in table 3 revealed that module III gave maximum benefit cost ratio of 1:1.77 followed by module I; which resulted in benefit cost ratio of 1:1.75. Patel *et al.,* (2011) also reported the IPM modules proved more effective and economical against cotton pests than the insecticide module in north Gujarat a giving higher ICBR and promoted activities of natural enemies of insect pests.

REFERENCES

Anonymous, 2017. Annual Progress Report of All India Coordinated Cotton Improvement Project, Cooinbatore, A1-15PP.

Balakrishnan, N., Murali Baskaran, R. K. and Mahadevan, N. R. 2010. Influence of intercrops/trap crops on the preference of major pests of cotton in different IPMmodules under rainfed condition. *Journal of Biopesticides*, **3** : 373-78.

Bharpoda, T.M., Patel, H.P., Patel Usha P., Patel, G.P., Patel, J.J.and Patel, J.R. 2000. Integrated pest management (IPM) in cotton H-6 cultivated in middle Gujarat. *Ind Jour Ento,* **62** : 327-31.

Gulsar Banu, J., Surulivelu, T., Amutha, M. and Gopalakrishnan, N. 2010. Laboratory evaluation of insecticides and biopesticides against *Phenococcussolenopsis* and *Paracoccus marginatus* infesting cotton. *Jour. Biopest*, **3** : 343-46.

Murugesan, N. and Kavitha, A. 2008. Evaluation of an IPM module against the leafhopper, *Amrasca devastans* (Distant) in cotton. *Jour Biopest.* **1**: 98 –100.

Murugesan, N. and Kavitha, A. 2009. Seed treatment with *Pseudomonas fluorescens,* plant products and synthetic insecticides against the leafhopper, *Amrascadevastans* (Distant) in cotton. *Jour Biopest*, **2**: 22-25.

Patel, I.S., Patel, G.M., Patel, V.J. and Chaudhary, F.K. 2011. Evaluation of biocontrol based IPM module on cotton Hybrid10. *Jour. Biopest*, **4** : 73 – 74.

Swamy, S.V.S., Gopala. and Prasad, N.V.V.S.D. 2010. Comparative evaluation of different Pest Management Strategies on Cotton. *Ann Plant Prot Sci,* **18**: 131-35.

Vimala, R., Suriachandraselvan, M., Murugesan, N. and Ramalingam, A. 2009. Development of a management strategy against stem weevil and root rot complex in cotton. *Jour Biopest*, **2**: 18-21.

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Resilience and relative virulence of entomopathogenic fungi against *Bemisia tabaci* with integrated pest management components in cotton

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ABSTRACT: *Bemisia tabaci*, a vector of cotton leaf curl virus disease is one of the most devastating and serious emerging problems that causes huge economic losses to cotton yield and quality. Till now, many outbreaks of whitefly were noticed in different cotton growing states in India, including the recent outbreak during 2015-2016 in the north zone. Thirty five chemical insecticides have been registered for its control in India but resistance and resurgence has been reported against many of these insecticides. Entomopathogenic fungi (EPFs) have played a uniquely important role as mycoinsecticides providing biological alternatives to chemical insecticides. However, EPFs have been evaluated under laboratory and greenhouse with a very narrow range; moreover, there is a little information available on their relative virulence with IPM components and field efficacy. Therefore, more than 300 EPF strains were individually evaluated under polyhouse conditions and the selected EPFs were evaluated under field conditions against whitefly. The highest nymphal mortality was recorded by (95.1%) by Bb 4511 followed by Bb 4565 and Ma 1299 and the lowest LC_{50} was recorded with Pj 089 followed by Bb 4511 and Pj 102 however, the overall biological efficacy index was recorded with Pj 102, Bb 4511 and Pj 089. The compatibility study conducted with the IPM components showed variable response among 10 EPF isolates. Mycelial growth inhibition of EPF strains namely Pj 102, Bb 4565, Bb 4543 were found least (-59.6 to 48.1 % reduction) with recommended dose of tested chemicals, IGRs and botanicals tested during the experiment. However, based on toxicity index entomopathogenic fungal strain namely, Pj 99, Pj 102, Ma 1299 were found to be the most compatible with full and half dose of the chemical and botanicals tested in the present study. The selected cultures showed reduction in whitefly nymphal mortality ranging from 81.4 to 93.6 per cent under field condition. Our results indicate that applications of EPFs showing best virulence and compatibility have the maximum likelihood for control of *B. tabaci* under field.

Key words: *Bemisia tabaci,* bioassay, biological control, entomopathogenic fungi, insecticides compatibility, mycoinsecticides

Cotton (*Gossypium* spp.) is words one of the most important commercial and natural textile fibre crops and a significant contributor of oilseeds. Cotton is one of the most insect pest infested crop and *Bemisia tabaci* and cotton leaf curl virus disease (CLCuD) are the most devastating and serious emerging problems that inflicted huge economic losses to cotton yield and quality. Whitefly is native to tropical and subtropical regions but has spread rapidly around the world (Barro *et al.,* 1998). It is highly polyphagous, invading more than 900 wild and cultivated species (Brown *et al.,* 1995) and transmitting more than 60 plant viruses worldwide. It is a serious threat to cotton production in India especially Northern parts. Till now, five outbreaks of whitefly were noticed in different cotton growing states in India, and recently during 2015-2016, a severe outbreak of whitefly was experienced in cotton in the north cotton growing zone of India. Damage results from direct feeding that reduces the yield (Jahan *et al.*, 2014; Polston *et al.*, 2014). Besides disease transmission, large amounts of honeydew excreted by the insect encourage the development of black sooty mould on leaves (Palumbo *et al.*, 2000). A direct shading of leaves by the powdery coating has been reported to significantly photosynthetic capabilities of crop plants, which results in economic loss (Pico *et al.*, 1996). The greatest economic threat is from the transmission of Cotton Leaf Curl Diseases (CLCuD) viruses that causes yield losses upto 88.4 -81.4 per cent in all northern cotton growing areas of India (Monga 2014).

At present there is no source of absolute resistance against CLCuD and its vector *B. tabaci* in cotton varieties and almost all the cultivated *Bt* and non-*Bt* cotton hybrids including about 250 new *Bt* cotton hybrids approved for cultivation in north India (Kranthi, 2014). The needs to obtain greater yields and quality cotton that fetch higher prices encouraging farmers to apply prophylactic sprays of pesticides to manage both whitefly and CLCuD. Although, 35 insecticides including 6 mixtures have been registered for whitefly management in India but it has acquired resistance to many insecticides (Basit *et al.*, 2013; Longhurst *et al.,* 2013; Dittrich and Ernest, 1983; Cahill *et al.,* 1996; Prasad *et al.*, 1993; Kranthi *et al.,* 2002; Horowitz and Ishaaya, 2014). More than 20 species of EPFs are known to infect whiteflies (Lacey, *et al.,* 1995; Scorsetti *et al.,* 2008) which could be an ecological compatible and a good insecticides resistance management alternative for whitefly management. Despite considerable research in North America, Europe, UK, and North Eastern Asia (Faria and Wraight, 2001; Lacey *et al.,* 2015, Borisade and Mahan, 2015), a little information exists on this important aspect in India. Until now, out of 109 pesticide products registered so far for cotton pest management in India there are only one mycoinsecticide (*Lecanicillium lecanii*) and 3 azadirectin products are recommended for whitefly management in cotton (CIBRC up to 31.08.2015). Hence, present situation emphasizing the need for research to find an environment friendly and sustainable methods of management of this tedious pest. Several EPFs including *Beauveria bassiana*, *Isaria farinosa* and *Metarhizium anisopliae* are reported to be potential biocontrol agents for *B. tabaci* ((Faria and Wraight *et al.,* 2001; Lacey *et al.,* 2008)). Further, effective entomopathogenic fungi and selective insecticide may act synergistically increasing the efficiency of the control, allowing the lower doses of insecticides, preservation of natural enemies, minimizing environmental pollution and decreasing the likelihood of development of resistance to either agent (Boman, 1980; Moino and Alves, 1998;

Ambethgar, 2009). The potential inhibitory effects of pesticides on germination and mycelial growth of entomopathogenic fungi often vary among fungal species and strains (Vanninen and Hokkanen, 1988; Anderson *et al.*, 1989). By contrast, use of incompatible insecticides may inhibit growth and reproduction of the pathogens and adversely affect integrated pest management (Duarte *et al.*, 1992; Malo, 1993). Therefore, fungal genotypes compatible to particular pesticides can be identified and manipulated to develop a suitable IPM or IRM programme.

Therefore, the present investigation was conceded to screen the entomopathogens for their resilience, relative virulence, compatibility with various insecticides and suitability to develop IPM technology for successful adoption in the field. This was presumed that, this study could ultimately help to develop an eco-compatible and effective fungal formulation which could help in reducing the whitefly populations as well as CLCuV incidence through a sustainable IPM/IRM system. The laboratory and polyhouse studies were conducted to evaluate the biocontrol efficacy of large number of EPF strains and strengthen management strategies for CLCuV vector *B. tabaci* in cotton.

MATERIALS AND METHODS

The works described below were conducted during the 2016-2017 and 2017-2018 crop year at ICAR Central Institute for Cotton Research Regional Station Sirsa (Haryana) (29°32’36.1"N 75°02’18.8"E & 29°32’43.6"N 75°02’05.2"E). Field site that hosted the experiment was former cotton fields of ICAR CICR Regional Station, Sirsa that have been subject to several cotton cropping.

Poly house screening of entomopathogenic strains : Pure cultures of a total of 373 entomopathogenic fungal strains were procured including 105 newly isolated cultures, 190 fungal cultures from MTCC and 75 isolates from NAIMCC. All the fungal entomopathogenic strains were cultured at Plant Pathology Laboratory, ICAR-CICR Regional Station, Sirsa, Haryana. The fungal cultures were incubated on Sabouraud Dextrose Agar (SDA) (Hi Media) amended with 0.2 per cent yeast and streptomycin sulfate (20 ìg l^{-1}) in sterilized Petriplates for 12–15 days at 28±2ÚC in dark. The growth of each fungal culture as well as sporulation was estimated 10 days after inoculation for compression of cumulative bioefficacy.

Conidia were harvested from the Pertiplates by flooding media with sterile 0.01% (v/v) Tween 80 (Polyoxyethylene sorbitan monolaurate) and stirring with a glass rod. The suspension was vigorously agitated and filtered through double layered of nylon cheesecloth. The filtered suspension (10 ml) was agitated again before spray application and conidial concentrations of the stock were estimated with an improved Neubauer hemocytometer at 400 X magnification. The conidia suspension was then diluted to get a series of concentrations between 10^4 to 10^8. In all bioassay conidial inoculum (1 x 10^7 conidia/ml) harvested from 15-day old cultures and suspended in 0.01 per cent (v/v) surfactant (Tween 80, Hi Media) were utilized. The viability of conidia (> 95% germination after a 24-h incubation on Sabouraud dextrose agar

Table 1. Mortality in the poly house, mycelia growth and spore production and summary of probit analysis of selected EPFs (at 33.7- 26.7 °C Max. Mini Temp & 80.3 - 68.4 % RH.)

Treatments	Mycelial growth Dia (mm)	Spore/ µgm/ ml/10	Per cent corrected mortality over control (1 x 10^6)*			Biological efficacy index[1]	LC_{50} ($1X10^4$)	Intercept	Slope ±SE	÷2
			3 DAI	5DAI	7DAI					
P.javanicus-089	**81.0**	5.47	42.4 (40.6)	73.9 (59.3)	77.6 (61.8)	**68.7**	**0.501**	3.371	3.449±0.47	15.07
P.javanicus-102	**80.1**	5.66	38.6 (38.4)	61.7 (51.8)	81.0 (64.2)	**70.1**	**0.602**	3.624	2.589±0.53	29.5
F.moniliforme-083	76.5	**6.33**	42.0 (40.4)	76.3 (60.9)	76.7 (61.1)	66.8	0.640	3.447	2.787±0.55	38.67
P.javanicus-099	**69.7**	3.47	49.3 (44.6)	78.3 (62.2)	81.1 (64.2)	66.1	0.993	3.187	2.081±0.87	139.19
M.anisopliae-1299	64.0	3.50	**77.4 (61.6)**	**82.7 (65.4)**	**86.7 (68.6)**	66.9	0.608	3.548	2.696±0.53	43.42
B. bassiana-409	64.0	**6.99**	20.3 (26.8)	62.1 (52.0)	78.2 (62.2)	63.1	0.636	3.580	2.582±0.54	27.59
B. bassiana-4565	62.4	1.46	57.2 (49.1)	76.6 (61.1)	**89.9 (71.5)**	67.6	0.615	3.595	2.638 ±0.53	10.83
B. bassiana-4511	59.3	**6.53**	**75.0 (60.0)**	**88.6 (70.3)**	**95.1 (77.2)**	**69.8**	**0.546**	3.497	3.00 ±0.49	146.08
B. bassiana-6097	51.7	4.39	23.6 (29.1)	64.4 (53.4)	81.7 (64.7)	60.1	5.771	3.377	1.173±1.38	147.07
B. bassiana-4543	50.3	5.86	67.4 (55.2)	**80.0 (63.4)**	**85.4 (67.5)**	61.6	0.978	3.312	1.691±0.99	315.96
SD at (p-0.05)			11.972	6.053	5.039					
Variance			143.326	36.638	25.387					

* figure in parenthesis are arcsign transformed values

[1] Biological efficacy index (BI)= mycelia growth (mm), sporulation (conidia 1 x 10^8); nymphal mortality 7 DAI (%); BI = 37* (MG) + 13 (SP) + 50 (MO at 5 DAI)

(SDYA) medium) was confirmed before the onset of bioassay.

For screening the virulence of entomopathogenic fungal strains a new modified poly house bioassay method described by Sain *et. el.,* (2017) was used. One month old potted plants (4-5 fully expanded leaves) were kept in whitefly rearing poly house containing whitefly infested plants (30-40 nymphs/leaf) for egg laying. After 24 hours whitefly adults were removed from the potted plants using the air pressure of commercial hand sprayer gently and transferred in an another nethouse aseptically for next 10 days. Subsequently, 10 days after post egg laying the number of nymphs was recorded before inoculation and marked on the leaf with water proof marker. Conidial suspension (1 x 10^7/ml) was applied to nymphs with a commercial hand sprayer at a volume of 10 ml/ plant (2 ml/leaf) in the poly house having relative humidity of around 75 per cent and temperature 30 ± 2°C. Control leaves were sprayed with 0.02 per cent Tween 80 solution only. One replicate comprised of three potted plants with three leaves in each plant. The mortality was recorded using 20X hand lance at 3, 5 and 7 days after treatment. If the whitefly larvae were opaque or white greenish and shiny with eyes or visible honeydew droplets appearing on the excretions they were considered as alive while the nymphal bodies were yellowish-brown mat and shriveled were considered as dead.

The overall bioefficacy index (BI) was compared using the formula BI= 37* (MG) + 13 (SP) + 50 (MO at 5 DAI). Where, MG= mycelia growth 50mm, SP= conidia production 1 x 10^8 ; MO= mortality at 7 DAI.

Pathogenicity bioassay and Log Dose Probit Analysis : The pathogenicity of selected entomopathogenic fungal strains was determined on whitefly nymphs using five concentrations from 10^4 to 10^8 conidia/ml in three replicates. The abovementioned method was used for the bioassay. Corrected Abbott's formula was used to correct for control mortality (Abbott, 1925) before subjecting mortality data to analysis of variance (ANOVA).

$$\text{Abbott corrected mortality} = \frac{\text{(\%) mortality in treatment} - \text{(\%) mortality in control}}{\text{100} - \text{(\%) mortality in control x100}}$$

Data of selected EPFs from three replications of four concentrations were pooled and subjected to Probit analysis (Finney, 1971) and the median lethal concentration (LC50).

COMPATIBILITY STUDY

Mycelia growth inhibition and spore production: All the selected entomopathogenic fungal strains were evaluated for their compatibility with the chemical and botanical pesticides being used against whitefly in North India using poisoned food techniques (Nene and Thapliyal, 1997)(Table 2).The *in vitro* compatibility of test compounds was determined based on recommended dose and the half of the recommended dose by the poison food technique (Moorhouse *et al.*, 1992). To get desired concentration each insecticide based on field application rate/dose as well as the half dose (Table 2) was added to the melted SDYA medium (100 ml) in flask aseptically and mixed thoroughly before solidification (medium temperature

Table 2. Effect of commercials chemical pesticides and botanicals on mycelial growth of selected entomopathogenic fungi

Treatments	Mycelial growth 7 days after incoculation (mm)									Mycelial growth inhibition (%)								
	Pj-99	Ma-1299	Pj-89	Bb-6097	Fm-83	Bb-4543	Bb-4511	Pj-102	Bb-4565	Pj-99	Ma-1299	Pj-89	Bb-6097	Fm-83	Bb-4543	Bb-4511	Pj-102	Bb-4565
Neem 300 ppm (1ml/L)	65.0	24.0	23.5	67.5	70.0	92.0	35.2	25.0	59.5	**23.5**	**52.0**	**26.9**	**6.9**	**35.8**	**3.2**	68.4	**29.6**	**4.0**
Neem 300 ppm (5ml/L)	25.0	20.5	19	35.0	62.5	70.0	30.0	21.0	43.0	70.6	59.0	**9.6**	51.7	**28.2**	**26.3**	68.4	**40.8**	**30.6**
Pongamia (1ml/L)	57.5	25.0	23.0	45.0	87.5	97.5	85.0	33.0	55.0	**32.4**	55.0	**-25.0**	48.3	**10.3**	**5.3**	10.5	**7.0**	**11.3**
Pongamia (5ml/L)	27.5	22.5	32.5	37.5	74.3	90.0	65.0	22.0	55.0	67.6	50.0	**11.5**	**37.9**	**23.8**	**-2.6**	31.6	**38.0**	**11.3**
Spiromecifen (22.9 %SC) (0.5ml/L)	65.0	45.0	26.0	67.5	67.4	100.0	37.5	40.0	68.0	**23.5**	**10.0**	**0.0**	**6.9**	**30.9**	**-5.3**	60.5	**-12.7**	**-9.7**
Spiromecifen (22.9 %SC) (1 ml/L)	77.5	70.0	41.5	82.5	73.9	100.0	50.0	36.5	57.5	**8.8**	-40.0	**-59.6**	**-13.8**	**24.2**	**-5.3**	47.4	**-2.8**	**7.3**
Flonicamid (50% WG) (0.2g/L)	42.5	75.0	25.0	37.5	76.9	100.0	57.5	34.0	67.0	50.0	-50.0	**3.8**	48.3	**21.2**	**-5.3**	39.5	**4.2**	**-8.1**
Flonicamid (50% WG) (0.4g/L)	67.5	45.0	23.5	35.0	74.1	97.5	50.0	47.5	56.5	**20.6**	**10.0**	**9.6**	51.7	**24.0**	**-2.6**	47.4	**-33.8**	**8.9**
Diafenthuron (50% WP) (0.5g/L)	22.0	55.0	21.5	35.0	37.6	82.5	27.5	22.5	45.0	74.1	**-10.0**	**17.3**	51.7	61.4	**13.2**	71.1	**42.3**	**27.4**
Diafenthuron (50% WP) (1. g/L)	19.5	28.5	13.5	31.0	39.5	51.2	30.0	20.5	35.5	77.1	**43.0**	**48.1**	57.2	59.5	46.1	68.4	**42.3**	**42.7**
Buprofegin (25% SC) (0.8ml/L)	42.5	85.0	31.5	77.5	85.5	95.0	75.5	29.5	58.5	50.0	-70.0	**-21.2**	-6.9	**12.3**	**0.0**	20.5	**16.9**	**5.6**
Buprofegin (25% SC) (1.6ml/L)	67.5	40.0	26.5	37.5	79.8	90.0	60.0	30.0	57.0	**20.6**	**20.0**	**-1.9**	48.3	**18.2**	**5.3**	36.8	**15.5**	**8.1**
Pyriproxifen (10% EC) (1.25 ml/L)	65.0	40.0	26.5	35.0	64.0	82.5	50.0	30.0	49.0	**23.5**	**20.0**	**-1.9**	51.7	**34.4**	**13.2**	47.4	**15.5**	**21.0**
Pyriproxifen (10% EC) (2.5ml/L)	57.5	30.0	22.0	25.0	98.8	100.0	97.5	21.5	42.0	**32.4**	**40.0**	**15.4**	65.5	**-1.3**	**-5.3**	-2.6	**39.4**	**32.3**
Control	85	50	26	72.5	97.5	95	95	35.5	62	**23.5**	**52.0**	**26.9**	**6.9**	**35.8**	**3.2**	68.4	**29.6**	**4.0**
C.D.(P=0.05)	N/A	26.747	7.461	34.063	10.632	28.472	30.064	N/A	7.903									
SEM) ±	14.091	8.793	2.453	11.198	3.495	9.36	9.883	5.726	2.598									

48Ë%C) to get desired concentration (De Olivera and Neves, 2004). About 25 ml of medium was then poured equally into 9 cm diameter sterile Petri dishes and allowed to solidify under laminar flow chamber. After solidification Petri plate containing the desired pesticides poisoned medium was inoculated aseptically by transferring five mm diameter SDYA disc in the center of each Petri plate by sterile cork borer from 10 days old entomopathogenic cultures (Todorova *et al.,* 1998)**.** Petri plates were sealed with parafilm and incubated at 28 ± 2Ë%C, 80 ± 5 per cent relative humidity and 12 hours photoperiod. For each treatment three replications were maintained. Pesticide unamended SDYA media served as control for comparison under the same conditions**.**

The radial growth of individual treatment and each entomopathogenic fungal strain was measured in all treatments after seven, 7 and 10 days after inoculation and compared with standard check. The percent growth inhibition of each entomopathogenic fungal strain over untreated check was estimated separately for the respective insecticides by using the following formula (Vincent, 1927) and then converted into percent compatibility: I = C – T/C x 100. Where: I = Percent growth inhibition, C = Colony diameter in control, T = Colony diameter in treatment.

Additionally, to estimate the effect of chemical and botanical pesticides on the spore production of each entomopathogenic fungal strains the conidial production was enumerated. Spore concentration was recorded by using a 5 mm disc of SDYA containing each dose of above pesticides and inoculated with individual entomopathogenic fungal strains, separately. The spore position was compared with unlamented SDYA media. The toxicity of chemicals and botanicals against entomopathogenic fungi was calculated using the formula of Alves *et al.*, (1998); T= [20 (VG) + 80 (ESP)]/100 . In this formula, values for vegetative growth (VG) and sporulation (ESP) were given in relation to control (100%). Where T = 0 to 30 (very toxic); 31 to 45 (toxic); 46 to 60 (moderately toxic); >60 (compatible).

Comparative evaluation of entomopathogenic fungi and chemicals against whitefly in field : Selected four entomopathogenic fungal formulation along with Diafenthuron (50%) WP (1. g/L), Pyriproxifen (10%) EC (2.5ml/L), *Neem* (300 ppm) (5ml/L), *L. lecanii* commercial formulation (0.1%) *WP* (2 g/L) and unsprayed and water sprayed control. Each treatment was replicated thrice in a randomized block design. The data was analyzed using the online statistical software OP State (Sheoran *et al.,* 1998). Means were separated using T- test at 5 per cent level of significance.

RESULTS AND DISCUSSION

Poly house screening of entomopathogenic strains and Log Dose Probit Analysis : The experiments conducted against whitefly nymphs following new modified poly house bioassay method with entomopathogenic fungal conidial suspension @ 1 x 10^7 conidia / ml. The observations on percent nymphal mortality were recorded at 3, 5 and 7 days after post inoculation using Abbotts corrected formula. Among the top 10 entomopathogenic fungi, the highest nymphal mortality was recorded in Bb-

4511 (95.1%) (*B. bassiana*) followed by Bb-4565 (89.9%) (*B. bassiana*) and Ma-1299 (86.7%) (*M. anisopliae*) at 33.7- 26.7 ^{O}C Max. Mini Temp & 80.3 - 68.4 % RH. However, local isolated showed faster and more mycelial growth compared to the others. However, the highest suitability based on overall biological efficacy was found to be the best in Pj 102 (70.1) followed by Bb 4511 (69.8) and Pj 089(68.7) (Table 1). The lowest LC_{50} was recorded with Pj 089 (0.501 x 10^4) followed by Bb 4511 (0.546 x 10^4) and Pj 102 (0.602 x 10^4). However, the comparison based on biological efficacy index (BI) the entomopathogenic strain namely Pj 102 (70.1) followed by Bb 4511 (69.8) and Pj 089 (68.7) were found to be superior over others (Table.1).

Similarly, the isolates of *B. bassiana* and *I. fumosorosea* were reported to be the most virulent against nymphs (71–86% mortality within 8 d), with LT_{50} values ranging from 3 to 4 d after post treatment with 10^7 conidia/ml (150 conidia/mm^2) (Mascarin *et al.,* 2013a). These applications have been successful in cases where environmental conditions of high relative humidity and moderate temperatures are appropriate (Fransen *et al.,* 1987; Chandler *et al.,* 1994). Several workers have reported that biopesticides provide good control of whitefly both in greenhouse and field crops. *B. bassiana* cause mortality from 76.7 to 91.6 per cent of whitefly *B. tabaci* nymphs ((Faria and Wraight, 2001; Liu and Stansly, 2000) and upto 100 per cent adults at 1 mg/ml (Zaki 1998). Average nymphal mortality of *B. tabaci* biotype B at day seven post spray can at maximum value of 25.7 per cent and average mortality at day 14 post sprays varied from 6.1 to 92.3 per cent in a melon leaves bioassay method has been reported (Vicentini *et al.,* 2001). Different isolates of *B. bassiana* at the concentration of 10^7 on the fourth instar nymphs gave 3-85 per cent mortality (Quesada-Moraga *et al.,* 2006).

Thus it is important to consider all the biological efficacy parameters for screening the virulent isolates of entomopathogens as well as their pesticide compatibility study should be carried out to develop an effective IPM system.

COMPATIBILITY STUDY

Mycelial growth inhibition: It is well understood that insecticides have potential to affect the various developmental stages of insects as well as entomopathogenic fungi. All tested insecticides showed varying degree of potential to inhibit or enhance growth and conidial production of selected entomopathogenic fungi. The data in Table 2 showed that the lowest mycelial growth inhibition of Pj 99 was recorded with full rate of Spiromecifen, followed by full dose of Buprofegin and half dose of Pyriproxifen. Lowest mycelial growth inhibition of Ma 1299 was recorded with half dose of Buprofegin, half dose of Flonicamid and full dose of Spiromecifen. Lowest mycelial growth inhibition of Pj 89 was recorded with full dose of Spiromecifen, half dose of Pongamia oil and half dose of Buprofegin. Lowest mycelial growth inhibition of Bb 6097 was recorded with full dose of Spiromecifen, half dose of Buprofegin followed by half dose of neem oil and half dose of Spiromecifen. In case of Fm 83 the lowest mycelial growth inhibition was recorded with full dose of Pyriproxifen, half dose of Pongamia, and half dose of Buprofegin. The lowest inhibition of Bb 4543 was recorded with full dose of Pyriproxifen, full and half dose of

Spiromecifen. The Bb 4511 was most compatible in terms of mycelial growth with full dose of Pyriproxifen, half dose of Pongamia oil and half dose of Buprofegin. The Pj 102 was most compatible with full dose of Flonicamid, half and full dose of Spiromecifen. Bb 4565 showed most compatibility with half dose Spiromecifen, half dose of Flonicamid and half dose of *neem* oil.

Spore production : The data in Table 3 showed that the almost all test chemicals showed the reduction of conidial production irrespective to the fungal strains. However, highest conidia production (10^7) of Pj 99 was recorded with half dose of Spiromecifen, followed by half dose of neem oil, half dose of Pongamia oil and Flonicamid. highest conidia production of Ma 1299 was recorded with full dose of Spiromecifen, full dose of Diafenthuron and full dose of Pyriproxifen. The highest conidia production of Pj 89 was recorded with half dose of Diafenthuron, half dose of Spiromecifen, and half dose of Flonicamid. Highest conidial concentration of Bb 6097 was recorded with half and full dose of Flonicamid, full dose of Diafenthuron. In case of Fm 83 the highest conidia production was recorded with half and full dose of Diafenthuron, and half dose of Spiromecifen. The highest conidial concentration of Bb 4543 was recorded with half and full dose of Buprofegin and half dose of Diafenthuron. The conidia production of Bb 4511 was highest in half dose of Buprofegin and neem oil and Pongamia oil. The Pj 102 showed highest conidial production in full dose and half dose of Spiromecifen and half dose of neem oil. Bb 4565 showed highest conidial production with half dose Diafenthuron, half and full dose of Pyriproxifen.

Variations in toxicity response of entomopathogenic fungi from synergistic,

Table 3.: Effect of commercials chemical pesticides and botanicals on spore production of selected entomopathogenic fungi

Treatments	Spore production/10 mm disc (1×10^7)								
	Pj 99	Ma 1299	Pj 89	Bb 6097	Fm 83	Bb 4543	Bb 4511	Pj 102	Bb 4565
Neem 300 ppm (1ml/L)	42.4	36.0	15.2	48.0	30.0	12.8	40.0	43.2	19.6
Neem 300 ppm (5ml/L)	40.4	29.2	10.8	20.4	21.2	9.6	23.2	36.8	14.0
Pongamia (1ml/L)	42.0	30.8	14.4	61.6	29.6	12.8	38.8	35.2	18.0
Pongamia (5ml/L)	41.2	28.4	11.2	21.2	26.0	12.4	32.4	28.8	18.0
Spiromecifen (22.9 %SC) (0.5ml/L)	43.6	34.4	20.0	55.2	50.8	22.8	36.8	56.0	18.0
Spiromecifen (22.9 %SC) (1 ml/L)	38.8	54.0	16.0	58.4	34.0	24.4	32.0	53.6	12.4
Flonicamid (50% WG) (0.2g/L)	42.0	36.8	16.4	73.6	42.8	20.0	33.6	32.4	18.4
Flonicamid (50% WG) (0.4g/L)	32.8	37.2	13.2	67.6	44.8	15.6	24.8	22.8	18.8
Diafenthuron (50% WP) (0.5g/L)	38.0	38.8	24.4	42.0	56.8	32.4	40.0	31.6	36.4
Diafenthuron (50% WP) (1. g/L)	36.4	44.4	11.6	65.6	52.8	22.4	29.6	28.8	19.6
Buprofegin (25% SC) (0.8ml/L)	29.6	38.4	15.2	56.8	41.2	37.6	42.4	30	19.2
Buprofegin (25% SC) (1.6ml/L)	26.0	30.4	12.4	42.0	31.6	32.8	37.2	34.8	17.6
Pyriproxifen (10% EC) (1.25 ml/L)	32.0	28.4	15.6	57.6	50.4	16.8	28.0	37.2	30.0
Pyriproxifen (10% EC) (2.5ml/L)	38.0	40.4	10.8	56.4	42.0	13.2	23.2	36.0	30.0
Control	50.8	50.4	26.4	94.8	52.4	44.0	50.8	54.4	57.2
C.D.(P=0.05)	12.6	8.694	4.754	14.524	9.811	8.264	9.237	11.77	7.222
SEM) ±	4.443	3.066	1.677	5.121	3.459	2.914	3.257	4.149	2.547

antagonistic or neutral to insecticides. Previous findings of Mietkiewski and Gorski (1995) and Gupta *et al.*, (1999), Hassan and Charnley (1989) have also reported inconsistent interaction between fungus and insecticides. Thus, the toxicity index was calculated and the data recorded in the in the present study showed that the entomopathogenic fungal strain namely, Pj 99, Pj 102, Ma 1299 were found to be the most compatible with full and half dose of the chemical and botanicals tested in the present study (Table 4). Thus, the compatible entomopathogenic fungal strains along with pesticides could be simultaneously used with entomopathogenic fungi for integrated pest management.

Previous study showed that chlorpyriphos 20 EC was less toxic to *B. bassiana,* while, spinosad (45 % SC), econeem (1%), quinalphos (25 EC), acetamprid (20%), endosulfan (35 EC) and thiodicarb (75 WP) were slightly toxic. Imidacloprid (17.80% SL) and triazophos (40 EC) were moderately toxic and profenofos (50 EC), indoxacarb (14.5 % EC) and methyldemeton were highly toxic (Amutha *et al.,* 2010). Lorsban was reported to be the most toxic insecticide to mycelial growth and conidial germination followed by Lannate, Larvin and Pirate. Cascade, Match, Steward and Proclaim were comparatively less toxic to mycelial growth (36.78-48.67% inhibition) and conidial germination (40.32-49.97% inhibition) of the *M. anisopliae* and *P. fumosoroseus*. Conversely, Runner, Capture, Abamectin and Curacron were compatible with significantly lesser inhibition in growth (25.19-36.47%) and conidial germination (27.78-43.66%) of the fungi. Tracer was found safe to conidial germination and growth of the fungi (Muhammad *et al.,* 2010). Faraji *et al.,* (2016) have reported that Spinosad was most compatible *B. bassiana* and *M. anisopliae,* however Abamectin, imidachloprid and deltametrin were compatible with *B. bassiana* and half concentration of Deltametrin, abamectin and hexafloron with *M. anisopliae. Similarly,* James and Elzen (2001), Alizadeh *et al.,* (2007) and Singh *et al.,* (2014) had recorded imidacloprid to have no negative effect on *B. bassiana.*

Comparative field study : The results of the field trial (Table 6) showed that the entomopathogenic fungal strain and chemical treatments were significantly superior in terms of nymphal mortality in field conditions. The highest nymphal mortality 7 days after spray was recorded with *B. bassiana* 4511 (93.65%) followed by *P. javanicus* 102 (91.78%) which were significantly superior than Diafenthuron 50% WP (1. g/L) and *neem* oil (300 ppm) and commercial formulation of *L. lecanii (*0.1% WP) .

The results of the present study demonstrated that while screening the bioefficacy of entomopathogenic fungi for a sustainable and successful integrated pest management a thorough bioefficacy and compatibility study should be conducted. If the entomopathogenic strains are found to be with better bioefficacy in term of insect mortality along with mycelial growth and sporulation they should also be evaluated for their compatibility with the recommended insecticides for a particular IPM programme. If the selected entomopathogenic fungal strains are found compatible with either full or reduced dose of these chemical components of IPM then these could be used with pesticides in integrated pest

Table 4. "T" values and compatibility classification of chemical and botanical insecticides, in relation of fungitoxic effect on selected strains of entomopathogenic fungi

Treatment	T value and compatibility of test chemicals with EPF strains[1&2]																	
	Pj 99		Ma 1299		Pj 89		Bb 6097		Fm 83		Bb 4543		Bb 4511		Pj 102		Bb 4565	
Neem 300 ppm (1ml/L)	82.07	**C**	66.74	**C**	64.14	C	59.13	MT	60.16	C	42.64	**T**	70.40	C	77.61	**C**	46.61	**MT**
Neem 300 ppm (5ml/L)	69.50	**C**	54.55	**MT**	47.34	MT	26.87	VT	45.19	**T**	32.19	**T**	42.85	**T**	65.95	**C**	33.45	**T**
Pongamia (1ml/L)	79.67	**C**	58.89	**MT**	61.33	C	64.40	C	63.14	C	43.80	**T**	79.00	C	70.36	**C**	42.92	**T**
Pongamia (5ml/L)	71.35	**C**	54.08	**MT**	58.94	MT	28.24	VT	54.93	MT	41.49	**T**	64.71	C	54.75	**MT**	42.92	**T**
Spiromecifen (22.9 %SC) (0.5ml/L)	83.96	**C**	72.60	**C**	80.61	C	65.20	C	91.38	C	62.51	C	65.85	C	104.89	**C**	47.11	**MT**
Spiromecifen (22.9 %SC) (1 ml/L)	79.34	**C**	113.71	**C**	80.41	C	72.04	C	67.06	C	65.42	C	60.92	C	99.39	**C**	35.89	**T**
Flonicamid (50% WG) (0.2g/L)	76.14	**C**	88.41	**C**	68.93	C	72.45	C	81.11	C	57.42	MT	65.02	C	66.80	**C**	47.35	**MT**
Flonicamid (50% WG) (0.4g/L)	67.54	**C**	77.05	**C**	58.08	MT	66.70	C	83.60	C	48.89	MT	49.58	MT	60.29	**C**	44.52	**T**
Diafenthuron (50% WP) (0.5g/L)	65.02	**C**	83.59	**C**	90.48	C	45.10	**T**	94.44	C	76.28	C	68.78	C	59.15	**MT**	65.43	**C**
Diafenthuron (50% WP) (1. g/L)	61.91	**C**	81.88	**C**	45.54	**T**	63.91	C	88.71	C	51.51	MT	52.93	MT	53.90	**MT**	38.86	**T**
Buprofegin (25% SC) (0.8ml/L)	56.61	**MT**	94.95	**C**	70.29	C	69.31	C	80.44	C	88.36	C	82.67	C	60.74	**C**	45.72	**T**
Buprofegin (25% SC) (1.6ml/L)	56.83	**MT**	64.25	**C**	57.96	MT	45.79	**T**	64.60	C	78.58	C	71.21	C	68.08	**C**	43.00	**T**
Pyriproxifen (10% EC) (1.25 ml/L)	65.69	**C**	61.08	**C**	67.66	C	58.26	MT	90.07	C	47.91	MT	54.62	MT	71.61	**C**	57.76	**MT**
Pyriproxifen (10% EC) (2.5ml/L)	73.37	**C**	76.13	**C**	49.65	MT	54.49	MT	84.38	C	45.05	**T**	57.06	MT	65.05	**C**	55.51	**MT**
Control	100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00		100.00	

Formula proposed by Alves *et al.* (1998).[2] T = VT 0 to 30 (very toxic); T- 31 to 45 (toxic); MT 46 to 60 (moderately toxic); C >60 (compatible).

Table 6. Effect of selected entomopathogenic fungal strains and pesticides on whitefly nymphal mortality (mean ± S.E.) under field conditions

Treatments	Per cent Abbott corrected nymphal mortality over control (1 x 10^6)*		
	3 DAI	5 DAI	7 DAI[@]
Diafenthuron (50% WP) (1. g/L)	31.27 (32.16) ± 9.97	45.80 (41.89) ± 10.95	72.57 (60.51)[bcd] ± 10.64
Pyriproxifen (10% EC) (2.5ml/L)	23.53 (28.75) ± 3.60	54.78 (47.78) ± 5.58	86.86 (68.78)[a b] ± 0.99
Neem 300 ppm (5ml/L)	18.76 (24.04) ± 7.051	27.65 (29.23) ± 10.58	77.92 (62.18)[bc] ± 2.92
L. lecanii commercial formulation *(0.1% WP)* (2 g/L)	16.06 (23.27) ± 3.319	42.86 (40.71) ± 5.41	60.66 (51.24)[d] ± 3.68
P. javanicus 102	26.31(29.84) ± 6.725	65.28 (53.93) ± 1.59	**91.78 (73.41)[ab] ± 1.07**
M. anisoplii 1299	44.27 (41.53) ± 5.515	44.57 (38.16) ± 16.43	86.13 (69.86)[a b] ± 6.86
F. moniliformae 083	22.49 (22.76) ± 15.14	45.33 (41.92) ± 7.96	81.41 (65.29)[ab] ± 5.45
B. bassiana 4511	43.62 (41.24) ± 7.18	62.41 (53.14) ± 8.66	**93.65 (75.68)[ab] ± 2.10**
Water spray	11.71 (19.63) ± 3.04	9.767 (17.61) ± 3.49	14.71 (21.34) ± 5.60
C.D. (p=0.05)	N/A	N/A	13.461
SE(m)	7.377	7.474	4.452
SE(d)	10.433	10.57	6.296
C.V. %	43.687	31.977	12.656

* figure in parenthesis are arcsign transformed values

[@]Means followed by different letters within each column are significantly different (P=0.05) from control treatment

management programs. Combination of compatible and or sub-lethal concentrations of chemical/botanical insecticides and entomopathogenic fungi can cause increased stress, immunocompromise, and alteration in insect physiology and behavior leading to improved performance in an integrated insect-control programs that include a better biological component (Pelizza *et al.,* 2015)

The results of this research suggest that pesticides were not compatible with all the effective entomopathogenic strains. However, *P. javanicaus* strains Pj- 99, Pj-102, *M. anisopliae strain* Ma-1299 were found to be more compatible with full and half doses of all the tested chemicals. Moreover, all strains of *B. bassiana* showed varying level of compatibility with respect the chemicals and their doses. These *in vitro* studies expose the entomopathogenic to the maximum action of the pesticides that usually do not happen under field conditions. However, the study indicate the great scope of the best virulent and compatibility entomopathogenic fungal strains have the maximum likelihood for successful Integrated pest management of *B. tabaci* under field. The further experiments under field conditions for evaluating the efficacy of these entomopathogenic fungi in combination with chemical pesticides are recommended.

REFERENCES

Alizadeh, A., Samih, M. A., Khezri, M. & Saberi, R. 2007. Compatibility of *Beauveria bassiana* (Bals.) Vuill. with several pesticides. *Internat. Jour. Agri. Bio.* **9:** 31-34.

Alves, S.B., Moino, Jr. A., Almeida, J.E.M. 1998. Produtos fitossanitários e entomopatógenos. In: Alves SB, ediotor. Controle microbiano de insetos. *Fealq: São Paulo.* 217-238.

Ambethar, V. 2009. Potential of entomopathogenic fungi in insecticide resistance management (IRM): A review. *J. Biopestic.* **2** : 177-93.

Amutha, M., Gulsar Banu, J., Surulivelu T. and Gopalakrishnan, N. 2010. Effect of commonly used insecticides on the growth of white Muscardine fungus, *Beauveria bassiana* under laboratory conditions. *J. Biopesticides.* **3**: 143 - 46

Anderson, T.E., Hajek, A.E., Roberts, D.W., Preisler, K. and Robertson, J.L. 1989. Colorado potatobeetle (Coleoptera: Chrysomelidae): Effects of combinations of *Beauveria bassiana* with insecticides. *J. Econ. Entomol*., **82 :** 83-89.

Asi, M.A., Bashir, M.H., Afzal, M., Ashfaq, M. and Sahi, S.T. 2010. Compatibility of entomopathogenic fungi, *Metarhizium anisopliae* and *Paecilomyces fumosoroseus* with selective insecticides. *Pak. J. Bot.*, **42:** 4207-14

Barro, P.J.D., W. Liebregts and Carver, M. 1998. Distribution and identity of biotypes of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) in member countries of the Secretariat of the Pacific Community. *Australian J. Entomol.* **37:** 214–18.

Basit, M., Saeed, S., Saleem, M. A., Denholm, I. and Shah, M. 2013. Detection of resistance, cross-resistance, and stability of resistance to new chemistry insecticides in *Bemisia tabaci* (Homoptera: Aleyrodidae). *J. Econ. Entomol.* **106**: 1414–22

Boman, H.G. 1980. Insect responses for microbial infections. In: *Microbial control of pests and plant diseases*. (Ed.): H.D. Burges. Academic Press, New York. pp. 769-44.

Borisade, O.A. and Mahan, N. 2015. Resilience and relative virulence of strains of entomopathogenic fungi under interactions of abiotic and stress. *African J. Microbio. Res.* **9** : 988-1000

Brown, J., Frohlich, D. and Rosell, R. 1995. The sweetpotato or silverleaf whiteflies: biotypes of *Bemisia tabaci* or a species complex? *Annu. Rev. Entomol.* **40:** 511–34.

Cahill, M., Groman, K., Day, S., Denholm, I., Elbert, A. and Nauen, R.1996. Baseline determination and detection of resistance to imidacloprid in *Bemisia tabaci* (Homoptera:Aleyrodidae). *Bull. Ento. Res.* **86** : 343-49.

De Olivera, R.C. and Neves, P.M.O.J. 2004. Biological control compatibility of *Beauveria bassiana* with acaricides. *Neotropical Entomol.*, **33**: 353–58.

Dittrich, V., and Ernast, G.H.1983. The resistance pattern in white flies of Sudanese cotton. *Mitteilumgen der Deutschen Gesellschatt Fuir Allgemeine and Augewandte and Entomologie* **4**: 96-97

Duarte, A., Menendez, J.M. and Trigueiro, N. 1992. Estudio preliminar sobre la compatibilidad de *Metarhizium anisopliae* com algunos plaguicidas quimicos. *Revista Baracoa*, 22: 31-39.

Faraji, F., Shadmehri, A.D. and and Mehrvar, A.. 2016. Compatibility of entomopathogenic fungi *Beauveria bassiana* and *Metarhizium anisopliae* with some pesticides. Journal of Entomological Society of Iran. **36 :** 137 - 46.

Faria, M and Wraight, S.P. 2001. Biological control of *Bemisia tabaci* with fungi. *Crop Protect* **20**:767–78.

Finney, D. J. 1971. *Probit analysis*, 3rd edn. Cambridge University Press, 333 pp

Gupta, P., M.S. Paul and S.N. Sharma. 1999. Studies on compatibility of white muscardine fungus *Beauveria bassinia* with *neem* products. *Indian Phytopathol.*, **52** : 278-80.

Hassan, A.E.M. and Charnely, A.K. 1989. Ultrastructural study of the penetration by *Metarhizium anisopliae* through dimilin affected cuticle of *Mandusa sexta. J. Invertebr. Pathol.*, 54 : 117-24.

Hassan, S. A. 1989. Testing methodology and the concept of the IOBC/WPRS working group. **In:** *Pesticides and Non-Target Invertebrates* (P.C.Jepson, ed.), Intercept, Wimborne, Dorset 1-8 pp.

Horowitz, A.R. and Ishaaya, I. 2014. Dynamics of biotypes B and Q of the whitefly *Bemisia tabaci* and its impact on insecticide resistance. *Pest Manag Sci.* (wileyonlinelibrary.com) DOI 10.1002/ps.3752

Jahan, S.M. H., Lee, G., Lee, S. and Lee, K. 2014. Acquisition of Tomato yellow leaf curl virus enhances attraction of *Bemisia tabaci* to green light emitting diodes. *Jour. Asia Pacific Ent.* **17** :79-82.

James, R. R. and Elzen, G. W. 2001. Antagonism between *Beauveria bassiana* and imidacloprid when combined for *Bemisia argentifolii* (Homoptera: Aleyrodidae) control. *Jour. Eco. Ento.* **94** : 357-61.

Kranthi, K. R., Jadhav, D. R., Kranthi, S., Wanjari, R. R., Ali, S. and Russell, D. 2002. Insecticide resistance in five major insect pests of cotton in India. *Crop Protection* **21**: 449-60.

Kranthi, K.R. 2014. *Cotton Leaf Curl Virus Time Bomb.* Cotton Statistic and News. No. 04 22nd April, 2014

Lacey, L.A., Fransen, JJ, and Carruthers, R. 1995. Global distribution of naturally occurring fungi of *Bemisia,* their biologies and use as biological control agents. In: Gerling D, Andover H (Eds) *Bemisia*: *Taxonomy, biology, damage, control and management.* Intercept Ltd, UK, pp 401–433

Lacey, L.A., Grzywacz, D., Shapiro-Ilan, D.I., Frutos, R., Brownbridge, M., and Goettel, M.S. 2015. Insect pathogens as biological control agents: Back to the future. *Jour. Invert. Path.* **132** : 1–41

Lacey, L.A., Wright, S.P. and Kirk, A.A. 2008. Entomopathogenic fungi for control of Bemisia tabaci biotype B: foreign exploration, research and implementation. In: Gould, J., Hoelmer, K., Goolsby, J. (Eds.), Classical Biological Control of *Bemisia tabaci* in the United States – A Review of Interagency Research and Implementation. *Progr. Biol. Control,* **4**: 33–69.

Liu, T.-X. and Stansly, P.A., 2000. Insecticidal activity of surfactants and oils against silverleaf whitefly (*Bemisia argentifolii*) nymphs (Homoptera: Aleyrodidae) on collards and tomato. *Pest Manag. Sci.* **56**: 861–66.

Longhurst, C., Babcock, J.M., Denholm, I., Gorman, K., Thomas, J.D. and Sparks, T.C. 2013. Cross-resistance relationships of the sulfoximine insecticide sulfoxaflor with neonicotinoids and other insecticides in the whiteflies *Bemisia tabaci* and *Trialeurodes vaporariorum. Pest Manag Sci.* **69 :** 809–13.

Malo, A.R. 1993. Estudio sobre la compatibilidad del hongo *Beauveria bassaina* (Bals.) Vuill. con formulaciones comerciales de fungicidas e insecticidas. *Revista Colombiana de Entomologia,* **19:** 151-58.

Meitkiewski, R. and R. Gorski. 1995. Growth of selected entomopathogenic fungi species and isolates on media containing insecticides. *Acta. Mycol.*, **30 :** 27-33.

Moino Jr., A.R. and Alves, S.B. 1998. Efeito de Imidacloprid e Fipronil sobre Beauveria bassiana (Bals.) Vuill. E Metharhizium anisopliae (Metsch.) Sorok. e no comportamento de limpeza de *Heterotermes tenuis* (Hagem). *Anais da Sociedade Entomológica do Brasil,* **27**: 611-19.

Monga, D. 2014. *Cotton Leaf Curl Virus diseases*. Central Institute for Cotton Research, Regional Station, Sirsa -125055, India. Page 34

Moorhouse, E. R., Gillsepie, A. T., Sellers, E. K and. Charnley, A. K. 1992. Influence of fungicides and insecticides on the entomogenous fungus, *Metarhizium anisopliae*, a pathogen of the vine weevil, Otiorhynchus sulcatus. *Bio. Sci. Tech.*, **82**: 404 - 07.

Nene Y.L. and Thapliyal P.N. 1997. *Fungicides in plant disease control*. Oxford & IBH Publishers, New Delhi.

Palumbo, J.C., Toscano, N.C., Blua, M.J. and Yoshida, H.A. 2000. Impact of *Bemisia* whiteflies (Homoptera: Aleyrodidae) on alfalfa growth, forage yield, and quality. *J. Eco. Ento.* **93** :1688-94.

Pelizza , S. A., Scorsetti, A. C., Fogel, M. N., Pacheco-Marino, S. G., Stenglein, S. A., Cabello, M. N. and Lange, C. E. 2015. Compatibility between entomopathogenic fungi and biorational insecticides in toxicity against *Ronderosia bergi* under laboratory conditions. *Biocontrol* **60** : 81-91.

Picó, B., Díez, M. J. and Nuez, F. 1996. Viral diseases causing the greatest economic losses to the tomato crop. II. The Tomato yellow leaf curl virus: A review. *Scientia Horticulturae* **67 :**151-96.

Polston, J.E., De Barro, P. and Boykin, L.M. 2014. Transmission specificities of plant viruses with the newly identified species of the *Bemisia tabaci* species complex. Pest Management Science **70** : wiley online library.com) DOI 10.1002/ps.3738

Prasad, V. D., Bharati. M. and Reddy, G .P. V. 1993. Relative resistance to conventional insecticides three populations of cotton whitefly *Bemisia tabaci* (Genn.) in Andhra Pradesh. *Ind. Jour. Plant Prot.* **21** : 102-03.

Quesada-Moraga, E., Maranhão, E.A., Valverde-Garcia, P., Santiago-Álvarez, C. 2006. Selection of *Beauveria bassiana* isolates for control of the whiteflies *Bemisia tabaci* and *Trialeurodes vaporarium* on the basis of their virulence, thermal requirement and toxicogenic activity. *Biol. Control.* **36**, 274–87.

Rossi-Zalaf, L. S., Alves, S. B., Lopes, R. B., Silveira- Neto, S., and Tanzini, M. R. 2008. Interação de microrganismos com outros agentes de controle de pragas e doenças, pp. 279-302 *In* S. B. Alves and R. B. Lopes [eds.], Controle microbiano de pragas na América Latina: avanços e desafios. FEALQ Piracicaba 1163 pp.

Sain, S.K., Monga, D., Rishi Kumar, Nagrale, D., and Kranthi, S. 2017. Studies to identify most virulent strains of entomopathogenic fungi for microbial control of sweetpotato whitefly (*Bemisia tabaci*) infesting cotton in North India. *Book of Abstracts 7th Asian Cotton Research & Development Network Meeting*, Held at Nagpur from 15-17 September, 2017.

Scorsetti A. C., Gregorio C. De and Lo´pez Lastra C. C.. 2008. New records of entomopathogenic fungi infecting *Bemisia tabaci* and *Trialeurodes vaporariorum*, pests of horticultural crops, in Argentina. *Bio Control* **53**:787–96.

Sheoran, O.P., Tonk, D.S., Kaushik, L.S., Hasija, R.C., Pannu, R.S., 1998. Statistical Software Package for Agricultural Research Workers. In: Hooda, D.S., Hasija, R.C., (Eds.), *Recent Advances in information theory, Statistics and Computer Applications.* Department of Mathematics Statistics, CCS HAU, Hisar, India, pp.139-43.

Singh, R. K., Vats, S., Singh, B. 2014. Compatibility Analysis of Entomopathogenic Fungi *Beauveria bassiana* (NCIM No-1300) With Several Pesticides. *Res. Jour. Pharma., Biol. Chem. Sci.* **5** : 837-44.

Todorove, S.I., Coderre, D., Duchesne, R.M. and Côté, J.C. 1998. Compatibility of *Beauveria bassiana* with selected fungicide and herbicides. *Environ. Entomol.*, **27:** 427–33

Vanninen, I. and H. Hokkanen. 1988. Effects of pesticides on four species of entomopathogenic fungi. *Ann. Agri. Fenn.*, **27:** 345-53.

Vicentini, S., Faria, M., De Oliveira, R.V.M. 2001. Screening of *Beauveria bassiana* (Deuteromycotina: Hyphomycetes) Isolates against nymphs of *Bemisia tabaci* (Genn.) biotype B (Hemiptera: Aleyrodidae) with description of a bioassay method. *Neotrop. Entomol.* **30**, 97–103.

Vincent, J.M. 1927. Distortion of fungal hyphae in the presence of certain inhibitors. *Nature,* **159**: 800.

Zaki, F. N. 1998. EfÞciency of the entomopathogenic fungus, *Beauveria bassiana* (Bals.), against Aphis crassivora Koch and *Bemisia tabaci* Gennandius*. J. Appl. Entomol.* **122**: 397-99.

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Australian Lady Bird Beetle Biological aspects on Cotton Mealy bug

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ABSTRACT : The biological aspects of Australian Lady Bird Beetle on Cotton mealy bug, *Phenacoccus solenopsis* Tinsley were studied under laboratory conditions. The average incubation and total periods were 4.40 and 18.05 days, respectively. The pre-pupal, pupal and total development periods were 2.30, 8.95 and 32.75 days, respectively. The pre-oviposition, oviposition and post oviposition periods were 7.40, 45.70 and 7.60 days, respectively. Males lived longer than females with life cycle duration of 99.20 and 93.10 days, respectively. The mean fecundity was 99.70 eggs per female and sex ratio (Male : female) was 1:1.25. The per cent hatchability and adult emergence observed were 80 and 90, respectively.

Key words : Biology, Australian Lady Bird Beetle, *Phenacoccus solenopsis*

The management of Solenopsis mealy bug is difficult due to wide host range, presence of waxy coating on body and high reproductive potential. The use of biocontrol agents like Parasitoids, predators and pathogens play an important role in the management of insect pests, the use of which became popular as they are non-toxic. Among the predators, coccinellids check mealybugs, scales, aphids, coccids, aleyrodids etc. (Mani and Krishnamoorthy, 1997). The predator, *Cryptolaemus montrouzieri* Mulsant naturally controls the mealybug population. The information regarding biology of *C. montrouzieri* on the cotton mealybug, *P. solenopsis* is very scanty and hence present study was undertaken.

MATERIALS AND METHODS

The present investigation were carried out in the Bio-control laboratory, Department of Entomology, College of Agriculture, Junagadh Agricultural University, Junagadh during *Kharif* 2010. The mealybug *P. solenopsis* collected from infested cotton field and mass multiplied on sprouted potato and pumpkin. The culture of *C. montrouzieri* was obtained from NBAII, Bangalore and maintained on different instar nymphs of the mealybug. Newly emerged 10 male and female pairs were confined into transparent plastic container (9-11 cm) closed with muslin cloth. The mealybugs along with cotton leaves were provided to the pairs as food. The pairs were observed for their pre-ovipositon, oviposition, post-oviposition, fecundity and longevity. Total life cycle and adult longevity of both sexes were also calculated. Time taken from egg laying to hatching, duration of larval stages pre-pupal and pupal stages and sex ratio were recorded. Mean and standard error for all these biological parameters were worked out. Statistical analysis of data was done by the analysis of variance technique given by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

The results on biological parameters (Table 1) revealed that incubation period, durations of 1st, 2nd, 3rd and 4th instar grubs and total grub period were 4.40±0.88, 2.90±0.79, 4.85±0.88, 6.45±0.83 and 3.85±0.75 and 18.05±2.04 days, respectively. The pre-pupal period, pupal period and total developmental period recorded were 2.30±0.73, 8.95±1.05 and 32.75±3.58 days, respectively. Pre-oviposition, ovipositon and post oviposition periods were 7.40±0.70, 45.70±1.49 and 7.60±0.70 days, respectively. The longevity of male and female were 66.60±1.35 and 60.50±1.58 days, respectively, and males lived longer than females. The life cycle was completed within 99.20±1.55 and 93.10±1.85 days by males and females, respectively. Mani and Krishnamoorthy (1997) reported the incubation period of 4 to 6 days. Rao and David (1958) revealed that total grub period of the predator was 14 to 16 days, and pre-pupal and pupal periods were 2-3 and 7-9 days, respectively on *M. hirsutus*. Kaur *et al.* (2010) reported that pre-oviposition, ovipositon and post oviposition period of *C. montrouzieri* on *P. solenopsis* was 7.23±0.13, 46.75±2.17 and 7.80±0.47 days, respectively and the longevity of male and female was 68.30±2.85 and 61.78±2.16 days respectively. Thus, the present findings are in close agreement with those recorded by earlier workers.

The data on values of biological parameters of *C. montrouzieri* (Table 2) revealed that fecundity of *C. montrouzieri* was 99.70±1.70 eggs with 80 per cent fecundity. The adult emergence was 90 per cent and the male to female ratio was 1:1.25. Kaur *et al.* (2010) revealed that fecundity, hatchabilityity (%), adult emergence (%) and male to female sex ratio of *C. montrouzieri* on *P. solenopsis* was 98.15±7.32, 79.00±1.03, 88.50±1.06 and 1:1.36 respectively.

Table 1. Biological parameters of *C. montrouzieri* on *P. solenopsis* under laboratory conditions.

Sr. No.		Biological parameters duration (days)	
		Range	Mean
1	Incubation period	3-6	4.40±0.88
2	**Grub Period**		
3	First instar	2-4	2.90±0.78
4	Second instar	3-6	4.85±0.88
5	Third instar	5-7	6.45±0.83
6	Fourth instar	3-5	3.85±0.75
7	Total grub period	13-21	18.05±2.04
8	Pre-pupal period	1-3	2.30±0.73
9	Pupal Period	7-10	8.95±1.05
10	Total developmental period	23-37	32.75±3.58
11	Pre-oviposition period	6-8	7.40±0.70
12	Oviposition period	42-47	45.70±1.49
13	Post oviposition period	6-8	7.60±0.70
14	**Longevity**		
	Male	64-68	66.60±1.35
	Female	58-62	60.50±1.58
15	Life cycle duration		
	Male	98-103	99.20±1.55
	Female	90-95	93.10±1.85

Table 2. Average Fecundity, hatchability adult emergence and sex ratio of *C. montrouzieri* on *P. solenopsis* under laboratory conditions.

Sr. No	Biological parameters	Mean±SE
1	Fecundity (No of Eggs)	99.70 ± 1.70
2	Hatchability (%)	80.00 %
3	Adult emergence (%)	90.00 %
4	Sex ratio (Male to Female)	1:1.25

REFERENCES

Kaur, H.Virk, J.S. and Kaur, R. (2010).. *J. Bio-Control*, **24** :123.

Mani, M. and Krishnamoorthy, A. (1997). *Madras Agric. J.*,**84** : 237.

Panse, V. G. and Sukhatme, P. V. (1985). Statistical methods for agricultural workers, ICAR, New Delhi, pp 361.

Rao, T. V. and David, L. A. (1958). *Indian J. Agnc. Sci.*, **28**: 545.

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Leaf trichome density analysis through scanning electron microscope and comparison of resistance to herbivorous insects in cotton

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ABSTRACT : This study assessed the contribution of leaf trichome density as a component of resistance to herbivores, in six species of wild and cultivated cotton. In all species of cotton plant, the trichome densities are varying in each entries and pest population also vary. In this aspect, experiments carried out to the herbivore populations against trichome density. Among population differences in leaf trichome density, relative resistance and fitness were found. Leaf trichome densities were positively correlated to resistance across herbivores populations. Trichome density affects interactions with insect herbivores, but may also affect the abundance and effectiveness of predators and parasitoids feeding on herbivores. This suggests that results are considered in the light of the adaptive role of leaf trichomes as a component of defence to herbivores and variable selection among populations.

Keywords : Defense, herbivory, leaf trichomes trichome density, wild and cultivar

Host plant resistance (HPR) is the foundation stone of Integrated Pest Management programme while other components viz., cultural, physical, mechanical and chemical control act as pillars. The physical component of trichome density plays a major role against plant herbivore insects. Leaf trichome density is considered a mechanism of defense in plants to prevent or diminish damage by herbivores (Marquis, 1992). Evidence from wild and cultivated species gives support to this ecological role (Romeis *et al.,* 1999).

Trichomes play an imperative role in plant defense against many insect pests and involve both toxic and deterrent effects (Chamarthi *et al.*, 2010). Trichome density negatively affects the ovipositional behavior, feeding and larval nutrition of insect pests (Handley *et al.*, 2005). In addition, dense trichomes affect the herbivory mechanically, and interfere with the movement of insects and other arthropods on the plant surface, thereby, reducing their access to leaf epidermis (Agrawal *et al.*, 2009. These can be, straight, spiral, hooked, branched, or un-branched and can be glandular or nonglandular (Hanley *et al.*, 2007).

The observation on trichome density has to be taken in the following six parent's *viz., Gossypium sturtianum*, *Gossypium gossypioides,* *Gossypium triphyllum, Gossypium aridum,* Co14 and RG8. The trichome studies of different plant leaves of the six species of *Gossypium* spp were studied and compared.

REVIEW OF LITERATURE

Trichomes are hairlike projection that develop from cells of the aerial epidermis and are produced by most plant species (Werker 2000). Leaf trichomes can serve several functions including protection against damage from herbivores (Levin 1973). While most plants produce trichomes constitutively, some species respond to damage by increasing trichome density in new leaves. The purpose of this paper is to review processes affecting trichome formation, and the importance of trichomes in plant resistance. We mainly focus on leaf trichomes density in response to damage caused by herbivorous insects. We begin by brieûy reviewing current understanding of the HPR mechanically regart basis of trichome formation. Based on literature data, we explore the magnitude of damage-induced increases in trichome density and types of trichomes. We then discuss the effects of density of trichome production on interactions with herbivorous insects, their natural enemies and on plant ûtness. Finally, we identify problems in need of further research for a better understanding of the functional and non-preference of trichome density in plants.

The morphology and density of leaf trichomes vary considerably among plant species, and may vary among populations and within individual plants. The structure of trichomes can range from unicellular to multi cellular, and the trichomes can be straight, spiral, hooked, branched, or un-branched (Southwood 1986; Werker 2000). In some species, individual plants produce glandular and non glandular leaf trichomes (e.g., Hare and Elle 2002; Rautio *et al.* 2002).

Insects may evolve physiological or behavioral traits that allow them to cope with structural plant defenses. For example, several mirid bugs (Heteroptera: Miridae) have special structures on their legs, which facilitate movement across trichome covered plant surfaces (Southwood 1986; van Dam and Hare 1998). The evolution of mouthparts strong enough to handle structural plant traits is thus one possible mechanism for insects to circum vent structural plant defenses such as leaf trichomes (Levin 1973; Raupp 1985).

Leaf trichomes do not only affect herbivores, but also their natural enemies. This may indirectly affect the intensity of damage caused by herbivores

The present study aimed specifically the relationship between leaf trichome density and resistance differs across populations among the wild and cultivated species of cotton and also what extent phenotypic differences are the results of resistance among wild populations.

The mechanism of resistance was studied in the selected varieties / hybrid. Trichome density had significant negative correlations with the incidence of sucking pests, ovipositional preference of *Helicoverpaarmigera* (Hubner), predation by *Chrysoperla carnea* Stephens and parasitisation by *Trichogramma chilonis* Ishii. Leaf area showed significant positive relationships with the incidence of sucking pests. Gossypol glands on calyx showed significant negative relationships with *H. armigera* larvae/plant, per cent square and boll damage.

MATERIALS AND METHODS

Scanning electron microscope (SEM) : Scanning electron microscope (SEM) is a type of electron microscope that images the sample surface by scanning it with a high energy beam of electrons. SEM is considered being the most popular of the microscopic techniques because of the ease of specimen preparation, and the general simplicity of image interpretation. The SEM (Quanta 250, FEI, Netherlands) examine any part of a 6-inch (15 cm) semiconductor wafer, and some can tilt an object of that size to 45°.The small piece of the freshly prepared matrix was placed on the stub. The stub was mounted on sample stage and the images were taken in 16,000x magnification and 10 KV. Morphological details at length scales from the visible up to a few nm can be detected by using SEM. In general, the electrons interact with the atoms of the samples that make up the sample producing signals contains information about surface topography of the sample. Furthermore, the observation must be performed in a vacuum to prevent scattering of the electrons by stray air molecules. Basically, the sample is placed into the SEM chamber and the air is pumped out of the chamber creating a vacuum. Then, high energy electrons beam is emitted by electron gun positioned at the top of the set-up which travels down the column through a series of magnetic lenses in order to focus the beam to a very fine spot. The focused beam hits the sample surface producing secondary electrons which are attracted and collected by a detector and then translated into signals. These signals are then amplified, analyzed, and translated into images for the surface topography of the sample. In the present work, the size and morphology of the electro spun fibers were investigated by a scanning electron microscope (Quanta 250, FEI, Netherlands).

Quantitative characters of taxonomic importance, as revealed by analysis of variance (ANOVA) and duncan multiple range test (DMRT) were length and width of epidermal cells, stomatal index and stomatal size. Two trichome types, glandular and non-glandular were observed in the genus.

Afzal *et al.,* 2012 reported that trichome density on leaf lamina, thickness of leaf lamina and gossypol glands on leaf lamina had significantly but negative correlation having the correlation coefficient of -0.783, -0.688 and -0.858 with the oviposition of cotton bollworm, *Helicoverpa armigera*.

Statistical analyses : The effect of trichome density on plant resistance to herbivores among and within populations was analysed using covariance analysis (ANOVA), under the null hypothesis that trichome density, the covariate, is not a plant resistance component. In the same way, the effect of leaf area on trichome density was analysed (Roy *et al.,* 1999). Differences in average values among populations in plant resistance and trichome density were obtained through Tukey Kramer HSD tests. The relationship between fitness and plant resistance, within and among populations, was analysed by means of ANOVA, where plant resistance was the covariate. The relationship between average resistance and average trichome density per population was assessed by means of a Spearman rank correlation (Sokal and Rohlf, 1995).

We estimated the selection coefficients only on resistance to herbivores following the reasoning that leaf trichome density is a putative component of resistance and correlated with it (Elle *et al.,* 1999). Data of this study indicated that relationship between trichome density and herbivore. Then a covariance analysis was performed to assess if trichome density is related to resistance. Because trichome density is correlated with resistance in 6 populations, this validates our criterion for not including trichome density in the selection analyses given the lack of independence between both traits (Mitcheli-Olds and Shaw, 1987).

Trichome density measurement : Trichome density and interaction of insect population were determined in all cotton entries. For the preference and non preferences by jassid five fully expanded uniformly sized leaves/cotton line of all lines were collected from the peak blooming staged field grown plants in the laboratory and counting numbers of trichomes density/cm² of leaf was carried out by using one cm² stopper cutter/borer to punch in a fixed area at one side of the midrib and the stopper was used for tracing on the leaf then within the one cm² the number of trichomes were counted. The process of counting trichomes was done under the microscope with the aid of 10x lens and objective on microscope 10/0.25-160/0.17 Kyowa optical Co. Ltd. Japan. Ten trichomes were selected for size measurement from the midrib of the central portion of the leaf blade. Size of trichomes was measured on Microscope (Nikon Alphaphot, Ys, Japan) by ocular micrometer in micron on 5x eyepiece and objective then converted in (mm) millimeter.

Population differentiation in trichome density : To determine possible differences among populations in leaf trichome density, wildcottons were collected fromdifferent parts of Tamil Nadu and grown in a wild species garden. The samples and cultivated were collected from this garden at randomly for trichome density analysis.

RESULTS AND DISCUSSION

Trichome density and resistance to herbivores : Populations experienced different average levels of damage (10-50% of total leaf area). In each population, all individual plants had some degree of foliar damage. In all populations, leaf damage was caused mainly by leafhopper and thrips. Trichome density varied from 3.041 to 15.429 trichomes x mm-2. ANOVA detected statistically significant

Table 1. Leaf trichome density of *Gossypium* spp. in Tamil Nadu

Name of Cotton species	No of Trichomes 400µm			No of Trichomes 300µm		
	Total tills	Branches/tills	**Total**	Total tills	Branches/tills	**Total**
Gossypium sturtianum	12	1	**12**			
Gossypium gossypioides	11	4	**44**	5	3	**15**
Gossypium triphyllum	12	10	**120**	4	10	**40**
Gossypium aridum	6	4	**24**			
Co14	6	1	**6**	4	1	**4**
RG8	18	2	**36**			

differences among populations in plant resistance to herbivores, and a significant effect of trichome density on plant resistance. Furthermore, the significant trichome density population interaction indicated that the slope for the relationship between trichome density and resistance varied among populations. In contrast, differences among populations in trichome density were not related with leaf area. In five out of six populations, a significant relationship between trichome density and plant resistance was detected and the explained variance ranged from 0.50 to 0.68. Populations I, II. IV and V showed positive relationships, whereas population VI had a concave downward relationship between leaf trichome density and resistance. Multiple comparisons also showed differences in trichome density and resistance among populations. Finally, population mean resistance and trichome density were highly positively correlated across populations (Fig. L *R5* = 0.83, *n* = 6, *P* = 0.0416).

Significant among population variation in both leaf trichome density and plant resistance to herbivores coupled with the association of trichome density with resistance in most populations of *Gossypium* spp. support the expectation of a defensive role of trichomes within populations. In addition, trichome density affected plant fitness through its association with plant resistance. However, the effectiveness of leaf trichome density varied among populations. Directional selection of phenotypes with higher resistance to herbivores was significant in only three populations of *Gossypium* spp. Thus, these results support the adaptive hypothesis of trichome density as a defensive trait against herbivory.

Leaf trichome density is regarded as a component of plant defense against herbivores (Levin, 1973 and Elle *et al.,* 1999). However. few studies have estimated phenotypic selection on resistance to herbivores in different populations of the same species. Relevant to this goal. the present results demonstrated that trichome density is a component of plant resistance to herbivores in most populations *Gossypium* spp. sampled. Selection is expected to vary spatially and temporally in plant-animal interactions, and this constitutes the raw material of the co-evolutionary process (Thompson, 1999). Yet the experimental study of adaptation makes necessary, first, the analysis of natural populations (Sinervo, 2000) to identify potential coevolutionary hotspots (Thompson, 1999).

The relative effectiveness of trichome density as a defensive trait differed among populations. In addition, the result that resistance may or may not be selectively advantageous in a given population is reflected in the interaction between population and resistance.

It must be stressed that population differences in leaf trichome density may occur even if it is not a component of plant resistance. For instance, trichome number might be positively or negatively selected in different stressful environments because it is correlated with other characters (Roy *et al.,* 1999). However, if trichome density were not a resistance component in *Gossypium* spp. no relationship between trichomes and resistance would be expected either among or within populations. In this study, the results for *Gossypium* spp. show that variation in trichome density is independent on leaf size. The present data support leaf trichome density as a component of resistance regardless of selection imposed by other environmental factors.

Several studies have detected heritable variation for leaf trichomes (van Dam and Hare, l998; Elle *et al.,* 1999; van Dam *et al.,* 1999). In *Gossypium* spp. experiment revealed the leaf trichome density since the population averages tended to converge.

Resistance against *B. tabaci* in cotton is significantly correlated with leaf hairiness, with seasonal variability due to differences in leaf color, shape, and hair types (Alexander *et al.* 2004),

CONCLUSION

Host plant resistance, an easy tool of IPM for implementation by farmers would have its say in the crop protection. Being compatible with other methods of pest management besides its most important character of eco friendliness, scientists would strive hard to promote the field using latest technologies for the advantages of farming community in turn the society as a whole. Host plant resistance could be very successful only when strong collaboration of plant protection scientists with plant breeders and biotechnologists.

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REFERENCES

Agrawal, A.A. 1999. Induced responses to herbivory in wild radish: effects on several herbivores and plant ûtness. *Ecology* **80 :** 1713–23

Agrawal, A.A. 2004. Resistance and susceptibility of milkweed: competition, root herbivory, and plant genetic variation. *Ecology* **85 :** 2118–33

Agrawal, A.A., Fishbein, M., Jetter, R., Salminen, J.P., Goldstein, J.B., Freitag, A.E. 2009. Phylogenetic ecology of leaf surface traits in the milkweeds (*Asclepias* spp.): chemistry, ecophysiology, and insect behavior. *New Phytol.* **183 :** 848–67.

Alexander, P. J., Forlow-Jech, L., Henneberry, T. J. 2004. Preliminary screening of different cottons for resistance to sweet potato whitefly infestations. Cotton, College of Agriculture and Life Sciences Report, Series P-138. *University of Arizona, College of Agriculture and Life Sciences.* Tucson, pp. 209-212.

Chamarthim, S.K., Sharma, H.C., Sahrawat, K.L., Narasu, L.M., Dhillon, M.K. 2010. Physico-chemical mechanisms of resistance to shoot fly, *Atherigona soccata* in sorghum, *Sorghum bicolor. J Appl Entomol.* **35 :** 446–55.

Eigenbrode, S.D., Stoner, K.A., Shelton, A.M. and Kain, W.C. 1991. Characteristics of glossy leaf waxes associated with resistance to diamondback moth (Lepidopera: Plutellidae in *Brassica oleracea. J. Econ. Entomol.* **84 :** 1609.

Elle, E.E., Van Dam, N.M. and Hare, J.D. 1999. Cost of glandular trichomes, a ‘resistance’ character in *Datura wrightii* Regel (Solanaceae). *Evolution* **53 :** 22-75.

Feeny, P.P. 1976. Plant apparency and chemical defense. In: Wallace JM, Mansell RL (eds)

Biochemical interaction between plants and insects. Plenum Press, New York, pp 1–40

Hare, J.D., Elle, E. 2002. Variable impact of diverse insect herbivores on dimorphic *Datura wrightii.Ecology* **83 :** 2711–20

King, B.L. 1988. Design and evaluation of a simple penetrometer for measuring leaf toughness in studies of insect herbivory. *Virginia J. Sci.* **39 :** 405.

Maite, R.K., Bidinger, F.R., Sheshu Reddy, K.V. and Davies, J.C. 1980. Nature and occurrence of trichomes in sorghum lines with resistance to the sorghum shootfly, *Joint Progress Rep. Sorghum physiology-3 Sorghum Entomology -3* ICRISAT, Patancheru, India.

Maite, R.K. Bidinger, F.R., Sheshu Reddy K.V. and Davies, J.C. 1980. Nature and occurrence of trichomes in sorghum lines with resistance to the sorghum shootfly, *Joint Progress Rep. Sorghum physiology-3 Sorghum Entomology -3* ICRISAT, Patancheru, India.

Marquis, R. J. 1992. The selective impact of herbivory. In: *Plant Resistance to Herbivory and Pathogens. Ecology, Evolution and Genetics* (R. S. Fritz and E. L. Simms. eds). pp. 301-325. The University of Chicago Press. Chicago.

Mitchell-Oids. T. and Shaw, R.G. 1987. Regression analysis of natural selection: statistical inference and biological interpret ation. *Evolution* **41 :** 1149-61.

Navon, A., Melamed – Madjar, V., Zur, M. and Ben-Moshe, E. 1991. Effects of cotton cultivars on feeding of *Heliothis armigera* and *Spodoptera littoralis* larvae and on oviposition of *Bemisiatabaci. Agric. Ecosyst. Environ.,* **34 :** 73.

Nayar, P.K.,Misra, A. K. and Patnaik, S. 1975. Rapid microdetection of silicon in rice plant. *Plant and Soil,* **42 :** 491-94.

Patanakamjorn, S. and Pathak, M.D. 1967. Varietal resistance of rice to Asiatic rice borer, *Chilosuppressalis*(Lepidoptera: Crambidae) and its association with various plant characters, *Ann. Entomol. Soc. Am.,* **60:** 287.

Rautio P, Markkola A, Martel J, Tuomi J, Ha¨rma¨ E, Kuikka K, Siitonen A, Riesco IL, Roitto M 2002. Developmental plasticity in birch leaves: defoliation causes shift from glandular to nonglandulartrichomes. *Oikos* **98 :** 437–46

Romeis, J., Shanower, T.G., Zebitz, C.P.W. 1999. Trichogramma egg parasitism of Helicovarpaarmigera on pigonpea and sorghum in southern India. *Entomol. Exp. Appl.* **90 :** 69–81

Roy, B.A., Stanton, M.L., Eppley, S.M. 1999. Effects of environmental stress on leaf hair density and consequences for selection. *J. Evol. Biol.* **12 :** 1089–1103

Sands, D.P.A. and Brancatini, V.A. 1991. A portable penetrometer for measuring leaf toughness in insect herbivory studies. *Proc. Entomol. Sco. Wash.,* **93 :** 786.

Sharma, H.C., Agarwal, R.A. and Singh, M. 1982. Effect of some antibiotic compounds in *Gossypium* on post embryonic development of spotted bollworm (*Eariasvittella*). *Proc. Indian Acad. Sci.* (Animal Sci.) **91:** 67-77.

Sinervo, B. 2000. Adaptation, natural selection. and optimal life history allocation in the face of genetically based trade-offs. In: *Adaptive Genetic Variation in the Wild* (T. A. Mousseau,B. Sinervo& J. Endler, eds), Oxford University Press, Oxford.pp. 241-264.

Sokal. R.R. and Rohlf, F.J. 1995. *Biometry,* 3rd edn W.H. Freeman and Co., New York.

Van Dam, N.M., Hare, J.D. 1998. Differences in distribution and performance of two sap sucking herbivores on glandular and non glandular *Datura wrightii. Ecol Entomol* **23 :** 22–32

Van Dam, N.M. and Hare, J.D. 1998. Biological activity of *Datura wrightii*(Solanaceae) glandular trichome exudate against *Manduca sexta* (Lepidoptera : Sphingidae) larvae. *J. Chern. Ecol.* **24 :** 1529-1549.

Van Dam, N.M., Hare, J.D. and Elle. E. 1999. Inheritance and distribution of trichome phenotypes in *Datura wrightii. Hered.* **91 :** 220-27.

Werker, E. 2000. Trichome diversity and development. *Adv. Bot. Res.* **31 :** 1–35.

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Evaluation of *Bt* and Non *Bt* hybrids against major pests under high density planting

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ABSTRACT : Present study was conducted with a view to study the abundance of major pests and predators in PKH Hy-2 non *Bt* and RCH- 2 BG II hybrid at different planting spacing. Results revealed that highest aphids (13.80/leaf) whiteflies (3.12/leaf) and thrips (7.76/leaf) were noted in PKV Hy-2 at spacing of 120 x 15 (55,556 pl./ha) and 120 x 30 (27,778 pl./ha) and 90 x 60 cm (18,519 pl./ha), respectively. Lowest aphid (7.50/leaf), thrips (1.40/leaf) and whiteflies (1.69/leaf) were registered in RCH-2 BG II with spacing of 120 x 30 cm. While , RCH-2 BG II harboured highest leafhoppers (3.96/leaf) at dense spacing of 120 x 15 cm and lowest in PKV Hy-2 at 120 x 45 cm spacing (18,518 pl./ha)

Lowest *H. armigera* eggs (0.45/pl.) and *P. gossypiella* larvae (0.02/boll) was recorded in RCH-2 BG II at 90 x 60 and 120 x 45 cm spacing, respectively. No *H. armigera* and *E. vitella* larvae was noticed so far in RCH-2 BG-II at all spacing studied. However, highest *H. armigera* eggs (1.93/pl.) and larvae (0.37/pl.) and *E. vitella* (0.49/pl.) and *P. gossypiella* larvae (1.01/boll) were recorded in PKV Hy-2 at 120 x 15 , 90 x 30 , 120 x 15, 120 x 15 cm , respectively. Highest lady beetles (2.06/pl.) were noted in RCH-2 BG II with 120 x 45 cm than PKV Hy-2 with 120 x 30 cm spacing. It was noticed that decrease in plant to plant distance particularly below one foot (30 cm) indicates increase of pest incidence besides the plant density.

Key words : *Bt* cotton, bollworms, sucking pests

It is widely accepted that under rainfed situation, increasing plant density is an option to minimize the risk of crop failure, increase yield or profits and also to improve input use efficiency. The pest population becomes higher in higher plant density, however, due to the availability of effective insect pest management strategies has rekindled interest on high density planting systems (Reddy *et al.*, 2009). The crop geometry decides the population of pest rather plant density as such. Crop geometry which creates the competition among the plants for the sunlight and air and crop becomes more succulent and raise higher due to closure canopy. This would have again aggravated as the plant canopy becomes closure and closure. Since, the introduction of *Bt* cotton, a crop geometry (trend of planting) has changed. Farmers in Vidarbha preferred row planting rather than square planting which serve as a heaven for pests due to crowdedness as against square planting facilitate ample sunlight and, air circulation among the plant canopy. Moreover, decrease in plant to plant distance revealed higher temperature and humidity among the crop canopy with less fluctuation which favors the buildup of pest population. Hence, present investigation was aimed to study the abundance of sucking pests, bollworms and natural enemies (lady bird beetle, chrysopa, syrphid fly, spider) under different planting spacing of cotton.

MATERIALS AND METHODS

Field experiment was conducted at Experimental Farm of Department of Entomology, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola during *Kharif*, 2013 in Factorial Randomized Block Design with two cotton hybrids (A) and six planting spacing i.e. twelve interactions (treatments) and three replications. The experiment was sown on 24.06.2013. All the agronomical practices were followed as per recommendations, except plant protection. The crop was raised under unprotected condition.

The observations on aphids, leafhoppers, thrips, whiteflies were recorded at weekly interval from 37 to 91 days after sowing (DAG) on 5 randomly selected plants from each plot. Three leaves each from top, middle and bottom canopy of selected plant were observed for sucking pest count. The data on each pest was averaged as number per leaf and subjected to statistical analysis.

Counts on american bollworm eggs, larvae, spotted bollworm larvae and predators (grubs and adult of lady bird beetle, larvae of chrysopa and syrphid fly and spiders) were recorded at fortnightly interval by randomly selecting 5 plants from each net plot on whole plant from 51 to 94, 51 to 94, 51 to 109 and 37 to 79 DAG, respectively. The average per plant was then worked out. The number of pink bollworm larvae after dissecting 20 green bolls of same size by randomly plucked from border rows of each plot were counted at 94, 109, 124 DAG and the number per boll was computed.

RESULTS AND DISCUSSION

The data on pests population presented in Table 1 revealed significant differences among hybrids (RCH-2 BG II and PKV Hy-2 non *Bt*), plant spacing and their interactions.

Sucking Pests : PKV Hy-2 (non *Bt*) harbour higher population of aphid (10.36 /leaf) thrips (2.12/leaf) and whiteflies (2.65/leaf) as compared to RCH-2 BG II hybrid (8.18, 1.49, 2.01, respectively). Whereas, RCH-2 BG II noted higher leafhoppers (3.49/leaf) than PKV Hy-2 (1.45/leaf).

Aphids : The lowest aphids (8.32/leaf) was noted in plant spacing of 90 x 60 cm (18,519 plants/ha) which was at par with the remaining spacing, except, 120 x 15 cm (55,556 pl./ha) in which statistically higher aphids (8.32/leaf) were noticed.

Among the interactions, lowest population of aphids (7.50/leaf) was noticed in RCH-2 BG II with spacing of 120 x 30 cm (27778 pl./ha) and being on par with rest of the interactions except, PKV Hy-2 with 120 x 15 and 120 x 30 cm spacing, wherein significantly higher aphids of 13.80 and 11.30 per leaf was noticed, respectively.

Leafhoppers : The leafhoppers were lowest (2.25/leaf) in plant spacing of 120 x 30 cm (27, 778 plants/ha) being on par with rest of the plant spacing. Highest leafhoppers were recorded in plant spacing of 120 x 15 cm (55,556 pl./ha).

Minimum and equal leafhoppers (1.22-1.26 /leaf) were noted in PKV Hy 2 with plant spacing of 120 x 30 and 120 x 45 cm followed by rest of the spacing. RCH-2 BG II with 90 x 60 cm spacing stood third and being equal with 120 x 45 and 90 x 45 cm spacing. Maximum and equal leafhoppers (3.59-3.96 / leaf) was noted in RCH-2 BG II with 120 x 15 , 120 x 30 and 90 x 30 cm spacing.

Thrips : Lowest thrips (1.62/leaf) were recorded in 120 x 45 cm spacing (18,519 plants/ha), being on par with 120 x 15 cm spacing (55,556 pl./ha). Highest thrips (2.03/leaf) were observed in 90 x 60 spacing (18,519 pl./ha) which was at par with 90 x 45 (24,691 pl./ha) followed by 120 x 30 (27, 778 pl./ha) and 90 x 30 cm spacing (37,037 pl./ha).

RCH -2 BG II with 120 x 15 cm spacing noted lowest thrips (1.39/leaf), being on par with same hybrid in rest of the spacings and PKV Hy-2 with 120 x 45 cm. PKV Hy-2 with 120 x 15 and 90 x 30 cm spacing being equal and stood second. Highest thrips (7.76/leaf) were noted in PKH Hy-2 with 90 x 60 followed by 90 x 45 cm spacing.

Whiteflies : The lowest whiteflies (2.21/leaf) were noted in 90 x 60 cm spacing (18,519 plants/ha) which was at par with the remaining spacing, except, 90 x 30 cm (37,037 plants/ha) in which highest population (8.32/leaf) was observed.

Minimum whiteflies (1.69/leaf) were recorded in RCH -2 BG II with 120 x 30 spacing (27, 778 plants/ha), being on par with same hybrid in remaining spacing and PKV Hy-2 with 90 x 60, 120 x 45 , 90 x 45 cm spacing. PKV Hy-2 with 120 x 30 cm spacing recorded highest whiteflies (3.12/leaf) followed by PKV Hy-2 (2.80/leaf) with 90 x 30 cm spacing.

These results of abundance of sucking pests on hybrids under study are endorsed by Kolhe *et al.*(2017) who noticed higher population of leafhopper and lower population of aphids and thrips and whiteflies on RCH 2 BG II hybrid as compared to PKV Hy-2 non Bt. Since, PKV Hy-2 having higher leaf hair density compared to RCH-2 BG II preferred less and became difficult for livelihood of the leafhoppers as against it carries higher number of thrips and whiteflies. These findings are also endorsed by Khalil *et al.* (2015) who reported that population of whitefly and thrips revealed positive and adult and nymphal population of leafhoppers revealed negative response with leaf hair density.

The sucking pest population is also influenced by planting distance of the hybrids, wherein dense planting (> 18519 pl/ha) carries higher population of sucking pests as compared to sparse planting (18519 pl/ha). These findings are in line with the study carried out by Harshana *et. al.* (2017) who reported higher number of sucking pests (thrips, aphids and leafhoppers) in dense planting 45 x 15 cm (1,48,148 pl./ha) than normal planting of 90 x 60 cm i.e. 18,519 pl/ ha in non Bt variety (ARBC-64) and BG II hybrid (Bindhast). Similarly, the dense planting 60 x 10 cm (1,66.666 pl./ha) carries higher population of sucking pests (aphids 9.67/ leaf, thrips 10.92/leaf, leafhoppers

2.06/leaf and whiteflies 4.76/leaf), decreases towards less dense planting (1,33,333pl./ ha) and became lower (aphids 3.80/leaf, thrips 5.76/leaf, leafhoppers 1.27/leaf and whiteflies 1.50/leaf) in planting spacing of 90 x 10 cm i.e.1,11,111 pl./ha. (Anonymous, 2017).

Bollworms: The data on bollworm incidence indicated significantly higher population of *H. armigera* eggs (1.10/pl), larvae (0.23/pl), *E. vitella* larvae (0.26/pl) and *P. gossypiella* larvae (0.69/ boll) in PKV Hy-2 non *Bt* than RCH-2 BGII (0.95, 0.00, 0.00 and 0.08, respectively). Moreover, no incidence of *H. armigera* and *E. vitella* larvae was recorded in RCH-2 BG II Hybrid but survival of *P. gossypiella* was noticed, so far, with 0.08 larva per boll.

***Helicoverpa armigera* eggs:** Cotton planted at 90 x 60 cm (18,519 plants/ha) recorded lowest *H. armigera* egg (0.75/pl.) which was on par with remaining plant spacing and eggs (1.23/ pl.) became highest in plant spacing of 120 x 15 cm (55,556 pl./ha). Lowest eggs of 0.45 per plant was noticed in RCH-2 BG II with 90 x 60 cm spacing, being superior to other interactions and highest eggs of 1.93 per plant was deposited on PKV Hy-2 non *Bt* with 120 x 15 cm spacing and it was on par with rest of the interactions.

***Helicoverpa armigera* larvae :**The data on *H. armigera* larvae was non-significant, wherein plant spacing of 120 x 45 cm registered lowest larval population (0.07/pl.) and highest (0.19/pl.) in 90 x 30 cm spacing (37,037 pl./ha). RCH-2 BG II with all spacing reported 100 per cent suicidal population of *H. armigera* larvae (0.00/pl.). However, PKV Hy-2 non *Bt* with 90 x 30 cm spacing noticed highest larval population (0.37/pl.), being superior to remaining spacing in noting higher population.

***Erias vitella* larvae :** Minimum population of *E. vitella* larvae (0.04/pl.) was noticed in plant spacing of 90 x 45 cm (24,691 pl./ha) and it was at par with remaining spacing and population became highest (0.25/pl.) in 90 x 60 cm spacing (18,519 pl./ha). RCH-2 BG II with all spacing noted 100 per cent suicidal population of *E. vitella* larvae (0.00/pl.). However, highest and on par population of 0.37-0.49 per plant was noted in PKV Hy-2 with 90 x 60 and 120 x 15 cm followed by rest of the spacing being equal to each other (0.18-0.25/pl.).

***Pectinophora gossypiella* larvae :** Minimum *P. gossypiella* larvae (0.14/boll) was registered in 120 X 45 cm spacing (18,519 plants/ha) followed by 90 x 45 cm (24,691 pl./ ha). Plant spacing of 90 x 30 cm (37,037 pl./ha) stood third and being on par with 90 x 60 cm (18,519 pl./ha) spacing. Significantly higher population of *P. gossypiella* larvae (0.56/boll) was observed in plant spacing of 120 x 15 cm (55,556 pl./ha).

Lowest *P. gossypiella* larvae (0.02/boll) was noted in RCH-2 BG II with 120 x 45 cm spacing (18,519 pl./ha) and being on par with each other to rest of the spacing with larval survival ranging from 0.05-0.10 per boll. PKV Hy-2 with 90 x 45 and 120 x 45 cm spacing were equal and next to record *P. gossypiella* larvae (0.26-0.37/boll). PKV Hy-2 with 120 x 15 and 120 x 30 cm spacing (27, 778 pl./ha) recorded highest and equal larval population (0.92-1.01/boll) followed by 90 x 60 and 90 x 30 cm spacing being

Table 1. Effect of plant spacing on population of pests and predators in *Bt* & non *Bt* cotton hybrid

Treatments	Sucking pests population / leaf				Bollworm population /plant					Predators/ plant		
	Aphids	Leaf hoppers	Thrips	Whitefly adults	Ha eggs	Ha larvae	Ev larvae	Pg larva / boll	LBB (A&G)	Crysopa larvae	Spider	Syrphid fly larvae
A. Variety (V)												
PKV Hy-2 non *Bt*	10.36 (3.21)*	1.45 (1.20)*	2.12(1.45)*	2.65 (1.62)*	1.10 (1.26)*	0.23 (0.85)*	0.26 (0.87)*	0.69 (1.08)*	1.47 (1.21)*	0.14 (0.80)*	0.25 (0.49)*	0.36 (0.59)*
RCH-2 BG II	8.18 (2.86)	3.49(1.87)	1.49(1.22)	2.01(1.42)	0.95 (1.20)	0.00 (0.71)	0.00 (0.71)	0.08 (0.76)	1.79 (1.33)	0.09 (0.77)	0.22(0.45)	0.43 (0.63)
SE (m)±	0.03	0.01	0.00	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.04
CD at 5%	0.08	0.02	0.01	0.02	0.06	0.02	0.02	0.02	0.07	-	-	-
B. Spacing (S) in cm												
90 x 60	8.32 (2.88)	2.33(1.50)	2.03(1.41)	2.21(1.48)	0.75(1.11)	0.09 (0.77)	0.25 (0.85)	0.47 (0.96)	1.72 (1.31)	0.15 (0.80)	0.28 (0.52)	0.43 (0.65)
90 x 45	9.28 (3.04)	2.45(1.54)	1.95(1.39)	2.27(1.51)	1.10(1.26)	0.09 (0.77)	0.04 (0.73)	0.26 (0.87)	1.57 (1.25)	0.14 (0.79)	0.21 (0.45)	0.38 (0.60)
90 x 30	9.00 (3.00)	2.58(1.57)	1.72(1.31)	2.48(1.58)	1.11(1.27)	0.19 (0.82)	0.09 (0.77)	0.40 (0.93)	1.67 (1.29)	0.07 (0.75)	0.23 (0.47)	0.38 (0.60)
120 x 45	8.88 (2.98)	2.25(1.46)	1.62(1.27)	2.24(1.49)	0.99(1.22)	0.07 (0.75)	0.13 (0.79)	0.14 (0.80)	1.65 (1.27)	0.09 (0.77)	0.21 (0.45)	0.32 (0.56)
120 x 30	9.40 (3.05)	2.50(1.52)	1.87(1.36)	2.41(1.54)	0.98(1.21)	0.11 (0.78)	0.10 (0.77)	0.49 (0.97)	1.49 (1.21)	0.11 (0.78)	0.23 (0.48)	0.54 (0.67)
120 x 15	10.76 (3.24)	2.71(1.60)	1.65(1.28)	2.37(1.53)	1.23(1.31)	0.12 (0.79)	0.19 (0.82)	0.56 (1.01)	1.67 (1.29)	0.15 (0.80)	0.21 (0.43)	0.34 (0.58)
SE (m)±	0.05	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.04	0.03	0.04	0.07
CD at 5%	0.13	0.04	0.02	0.03	0.10	-	0.04	0.04	-	-	-	-
C. Variety X Spacing												
V1S1	7.76 (2.78)	1.56(1.25)*	2.61(1.61)	2.28 (1.51)	1.04 (1.24)	0.18 (0.82)	0.49 (0.99)	0.86 (1.16)	1.72 (1.31)	0.23(0.85)	0.25 (0.49)	0.38 (0.62)*
V1S2	9.96 (3.15)	1.60(1.26)	2.33(1.52)	2.44 (1.56)	0.96 (1.21)	0.19 (0.83)	0.08 (0.76)	0.37 (0.93)	1.63 (1.27)	0.19(0.81)	0.20 (0.44)	0.33 (0.56)
V1S3	9.69 (3.11)	1.57(1.25	1.94(1.39)	2.80 (1.67)	1.09 (1.25)	0.37 (0.93)	0.18 (0.82)	0.73 (1.11)	1.50 (1.23)	0.08(0.76)	0.28 (0.53)	0.38 (0.60)
V1S4	9.65 (3.10)	1.26(1.12)	1.58(1.25)	2.41 (1.55)	0.99 (1.21)	0.14 (0.79)	0.25 (0.86)	0.26 (0.87)	1.23 (1.11)	0.08(0.76)	0.22 (0.46)	0.28 (0.53)
V1S5	11.30 (3.36)	1.22(1.10)	2.33(1.52)	3.12 (1.76)	1.08 (1.25)	0.22 (0.84)	0.19 (0.82)	0.92 (1.19)	1.16 (1.07)	0.12(0.78)	0.26 (0.52)	0.38 (0.61)
V1S6	13.80 (3.71)	1.46(1.21)	1.91(1.38)	2.79 (1.67)	1.93 (1.39)	0.25 (0.86)	0.37 (0.93)	1.01 (1.23)	1.56 (1.25)	0.15(0.80)	0.26 (0.52)	0.40 (0.63)
V2S1	8.87 (2.97)	3.08(1.75)	1.44(1.20)	2.12 (1.45)	0.45 (0.97)	0.00 (0.71)	0.00 (0.71)	0.07 (0.75)	1.71 (1.30)	0.06(0.75)	0.32(0.55)	0.48 (0.68)
V2S2	8.59 (2.92)	3.29(1.81)	1.56(1.25)	2.10 (1.44)	1.12 (1.31)	0.00 (0.71)	0.00 (0.71)	0.15 (0.80)	1.50 (1.22)	0.08(0.76)	0.22 (0.46)	0.42 (0.64)
V2S3	8.30 (2.88)	3.59(1.89)	1.49(1.22)	2.14 (1.46)	1.13 (1.27)	0.00 (0.71)	0.00 (0.71)	0.05 (0.74)	1.83 (1.35)	0.05(0.74)	0.18 (0.42)	0.36 (0.60)
V2S4	8.11 (2.84)	3.24(1.80)	1.66(1.28)	2.06 (1.43)	0.97 (1.21)	0.00 (0.71)	0.00 (0.71)	0.02 (0.72)	2.06 (1.44)	0.10(0.77)	0.20 (0.44)	0.35 (0.59)
V2S5	7.50 (2.73)	3.76(1.94)	1.40(1.18)	1.69 (1.30)	0.87 (1.16)	0.00 (0.71)	0.00 (0.71)	0.05 (0.74)	1.81 (1.35)	0.08(0.76)	0.20 (0.44)	0.70 0.72)
V2S6	7.71 (2.77)	3.96(1.98)	1.39(1.17)	1.95 (1.39)	1.02 (1.23)	0.00 (0.71)	0.00 (0.71)	0.10 (0.77)	1.76 (1.33)	0.14(0.80)	0.18 (0.42)	0.28 (0.52)
SE (m)±	0.06	0.02	0.01	0.02	0.03	0.02	0.02	0.02	0.06	0.04	0.05	0.10
CD at 5%	0.19	0.05	0.03	0.05	0.10	-	0.06	0.06	0.17	-	-	-

*(Figures in parenthesis are square root values)

equal to each other.

The bollworm incidence was significantly lower in RCH-2 BG II hybrid compared to PKV Hy-2 in all planting spacing. The *H. armigera* and *E. vitella* larvae were not observed on RCH-2 BG II Hybrid, however, survival of *P. gossypiella* larvae was noticed. These findings are in conformity of the work by Gujar *et al.* (2011), Nadaf and Goud (2015) and Kolhe *et al. (2017)*

In present investigation, the bollworm incidence was also higher in denser plant spacing than normal or sparsely planted spacing. Hence, these findings are in accordance with Harshana *et al.* (2017) who reported higher number of bollworms (0.13 *H. armigera* larvae/ pl and 4.31 *P. gossypiella* larvae/ boll) in dense planting of 45 x 15 cm (1,48,148 pl./ha) than normal planting of 90 x 60 cm i.e. 18,519 plants per ha in non Bt variety (0.09 *H. armigera* larvae/ pl and 3.63 *P. gossypiella* larvae/ boll). Similar trend was observed in *Bt* hybrid (Bindhast).

Predators: Data pertaining to predators (lady bird beetle adults and grubs, chrysopa larvae, syrphid fly larvae and spider) shown non - significant differences among the hybrids, plant spacing and their interactions except, lady bird beetle in different hybrids and interactions. RCH-2 BG II harboured (1.79/pl.) higher lady beetles than PKV Hy-2 (1.47/pl.). Highest lady beetles (2.06/pl.) were noted in RCH-2 BG II with 120 x 45 cm (18,519 pl./ha) and being equal to each other with rest of the interactions, except, PKV Hy-2 with 120 x 30 cm spacing (27, 778 pl./ ha), wherein lowest populations of lady beetles were noticed (1.16/pl.). The data on predators indicated higher population trend at denser plant spacing which are in line with the study conducted by Harshana *et al. (*2017).

REFERENCES

Anonymous, 2017. Observations in the Agron1B (HDPS evaluation trial) and Agron –V (Tech for organic cotton production): Agron IB: Evaluation of compact culture under HDPS with different nutrient levels in ICAR - All India Coordinated Research Project on Cotton – Annual Report (2016 – 17), Central Institute for Cotton Research, Sub-Centre, Coimbatore :E-202.

Gujar G.T., Bunkar G.K., Sing B.P. and Kalia V. 2011. Field performance of F1-F2 and non Bt of BTI (MRC7017 Bt and JKCH-1947 Bt) against bollworms of cotton. In *World Cotton Research Conference*, November 7-11, 2011 at The Renaissance Hotel and Convention Centre, Mumbai, India. Pp.165-173

Harshana Anand, S. B. Patil And S. S. Udikeri. 2017. Validation of existing IPM module of cotton under high density planting system. *J. Entomol. Zool. Studies* 2017; **5** (5): 687-690.

Khalil Huma, Abu Bakar Muhammad Raza, Muhammad Afzal, Muhammad Anjum Aqueel, Muhammad Sajjad Khalil, Muhammad Mudassir Mansoor. 2015. Effects of plant morphology on the incidence of sucking insect pests complex in few genotypes of cotton. *J. Saudi Soci. Agric. Sci.* (2015) xxx, xxx–xxx (http://dx.doi.org/ 10.1016/j.jssas.2015.11.003)

Kolhe, A.V. , Jayashri Ughade and D.B. Undirwade. 2017. Performance of *Bt* cotton hybrids and their counterparts under IPM in rainfed condition of Vidarbha region. *J. Cotton Res. Dev.* **32** (1) 108-115.

Nadaf Abdul Rahaman M and Goud K Basavana.2015. Performance of *Bt* and non *Bt* cotton hybrids against pink bollworm, *Pectinophora gossypiella*. *Indian J. Pl. Prot.*, **43**: 434-438

Reddy, K.N., Burke, I.C., Boykin J.C. and Williford, R., 2009. Narrow row cotton production under irrigated and non-irrigated environment: plant population and lint yield. The Journal of Cotton Science **13**: 48–55.

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Growth and physiology of cotton (*Gossypium arboreum* L.) at mid altitudes of Meghalaya

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Meghalaya, an important territorial hilly state of north eastern India (NER) in eastern Himalaya witness different agro-climate and micro habitats with varied altitudes ranging from 100-1600m. Arboretum Cotton (*Gossypium arboreum* L.) traditionally cultivated as Garo hills and Karbi angling areas of Meghalaya and conventionally known as Comilla cotton considered as one of the important potential crop for subtropical stretches of Meghalaya. It is less known and cultivated due to less input supply and lack of scientific package. Moreover, under changing climate, several agro physiological and growth constraints also matter for developing suitable package of practice and there by attain the optimum productivity of cotton under organic production scenario of NER. In this connection present study was undertaken to study the agro-climatic suitability and feasibility of cultivating cotton by evaluating suitable morpho-physiological traits at Institute farm of ICAR research complex for NEH region, Umiam, Meghalaya. Two varieties of cotton *viz.,* HD 123 and HD 432 have been grown with sowing date at 1st forth night of May, 2017 under organic production systems. Several growth and morpho-physiological traits like root architecture, R/S ratio, leaf characteristics (leaf area, leaf weight and pigmentation etc), stomatal characters (size and density), plant biomass etc which are important for determining the robust crop growth and yield has been documented. The experimental location i.e ICAR NEH Umiam, Meghalaya have an altitude of 950 m above mean sea level with 25^{0}30'N latitude and 91^{0}51'E longitude characterized by subtropical climate with mild winter and warm summer condition as ambient temperatures ranged from higher level *i.e.* 25-32.3^{0}C observed during the month of July and lower temperatures of 3-14^{0}C recorded during the Jan-Feb months. The average annual rainfall received at experimental location varies from 1800-2500 mm with 80-100 rainy days and range of daily rainfall of 1-20 mm.

Recorded experimental data reveal that out of two cotton varieties sown, only one HD 123 was successful in establishing in the planted field whereas another variety HD-432 did not establish and put forth its growth in this climate. All data recorded is only refer to one established variety *i.e.* HD 123. In this variety, leaf chlorophyll pigments like chl a, chl b, carotenoids and anthocyanin content has indicated higher values ranging from 2.39, 0.88mg, 0.17 and 0.025mg respectively. The content of accessory pigments *viz.,* carotenoid and anthocyanin was higher as they may act both as antioxidant and protectant of chlorophyll during stressful conditions. Moreover, higher anthocyanin (0.025mg/g) and chl a/b ratio (2.84) recorded was useful to assist the plant to harness more incident light and significantly help in better adaptation under stressful environment (Silva *et al.,* 2007). At active growth stage, the values of root architecture parameters like total root length and root surface area noticed was 153cm and 112cm^2 whereas root volume and root dry weight witnessed was around 3.1cm^3 and 0.89 g. Functional root traits like root length ratio and root tissue density was observed around 45.3g/cm and 0.3g/cm^3 . The extent of increase in root parameters in established variety *i.e.* HD 432 was advantageous to the plant to enhance nutrient uptake especially phosphorus deficiency and efficient water absorption. In addition, higher Root length ratio (RLR), root mass ratio(RMR) and root tissue density(RTD) traits contribute to the increased biomass allocation and helpful in improving stress resistance (Romano *et al.,* 2013). Many studies on plant growth under prevailing abiotic stress by previous researchers have been emphasized on the maintenance of better root morphology and root architecture which serve as integral part of plant resistance response for improved growth and yield under stress conditions (Abenavoli *et al.,* 2016). As increased concentrations of Al, Fe, Mn, Cu and reduced the availability of phosphorus and significantly affect root growth and leaf pigmentation of the plant, characterizing the physiogical and biochemical response was very pertinent to understand the extent of crop adaptability in cotton.

Apartment from these, increased leaf thickness, leaf temperature and specific leaf weight recorded was around 280µm, 25.4°C and 30mg/cm^2 which are very helpful for attaining robust shoot growth and optimum biomass accumulation as it reflect the number of layers of mesophyll cells available for photosynthesis during the process of growth (Vile *et al.,* 2005). The stomatal distribution studied in abaxial surface of cotton leaves shows that the stomatal frequency ranged from 350-400 per cm^2 and stomtal index of 27.5-30.2%. This enhanced stomatal number may be advantageous for better exchange of beneficial gases for enhanced photosynthesis. Similar results with stomatal size and stomatal density variation reported to be considerably influenced by plant species and abiotic environmental perturbations such as changes in atmospheric CO_2 concentration and increased ambient temperature under changing climate with altered nutritional status (Xu and Zhou, 2008). Improved leaf characters are important for maximizing light harvesting and utilization of light and CO_2 for higher photosynthesis which is closely associated with higher biomass accumulation and seed yield of the crop (Rajbhari *et al.*, 2008). Biomass characteristics like shoot biomass and total dry matter of cotton was observed 2.59g and 3.39g/ plant with root to shoot ratio of 0.35. Higher shoot biomass, R/S ratio and TDM will be helpful to produce better cotton yield with indicated harvest index of 60-70 per cent.

The overall growth observed in present study in the established cotton variety was moderate and sub optimal which further giving the scope for studying the appropriate agronomic practices to improve the cotton crop physiology and resilient growth for better productivity to suit changing climate in mid altitudes of Meghalaya. These results on agro-physiological characterization and identification of efficient cotton cultivars can be further used in development of scientific agronomical package and adhoc breeding programs for developing suitable cotton variety tolerant to unabated climatic and edaphic stresses of the region.

REFERENCES

Abenavoli, M. R., Leone, M., Sunseri, F., Bacchi, M., Sorgona, A. 2016. Root phenotyping for drought tolerance in bean landraces from Calabria (Italy) *J Agron Crop Sci.,* **202 :** 1–12.

Rajbhandari B. P. 2004. Eco Physiological Aspects of Common Buckwheat. Proceedings of the 9th International Symposium on Buckwheat, Prague, 101-08.

Romano, A., Sorgona, A., Lupini, A., Araniti, F., Stevanato, P., Cacco, G., Abenavoli M.R., 2013. Morpho physiological responses of sugar beet (*Beta vulgaris* l.) genotypes to drought stress. *Acta Phys. Plant.* **35 :** 853–65.

Silva M A, Jifon J L, DaSilva JAG, Sharma V. 2007. Use of physiological parameters as fast tools to screen for drought tolerance in sugarcane. *Brazilian Journal Plant Physiology* **19 :** 193-201.

Vile, D, Garnier, E., Shipley,B., Laurent, G., Navas, M.L., Roumet, C., Lavorel, S., Diaz, S., Hodgson, J.S., Lloret, F., Midgley, G.F., Poorter, H., Rutherford, M.C., Wilson, P.J., Wright, I.J.,2005. Specific leaf area and dry matter content estimate thickness in laminar leaves. *Ann. Bot.* **96 :** 1129–36.

Xu Z and Zhou G. 2008. Responses of leaf stomatal density to water status and its relationship with photosynthesis in a grass. *Journal Experiment Botany*, **59 :** 3317–25

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Integrated weed management and herbicide residues in cotton

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ABSTRACT : To study the bio efficacy and phyto-toxicity of various herbicides *viz.,* pendimethalin, quizalofop, propaquizafop, pyrithiobac-Na alongwith protected spray of glyphosate and paraquat against complex weed flora and their effect on growth and yield of cotton was conducted at Agronomy Research Area of CCS, HAU Hisar during the year 2014 and 2015. Herbicides residues were quantified in cotton lint, seed and soil under cotton crop following validated experimental procedures using GC-MS tandem mass spectrometry and high pressure liquid chromatography (HPLC). Results of two years study revealed that PRE application of pendimethalin at 1.0 kg/ha supplemented with two hoeings at 30 and 60 days after application (DAA), one hoeing and post emergence application of quizalofop at 60 g/ha or propaquizafop at 62.5 g/ha at 60 DAA caused significant reduction in density and dry weight of weeds as compared to weedy check up to harvest. Protected spray of glyphosate (0.5%) integrated with pendimethalin being *at par* with three mechanical weedings helped to reduce the population and dry weight of weeds up to 90 DAS. Among herbicide treatments, maximum seed cotton yield (2280 and 2371 kg/ha) was recorded with three hoeings at 20,50 and 70 DAS which was *at par* with weed free during both the years. Pendimethalin at 1.0 kg/ha supplemented with protected spray of glyphosate although with higher weed controlling efficiency(82-97%) could not produce yield significantly *at par* with weed free due to phytotoxic effect on cotton. None of the herbicide treatment except involving protected spray of paraqaut (360 g/ha) and glyphosate (1000g/ha) caused phytotoxicity(5-10%) on cotton with slight yield reductions. Pendimethalin (PRE) was found persistent in soil at 1.0 and 1.5 kg/ha. Quizalofop, propaquizafop, pyrithiobac-Na, glyphosate and paraquat reached below detection limit (BDL) 0.05 ìg/g within 10 days after application and dissipation followed first order kinetics in soil. Residues were not detected in cotton lint and seed.

Key words : Bio efficacy, cotton, herbicides, phyto toxicity, residues

Weed competition is one of the important biological constraints in cotton cultivation. Carpet weed (*Trianthema portulacastrum* L.), jungle rice (*Echinochloa colona* L.) and purple nut sedge (*Cyperus rotundus* L.) are major weeds that infest cotton crop in north west India and cause yield losses by 10-70 per cent or more depending upon type and density of weeds weeds (Balyan *et al.*, 1983; Brar and Brar, 1992).. Cotton grows slowly in summer due to very high temperature varying from 41 to 47 °C and weeds get an ample space to grow profusely particularly in the initial two months of crop stage. Pre plant incorporation of fluchloralin and trifluralin and pre emergence application of pendimethalin were found effective for the control of these weeds. Pre emergence application of herbicides minimizes the early weed competition and problem of late emerging weeds becomes more serious(Panwar *et al.*, 1989).. To manage late emerging weeds, other manual or chemical methods need to be integrated with these pre plant or pre emergence herbicides. Information on directed spray of post-emergence herbicides in a wide spaced crop like cotton is limited and hence the present study was undertaken with the objectives to study the bio efficacy of combination of herbicides against complex weed flora and their effect on growth, yield of cotton and phyto toxic effects on the crop, if any. Most herbicides, because of their pre emergence application or pre-plant incorporation ultimately finds their way into the soil. Pimental (1995) reported that less than 0.1% of the pesticide applied for the pest control reach their target pests and more than 99.9 per cent of pesticides move into the environment, predominantly in soil. Hence, the knowledge of the potential of herbicides residues to persist in crop produce and the soil is important while developing or recommending weeds management strategies. Another objective of this study was to estimate the herbicide residues in cotton lint, seed and soil under cotton crop following validated experimental procedures using GC-MS tandem mass spectrometry and high pressure liquid chromatography (HPLC).

MATERIALS AND METHODS

Bio efficacy study: The present studies were conducted during *kharif* season of 2014 and 2015 at Department of Agronomy, CCS Haryana Agricultural University, Hisar under irrigated conditions. The soil of the experimental field was sandy loam in texture, having pH 8.1, low in organic carbon (0.3%) and nitrogen (180 kg/ha), medium in available phosphorus (18 kg/ha) and high in potassium (370 kg/ha) content. Fifteen treatments (Table 1 and 2) were tried in randomized block design replicated thrice. The maximum temperature was recorded in May and June and minimum temperature was recorded in the month of November in both the years. Rainfall received during cotton growing period was 180 and 392 mm during July, August and September, 2014 and 2015, respectively. The American cotton hybrid RCH 134 was dibbled with 90 x 60 cm spacing on 17 and 14^{th} May 2014 and 2015 respectively. The standard package of practices other than weed control treatments recommended for cotton was adopted. Data on weed count and dry matter accumulation by weeds were recorded at 90 DAS and at harvest using a quadrate of 0.25 m^2 from four places in a plot. Seed cotton yield was recorded on net plot basis. Phyto toxic effect of different herbicides on cotton was recorded at 90 DAS using 0-100 scale.

Residues study: Pendimethalin, quizalofop and propaquizafop were extracted by taking a representative 20 g soil, 20 g grinded cotton seeds and 10 g cotton lint were taken in 250 ml conical flask and added 50 ml of acetone and extracted over rotary shaker for one hour. The concentrated samples were partitioned with hexane: ethyl acetate (9:1) thrice by taking 50, 30 and 20 ml after adding 50 ml saturated brine solution. The organic phases were collected by passing over Na_2SO_4 in a separate bottle. The organic phase was concentrated over rotary evaporator to 10 ml at 35°C. No further clean-up was required for soil and lint samples as the samples were clear and containing no colour. But the grain samples were further cleaned-up by column containing 10 g alumina and 0.5 g charcoal sandwiched between Na_2SO_4 layer above and below. 100 ml of hexane: ethyl acetate (9:1) was used as eluent for each sample. The extracts were collected by passing over anhydrous Na_2SO_4, concentrated up to dryness over rota-vapour and the final volume was made in n-hexane for analysis over GCMS/MS Triple Quadrupole. Extraction and clean-up of glyphosate and propaquizafop from soil, cotton seeds and lint was achieved by the method of Hu *et al.,* (2008) through derivatization with triflouroacetic anhydride (TFAA) and triflouroethane (TFE) and analysis over GC-MS/MS with following operating parameters: injection port temperature: 280°C. Column: HP-5 (30 m x 0.32 mm i.d. x 0.25 µm film thickness) containing 5 percent diphenyl and 95 percent dimethyl polysiloxane. Oven temperature ramping was: 70°C (2 min) ® @ 25°C/min ® 150°C (0 min) ® @ 15°C/min ® 200°C (0 min) ®@ 8°C/min ® 280°C (2 min). Detector: Mass 7000 GCMS/MS; detector parameters were: source temperature, 230 °C; emission current, 35 mA; energy, – 70 eV; repeller voltage, 11 V; ion body, 12 V; extractor, –7.2 V; ion focus, –7.4 V; quadrupole one (MS^1) temperature, 150°C; quadrupole two (MS^2) temperature, 150°C. Gas flow rates: helium (carrier gas), 1 ml/min though column and 2.25 ml/min as collision flow/quench flow, nitrogen (collision cell), 1.15 ml/min. Other parameters: split ratio, 1:10; vacuum (high pressure), $2.23x10^{-05}$ torr; rough vacuum, $1.51x10^{+02}$ torr; injection volume, 2 ml.

For pyrithiobac-Na extraction 20, 20 and 10 g of representative samples of soil, cotton seeds and lint respectively were taken in a high speed blender and added 2 ml of 0.1 N silver nitrate and 25 ml mixture of (0.1%) phosphoric acid: acetonitrile (1:1) solutions. The homogenized sample was extracted with 100 ml of methanol. Extraction process was done twice on an end over end mechanical shaker for a period of 15 minutes. The combined filtrate was concentrated to dryness using rotary vacuum evaporator at temperature of 40°C and reconstituted to approximate 5 ml volume in HPLC grade methanol. For clean up, ProElut PXA and Oasis cartridges were conditioned using 3 ml methanol and 3 ml ultra-pure water. For the Supelco LC-Florisil cartridge, conditioning was carried out using 3 ml of acetonitrile and 3ml ultra-pure water before an appropriate aqueous solution sample volume was passed through each cartridge at the optimized flow rate by a vacuum pump. The ProElut PXA and Oasis cartridges were then washed with 3 ml 0.05M sodium acetate solution to remove the co-adsorbed matrix materials from the cartridges. Subsequently, pyrithiobac-Na retained on the cartridges was eluted with 3 ml 2 per cent formic acid methanol solution. For the Supelco LC-Florisil cartridge, 3 ml 0.1M acetic acid was used to remove the un-adsorbed sample and 3 ml iso-pentane to elute the pyrithiobac-Na. The elute was blown to near dryness using rotary vacuum evaporator. Finally the residue was reconstituted in 2 ml methanol and analyzed by HPLC-PDA (Waters e-alliance 2695) having RP C 18 column (250 x 4.6 mm) and 5ì particle size. Acetonitrile: water (70:30 v/v) was used as mobile phase with an isocratic flow rate of 1 ml/min. Injection volume was 10 ìl.

RESULTS AND DISCUSSION

Weed flora: During both the years, the experimental field was pre dominantly infested with natural population of jungle rice (*Echinochloa colona* L.) and carpet weed (*Trianthema portulacastrum* L.) upto harvest.

Effect on weeds: All the weed control treatments significantly reduced density and dry weight of weeds as compared to untreated check at 90 DAS and harvest. Pendimethalin at 1.0 kg/ha as pre emergence provided effective control of *T. portulacastrum* and *E. colonum* and this effect remained consistent up to 90 DAS (Table 2). When application of pendimethalin at 1.0 kg/ha was supplemented with two hoeing at 30 and 60 DAS, one hoeing and post emergence application of quizalofop-p-ethyl at 60 g/ha or propaquizafop-p-ethyl at 62.5 g/ha at 60 DAS caused significant reduction in density and dry weight of weeds as compared to weedy check up to harvest (Table 1 and 2). Treatments involving use of parthiobac at 20 DAS were not effective as at 20 DAS, due to less moisture and higher temperature at that time, it did not cause any reduction in weed density (data not given). Protected spray of glyphosate (0.5%) integrated with pendimethalin and paraquat (0.3%) with parthiobac Na *fb* quizalofop-p-ethyl being *at par* with three mechanical weeding helped to reduce the population and dry weight of weeds at 90 DAS significantly over weedy check (Table 2). Pendimethalin integrated with non-selective herbicides (paraquat or glyphosate) proved superior over application of pendimethalin *fb* quizalofop-p-ethyl or parthiobac Na *fb* quizalofop-p-ethyl against both weeds as shown by weed control efficiency. These results are in conformity with the findings of Panwar *et al.,* (2001). Treatments involving directed spray paraquat caused 5-8 per cent toxicity to cotton crop during 2014 but during 2015, glyphosate also caused 8.3-10 per cent toxicity. Weed control efficiency in all treatments except pendimethalin *fb* quizalofop-p-ethyl or parthiobac Na *fb* quizalofop-p-ethyl varied between 60.3-83.2 per cent both at 90 DAS and at harvest during 2014 but suring 2015, it was more ranging from 88-99 per cent at 90 DAS and at harvest.

Effect on crop: All the weed control treatments gave significantly higher seed cotton yield over weedy check (Table 3). The numbers of bolls/plant were affected significantly due to different herbicide treatments. During 2014, bolls/plant were maximum (46) in weed free treatment which were significantly *at par* with three mechanical weedings and parthiobac Na/pendimethalin *fb* quizalofop-p-ethyl *fb* directed spray of glyphosate but during 2015, numbering of bolls/plant were maximum in weed free treatment which was significantly higher than all other treatments except three mechanical weedings. Maximum seed cotton yield (2364 kg/ha) was obtained in weed free plots, which was significantly higher than all other treatments. Among herbicidal treatments, early post emergence application of pendimethalin *fb* quizalofop-ethyl *fb* direct spray of glyphosate gave seed cotton yield of 2244 kg/ha which was *at par* with pendimethalin at 1.0 kg/ha supplemented with protected spray of glyphosate

Table 1. Density and dry of weeds and WCE (%) at different crop growth stages as affected by different treatments in cotton.

Treatments	Dose (g/ha)	Time of application	Weed density(No./m²) 90 DAS				Harvest				Phyto-toxicity on crop (%) at 90 DAS
			T. portu-lacastrum	*Echin-ochloa* spp.	Dry wt. (g/m²)	WCE *(%)*	*T. portu-lacastrum*	*Echin-ochloa* spp.	Dry wt. (g/m²)	WCE *(%)*	
Pendimethalin fb 2 HW	1000	PRE, 20 and 50 DAS	3.1(8.6)	1.7(2.0)	3.92(14.43)	88.5	8.1(2.8)	1.7(2.0)	3.09(8.53)	92.3	0
Pendimethalin *fb* hoeing *fb* quizalofop-p-ethyl	1000/60	PRE *fb* 30 DAS *fb* 60 DAS	1.7(2.0)	1.7(2.0)	3.09(8.57)	93.2	1.7(3.0)	1.5(1.2)	2.73(6.43)	92.2	0
Pendimethalin *fb* hoeing *fb* propaquizafop-p-ethyl	1000/65	PRE *fb* 30 DAS *fb* 60 DAS	2.2(4.0)	1.4(1.0)	2.89(7.37)	94.1	2.2(2.4)	1(0.0)	2.68(6.20)	93.7	0
Pendimethalin *fb* parthiobac-sodium	1000 /62.5	PRE *fb* 20 DAS	3.2(9.2)	3.1(8.4)	5.95(34.40)	72.8	3.2(7.1)	3.1(8.4)	6.31(38.83)	60.7	0
Pendimethalin *fb* hoeing *fb* parthiobac-sodium	1000/62.5	PRE *fb* 30 DAS *fb* 50 DAS	2.4(4.6)	2.1(3.5)	3.66(12.37)	90.2	2.4(2.4)	1.8(2.3)	3.10(8.63)	89.0	0
Pendimethalin *fb* quizalofop-p-ethyl	1000 / 60	PRE *fb* 20 DAS	2.7(6.2)	1.7(2.0)	3.95(14.57)	88.4	2.7(3.7)	2.1(3.5)	3.18(9.13)	90.7	0
Parthiobac Na *fb* quizalofop-p-ethyl	62.5/ 60	20 and 60 DAS	1.5(11.4)	2.6(5.6)	6.72(44.20)	65.1	3.5(19.2)	1.8(2.4)	6.88(46.40)	53.0	0
Mechanical Weeding(3)	-	20, 40 and 60 DAS	1.4(1.0)	1.9(2.5)	2.39(4.70)	96.2	1.4(3.5)	1.7(2.0)	2.62(5.87)	92.8	0
Parthiobac Na *fb* quizalofop-p-ethyl *fb* mechanical Weeding	62.5/60	20 , 50 and 70 DAS	1.5(1.2)	1(0.0)	1.56(1.43)	98.8	1.5(2.5)	2(3.2)	2.93(7.60)	91.1	0
Parthiobac Na *fb* quizalofop-p-ethyl *fb* directed spray of paraquat	62.5/60 / 360	20 , 50 and 70 DAS	1.4(1.0	1(0.0)	1.37(0.87)	99.3	1.4(5.8)	1.8(2.3)	3.53(11.50)	87.1	10
Parthiobac Na *fb* quizalofop-p-ethyl *fb* directed spray of glyphosate	62.5/60/ 1000	20 , 50 and 70 DAS	1(0.0)	1(0.0)	1(0)	100	1(0.0)	1(0.0)	1(0)	100	10
Pendimethalin *fb* directed spray of glyphosate	1000/ 0.5%	PRE and 60 DAS	1.5(1.3)	1(0.0)	1.4(0.97)	99.2	1.5(2.0)	1(0.0)	1.69(1.87)	96.9	8.3
Weedy check	-	-	8.1(65.0)	4.1(18.4)	11.28(126.47)	0	8.1(46.3)	3.5(11.7)	9.99(98.83)	0	0
Weed free	-	-	(0.0)	1(0)	1(0)	100	1(0)	1(0)	1(0)	100	0
SEm +			**0.2**	0.1	0.10		0.2	0.1	0.07		
LSD (P= 0.05)			**0.5**	0.2	0.29		0.5	0.4	0.22		

*Original figures in parenthesis were subjected to square root transformation (“X+1) before statistical analysis.

Table 2. Density and dry of weeds and WCE (%) at different crop growth stages as affected by different treatments in cotton

Treatments	Dose (g/ha)	Time of application	Weed density(No./m²) 90 DAS				Harvest				Phyto-toxicity on crop (%) at 90 DAS
			T. portulacastrum	*Echinochloa* spp.	Dry wt. (g/m²)	WCE *(%)*	*T. portulacastrum*	*Echinochloa* spp.	Dry wt. (g/m²)	WCE *(%)*	
Pendimethalin fb 2 HW	1000	PRE, 20 and 50 DAS	2.93(7.6)	2.0(3.0)	3.83(13.70)	63.1	2.04(3.2)	1.8(2.3)	3.22(9.41)	65.7	0
Pendimethalin *fb* hoeing *fb* quizalofop-p-ethyl	1000/ 60	PRE *fb* 30 DAS *fb* 60 DAS	2.2(4.0)	1.4(1.0)	2.91(7.50)	72.0	1.5(2.5)	1(0)	2.61(5.82)	72.2	0
Pendimethalin *fb* hoeing *fb* propaquizafop-p-ethyl	1000/ 60	PRE *fb* 30 DAS *fb* 60 DAS	2.44(5.0)	1(0)	2.74(6.54)	73.6	1.71(2.0)	2.04(3.2)	2.77(6.70)	70.5	0
Pendimethalin *fb* parthiobac-sodium	1000 /62.5	PRE *fb* 20 DAS	3.78(14.3)	3.53(11.5)	6.44(40.5)	38.0	3.71(12.8)	3.22(9.4)	7.78(59.56)	17.1	0
Pendimethalin *fb* hoeing *fb* parthiobac-sodium	1000/62.5	PRE *fb* 30 DAS *fb* 50 DAS	2.12(3.5)	2.23(2.0)	3.43(11.77)	63.1	1.71(2.0)	2.64(6.0)	3.55(11.64)	62.1	0
Pendimethalin *fb* quizalofop-p-ethyl	1000 / 60	PRE *fb* 20 DAS	3.30(8.9)	2.12(3.5)	4.22(16.89)	59.4	2.72(6.4)	8.30(5.9)	4.34(17.85)	53.4	0
Parthiobac Na *fb* quizalofop-p-ethyl	62.5/ 60	20 and 60 DAS	4.03(15.3)	2.61(5.82)	7.72(58.60)	25.7	5.37(27.9)	3.22(9.4)	7.72(58.7)	17.8	0
Mechanical weeding(3)	-	20, 40 and 60 DAS	1.81(2.3)	2.23(4.0)	2.93(7.62)	71.8	2.40(5.8)	2.36(4.6)	2.92(7.57)	69.0	0
Parthiobac Na *fb* quizalofop-p-ethyl *fb* mechanical weeding	62.5/60	20 , 50 and 70 DAS	1(0)	1.51(1.3)	1.58(1.51)	80.9	1.5(2.5)	2(3.2)	2.93(7.60)	68.7	0
Parthiobac Na *fb* quizalofop-p-ethyl *fb* directed spray of paraquat	62.5/60/ 360	20 , 50 and 70 DAS	1.71(2)	1(0)	2.13(3.56)	79.5	2.62(5.9)	1.71(1.0)	3.72(12.87)	60.3	8
Parthiobac Na *fb* quizalofop-p-ethyl *fb* directed spray of glyphosate	62.5/60/ 1000	20 , 50 and 70 DAS	1(0)	1.71(2)	1.85(2.43)	82.2	1.71(2)	1(0.0)	1.56(1.45)	83.3	0
Pendimethalin *fb* directed spray of glyphosate	1000/0.5%	PRE and 60 DAS	1(0)	2.0(3)	1.69(1.86)	83.7	1.5(2.0)	1(0.0)	1.69(1.87)	82.0	5
Weedy check	-	-	7.68(59)	5.04(24.5)	10.4(109.7)	0	6.44(40.58)	3.93(14.5)	9.39(87.21)	0	0
Weed free	-	-	1(0)	1(0)	1(0)	100	1(0)	1(0)	1(0)	100	0
SEm +			**0.2**	0.1	0.10		0.2	0.1	0.07		
LSD (P= 0.05)			**0.5**	0.2	0.29		0.5	0.4	0.22		

*Original figures in parenthesis were subjected to square root transformation ("X+1) before statistical analysis.

Table 3. Seed cotton yield, no. of bolls/plant and nutrient uptake by weeds as affected by different treatments

Treatments	Dose (g/ha)	Time of application	Bolls/ plant		Seed cotton yield (kg/ha)		N uptake by weeds (kg/ha)		P uptake by weeds (kg/ha)	
			2014	2015	2014	2015	2014	2015	2014	2015
Pendimethalin *fb* 2 HW	1000	PRE, 20 and 50 DAS	39	41	2160	1980	5.16	5.32	1.55	1.65
Pendimethalin *fb* hoeing *fb* quizalofop-ethyl	1000/60	PRE *fb* 30 DAS *fb* 60 DAS	42	42	2303	2148	3.89	3.77	1.18	1.28
Pendimethalin *fb* hoeing *fb* propaquizafop-p-ethyl	1000/65	PRE *fb* 30 DAS *fb* 60 DAS	40	42	2150	2172	3.74	4.05	1.16	1.65
Pendimethalin *fb* pyrithiobac-sodium	1000 /62.5	PRE *fb* 20 DAS	37	34	1868	1265	23.37	24.68	6.60	7.53
Pendimethalin *fb* hoeing *fb* pyrithiobac-sodium	1000/62.5	PRE fb 30 DAS *fb* 50 DAS	42	39	2207	1872	5.19	6.85	1.47	1.95
Pendimethalin *fb* quizalofop-p-ethyl	1000 / 60	PRE *fb* 20 DAS	42	40	1960	1920	5.57	7.85	1.61	2.15
Pathiobac Na *fb* quizalofop-p-ethyl	62.5/ 60	20 and 60 DAS	37	33	1810	1360	29.2	31.5	8.49	9.78
Mechanical weeding(3)	-	20, 40 and 60 DAS	51	45	2371	2280	3.63	4.52	10.1	1.35
Parthiobac Na *fb* quizalofop-p-ethyl *fb* mechanical weeding	62.5/60	20 ,50 and 70 DAS	44	42	2260	1980	4.78	5.42	1.33	1.56
Parthiobac Na *fb* quizalofop-p-ethyl *fb* directed spray of paraquat	62.5/60 / 360	20 ,50 and 70 DAS	39	40	1941	1926	6.91	3.91	2.01	2.58
Parthiobac Na *fb* quizalofop-p-ethyl *fb* directed spray of glyphosate	62.5/60 / 1000	20 ,50 and 70 DAS	41	44	1967	2244	0	0	0	0
Pendimethalin *fb* directed spray of glyphosate	1000/0.5%	PRE and 60 DAS	45	43	2081	2200	0.72	4.95	0.33	1.32
Weedy check	-	-	30	30	1210	1248	62.3	62.3	17.88	17.88
Weed free	-	-	52	46	2414	2364	0	0	1(0)	1(0)
SEm +			1.2	0.97	20.3	20.8		-		-
LSD (P= 0.05)			3.5	2.9	59.4	62.0		-		-

Table 4. Calibration details and residues

Herbicides	Calibration parameters						Average* Recovery(%) ±SD						Average* Residues (ig/g)		
	Soil		Cotton seeds		Cotton lint		Soil Fortification levels (ig/g)		Cotton seeds Fortification levels (ig/g)		Cotton lint Fortification levels (ig/g)		Soil	Cotton seeds	Cotton lint
	LOD (ig/g)	LOQ (ig/g)	LOD (ig/g)	LOQ (ig/g)	LOD (ig/g)	LOQ (ig/g)	(0.01)	(0.05)	(0.01)	(0.05)	(0.01)	(0.05)			
Pendimethalin	0.003	0.005	0.005	0.01	0.003	0.006	85.1±0.2	89.5±1.1	81.2±0.6	81.9±0.6	90.3±1.0	93.2±0.2	0.08	BDL	BDL
Quizalofop	0.003	0.006	0.01	0.05	0.005	0.01	87.0±0.4	89.3±0.2	83.5±0.1	84.3±0.3	85.8±0.7	88.2±0.3	BDL	BDL	BDL
Propaquizafop	0.003	0.005	0.05	0.09	0.003	0.005	83.2±0.1	85.4±0.3	87.4±0.1	89.1±0.2	87.2±0.6	92.4±0.4	BDL	BDL	BDL
Pyrithiobac-Na	0.01	0.03	0.01	0.05	0.01	0.03	82.4±1.0	82.8±1.2	80.5±0.2	81.7±0.6	83.0±0.4	86.5±0.2	BDL	BDL	BDL
Glyphosate	0.01	0.05	0.01	0.06	0.01	0.05	85.2±1.2	83.9±0.3	80.4±0.5	82.4±1.5	83.4±1.5	86.8±0.1	BDL	BDL	BDL
Paraquat	0.03	0.08	0.05	0.08	0.03	0.05	81.0±1.1	82.1±0.5	80.0±0.7	81.4±0.5	84.1±0.5	85.2±0.5	BDL	BDL	BDL

*Average of three replicates

(0.5 %) or paraquat (Table 3), but during 2015, maximum cotton seed yield (2414 kg/ha) was obtained in weed free plots which was significantly *at par* with three mechanical weedings. Weedy condition throughout crop growth period caused 47.2-49.9 per cent reduction in seed cotton yield.

Herbicides residues: Recovery experiments were carried out to check the validity of the method in soil, cotton seed and lint samples by fortifying the control samples of each matrix @ 0.01 ìg/g and 0.05 ìg/g levels in triplicate. Percent recoveries in all the samples of soil, cotton seed and lint were greater than 80 (Table 4); therefore no correction factor was need for calculation of residues. Quizalofop, propaquizafop, pyrithiobac-Na, glyphosate and paraquat reached below detection limit (BDL) 0.05 ìg/g within 10 days after application and dissipation followed first order kinetics in soil. Residues were not detected in cotton lint and seed. Pendimethalin was found persistent in soil (0.08 µg/g on 120 days after application) at both the doses and thus may be effective for weed control almost throughout the crop season (Table 4).

REFERENCES

Balyan, R.S., Bhan, V. M. and Malik, Malik, R. K. 1983. The effect of weed removal at different times on the seed yield of cotton**.** *Cotton Dev.***13 :** 9-10

Brar, A. S. and Brar, L.S. 1992. Bioefficacy of herbicides for weed control in American cotton**.** *J.Cotton Res. Dev.* **6:** 143-50

Hu, J.Y., Chen, C.L. and Li, J.Z. 2008. A simple method for the determination of glyphosate residues in soil by capillary gas chromatography with NPD. *J. Anal. Chem,* **63**: 371-75.

Panwar, R.S, Malik, R.K., Bhan, V.M. and Malik. R. S. 1989. Evaluation of pre-emergence and post-emergence herbicides in cotton. *Haryana agric. Univ. J. Res.* **21**: 235-39.

Panwar, R.S., Rathee, S.S, Malik, R.S and Malik, R.K. 2001. Weed control in cotton. *Indian J. Weed Sci.* **33**: 164-67

Pimental, D. 1995. Amounts of pesticides reaching target-pests: Environmental Inputs and Ethics. *J Agric. Environ. Ethics*, **8** : 17-29.

YOUNG SCIENTIST AWARD PAPERS

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Impact of weather parameters and effect of date of sowing on the seed development in *desi* cotton (*Gossypium arboreum*)

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Cotton is the most important renewable natural fibre crop and continues to be the predominant and sustainable fibre in the Indian textile scene, despite stiff competition from the man made synthetic fibers. It is grown in an area of 329.49 lakh ha in about 80 countries across the world. In India cotton is grown in 105 lakh ha area with production of 351 lakh bales during the year 2016-2017. In Haryana area under cotton cultivation was 4.98 lakh ha with production 20 lakh bales with productivity of 683 kg lint /hectare compared to 568 kg lint/hectare of India (Anonymous, 2017). There are numerous abiotic stress factors, particularly moisture surpluses and deficits, high and low temperatures and low light imposes limitations to the growth and development and ultimately yield of cotton crop. All processes such as square formation, blossom and boll initiation and maturation of the crop are affected by temperature. Cool nights observed beneficial during the fruiting period but extremes in temperature can result in delayed growth and aborted fruiting sites. Temperature significantly affects phenology, leaf expansion, internodes elongation, biomass production and the partitioning of assimilates to different plant parts. The environment affects the development of plant growth and seed development (Khaliq *et al.*, 2014). The most important weather variables for agricultural production are air temperature, solar radiation and precipitation. Seed germination in cotton is a big problem under North Indian conditions particularly since 2013-2014. Cotton seed quality is very much affected by environment. Sometimes seed germination in cotton may be reduced as low as 10 per cent due to adverse environmental conditions and exact reasons for poor development of seed are still unknown. Keeping the above points in mind, the present investigation was carried.

MATERIALS AND METHODS

The experiment was conducted at the Research Farm of Cotton Section, Department of Genetics and Plant Breeding, Chaudhary Charan Singh Haryana Agricultural University, Hisar. The experimental material comprised of 3 varieties of *desi* cotton *i.e.* HD 123, HD 324 and HD 432 in a randomized block design (RBD) with six replications. All the experimental material was grown in six environments comprised of three different sowing times (early, normal and late sown) and two *kharif*, 2015 and 2016.

The plants were tagged in each plot for flowering and boll development. The observations were taken weekly from flowering initiation to boll opening. As and when flowering started, opened flowers were tagged. The flowering during both the years started from early July to end of September during 2015 and 2016. After ginning the seeds obtained were subjected to germination (%) test under laboratory conditions.

Germination test was conducted using four replicates of 100 seeds each by adopting "Between paper method" as described by ISTA. Weekly meteorological data were recorded at agro meteorological observatory during the seed development period of both seasons and converted to weekly data. Agro meteorological indices like heat unit, heliothermal unit and photothermal unit were calculated for seed development period 14 days after flower opening to 35 days. Germination of cotton seeds was correlated with weather parameters averaged during the seed development period of three varieties in three growing environments. Based on significant value of correlation coefficients, weather seed development functions were developed.

RESULTS AND DISCUSSION

The per cent germination of different varieties for the year 2015 and 2016 (Fig.1) indicated that it was significantly reduced from early sowing (63.43 %) to late sown conditions (40.68%) *i.e.* superiority of early sowing for better seed development. The variety HD 432 recorded the highest seed germination (54.90%) while the lowest seed germination was recorded in HD 123 (49.11%). These results were in the confirmity with the findings of Sarwar *et al.,* (2012). The correlation of various weather parameters affecting seed development during their critical development phases during the crop season was necessary to find out the reasons for differences in seed development/germination (%) in different varieties under various environmental conditions. Significant weather parameters were selected based on the correlation coefficients obtained with germination in different varieties grown in these environments. In most of the cases among various response functions; polynomial response function was found best fit with R^2 values ranged between 0.20 and 0.88. Relationship of agro meteorological variables with germination was quantified mathematically using best fit weather germination response function in respect of different varieties grown during 2015 and 2016 (Table 1). On the basis of "R^2 values" quantified

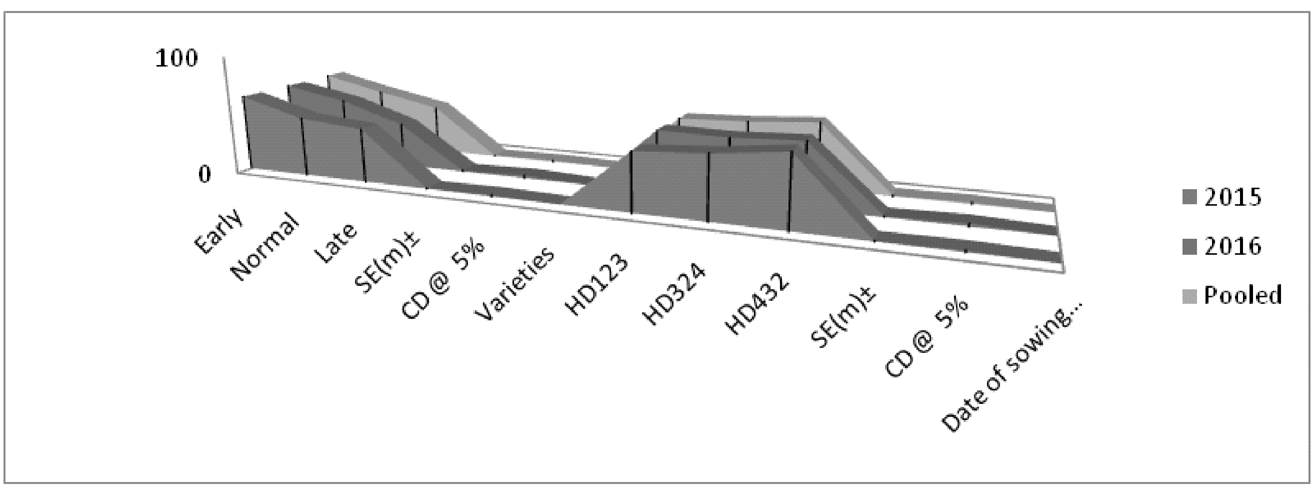

Fig. 1. Influence of date of sowing on germination in different varieties

Table 1. Best fit weather-seed germination response function (polynomial) for cotton varieties under different growing environments

Growing environments	Weather parameters	HD123		HD324		HD432	
		$Y= ax^2+bx+c$	R^2	$Y= ax^2+bx+c$	R^2	$Y= ax^2+bx+c$	R^2
E1	**RHm**	$Y=0.369x^2-61.35x+2597$	**0.256**	$Y= 0.038x^2-5.809x+274.9$	**0.255**	$Y= 0.263x^2-44.12x+1903$	**0.209**
	RHe	$Y= -0.059x^2+7.015x-129.9$	**0.225**	$Y= -0.015x^2+2.075x-3.827$	**0.362**	$Y= -0.042x^2+4.784x-62.43$	**0.296**
E2	**Tmin**	$Y=0.624x^2-25.04x+281$	**0.737**	$Y= -1.121x^2+56.19x-647$	**0.602**	$Y= -0.506x^2+27.13x-304.2$	**0.734**
	RHm	$Y=0.307x^2-49.06x+1991$	**0.830**	$Y= 0.433x^2-71.12x+2959$	**0.490**	$Y= 0.288x^2-46.79x+1947$	**0.508**
	RHe	$Y=0.037x^2-2.919x+90.18$	**0.821**	$Y= -0.032x^2+3.876x-58.59$	**0.213**	$Y= -0.024x^2+3.186x-37.95$	**0.485**
	PTU	$Y=9E-06x^2-0.075x+195.9$	**0.562**	$Y= -3E-05x^2+0.331x-869.1$	**0.682**	$Y= -1E-05x^2+0.154x-391.5$	**0.712**
E3	**Tmin**	$Y=0.402x^2-15.13x+169.1$	**0.667**	$Y= -0.833x^2+42.65x-494.3$	**0.664**	$Y= -0.762x^2+41.04x-489.9$	**0.795**
	RHm	$Y=0.333x^2-53.61x+2186$	**0.847**	$Y= 0.407x^2-66.79x+2772$	**0.570**	$Y= 0.360x^2-58.35x+2406$	**0.413**
	RHe	$Y=0.039x^2-3.219x+98.60$	**0.735**	$Y= -0.020x^2+2.670x-34.32$	**0.277**	$Y= -0.067x^2+7.886x-167.1$	**0.540**
	PTU	$Y=3E-06x^2-0.015x+40.63$	**0.516**	$Y= -2E-05x^2+0.238x-628.3$	**0.722**	$Y= -2E-05x^2+0.212x-570.3$	**0.770**
E4	**RHm**	$Y= -3.144x^2+553.4x-24278$	**0.663**	$Y= -2.494x^2+440.3x-19361$	**0.394**	$Y= -2.896x^2+510.4x-22419$	**0.554**
	RHe	$Y= -0.134x^2+15.63x+378.4$	**0.475**	$Y= -0.083x^2+9.858x-220.1$	**0.200**	$Y= -0.124x^2+14.42x-345.4$	**0.441**
E5	**Tmin**	$Y=0.449x^2-12.64x+93.18$	**0.599**	$Y= 0.931x^2-33.87x+322.4$	**0.600**	$Y=0.226x^2-2.647x-14.77$	**0.450**
	RHm	$Y=0.502x^2-79.31x+3142$	**0.662**	$Y= 0.717x^2-114.4x+4565$	**0.774**	$Y= 1.540x^2-261.6x+11146$	**0.485**
	RHe	$Y= -0.032x^2+5.051x-130.5$	**0.743**	$Y= 100.7(\ln)x-358.5$	**0.875**	$Y= -0.037x^2+5.550x-140.9$	**0.629**
	PTU	$Y= -1E-05x^2+0.133x-386.2$	**0.639**	$Y= -7E-06x^2+0.112x-350.5$	**0.650**	$Y= -1E-05x^2+0.167x-470.0$	**0.528**
E6	**Tmin**	$Y=0.993x^2-43.54x+505.7$	**0.598**	$Y= 1.065x^2-46.00x+523.1$	**0.691**	$Y= 1.69x^2-75.55x+872.0$	**0.609**
	RHm	$Y=1.335x^2-229.7x+9907$	**0.722**	$Y= 1.414x^2-242.5x+10430$	**0.808**	$Y= 2.439x^2-421.8x+18266$	**0.687**
	RHe	$Y=0.010x^2-0.588x+33.84$	**0.699**	$Y= 0.008x^2-0.250x+21.37$	**0.711**	$Y= 0.022x^2- 1.827x+64.96$	**0.591**
	PTU	$Y=5E-06x^2-0.034x+89.90$	**0.612**	$Y= 3E-06x^2-0.017x+37.37$	**0.667**	$Y= 1E-05x^2-0.088x+222.3$	**0.596**

optimum range of morning and evening relative humidity was 87 to 89 per cent and 60 to 70 per cent, respectively. Minimum temperature ranged from 25 to 26 °C whereas photothermal unit ranged from 5500 to 6000 °C day h. In early sown conditions major influence of morning and evening relative humidity was observed, while in case of normal and late sown conditions minimum temperature, photo thermal unit and morning and evening relative humidity played crucial role for better seed development during reproductive growth period. Early sown conditions were observed most suitable for seed development in all the three varieties and the period from August 1 to September 7 was best for seed development in all the sowing. The results showed early date of sowing had good seed germination for better seed development. The advantage of early sowing was supported by different workers (Soomro *et al.*, 2014).

REFERENCES

Anonymous 2017. Status Paper of Indian Cotton. Directorate of Cotton Development, Ministry of Agriculture and Farmers Welfare, Government of India. pp 182

Khaliq, A., Javed, M., Sohail, M. and Muhammad, Sagheer 2014. Environmental effects on insects and their population dynamics. *Jour. Ent. Zoo. Studies*, **2 :** 1-7

Sarwar, M., Farrukh Saleem, M., Ashfaq Wahid, M., Amir Shakeel and Faisal Bilal, M. 2012. Comparison of *Bt* and non *Bt* cotton (*Gossypium hirsutum* L.) cultivars for earliness indicators at different sowing dates and nitrogen levels. *Jour. Agri. Res.*, **50**:335-347

Soomro, A.W. Majidano, M. S., Ahsan, M.Z., Channa, A.R., Panhwar, F.H., Bhutto, H. and Kalhoro, A.H. 2014. Effects of picking dates on seed germination, got and fiber traits of upland cotton (*Gossypium hirsutum*L.) *European Acad. Res.*, **2** : 12339-45.

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Genetic polymorphism analysis of cotton genotypes using Microsatellite marker

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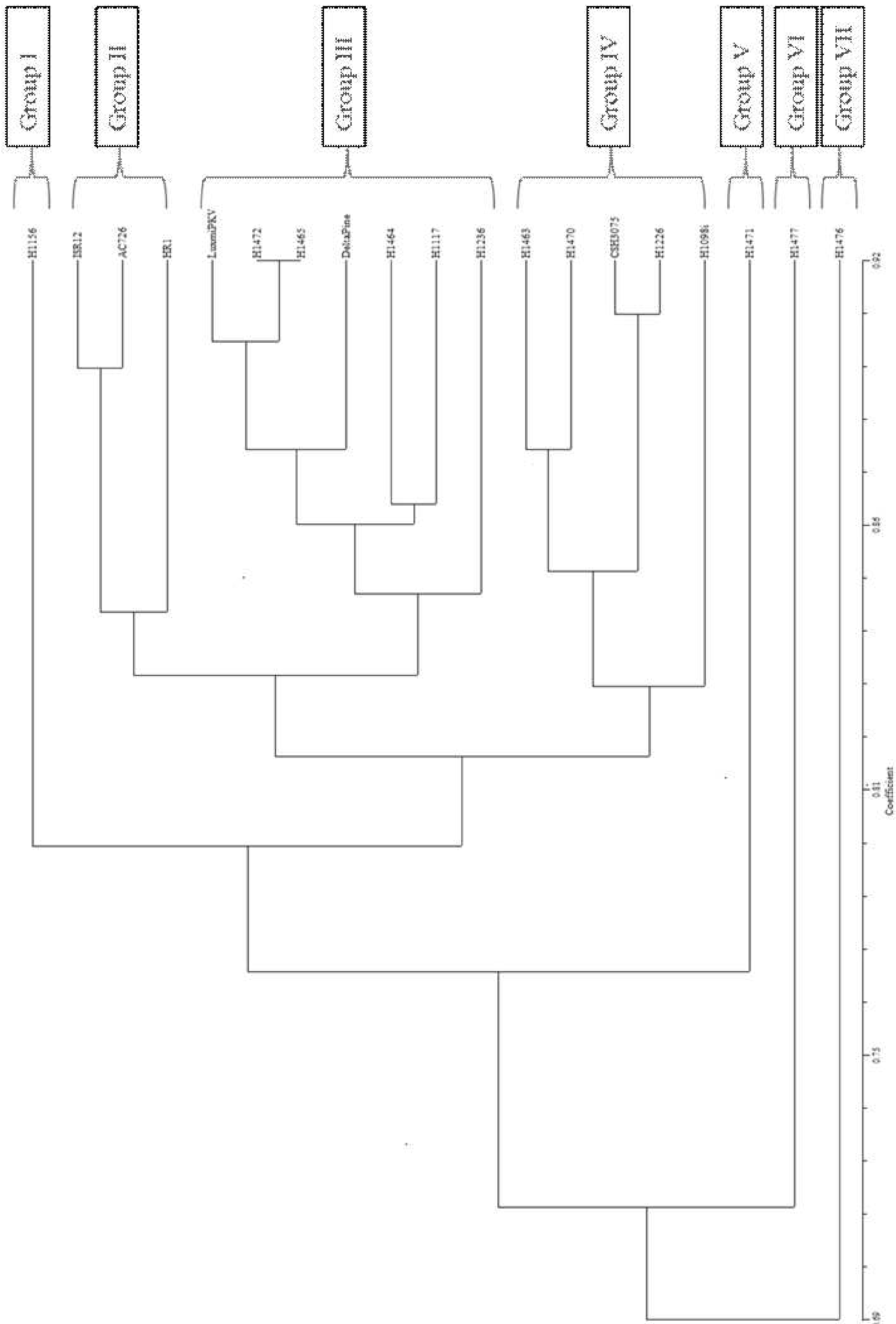
Cotton (*Gossypium hirsutum* L.) is an important fibre crop and plays a vital role in commerce of many countries. It contributes about 65 per cent of raw material for the textile industries. In India, cotton production, processing and trade of cotton goods provides livelihood directly and indirectly to over 60 million people and accounts about 16 per cent of India's export earnings. To make the productivity of Indian cotton comparable to other countries like USA and China, there is a need to give more emphasis on the magnitude of heterosis, *per se* performance and stability of genotypes. India is a pioneer country in exploitation of heterosis breeding by using conventional technique of hybrid seed production as well as genetic male sterility system. Selection of diverse parents is very important to achieve the target. Therefore, study on genetic diversity among parents is essential. Simple sequence repeats or microsatellite marker study was done for this purpose. This is the most preferred and reliable molecular marker system.

MATERIALS AND METHODS

The present study consisted of nineteen diverse cotton genotypes from Department of Genetics and Plant Breeding of CCS Haryana Agricultural University, Hisar in India, by employing forty-nine SSR primers. These genotypes were raised during kharif 2015 and DNA isolation in leaf tissue was done using CTAB method. PCR and PAGE analysis revealed DNA polymorphism for this trait among the genotypes. Based on 0/1 matrix of allele scoring, genetic similarity coefficient was calculated to estimate pair-wise similarity in the amplification product for all genotypes using "SimQual" sub-programme of NTSYS-pc (version 2.02e) software. Dendrogram was constructed by using distance matrix by Unweighted Pair-Group Method with Arithmetic average (UPGMA) sub-programme of NTSYS-pc.

RESULTS AND CONCLUSION

Genetic diversity at molecular level was done in this investigation by 49 SSR primers, in which seven markers did not show amplification. Out of remaining 42 SSR primers, 2 primers resulted monomorphic bands and 40 SSR primers exhibited polymorphism. One hundred and seventy three alleles were amplified by using 49 SSR primers, resulting in 4.10 alleles per primer. The overall size of PCR amplified products ranged from 80 bp (GH5) to 450 bp (MGH ES18, DPL0039 and NAU2083). Polymorphic information content (PIC) value



UPGMA dendrogram showing relationship among nineteen upland cotton genotypes based on similarity matrix data using 49 SSR markers

Table Distribution of nineteen *Gossipium hirsutum* genotypes in different clusters based on SSR markers analysis

Group	Genotypes	Number of genotypes
Group I	H1156	1
Group II	ISR12, AC726 and HR1	3
Group III	LuxmiPKV, H1472, H1465, Deltapine, H1464, H1117 and H1236	7
Group IV	H1463, H1470, CSH3075, H1226 and H1098-i	5
Group V	H1471	1
Group VI	H1477	1
Group VII	H1476	1

ranged from 0 to 0.948 with an average of 0.663. Primer BNL1721 have maximum PIC value and indicating that this primer show maximum contribution for diversity analysis in this study and also can be used to select divergent parents for future breeding programs.

The NTSYS-pc UPGMA tree cluster analysis exhibited that nineteen parental genotypes were quite distinct. At 69 per cent similarity index, nineteen genotypes formed seven groups where four groups had single genotype each. Genetic similarity coefficients ranged from 0.69 to 0.92. The least similarity (0.69) was observed between genotype H1156 and H1476, while the genotypes H1472 and H 1465 showed maximum similarity coefficient of 0.92. The use of genotypes in hybridization from these different groups is likely to produce heterotic combination in future breeding program.

REFERANCES

Abbas, A., Iqbal, M.A., Rahman, M. and Andrew, H.P. 2015. Estimating genetic diversity among selected cotton genotypes and the identification of DNA markers associated with resistance to cotton leaf curl disease. *Turkish Jour. Bot.* **39** : 1033-41.

Ashraf, J., Malik, W., Iqbal, M.Z., Khan, A.A., Qayyum, A., Noor, E., Abid, M.A., Cheema, H.M.N. and Ahmad, M.Q. 2016. Comparative analysis of genetic diversity among Bt-cotton genotypes using EST-SSR, ISSR and morphological markers. *Jour. Agri. Sci. Tech.,* **18** : 517-31.

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Stability and association analysis for seed cotton yield and its component traits in upland cotton (*Gossypium hirsutum* L.)

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ABSTRACT : Stability and association analysis were carried out in thirty elite breeding lines of upland cotton for eleven characters planted under three environments during *kharif* 2015. Correlation studies indicated that traits like bolls/plant, boll weight (g), plant height (cm), lint yield/plant (g) and ginning outturn (%) showed significant positive correlation with seed cotton yield/plant (g). Further partitioning of correlation coefficients in to direct and indirect effects showed that lint yield/plant (g) exhibited maximum positive direct effects on seed cotton yield (g) followed by seed index, boll weight (g), bolls/plant, monopods/plant, sympods/plant, days to first flower, plant height (cm) and whereas, negative direct effects on seed cotton yield/plant (g) was observed for lint index (g) and ginning outturn (%). The correlation and path analysis, therefore, clearly indicated that direct selection based on bolls/plant and boll weight (g) may be helpful in developing high seed cotton yield varieties in upland cotton. Whereas in Stability analysis, the genotype x environment interaction was highly significant for monopods/plant, seed index and lint yield/plant. The joint regression analysis revealed that the sufficient genetic variability was present among genotypes for monopods/plant, sympods/plant, days to first flower, seed index, lint index, lint yield/plant with highly variable environments chosen for the present study.

Key words : Correlation, joint regression analysis, path-analysis, stability analysis, upland cotton

Cotton (*Gossypium hirsutum* L.) popularly called as **"White Gold"**, is the most important renewable natural fiber crop and continues to be the predominant and sustainable fibre in the Indian textile scene, despite stiff competition from the man made synthetic fibers. It belongs to the family Malvaceae and the genus *Gossypium* with 50 species. It is a fibre yielding crop of global importance, which is grown in tropical and sub-tropical regions of more than 80 countries of the world. It played a triple role by producing lint, oil and protein. Cotton stalks are also used as fuel and for making paper board. It plays a key role in the national economy in terms of contribution in trade, industrial activities, employment and foreign exchange earnings in India (Gite *et al.,* 2006).

The productivity of upland cotton is fluctuating over a wide range of environments. A statistic that fully represents a genotype's stability and yield potential is a measure of genotypes desirability and provides a meaningful selection criterion of production for plant breeders, geneticists and production agronomists.

Stability analysis helps in understanding the adaptability of crop varieties over a wide range of environmental conditions and identification of the most adaptable genotypes. The use of adaptable genotypes helps in achieving stabilization in crop production. The genotype x environment interaction is the interplay of genetic and non-genetic effects on the phenotypic expression as indicated by the failure of a genotype to give consistent performance in different environments. G x E interaction was observed to be present in pure lines and different types of hybrids irrespective of their genetic composition. Keeping in view the importance of G x E interactions, the research work on the present study was selected with objective to identify the stable genotypes performing uniformly in all the environments.

Yield is a complex trait, polygenic in inheritance, more prone to environmental fluctuations than other traits. Understanding the association between yield and its components is of paramount importance for making the best use of these relationships in selection. Thorough knowledge about the mean performance, extent of relationship and correlation of yield with various agronomic traits is indispensable for breeder to tackle the problem of yield to increase successfully.

Genetic correlation measures the magnitude of cause effect relationship between various traits that determine the component traits on which selection can be made. The correlation coefficient provides a reliable measure of association among the traits and helps to differentiate vital associates useful in breeding from those of the non vital ones.

Path coefficient is a tool which provides an effective measure of direct and indirect cause of association and depicts the importance of each factor contributing towards yield, in order to perceive the most influencing traits to be utilized as selection criteria in cotton breeding programme. To obtain such developmental relations, the cause and effect relationship between seed cotton yield/se and yield components were studied in cotton through path-coefficient analysis. Further to have consistency in yield performance of a variety over various environments, it is very essential to develop most stable genotypes in addition to high yield.

MATERIALS AND METHODS

The present study was conducted for the thirty elite breeding lines/genotypes of upland cotton over different environments with the objective to identify the stable lines/genotypes for seed cotton yield and other component traits. These genotypes were sown under three environments which were created by different dates of sowing *i.e.* early (19th April, 2015), timely (13th May, 2015) and late (24th May, 2015) during *kharif* 2015 in the Research Area of Cotton Section at CCS Haryana Agricultural University, Hisar with 67.5 x 30 cm spacing of row to row and plant to plant, respectively in three replications of randomized block design. Observations were recorded for eleven traits *i.e.* plant height (cm), days to first flower, monopods/ plant, sympods/ plant, bolls/plant, boll weight (g), seed index (g), lint index (g), lint yield/plant (g), ginning outturn (%) and seed cotton yield/plant (g). Based on the significance of G x E interactions, the stability parameters S^2di and parameters of response bi were worked out for eleven traits mentioned.

RESULTS AND DISCUSSIONS

Based on pooled analysis, it was observed that highest mean value (100.33 cm) for plant height and monopods/plant (1.92). Highest range was observed for all the traits in E_1. E_2 had higher range for boll weight, seed index and sympods/ plant in comparison with E_3. E_3 had higher range for most of the traits, *viz.,* plant height, monopods/ plant, bolls/plant, lint index, lint yield/plant, ginning outturn and seed cotton yield/plant but had lower range for days to first flower (desirable earliness) in comparison with E_2 (Table 1).

The study of genotype x environment interactions forms an important aspect of all major breeding programmes. Breeders usually evaluate a large genotypes in different locations and take years in order to select the genotypes with high stability for yield, but significant G x E interactions often complicates the breeder to work as yield cannot be predicted in this case.

Significance of G x E interaction mean squares for monopods/plant, seed index and lint yield/plant indicated that genotypes showed differential response to the change in environmental conditions. It was further noticed that both linear and non linear components significantly contributed to the total G x E interaction for all the traits (Table-2). For plant height, boll weight, lint index and ginning outturn, only nonlinear component contributed to G x E interactions, whereas, for monopods/ plant and seed index there was preponderance of linear component of G x E interaction. In an earlier study, Patil and Patel (2010) also reported that substantial portion of the G x E interactions was linear for the sympodia/plant, bolls/plant, boll weight, seed index, lint index and seed cotton yield. Both linear and non linear components were equally important for days to 50 per cent flowering, monopodia/plant and seeds/boll. Variance due to genotypes, environments and G x E interaction was significant for all traits. Similar results also reported by Satish, *et al.,* 2009 and Dewdar, (2013) also observed significant differences among cotton genotypes for seed cotton yield/plant, lint yield/plant, bolls/plant,

Table 1. Mean and Range for various traits in cotton under different environments:

Sr. No.	Traits	E1		E_2		E_3		POOLED	
		Mean	Range	**Mean**	Range	**Mean**	Range	**Mean**	Range
1	Plant height (cm)	**122.4**	105.0-143.3	**84.8**	70.0-100.0	**93.8**	80.0-118.0	**100.3**	70.0-143.3
2	Monopods/ plant	**2.1**	1.0-3.3	**1.7**	1.0-3.0	**2.0**	1.0-3.0	**1.9**	1.0-3.3
3	Sympods/ plant	**22.6**	18.3-24.7	**21.0**	16.0-24.3	**17.0**	14.0-21.0	**20.2**	14.0-24.7
4	Days to first flower	**61.0**	54.0-69.0	**55.8**	52.0-61.0	**52.5**	48.0-60.0	**56.5**	48.0-69.0
5	Bolls/ plant	**31.5**	22.0-41.7	**21.5**	13.7-32.0	**23.9**	17.0-35.0	**25.6**	13.7-41.7
6	Boll weight (g)	**3.4**	2.7-4.1	**3.0**	2.2-3.9	**3.0**	2.3-3.4	**3.1**	2.15-4.12
7	Seed index	**6.0**	5.2-6.8	**5.7**	5.1-6.4	**5.4**	5.0-6.0	**5.7**	5.0-6.8
8	Lint index	**3.8**	3.2-4.5	**3.1**	2.5-3.5	**3.2**	2.7-3.9	**3.3**	2.5-4.5
9	Lint yield/ plant (g)	**38.4**	25.8-52.0	**20.8**	13.3-31.4	**24.4**	15.8-35.7	**27.8**	13.3-52.1
10	Ginning outturn (%)	**38.7**	35.9-40.7	**35.1**	32.7-37.3	**36.8**	34.0-39.1	**36.9**	32.7-40.7
11	Seed cotton yield/ plant (g)	**98.9**	68.0-128.5	**59.1**	39.6-85.1	**66.3**	44.0-95.0	**74.8**	39.6-128.5

boll weight, lint (%) and lint index. Genotype H 1502 was found to be stable and suitable for all types of environments, having b_i value approaching to one for monopods/plant. For bolls/ plant only one genotype *i.e.*, H 1505 was having b_i value approaching to one, indicating that these genotypes were suitable for all types of environments. Likewise, optimum test locations were identified for lint yield, lint percent, strength and UHML and across all test locations in Texas over 2 years suggesting a large genotypic component governing those traits reported by Ng *et al.,* 2013.

This was also noticed for boll weight that two genotypes H 1512 and H 1499 were found suitable for all types of environments as they were having b_i values approaching to one. In case of seed index, H 1513 was having b_i value approaching to one (0.746), indicating its suitability for general environment. H 1500 had $b_i > 1$ (1.312), indicating its suitability for favourable environments.

H 1491 was having maximum ginning outturn (mean = 37.758%) followed by H 1499 with mean 37.679 per cent but all genotypes were having $b_i < 1$, indicating their suitability for poor or unfavourable environments. while Singh *et al.,* 2012 were also observed highly significant mean squares for heterogeneity between regressions for all the traits which indicated that the predictions can be made about the stability of hybrids over the environments and Singh, *et al.,* (2014) predicted the genotype x environment mean square was significant for seed cotton yield and fiber strength indicating different response of the genotypes in different environments and for boll weight and seed cotton yield, among the two crosses with high mean which were stable and responsive to favorable environments as indicated by the regression coefficient more than unity.

Table 2. Magnitude (%) of linear and non linear components of G x E interaction:

Traits	Linear	Non linear
Plant height (cm)	48.77	51.23
Monopods/ plant	77.92	22.08
Sympods/ plant	45.75	54.25
Days to first flower	62.21	37.79
Bolls/ plant	65.81	34.19
Boll weight (g)	48.00	52.00
Seed index (g)	83.33	16.67
Lint index (g)	39.58	60.42
Lint yield/ plant (g)	71.87	28.13
Ginning outturn (%)	41.71	58.29
Seed cotton yield/ plant (g)	68.89	31.11

For seed cotton yield/plant, H 1505 was having highest seed cotton yield/plant (mean= 87.063 g) and b_i approaching to one that indicating its suitability to general environment (Table 4). It is evident from the results presented (Table 3) that majority of genotypes showed below average response to the environments. These results indicated that there was sufficient variation for performance of the genotypes under different environments. This suggested the presence of high Genotype x Environment interaction for seed cotton yield in upland cotton. For any breeding programme, variation in the material is the first requirement. The ultimate aim of studying the phenotypic stability under the present studies was to find out stable genotypes and which could be exploited further in breeding programmes. Dewdar, (2013) also reported that combined analysis showed highly significant between the genotypes, between environments and for G x E interaction of all traits under study.

This implied therefore, that the genotypes were low contribution to the genotypic by environment interaction. The results showed that high yield genotypes could be differed in yield stability and suggest that yield stability and high mean yield are not mutually exclusive. Seed cotton yield is poly genically inherited trait which depends on a component traits. The knowledge regarding the extent of association between yield and its contributing traits is helpful in breeding programme for making selections. Correlation coefficient was worked out to assess the association of traits among themselves and with seed cotton yield under three environments separately and also on pooled basis. The estimates of correlation coefficient have been presented in Table 5. A critical perusal of correlation coefficient revealed that seed cotton yield/plant has significant positive association with bolls/plant and lint yield/plant under all the environments. Non significant association was observed for seed cotton yield/ plant with sympods/plant, days to first flower and seed index in all the environments.

Plant height exhibited positive significant association with boll weight, seed index, lint yield/plant and seed cotton yield/ plant in E1 but negative association with seed index in E2 and in E3 it had negative association with sympods/plant. Number of monopods/plant revealed significant negative association with seed index, lint index, lint yield/plant and seed cotton yield/plant under E2 and with ginning outturn in E3. Number of sympods/plant and days to first flower showed significant positive association with all traits on the basis of pooled data. Bolls/plant had positive association with lint yield/plant and seed cotton yield/plant in all the environments whereas negative association with boll weight in E2.

Boll weight recorded significant positive association with lint yield/plant and seed cotton yield/plant in E1 and E2 but in E3 same trend with seed index and lint index. Seed index was observed positively associated with lint index in

Table 3. Distribution of different genotypes on the basis of different stability parameters for various traits

Traits	Predictable Genotypes		Unpredictable Genotypes	
	Genotypes for both bi and S^2di non significant	Genotypes for only bi significant	Genotypes for both bi and S^2di non significant	Genotypes for only bi significant
Plant height (cm)	28	0	0	2
Monopods/ plant	21	8	0	1
Sympods/ plant	30	0	0	0
Days to first flower	26	3	0	1
Bolls/ plant	22	2	1	5
Boll weight (g)	19	0	0	11
Seed index (g)	27	3	0	0
Lint index (g)	22	0	0	8
Lint yield/ plant (g)	15	2	2	11
Ginning outturn (%)	21	0	0	9
Seed cotton yield/ plant (g)	11	3	1	15

Table 4. Selected genotypes having general and specific adaptability for favourable and unfavourable environments

Traits	Genotypes for high mean	Non significant S^2d_i (stable)	b_i <1 for unfavourable environment	b_i = 1 for general adaptability	b_i >1 for favourable environment
Plant height (cm)	5	4	H 1462, GCA 28, H 1500	-	-
Monopods/ plant	13	12	-	H 1502	H 1503, GCA 28, H 1500
Sympods/ plant	11	11	H 1492, H 1503, H 1515, GCA 3, H 1516	-	-
Days to first flower	14 (early)	14	H 1482, H 1482, H 1513, H 1495, H 1515, GCA 28, H 1500	-	-
Bolls/plant	5	4	H 1491	H 1505	-
Boll weight (g)	6	5	H 1454, H 1511, H 1515	H 1512, H 1499	-
Seed index (g)	12	12	H 1454, H 1505, GCA 3, GCA 28	H 1500 H 1513	
Lint index (g)	9	6	H 1454, H 1510, H 1513, GCA 3, H 1500	-	-
Lint yield/ plant (g)	6	5	H 1475, H 1491, H 1505	-	-
Ginning outturn (%)	2	1	H 1491	-	-
Seed cotton yield/ plant (g)	5	2	HS 288	H 1505	-

all the environments. Lint index had positive association with ginning outturn in all the environments. Lint yield/plant showed significant positive association with ginning outturn and seed cotton yield/plant in all the environments.

Ginning outturn recorded positive association with seed cotton yield/plant in E1 and E2 only. Based on these results, it is concluded that the seed cotton yield/plant can be enhanced by increasing bolls/plant, boll weight and lint yield/plant. Many of the reports regarding positive correlation of plant height, bolls/plant, boll weight and ginning outturn with seed cotton yield as reported by Gite *et al.,* (2006), Patnaik and Sial (2010), Rajamani *et al.,* (2013), Vinodhana *et al.,* (2013), Farooq *et al.,* (2014), Pujer *et al.,* (2014) and Asha *et al.,* (2015) and Srinivas *et al.,* (2015).

Correlation studies alone are not sufficient to make the association picture clear. Path coefficient analysis provides more realistic and clear picture of the association between traits that exists complex at correlation level. Since, it takes into consideration the direct as well as indirect effect of one variable through the other on dependent trait. Only those traits were taken into consideration which had significant correlation with seed cotton yield/ plant (Table 6). The direct effect of plant height on seed cotton yield was positive in E1 and E2 but negative in E3. It contributed towards seed cotton yield *via* boll weight in E1 and E3 and via ginning outturn in all the environments. The direct effect of monopods/plant was positive in E1 and E3. However, the major contribution

Table 5. Correlation-coefficients for seed cotton yield and other traits:

	Env^{t}	Mono-pods/ plant	Sym-pods/ plant	Days to first flower	Bolls/ plant	Boll weight (g)	Seed index (g)	Lint index (g)	Lint yield/ plant (g)	Ginn -ing outturn (%)	Seed cotton yield/ plant (g)
Plant height (cm)	E1	0.202^{NS}	0.147^{NS}	0.158^{NS}	0.205^{NS}	0.339**	0.224*	0.157^{NS}	0.343**	-0.063^{NS}	0.373**
	E2	0.223*	0.088^{NS}	-0.059^{NS}	-0.048^{NS}	-0.149^{NS}	-0.304**	-0.140^{NS}	-0.130^{NS}	0.175^{NS}	-0.160^{NS}
	E3	0.019^{NS}	-0.210*	-0.132^{NS}	-0.006^{NS}	0.060^{NS}	-0.060^{NS}	-0.132^{NS}	-0.015^{NS}	-0.135^{NS}	0.008^{NS}
	P	0.281**	0.396**	0.588**	0.650**	0.514**	0.370**	0.699**	0.782**	0.706**	0.758**
Monopods/ plant	E1		0.043^{NS}	0.189^{NS}	0.039^{NS}	-0.058^{NS}	0.093^{NS}	0.108^{NS}	0.039^{NS}	0.049^{NS}	0.038^{NS}
	E2		0.085^{NS}	-0.093^{NS}	-0.051^{NS}	-0.187^{NS}	-0.297**	-0.329**	-0.229*	-0.150^{NS}	-0.223*
	E3		-0.202^{NS}	-0.134^{NS}	-0.107^{NS}	0.041^{NS}	0.250*	-0.051^{NS}	-0.132^{NS}	-0.303**	-0.075^{NS}
	P		0.002^{NS}	0.101^{NS}	0.149*	0.048^{NS}	0.055^{NS}	0.135*	0.158**	0.140*	0.151*
Sympods/ plant	E1			0.135^{NS}	-0.112^{NS}	-0.096^{NS}	0.036^{NS}	-0.031^{NS}	-0.160^{NS}	-0.098^{NS}	-0.150^{NS}
	E2			0.130^{NS}	0.161^{NS}	-0.103^{NS}	0.003^{NS}	-0.048^{NS}	0.017^{NS}	-0.075^{NS}	0.027^{NS}
	E3			0.078^{NS}	0.180^{NS}	-0.061^{NS}	0.030^{NS}	0.100^{NS}	0.156^{NS}	0.108^{NS}	0.143^{NS}
	P			0.647**	0.343**	0.285**	0.446**	0.413**	0.393**	0.218**	0.395**
Days to first flower	E1				0.045^{NS}	-0.054^{NS}	-0.010^{NS}	0.125^{NS}	0.061^{NS}	0.245*	0.032^{NS}
	E2				0.048^{NS}	-0.266*	0.120^{NS}	0.213*	-0.123^{NS}	0.198^{NS}	-0.151^{NS}
	E3				0.127^{NS}	-0.203^{NS}	-0.177^{NS}	0.009^{NS}	0.048^{NS}	0.176^{NS}	0.016^{NS}
	P				0.487**	0.337**	0.439**	0.597**	0.570**	0.498**	0.549**
Bolls/ plant	E1					0.010^{NS}	0.127^{NS}	0.204^{NS}	0.780**	0.156^{NS}	0.796**
	E2					-0.366**	-0.066^{NS}	0.075^{NS}	0.781**	0.218*	0.786**
	E3					-0.218*	-0.029^{NS}	0.031^{NS}	0.892**	0.080^{NS}	0.912**
	P					0.267**	0.306**	0.602**	0.899**	0.622**	0.910**
Boll weight (g)	E1						0.044^{NS}	0.136^{NS}	0.583**	0.175^{NS}	0.585**
	E2						0.001^{NS}	-0.025^{NS}	0.241*	-0.049^{NS}	0.254*
	E3						0.356**	0.346**	0.181^{NS}	0.171^{NS}	0.163^{NS}
	P						0.333**	0.494**	0.625**	0.436**	0.624**
Seed index (g)	E1							0.823**	0.077^{NS}	-0.105^{NS}	0.096^{NS}
	E2							0.802**	-0.044^{NS}	-0.002^{NS}	-0.046^{NS}
	E3							0.723**	0.093^{NS}	0.115^{NS}	0.078^{NS}
	P							0.759**	0.384**	0.262**	0.382**
Lint index (g)	E1								0.288**	0.477**	0.227*
	E2								0.178^{NS}	0.596**	0.102^{NS}
	E3								0.262*	0.768**	0.132^{NS}
	P								0.748**	0.825**	0.703**
Lint yield /plant (g)	E1									0.385**	0.990**
	E2									0.357**	0.991**
	E3									0.304**	0.984**
	P									0.769**	0.995**
Ginning outturn (%)	E1										0.250*
	E2										0.232*
	E3										0.130^{NS}
	P										0.703**

*Significant at P = 0.05; **significant at P = 0.01

Table 6. Direct (diagonal) and indirect effects (off diagonal) of different traits with seed cotton yield:

		Plant height (cm)	Mono-pods plant	Sym-pods/ plant	Days to first flower	Bolls/ plant	Boll weight (g)	Seed index (g)	Lint index (g)	Lint yield/ plant (g)	Ginn-ing out turn %	'r' with SCY
Plant height (cm)	E1	**0.0018**	0.0011	0.0003	0.0007	0.0085	0.0102	0.0115	-0.0097	0.3416	0.0069	0.373^{**}
	E2	**0.0019**	-0.0020	-0.0005	-0.0001	-0.0016	-0.0023	-0.0654	0.0378	-0.1316	0.0042	-0.160^{NS}
	E3	**-0.0019**	0.0001	-0.0003	0.0001	-0.0002	0.0012	-0.0036	0.0128	-0.0150	0.0150	0.008^{NS}
	P	**0.0038**	-0.0001	-0.0014	-0.0036	0.0568	0.0193	0.0721	-0.2387	0.7841	0.0657	0.758^{**}
Monopods/ plant	E1	0.0004	**0.0053**	0.0001	0.0009	0.0016	-0.0017	0.0048	-0.0067	0.0385	-0.0054	0.038^{NS}
	E2	0.0004	**-0.0088**	-0.0005	-0.0002	-0.0017	-0.0029	-0.0640	0.0888	-0.2307	-0.0036	-0.223^{*}
	E3	0.0001	**0.0068**	-0.0003	0.0001	-0.0037	0.0008	0.0150	0.0049	-0.1326	0.0338	-0.075^{NS}
	P	0.0011	**-0.0002**	0.0001	-0.0006	0.0131	0.0018	0.0108	-0.0461	0.1586	0.0130	0.151^{*}
Sympods/ plant	E1	0.0003	0.0002	**0.0017**	0.0006	-0.0046	-0.0029	0.0018	0.0020	-0.1598	0.0109	-0.150^{NS}
	E2	0.0002	-0.0007	**-0.0053**	0.0003	0.0053	-0.0016	0.0007	0.0128	0.0171	-0.0018	0.027^{NS}
	E3	0.0004	-0.0014	**0.0015**	-0.0001	0.0062	-0.0012	0.0018	-0.0097	0.1570	-0.0120	0.143^{NS}
	P	0.0015	0.0001	**-0.0035**	-0.0040	0.0300	0.0107	0.0870	-0.1411	0.3940	0.0203	0.395^{**}
Days to first flower	E1	0.0003	0.0010	0.0002	**0.0045**	0.0019	-0.0016	-0.0005	-0.0077	0.0610	-0.0272	0.032^{NS}
	E2	-0.0001	0.0008	-0.0007	**0.0023**	0.0016	-0.0042	0.0258	-0.0575	-0.1241	0.0047	-0.151^{NS}
	E3	0.0003	-0.0009	0.0001	**-0.0010**	0.0044	-0.0040	-0.0106	-0.0009	0.0484	-0.0196	0.016^{NS}
	P	0.0022	0.0001	-0.0022	**-0.0061**	0.0426	0.0126	0.0855	-0.2040	0.5724	0.0464	0.549^{**}
Bolls/ plant	E1	0.0004	0.0002	-0.0002	0.0002	**0.0414**	0.0003	0.0065	-0.0127	0.7769	-0.0174	0.796^{**}
	E2	-0.0001	0.0005	-0.0009	0.0001	**0.0327**	-0.0058	-0.0143	-0.0201	0.7883	0.0052	0.786^{**}
	E3	0.0001	-0.0007	0.0003	-0.0001	**0.0343**	-0.0043	-0.0017	-0.0030	0.8957	-0.0089	0.912^{**}
	P	0.0025	0.0001	-0.0012	-0.0030	**0.0875**	0.0100	0.0596	-0.2058	0.9022	0.0579	0.910^{**}
Boll weight (g)	E1	0.0006	-0.0003	-0.0002	-0.0002	0.0004	**0.0300**	0.0023	-0.0085	0.5802	-0.0195	0.585^{**}
	E2	-0.0003	0.0016	0.0005	-0.0006	-0.0120	**0.0157**	0.0003	0.0069	0.2431	-0.0012	0.254^{*}
	E3	-0.0001	0.0003	-0.0001	0.0002	-0.0075	**0.0195**	0.0213	-0.0336	0.1821	-0.0190	0.163^{NS}
	P	0.0020	0.0001	-0.0010	-0.0021	0.0233	**0.0375**	0.0649	-0.1685	0.6273	0.0406	0.624^{**}
Seed index (g)	E1	0.0004	0.0005	0.0001	0.0001	0.0053	0.0013	**0.0511**	-0.0510	0.0771	0.0117	0.096^{NS}
	E2	-0.0006	0.0026	0.0000	0.0003	-0.0022	0.0001	**0.2151**	-0.2160	-0.0448	0.0001	-0.046^{NS}
	E3	0.0001	0.0017	0.0001	0.0002	-0.0010	0.0069	**0.0600**	-0.0701	0.0929	-0.0128	0.078^{NS}
	P	0.0014	0.0001	-0.0015	-0.0027	0.0267	0.0125	**0.1949**	-0.2592	0.3854	0.0244	0.382^{**}
Lint index (g)	E1	0.0003	0.0006	-0.0001	0.0006	0.0085	0.0041	0.0421	**-0.0620**	0.2864	-0.0530	0.227^{*}
	E2	-0.0003	0.0029	0.0003	0.0005	0.0024	-0.0004	0.1724	**-0.2694**	0.1796	0.0142	0.102^{NS}
	E3	0.0003	-0.0004	0.0002	0.0001	0.0011	0.0068	0.0434	**-0.0969**	0.2633	-0.0855	0.132^{NS}
	P	0.0027	0.0001	-0.0014	-0.0037	0.0527	0.0185	0.1479	**-0.3415**	0.7505	0.0768	0.703^{**}
Lint yield/ plant (g)	E1	0.0006	0.0002	-0.0003	0.0003	0.0323	0.0175	0.0040	-0.0178	**0.9957**	-0.0428	0.990^{**}
	E2	-0.0002	0.0020	-0.0001	-0.0003	0.0256	0.0038	-0.0095	-0.0480	**1.0092**	0.0085	0.991^{**}
	E3	0.0001	-0.0009	0.0002	-0.0001	0.0306	0.0035	0.0056	-0.0254	**1.0041**	-0.0338	0.984^{**}
	P	0.0030	0.0001	-0.0014	-0.0035	0.0787	0.0235	0.0749	-0.2554	**1.0034**	0.0716	0.995^{**}
Ginning outturn (%)	E1	-0.0001	0.0003	-0.0002	0.0011	0.0065	0.0053	-0.0054	-0.0296	0.3836	**-0.1111**	0.250^{*}
	E2	0.0003	0.0013	0.0004	0.0005	0.0071	-0.0008	-0.0004	-0.1604	0.3599	**0.0239**	0.232^{*}
	E3	0.0003	-0.0021	0.0002	-0.0002	0.0027	0.0033	0.0069	-0.0745	0.3050	**-0.1113**	0.130^{NS}
	P	0.0027	0.0001	-0.0008	-0.0031	0.0544	0.0164	0.0511	-0.2819	0.7715	**0.0931**	0.703^{**}

*significant at P = 0.05; ** significant at P = 0.01; Residual are 0.00102 recorded via lint index in E2. The direct contribution of sympods/plant was positive in all the environments except E2. However, it contributed maximum via lint yield/plant in E3.

Days to first flower contributed positive direct effect in E1 and E2 only but it also contributed maximum *via* lint yield/plant in E3 and on pooled basis. Number of bolls/plant had positive direct effect on seed cotton yield and contributed maximum via lint yield/plant under all environmental conditions. Moreover, it had significant genotypic correlation with seed cotton yield/plant under all the environments. Almost similar trend was observed for boll weight except it had non-significant genotypic correlation with seed cotton yield in E3 only. The direct contribution of seed index was positive in all the environments and contributed positively via lint yield/plant in E3. Whereas, negative direct effect on seed cotton yield was observed for lint index but positively contributed via lint yield/plant.

Lint yield/plant recorded maximum direct effect on seed cotton yield in all the three environments. However, it contributed positively via bolls/plant and negatively via lint index. It also had positive significant genotypic correlation with seed cotton yield. Ginning outturn had negative direct effect on seed cotton yield in all the environments except E2 and contributed maximum via lint yield/plant under all the environments. The above results are in conformity with reports of Ekinci *et al.,* (2010), Kumar and Ravikesavan (2010), Vinodhana *et al.,* (2013), Farooq *et al.,* (2014), Pujer *et al.,*. (2014), Asha *et al.,* (2015) and Srinivas *et al.,* (2015).

In the present study, the genotype H 1505 was found to be stable and suitable for all types of environments and also deserves attention of the plant breeders for inclusion in breeding programme as adaptable and stable genotype for seed cotton yield. The correlation and path-analysis indicated that bolls/plant and boll weight had significant positive and positive direct effects on seed cotton yield/plant indicating the existence of true relationship among these characters and their exploitation in selection programmes.

REFERENCES

Asha, R., Ahamed, M. L., Babu, D. R. and Kumar, P. A. 2015. Character association and path-coefficient analysis for yield and component traits in upland cotton. *J. Cotton Res. Dev.,* **29** : 31-35.

Dewdar, M. D. H. 2013. Stability analysis and genotype x environment interactions of some Egyptian cotton cultivars cultivated. *African J. Agril. Res.* **8** : 5156-60.

E.-H. Ng, Jernigan, K., Smith, W., Hequet, E., Dever, J., Hague S. and Ibrahim, A. M. H. 2013. Stability Analysis of Upland Cotton in Texas. *Crop Sci. Soci. America.* ***53*** : 1347-55.

Ekinci, R., Basbag, S. and Gencer, O. 2010. Path-Coefficient Analysis between seed cotton yield and some characters in cotton (*Gossypium hirsutum* L.). *J. Environmental Biol.* **31** : 861-64.

Farooq, J., Anwar, J., Riaz, M., Farooq, M., Mahmood, A., Shahid, A., Rafiq, M.T.H. and Ilahi, F. 2014. Correlation And Path-coefficient analysis of earliness, fiber quality and yield contributing traits in cotton

(*Gossypium hirsutum* L.). *J. Animal & Pl. Sci.* **24** : 781-90.

Gite, V. K., Misal, M. B. and Kalpande, H. V. 2006. Correlation and path analysis in cotton (*Gossypium hirsutum* L.). *J.Cotton Res. Dev.,* **20** : 51-54.

Kumar, A. and Ravikesavan, R. 2010. Genetic studies of correlation and path coefficient analysis for seed oil, yield and fibre quality traits in cotton (*G. hirsutum* L.). *Aust. J. Basic. Appl. Sci.*, **4** : 5496-99.

Patil, H. E. and Patel, K. B. 2010. Stability analysis of seed cotton yield and its components of released Bt cotton hybrids of Gujarat state. *J. Cotton Res. Dev.*, **24 :** 17-22.

Patnaik, R. K. and Sial, P. 2010. Genetic variability, character association and component analysis in upland cotton (*Gossypium hirsutum* L.) under rainfed condition. *J. Cotton Res. Dev.,* **24 :** 155-59.

Pujer, S. K., Siwach, S.S., Sangwan, R. S., Sangwan, O. and Deshmukh, J. 2014. Correlation and path-coefficient analysis for yield and fibre quality traits in upland cotton (*Gossypium hirsutum* L.). *J. Cotton Res. Dev.,* **28 :** 214-16.

Rajamani, S., Sumalatha, P. and Gopinath, M. 2013. Correlation and path coefficient analysis in upland cotton (*Gossypium hirsutum* L.). *J. Cotton Res. Dev.,* **27** : 188-90.

Satish,Y., Jain, P. P. and Chhabra, B. S. 2009. Stability analysis for yield and its component traits in American cotton (*Gossypium hirsutum* L.). *J. Cotton Res. Dev.* **23** : 175-82.

Singh, S., Singh, V.V. and Choudhary, A. D. 2014. Genotype × Environment interaction and yield stability analysis in multienvironment [interacción genotipo x medio ambiente y análisis de la estabilidad de la produccion en múltiples ambientes]. *Trop. Subtrop. Agroecosyst.*, **17 :** 477– 82.

Singh, T., Sohu, R. S., Singh, P., Rathore, P., Sekhon, P. S., Butter, G. S., Hassan, H. and Singh, G. 2012. Stability analysis of *Bt* transgenic cotton hybrids of *Gossypium hirsutum* L. for lint yield and fiber quality traits. *J. Cotton Res. Dev.,* **26** : 163-66.

Srinivas, B., Bhadru, D. and Brahmeswara Rao, M. V. 2015. Correlation and path coefficient analysis for seed cotton yield and its components in American cotton (*Gossypium hirsutum* L.). *Agril. Sci. Digest*, **35 :** 13-18

Vinodhana, K.N., Gunasekaran, M. and Vindhiyavarman, P. 2013. Genetic Studies of Variability, Correlation and Path-Coefficient analysis in Cotton genotypes. *Int. J. Pure App. Biosci.* **1** : 6-10.

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Effect of nitrogen fertilizer on various phenolics compound and their role in incidence of important sucking insect pests in *Bt* non *Bt* and *desi* cotton cultivars

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ABSTRACT: The present study deals in evaluating the effect by different nitrogen doses 65, 100 and 130 kg/ac in six *Bt* cotton cultivars, namely, Ankur 3028, NCS 855, RCH 776, RCH 650, RCH 773, Bioseed 6588 and one each of American cotton LH2108 and *desi* cotton cultivar FDK 124on role of various biochemicals against infestation by sucking insect pests namely jassid, whitefly and thrips in infested and uninfested condition. Incidence of sucking insect pest, whitefly, jassids and thrips were significantly higher at higher dose of nitrogen (130 kg/ac) as compared to lower doses (65 and 100 kg/ac). Higher amount of total phenols, flavonols and *O*-dihydroxy phenols were recorded in cultivars infested with sucking insect pests over uninfested condition. Significantly higher levels of biochemical content were recorded at lower level of nitrogen (65 kg) followed by 100 and 130 kg/ ac. The biochemical components decreased as the plant get matured. Thrips population showed significantly negative correlation with *O*-dihydroxy phenols. However, total phenol and flavanols were non significant negative correlation with jassid, whitefly and thrips. The populations of sucking insect pests were high at lower amount of biochemical in the cotton leaves.

Key words : Biochemical, *Bt*, *desi* cotton, nitrogen, non *Bt*, sucking insect pest

Cotton is one of the most important fiber crop in India. Cotton crops have been attacked by various insect pests like lepidopteran pests (American bollworm, spotted bollworm, pink bollworm) and sucking insect pests (whitefly, jassid, thrips, mealybug, red cotton bug) throughout the growing period. Insecticides were applied to combat against the increased insect pests specially bollworm complex (Fitt, 2008). But the harmful chemicals affect the environmental ecology. After the commercialization of *Bt* cotton in India the crops profile has changed tremendously. Globally used insecticide active ingredient (*a.i.*) was reduced by 19 per cent, including India (Brookes and Barfoot, 2006). Due to this, there is a risk of outbreak of the non-target sucking insect pests population. There is always need to develop a strategy to reduce such risk and one of the strategies may include host plant resistance (HPR). Several biochemical factors are responsible to impart resistance to insect pests in *Bt* cotton. Host plant resistance is an important tool of an IPM programme that prevents the crop by making it unsuitable for the pest or by making the crop tolerant to the pest. HPR traits may help support resistance management in *Bt* cotton (Carrière *et al*., 2004). Non *Bt* cotton varieties may possess some morphological and chemical plant characters which impart resistance to sucking insect pests but demand intensive application of insecticides to avoid their populations from reaching up to injury levels (Ali and Aheer, 2007). The secondary plant metabolites that are produced by plants plays vital role in defense mechanism against some herbivores, pathogen and pests. Among biochemical constituents phenols, epicuticular waxes, nutrients, etc. have been reported to impart resistance to whitefly in cotton (Butter *et al*., 1992; Lege *et al*., 1995). Venkatesha (2014) and Shinde *et al*., (2014) observed that jassid population had significantly negative correlation with phenols concentration on various cotton genotypes. Inducing resistance through fertilizer are becoming more viable. Information on the effect of biochemical constituents of plants on the incidence of sucking insect pests of *Bt* cotton, non *Bt* and *desi* cotton cultivar under different nitrogen levels is limited. Therefore, the present investigation was made to establish a possible correlation between biochemical parameters with the sucking insects pests incidence in *Bt*, non *Bt* and *desi* cotton.

MATERIALS AND METHODS

The six *Bt* cotton cultivars, namely Ankur 3028, NCS 855, RCH 776, RCH 650, RCH 773, Bioseed 6588; and one each of American cotton LH2108 and *desi* cotton cultivar FDK 124 were sown at Entomological Research Farm, Department of Entomology, PAU, Ludhiana. Four application of 2 per cent potassium nitrate (13:0:45) were given at weekly interval starting from flowering stage of the crop. The plots were divided into sub plot treatment with nitrogen @ 65, 100 and 130 kg/ac (in two splits) during the growing season of the crop. The crop was raised as per the recommended package of practices PAU, Ludhiana (Anonymous, 2016). The experiment was laid out in split plot *design* with eight treatments and three replications in one acre area with plot size of 6 x 3.6 m. Biochemical analysis of the *Bt*, non *Bt* and *desi* cotton cultivars was carried out in Biochemistry Laboratory, Department of Biochemistry, PAU, Ludhiana. Biochemical analysis was done at an interval of 60, 90 and 120 days after sowing (DAS) in three replications. The uninfested crops were raised under screen house to maintain uninfested condition. No nitrogenous fertilizer was applied in these crops. For sampling, ten plants were selected at random from each treatment in 3 replications. The top three infested and uninfested leaves were chosen for the purpose of biochemical analysis.

Total phenolic: A 500mg dried leaves samples was weighed and refluxed with 80 per cent methanol for 2 h the refluxed material was filtered and volume was made 25 ml by washing with 80per cent methanol. The extract thus prepared was used for estimation of phenolic content *viz*., total phenols, ortho-dihydroxyphenols and flavonols.

Total phenolic content was estimated from leaves of different cotton genotypes by using the method given by Swain and Hills (1959). Methanolic extract (5ml) was evaporated to dryness and the residue was dissolved in 6.5 ml of distilled water. To this 0.5 ml Folin-Ciocateu reagent was added and shaken thoroughly. After 5 min, 1ml of saturated solution of Na_2CO_3 was added. The blue colour formed was read after 1 hour at 760 nm against the blank. The blank was prepared from water and reagents only. The concentration of total phenols was determined from standard curve prepared by using gallic acid (20-100 µg/ml). The data obtained was presented as mg/g dry weight.

Ortho dihydroxy phenols: For the determination of *ortho*-dihydroxy phenols contents from the leaves of cotton, the method given by Nair and Vaidyanathan (1964) was used. Methanolic extract (5 ml) was evaporated to dryness and residue left behind was dissolved in 1 ml of dissolved water. To this 0.5 ml of 10 per cent TCA, 1 ml of sodium tungstate, 0.5 ml of 0.5 N HCl and 1 ml of freshly prepared 0.5 per cent sodium nitrite were added. A yellow colour developed. After 5 min 2 ml of 0.5 N sodium hydroxide was added. The light cherry colour developed, whose absorbance was read after 15 min at 540 nm against the blank. The blank consisted of water and reagents only. The concentration of ortho-dihydroxyphenols was determined from standard curve prepared by using catechol (10-100 µg/ml).

Flavonol: Flavonol content from the leaves of the cotton was estimated by using the method given by Balabaa *et al.*, (1974). 5.0 ml of methanolic extract was evaporated to dryness. The residue left was dissolved in 10 ml of 0.1 M methanolic solution of aluminium chloride. The yellow colour developed was read at 420 nm against 0.1 M methanolic solution. The concentration of flavonols was determined from standard curve prepared by using rutin (50-250 µg/ml). The data obtained was presented as mg g^{-1} dry weight.

Factorial completely randomized design (FCRD) was applied to the data on different biochemical parameters for the analysis of variance using CPCS1 software version 1.0 (A program package for the analysis of commonly used experimental designs by Dr. Harjinder Singh Cheema and Dr. Balwant Singh, Punjab Agricultural University, Ludhiana. The correlations between biochemical parameters and population of sucking pests were also worked out.

RESULTS AND DISCUSSION

The biochemical plant characteristics namely total phenols, flavonol and orthodihydroxy phenols present in the leaves was estimated in *Bt*, non *Bt* and *desi* cotton cultivars at different nitrogen levels and different stages under infested and uninfested condition .

Total phenols: The total phenols content in leaves of *Bt*, non *Bt* and *desi* cotton cultivar differed significantly among different level of nitrogen fertilizer as well as at 60, 90 and 120 days after sowing (DAS) under infested and uninfested condition (Table 1).

The total phenols contents recorded at 60 DAS was significantly higher in 65 kg nitrogen (117.60 mg/g dry weight) and minimum at 130 kg nitrogen (97.86 mg/g dry weight). The levels increased significantly under infested condition (107.51 mg/g dry weight) than uninfested condition (88.58 mg/g dry weight). Among the different cotton cultivars, *Bt* cotton cultivar, Bioseed 6588 recorded significantly lowest total phenols content (95.78 mg/g dry weight) and highest in *Bt* cotton cultivar, RCH 650 (115.23 mg/g dry weight) and was statistically on par with *desi* cotton cultivar, FDK 124 (112.92 mg/g dry weight). The interaction between the different nitrogen levels and cotton cultivars revealed that *Bt* cotton cultivar, Ankur 3028 recorded significantly lowest total phenols content (91.39 mg/g dry weight) under infested condition at 130 kg nitrogen level whereas highest in *Bt* cotton cultivar, RCH 650 (148.19 mg/g dry weight) under infested condition at 65 kg nitrogen level. Under uninfested condition the *Bt* cotton cultivar, Bioseed 6588 recorded significantly lowest total phenols content (85.13 mg/g dry weight) and highest in *Bt* cotton cultivar, RCH 650 (91.60 mg/g dry weight). Per cent increase in the total phenols content of different *Bt*, non*Bt* and *desi* cotton cultivar ranged from 10.19 to 21.41.

At 90 DAS, total phenols content was significantly higher in 65 kg nitrogen and minimum in 130 kg nitrogen (236.04 and 174.22 mg/g dry weight, respectively).The total phenols contents increased significantly under infested condition than uninfested condition. Among the different cotton cultivars, *Bt* cotton cultivar, Bioseed 6588 recorded significantly lowest total phenols content (132.27 mg/g dry weight) and highest in *Bt* cotton cultivar, Ankur 3028 (291.67 mg/g dry weight) and was statistically higher than other cultivars under infested condition. The interaction between the different nitrogen levels and cotton cultivars revealed that *Bt* cotton cultivar, Bioseed 6588 recorded significantly lowest total phenols content (132.27 mg/g dry weight) under infested condition at 130 kg nitrogen level whereas highest in *Bt* cotton cultivar, Ankur 3028 (349.03 mg/g dry weight) under infested condition at 65 kg nitrogen level. Under uninfested condition the *Bt* cotton cultivar, Bioseed 6588 recorded significantly lowest total phenols content (74.03 mg/g dry weight) and highest inFDK 124 (96.55 mg/g dry weight). Per cent increase in the total phenols content of different *Bt*, non *Bt* and *desi* cotton cultivar was ranged from 44.03 to 71.67.

At 120 DAS, among the fertilizer the phenols content was significantly higher in 65 kg nitrogen and minimum in 130 kg nitrogen (102.12 and 61.50 mg/g dry weight, respectively).The total phenols contents increased significantly under infested condition (79.75 mg/g dry weight) than uninfested condition (54.69 mg/g dry weight). Among the different cultivars, *Bt* cotton cultivar, Bioseed 6588 recorded significantly lowest total phenols content (69.85 mg/g dry weight). However, *desi* cotton cultivar, FDK 124 recorded significantly highest total phenols content (92.70 mg/g dry weight) and was statistically higher than other cultivars under infested condition. The interaction between the different nitrogen levels and cotton cultivars revealed that *Bt* cotton cultivar, Bioseed 6588 recorded significantly lowest total phenols content (52.61 mg/g dry weight) under infested condition at 130 kg nitrogen level whereas highest in *Bt* cotton cultivar RCH 776 (112.64 mg/g dry weight) under infested condition at 65 kg nitrogen level. Under uninfested condition the *Bt* cotton cultivar, Bioseed 6588 recorded significantly lowest total phenols content (49.58 mg/g dry weight) and highest in *Bt* cotton cultivar, RCH 773 (57.64 mg/g dry weight). Per cent increase in the total phenols content of different *Bt*, non *Bt* and *desi* cotton cultivar was ranged from 22.78 to 39.62. Total phenols contents were higher in 90 as compared to 60 and 120 DAS.

Flavonols: The flavonols content in leaves of *Bt*, non *Bt* and *desi* cotton cultivar differed significantly among different level of nitrogen fertilizer as well as at 60, 90 and 120 days after sowing (DAS) under infested and uninfested condition (Table 2). The flavonols contents recorded at 60 DAS revealed that among the fertilizer the flavonol content was significantly higher in 65 kg nitrogen (23.61 mg/g dry weight) and minimum at 130 kg nitrogen (18.51 mg/g dry weight) which was on par with 100 kg nitrogen (19.08). The flavonols contents increased significantly under infested condition (20.36 mg/g dry weight) as compared to uninfested condition (16.24 mg/g dry weight). Among different cotton cultivars, the *Bt* cotton cultivar, RCH 773 recorded significantly lowest flavonols content of 18.04 mg/g dry weight being *at par* with *Bt* cotton cultivar RCH 776 (18.84 mg/g dry weight). However, *desi* cotton cultivar FDK 124 recorded significantly highest flavonols content of 21.92 mg/g dry weight and was *at par* with non *Bt* cotton cultivar LH 2108 (21.46 mg/g dry weight) and *Bt* cotton cultivar RCH 650 (21.35 mg/g dry weight) as compared to all other cultivars under infested condition. The interaction between the different nitrogen levels and cotton cultivars were found to be significantly different. *Bt* cotton cultivar RCH 776 recorded significantly lowest flavonol content (15.42 mg/g dry weight) at 130 kg nitrogen level whereas highest flavonol was recorded in non *Bt* cotton cultivar LH2108 (29.67 mg/g dry weight) at 65 kg nitrogen level under infested condition. Under uninfested condition the *Bt* cotton cultivar RCH 773 recorded significantly lowest flavonol content (14.35 mg/g dry weight) and highest flavonol was recorded in *Bt* cotton cultivar RCH 650 (17.72 mg/g dry weight). Per cent increase in the flavonol content of different *Bt*, non *Bt* and *desi* cotton cultivar was ranged from 17.00 to 30.05. At 90 DAS, among the fertilizer the flavonols content was significantly higher in 65 kg nitrogen and minimum in 130 kg nitrogen (29.69 and 20.08 mg/g dry weight, respectively).The contents increased significantly under infested condition than uninfested condition (25.63 and 14.51 mg/g dry weight, respectively). Among different cultivars, *Bt* cotton cultivar, Ankur 3028 recorded significantly lowest flavonols content of 22.39 mg/g dry weight being *at par* with *desi* cotton cultivar, FDK 124 (22.72 mg/g dry weight). However, *Bt* cotton cultivar, NCS 855 recorded significantly highest flavonols content (28.75 mg/g dry weight) which was *on par* with *Bt* cotton cultivar, RCH 773 and RCH 776 (28.11 and 27.42 mg/g dry weight, respectively) under infested condition. The interaction between the different nitrogen levels and cotton cultivars were found to be significantly different. *Bt* cotton cultivar RCH 650 recorded significantly lowest flavonols content (18.33 mg/g dry weight) at 130 kg nitrogen level whereas highest flavonol was recorded in *Bt* cotton cultivar NCS 855 at 65 kg nitrogen level under infested condition. Under uninfested condition the significantly lowest and highest flavonols content was recorded in *Bt* cotton cultivar, RCH 773 (13.25 mg/g dry weight)

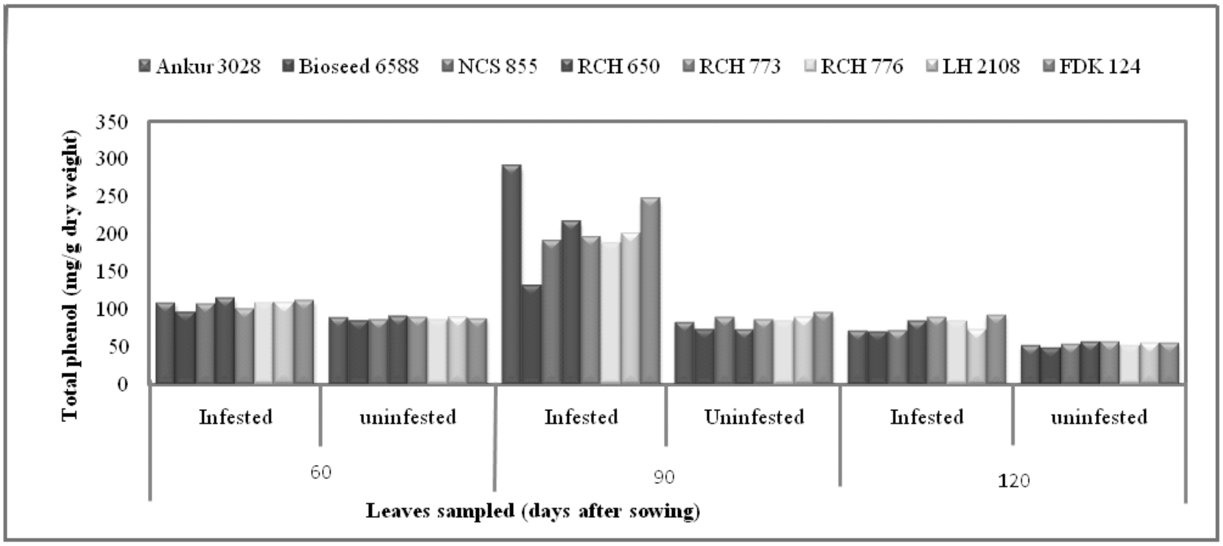

Fig 1. Total phenol contents in infested and uninfested Bt, non-Bt and *desi* cotton cultivar at different days after sowing

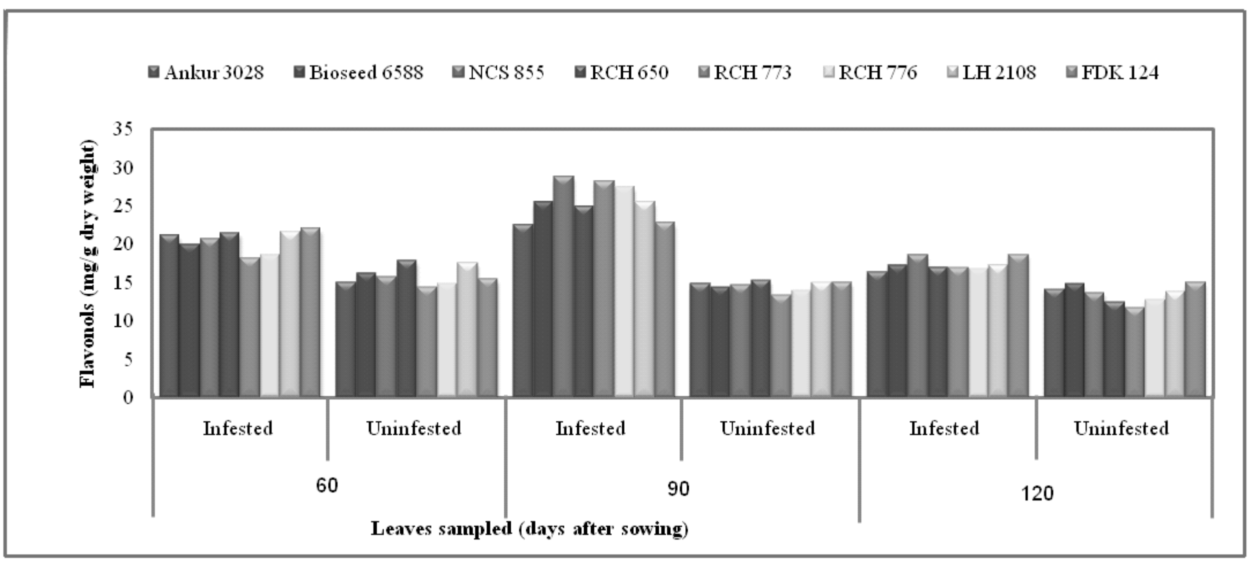

Fig 2. Flavonols contents in infested and uninfested Bt, non-Bt and *desi* cotton cultivars in different days after sowing

and RCH 650 (15.26 mg/g dry weight), respectively. Per cent increase in the flavonol content of different *Bt*, non *Bt* and *desi* cotton cultivar was ranged from 33.98 to 52.87.

At 120 DAS, among the fertilizer the flavonol content was significantly higher in 65 kg nitrogen (19.91 mg/g dry weight) and minimum flavonol was recorded in 130 kg nitrogen (15.35 mg/g dry weight).The flavonols contents increased significantly under infested condition (17.27 mg/g dry weight) as compared to uninfested condition (13.48 mg/g dry weight). Among different cotton cultivars, the *Bt* cotton cultivar, Ankur 3028 recorded significantly lowest flavonols content of 16.24 mg/g dry weight. However, *Bt* cotton cultivar, NCS 855 recorded

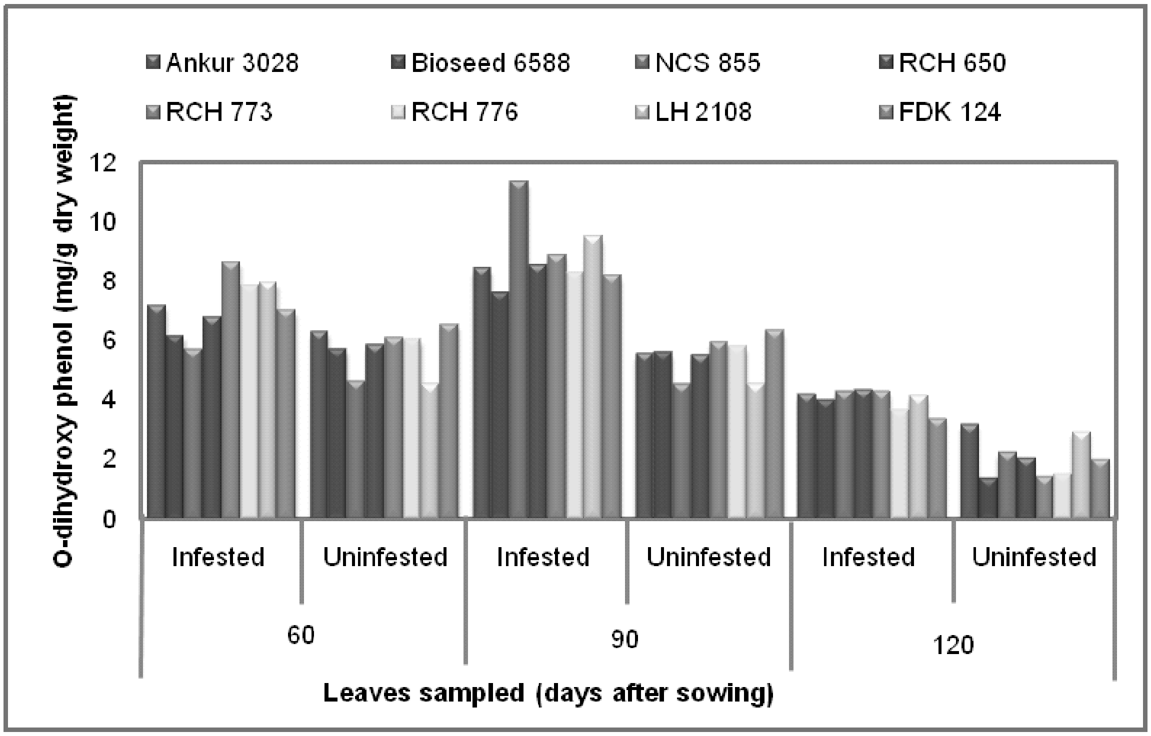

Fig 3. *O*-dihydroxy phenol contents in infected and uninfested Bt, non-Bt and *desi* cotton cultivar at different days after sowing

significantly highest flavonols content (18.54 mg/g dry weight) which was *on par* with *desi* cotton cultivar, FDK 124 (18.60 mg/g dry weight) than other cultivars under infested condition. The interaction between the different nitrogen levels and cotton cultivars were found to be significantly different. *Desi* cotton cultivar, FDK 124 recorded significantly lowest content (14.29 mg/g dry weight) at 130 kg nitrogen level whereas highest recorded in *Bt* cotton cultivar, NCS 855 (22.71 mg/g dry weight) at 65 kg nitrogen level under infested condition. Under uninfested condition the *Bt* cotton cultivar, RCH 773 recorded significantly lowest flavonol content (11.65 mg/g dry weight) and highest was recorded in *desi* cotton cultivar, FDK (14.94 mg/g dry weight). Per cent increase in the flavonols content of different cotton cultivar was ranged from 13.49 to 30.74. Flavonols contents were higher in 90 as compared to 60 and 120 DAS.

***O* dihydroxy phenols:** The data pertaining to the *O*-dihydroxy phenols content in leaves of *Bt*, non *Bt* and *desi* cotton cultivar differed significantly among different level of nitrogen fertilizer as well as at 60, 90 and 120 days after sowing (DAS) under infested and uninfested condition (Table 3).

The *O*-dihydroxy phenols contents recorded at 60 DAS showed significant variations among different *Bt*, non *Bt* and *desi* cotton cultivars as well as under different nitrogen fertilizer level and uninfested condition. Among the fertilizer, the *O* dihydroxy phenols content was significantly higher in 65 kg nitrogen (7.90 mg/g dry weight) which was *on par* with 100 kg nitrogen/ac (7.65 mg/g dry weight) and minimum *O* dihydroxy phenols was recorded in

Table 1. Total phenols in *Bt*, non-*Bt* and *desi* cotton under uninfested and infested condition at different days after sowing

Total phenols (mg/g dry weight) * — 60 days after sowing

Nitrogen / Cultivar	Infested condition 65 kg	100 kg	130 kg	**Mean**	Un-infested condition (N=0 kg)	(%) Increase over un-infested condition
Ankur 3028	139.86	98.19	91.39	**109.81**[cd]	89.35	18.63
Bioseed 6588	100.83	97.08	89.43	**95.78**[a]	85.13	11.12
NCS 855	110.83	109.86	100.56	**107.08**[c]	86.90	18.85
RCH 650	148.19	102.50	95.00	**115.23**[e]	91.60	20.51
RCH 773	99.03	105.69	97.36	**100.69**[b]	90.43	10.19
RCH 776	117.92	115.00	96.11	**109.68**[cd]	86.20	21.41
LH 2108 (Non *Bt*)	110.83	111.53	104.31	**108.89**[c]	90.15	17.21
FDK 124 (*Desi*)	113.33	116.67	108.75	**112.92**[de]	88.95	21.23
Mean	**117.60**[c]	**107.07**[b]	**97.86**[a]	**107.51**	**88.59**	

Total phenols (mg/g dry weight) * — 90 days after sowing

Nitrogen / Cultivar	Infested condition 65 kg	100 kg	130 kg	**Mean**	Un-infested condition (N=0 kg)	(%) Increase over un-infested condition
Ankur 3028	349.03	304.58	221.39	**291.67**[h]	82.64	71.67
Bioseed 6588	153.89	139.44	103.47	**132.27**[a]	74.03	44.03
NCS 855	205.83	186.67	184.44	**192.31**[c]	90.28	53.05
RCH 650	240.14	228.06	183.61	**217.27**[f]	74.31	65.80
RCH 773	211.39	199.17	178.61	**196.39**[d]	86.68	55.86
RCH 776	197.36	191.11	176.94	**188.47**[b]	84.86	54.97
LH 2108 (Non *Bt*)	225.42	208.19	170.69	**201.43**[e]	89.60	55.52
FDK 124 (*Desi*)	305.28	263.89	174.58	**247.92**[g]	96.55	61.06
Mean	**236.04**[c]	**215.14**[b]	**174.22**[a]	**208.47**	**84.87**	

Total phenols (mg/g dry weight) * — 120 days after sowing

Nitrogen / Cultivar	Infested condition 65 kg	100 kg	130 kg	**Mean**	Un-infested condition (N=0 kg)	(%) Increase over un- condition
Ankur 3028	97.08	60.97	56.40	**71.48**[ab]	53.31	25.42
Bioseed 6588	99.31	57.64	52.61	**69.85**[a]	49.58	29.02
NCS 855	99.44	59.72	55.07	**71.41**[ab]	55.14	22.78
RCH 650	104.31	90.14	59.92	**84.79**[c]	57.08	32.68
RCH 773	108.06	95.14	64.44	**89.21**[d]	57.64	35.39
RCH 776	112.64	72.78	67.64	**84.35**[c]	52.51	37.75
LH 2108 (Non *Bt*)	92.22	70.42	60.07	**74.24**[b]	56.25	24.23
FDK 124 (*Desi*)	103.89	98.33	75.88	**92.70**[e]	55.97	39.62
Mean	**102.12**[c]	**75.64**[b]	**61.50**[a]	**79.75**	**54.69**	

LSD (p=0.05)Nitrogen = 2.61, Cultivar = 3.69Nitrogen x Cultivar = 7.38Nitrogen = 2.51, Cultivar = 3.55 Nitrogen x Cultivar = 7.10Nitrogen = 2.43, Cultivar = 3.16 Nitrogen x Cultivar = 6.32

*Mean of three replications, N = Nitrogen

Table 2. Flavonols in *Bt*, non *Bt* and *desi* cotton under uninfested and infested condition at different days after sowing

Nitrogen	Flavonols (mg/g dry weight) *																	
Cultivar	60 days after sowing Infested condition						90 days after sowing Infested condition						120 days after sowing Infested condition					
	65 kg	100 kg	130 kg	**Mean**	Un-infested condition (N=0 kg)	(%) Inc-rease over un-infested condition	65 kg	100 kg	130 kg	**Mean**	Un-infested condition (N=0 kg)	(%) Inc-rease over un-infested condition	65 kg	100 kg	130 kg	**Mean**	Un-infested condition (N=0 kg)	(%) Inc-rease over un-condition
Ankur 3028	21.96	21.21	19.96	**21.04**^{bc}	15.00	28.72	24.38	22.21	20.58	**22.39**^{a}	14.75	34.12	17.04	16.04	15.63	**16.24**^{a}	14.05	13.49
Bioseed 6588	21.83	20.33	17.42	**19.86**^{b}	16.21	18.38	29.38	27.29	19.38	**25.35**^{b}	14.30	43.59	20.75	15.50	15.21	**17.15**^{a}	14.76	13.94
NCS 855	23.46	19.29	19.29	**20.68**^{bc}	15.72	23.98	35.42	29.17	21.67	**28.75**^{c}	14.59	49.26	22.71	16.88	16.04	**18.54**^{b}	13.65	26.38
RCH 650	24.46	22.63	16.96	**21.35**^{c}	17.72	17.00	29.42	26.92	18.33	**24.89**^{b}	15.26	38.69	18.33	16.25	16.08	**16.89**^{a}	12.33	27.00
RCH 773	18.75	17.25	18.13	**18.04**^{a}	14.35	20.47	32.46	31.13	20.75	**28.11**^{c}	13.25	52.87	19.42	15.50	15.54	**16.82**^{a}	11.65	30.74
RCH 776	23.67	16.42	15.42	**18.50**^{a}	14.79	20.07	31.25	30.71	20.29	**27.42**^{c}	13.92	49.23	17.71	17.71	14.79	**16.74**^{a}	12.75	23.84
LH 2108 (Non-Bt)	29.67	16.58	18.13	**21.46**^{c}	17.46	18.64	29.38	27.08	19.67	**25.38**^{b}	15.00	40.89	20.67	15.67	15.25	**17.20**^{a}	13.72	20.22
FDK 124 (*Desi*)	25.08	18.92	21.75	**21.92**^{c}	15.33	30.05	25.83	22.33	20.00	**22.72**^{a}	15.00	33.98	22.63	18.88	14.29	**18.60**^{b}	14.94	19.68
Mean	**23.61**^{b}	**19.08**^{a}	**18.38**^{a}	**20.36**	**16.20**		**29.69**^{c}	**27.10**^{b}	**20.08**^{a}	**25.63**	**14.51**		**19.91**^{c}	**16.55**^{b}	**15.35**^{a}	**17.27**	**13.48**	

LSD (p=0.05)Nitrogen = 0.94, Cultivar = 1.34 Nitrogen x Cultivar = 2.67Nitrogen = 1.05, Cultivar = 1.48 Nitrogen x Cultivar = 2.96Nitrogen = 0.77, Cultivar = 1.09 Nitrogen x Cultivar = 2.17

*Mean of three replications, N = Nitrogen

Table 3. *O*-dihydroxy phenols in *Bt*, non-*Bt* and *desi* cotton under uninfested and infested condition at different days after sowing

Nitrogen / Cultivar	*O*-dihydroxy phenols (mg/g dry weight) *																	
	60 days after sowing, Infested condition						90 days after sowing, Infested condition						120 days after sowing, Infested condition					
	65 kg	100 kg	130 kg	**Mean**	Un-infested condition (N=0 kg)	(%) Increase over un-infested condition	65 kg	100 kg	130 kg	**Mean**	Un-infested condition (N=0 kg)	(%) Increase over un-infested condition	65 kg	100 kg	130 kg	**Mean**	Un-infested condition (N=0 kg)	(%) Increase over un-condition
Ankur 3028	8.00	7.35	6.24	**7.20** [c]	6.32	12.18	9.30	9.29	6.77	**8.45** [b]	5.57	34.11	5.15	4.67	2.77	**4.20** [b]	3.21	23.51
Bioseed 6588	6.66	6.22	5.68	**6.19** [ab]	5.73	**7.38**	7.71	7.91	**7.19**	**7.60** [a]	5.61	26.22	5.03	5.46	1.63	**4.04** [b]	1.38	65.84
NCS 855	6.90	6.70	**3.64**	**5.75** [a]	**4.67**	18.74	14.13	13.12	6.82	**11.36** [d]	**4.54**	**60.02**	6.77	3.68	2.49	**4.31** [b]	2.27	47.37
RCH 650	7.71	6.63	6.09	**6.81** [bc]	5.89	13.51	9.39	8.85	7.46	**8.57** [b]	5.52	35.56	5.41	4.50	3.15	**4.35** [b]	2.09	51.99
RCH 773	**9.12**	9.05	7.80	**8.66** [e]	6.11	29.42	9.73	9.37	7.60	**8.90** [bc]	5.97	32.92	4.74	4.07	4.20	**4.34** [b]	1.44	66.79
RCH 776	8.97	8.97	5.73	**7.89** [d]	6.07	23.07	9.03	8.67	7.23	**8.31** [ab]	5.83	29.84	4.52	4.11	2.43	**3.69** [a]	1.53	58.50
LH 2108 (Non-Bt)	8.58	8.58	6.73	**7.96** [d]	4.58	**42.49**	10.81	9.23	8.47	**9.50** [c]	4.56	52.02	5.32	3.82	3.35	**4.16** [b]	2.97	28.66
FDK 124 (*Desi*)	7.30	7.69	6.08	**7.02** [c]	**6.56**	6.60	**10.45**	7.93	6.24	**8.21** [ab]	**6.38**	**22.26**	2.77	4.90	2.58	**3.42** [a]	2.04	40.29
Mean	**7.90** [b]	**7.65** [b]	**6.00** [a]	**7.19**	**5.74**		**10.07** [c]	**9.30** [b]	**7.22** [a]	**8.86**	**5.50**		**4.96** [c]	**4.40** [b]	**2.83** [a]	**4.06**	**2.12**	

LSD (p=0.05)Nitrogen = 0.47, Cultivar = 0.66 Nitrogen x Cultivar = 1.32Nitrogen = 0.56, Cultivar = 0.79 Nitrogen x Cultivar = 1.57Nitrogen = 0.22, Cultivar = 0.31 Nitrogen x Cultivar = 0.62

*Mean of three replications, N = Nitrogen

130 kg nitrogen (6.08 mg/g dry weight).The *O*-dihydroxy phenols contents increased significantly under infested condition (7.19 mg/g dry weight) as compared to uninfested condition (5.74 mg/g dry weight). Among different cultivars, *Bt* cotton cultivar NCS 855 recorded significantly lowest *O*-dihydroxy phenols being *at par* with *Bt* cotton cultivar Bioseed 6588 (5.75 and 6.19 mg/g dry weight, respectively). However, *Bt* cotton cultivar RCH 776 recorded significantly highest *O*-dihydroxy phenols content of 8.66 mg/g dry weight as compared to all other cultivars under infested condition. The interaction between the different nitrogen levels and cotton cultivars were found that *Bt* cotton cultivar, NCS 855 recorded significantly lowest *O* dihydroxy phenols content at 130 kg nitrogen level whereas highest *O* dihydroxy phenols was recorded in *Bt* cotton cultivar, RCH 773 at 65 kg nitrogen level under infested condition. Under uninfested condition, the non *Bt* cotton cultivar LH 2108 recorded significantly lowest *O* dihydroxy phenols content (4.58 mg/g dry weight) and highest *O*-dihydroxy phenols was recorded in FDK 124 (6.56 mg/g dry weight). Per cent increase in *O*-dihydroxy phenols content of different *Bt*, non *Bt* and *desi* cotton cultivar was ranged from 6.60 to 42.49.

Table 4. Correlation between biochemical parameters and sucking insect pest population in different *Bt*, non *Bt* and *desi* cotton cultivars

Sucking insect pest	Correlation co efficient		
	Total phenols	Flavonols	*O* dihydroxy phenols
Jassid	-0.429	-0.087	0.106
Whitefly	-0.621	-0.068	-0.422
Thrips	-0.569	-0.055	**-0.705***

***Significant at ($p<0.05$)**

At 90 DAS, *O* dihydroxy phenols showed significant variations among different *Bt*, non *Bt* and *desi* cotton cultivars as well as under different nitrogen fertilizer level and uninfested condition. Among the fertilizer the *O* dihydroxy phenols content was significantly higher in 65 kg nitrogen (10.07 mg/g dry weight) and minimum *O* dihydroxy phenols was recorded in 130 kg nitrogen (7.22 mg/g dry weight).The *O* dihydroxy phenols contents increased significantly under infested condition (8.86 mg/g dry weight) as compared to uninfested condition (5.50 mg/g dry weight). Among the *Bt*, non *Bt* and *desi* cotton cultivars at 90 DAS, the *Bt* cotton cultivar Bioseed 6588 recorded significantly lowest *O* dihydroxy phenols content of 7.60 mg/g dry weight being at par with FDK 124 (8.21 mg/g dry weight) and *Bt* cotton cultivar RCH 776 (8.31 mg/g dry weight). However, *Bt* cotton cultivar NCS 855 recorded significantly highest *O* dihydroxy phenols content of 11.36 mg/g dry weight as compare to all other cultivars under infested condition. The interaction between the different nitrogen levels and cotton cultivars were found to be significantly different. *Desi* cotton cultivar FDK 124 recorded significantly lowest *O* dihydroxy phenols content (6.24 mg/g dry weight) at 130 kg nitrogen level whereas highest *O* dihydroxy phenols was recorded in *Bt* cotton cultivar NCS 855 (14.13 mg/g dry weight) at 65 kg nitrogen level under infested condition. Under uninfested condition the *Bt* cotton cultivar NCS 855 recorded significantly lowest *O* dihydroxy phenols content (4.54 mg/g dry weight) and highest *O* dihydroxy phenols was recorded in *desi* cotton cultivar FDK 124 (6.38 mg/g dry weight). Per cent increase in the *O* dihydroxy phenols content of different

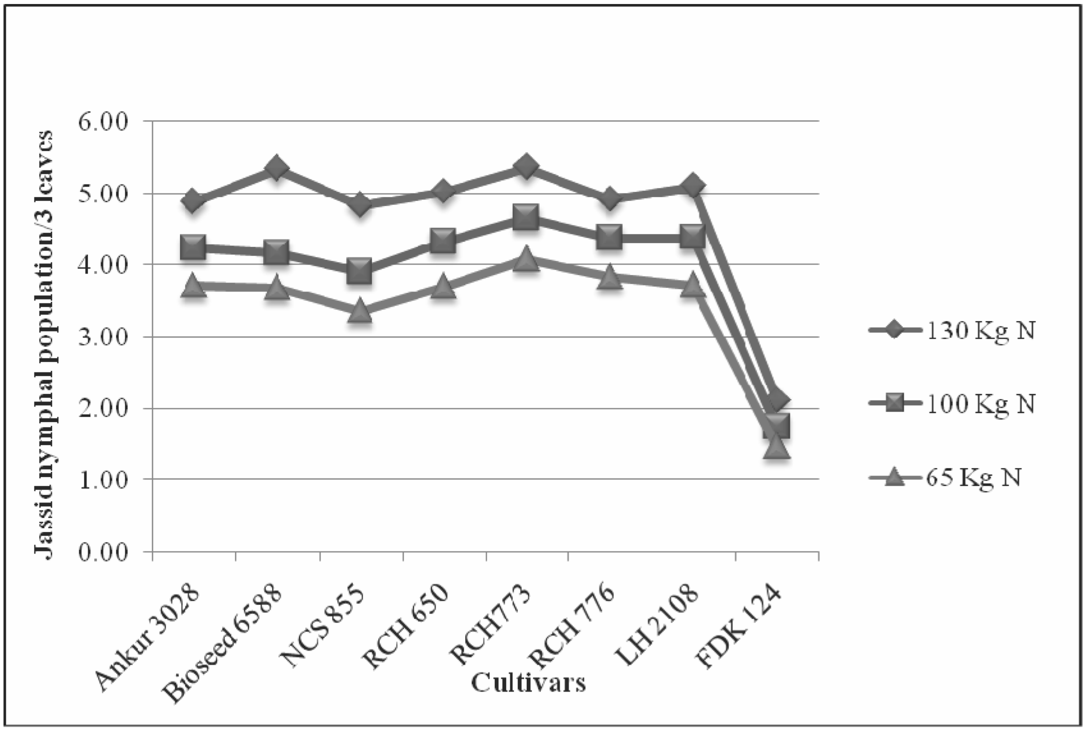

Fig 4. Incidence of jassid nymphal in different *Bt*, non-*Bt* and *desi* cotton cultivars at different levels of nitrogen during 2014-2015

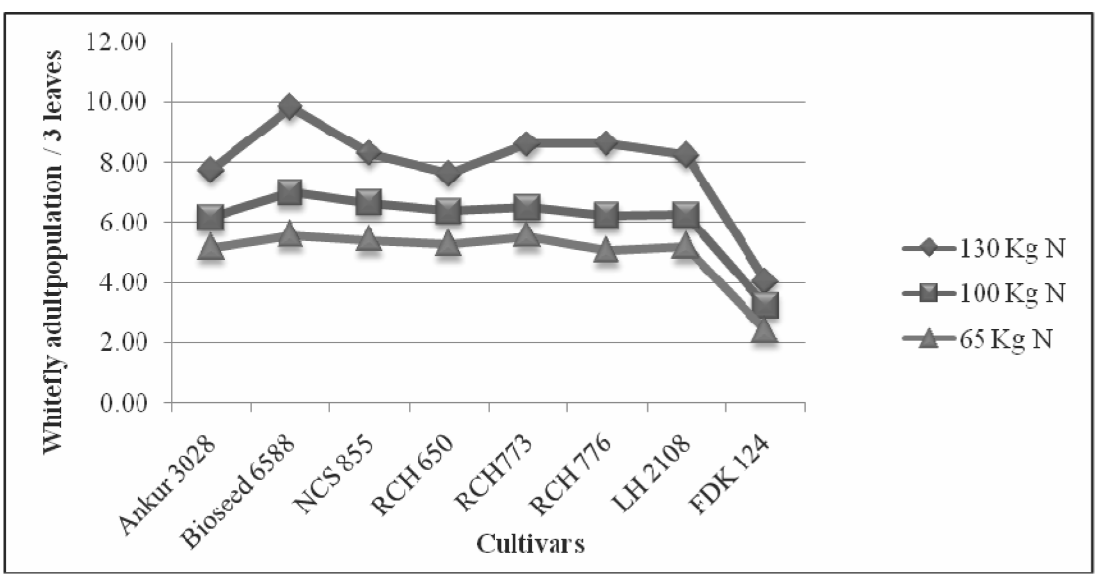

Fig 5. Incidence of whitefly adult in different *Bt*, non-*Bt* and *desi* cotton cultivars in different levels of nitrogen during 2014-2015

Bt, non *Bt* and *desi* cotton cultivar was ranged from 22.26 to 62.02.

The *O* dihydroxyphenols contents recorded at 120 DAS showed significant variations among different *Bt*, non *Bt* and *desi* cotton cultivars as well as under different nitrogen fertilizer level and uninfested condition. Among the fertilizer, the *O* dihydroxy phenols content was significantly higher in 65 kg nitrogen (4.96 mg/g dry weight) and minimum *O* dihydroxy phenols was recorded in 130 kg nitrogen (2.83 mg/g dry weight).The *O* dihydroxy phenols contents increased significantly under infested condition (4.06 mg/g dry weight) as compared to uninfested condition (2.12 mg/g dry weight). Among the *Bt*, non *Bt* and *desi* cotton cultivars at 120 DAS, the *Bt* cotton cultivar RCH 776 recorded significantly lowest *O* dihydroxy phenols content of 3.69 mg/g dry weight being *at par* with *desi* cotton cultivar FDK 124 (3.42 mg/g dry weight). However, *Bt* cotton cultivar RCH 650 recorded significantly highest *O* dihydroxy phenols content of 4.35 mg/g dry weight as compare to all other cultivars under infested condition. The interaction between the different nitrogen levels and cotton cultivars were found to be significantly different. *Bt* cotton cultivar Bioseed 6588 recorded significantly lowest *O* dihydroxy phenols content (1.63 mg/g dry weight) at 130 kg nitrogen level whereas highest *O* dihydroxy phenols was recorded in *Bt* cotton cultivar NCS 855 (6.77 mg/g dry weight) at 65 kg nitrogen level under infested condition. Under uninfested condition the *Bt* cotton cultivar Bioseed 6588 recorded significantly lowest *O* dihydroxy phenols content (1.38 mg/g dry weight) and highest *O* dihydroxy phenols was recorded in *Bt* cotton cultivar Ankur 3028 (3.21 mg/g dry weight). Per cent increase in the *O* dihydroxy phenols content of different *Bt*, non-*Bt* and *desi*

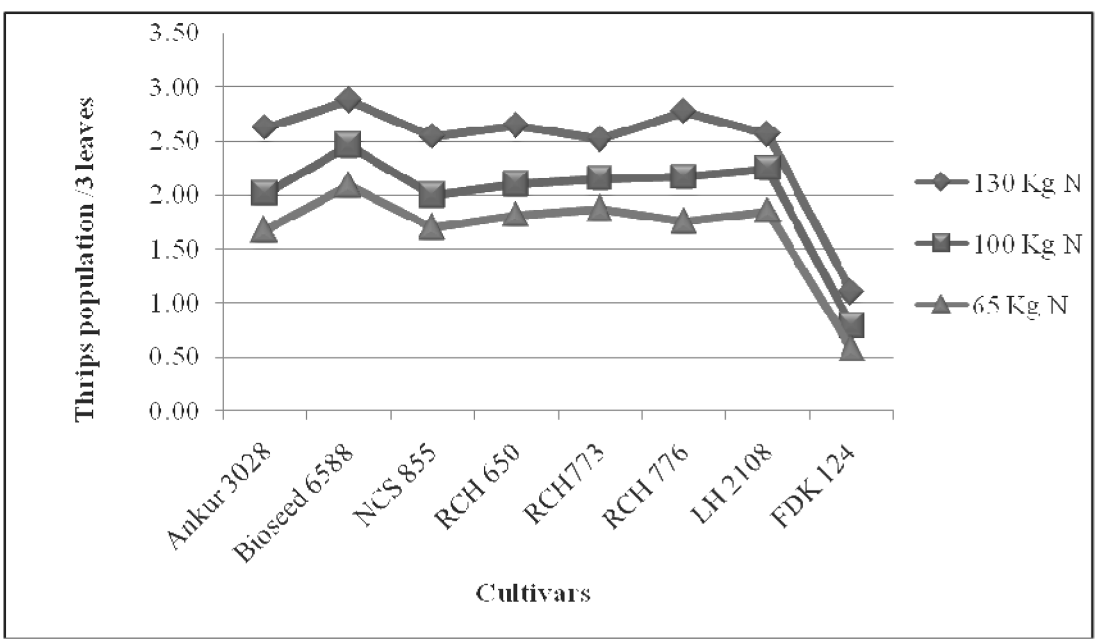

Fig 6. Incidence of thrips in different *Bt*, non *Bt* and *desi* cotton cultivars at different levels of nitrogen during 2014-2015

cotton cultivar was ranged from 23.51 to 66.79. *O* dihydroxyphenols contents were higher in 90 as compared to 60 and 120 DAS.

The present finding was in agreement with the finding of Balakrishnan (2006), Venkatesha (2014) and Shinde *et al.*, (2014) who reported total phenols concentration in cotton leaves has significant negative effects on jassid populations. Jindal and Dhaliwal (2009) reported a non-significant effect of phenols on population of whitefly. In accordance with the present finding Butter *et al.*, (1992) reported that higher levels of *O* dihydroxy phenols contents imparts resistance to *B. tabaci* in cotton. The present studies are also corroborates with the findings of Penueles *et al.*, (1997) who reported that low nutrient levels have been demonstrated with the increased in production of tannins and other phenols. This is due the accumulation of carbohydrate in the leaves tissue since there is decreased in sink size under low nitrogen. These excess carbohydrates stored in plant might channel the production of secondary plant metabolites (total phenols and flavonols) (Ibrahim and Zafer, 2011). In addition to this, the induction of resistance by feeding of whitefly nymphs resulting in the accumulation of phenolsic compounds in tomato seedlings has been also been reported by Murugan and Dhandapani (2007).

It was revealed in the result that the infested cotton plant has highest quantity of defensive biochemical and was significantly increased with the progressing of days in injured plants. The increased amount of biochemical *i.e.,* phenolics are an example of induced defenses of cotton against insect herbivores (Shafique *et al.,* 2014). The result also showed that physically wounded host plant tissue leading increased production of biochemical defenses (Korth 2003; Arimura *et al.,* 2005).

The plant biochemicals namely total sugars, reducing sugars, tannins, total phenols, *O* dihydroxy phenols and flavonols were analyzed by collecting leaves samples from 60, 90 and 120 days old infested and uninfested *Bt* and non *Bt* and *desi* cotton cultivars. Significantly higher total phenols, flavonols, *O* dihydroxy phenols, tannins, total sugar and reducing sugars were recorded at lower level of nitrogen (65 kg) followed by 100 and 130 kg/ac. Highest biochemical contents were recorded in infested over uninfested condition. Highest total phenols, flavanols and *O* dihydroxy phenols components were recorded at 90 days after sowing as compared to 60 and 120 days after sowing. Total phenol and flavanols were non significant negative correlation with jassid, whitefly and thrips. However, thrips population showed significantly negative correlation with *O* dihydroxy phenols. Therefore, the nitrogen fertilizer can be manipulate in order to incorporate in the integrated pest management programme of cotton crop so as to increase the defensive mechanism of the host plant against herbivores insect pests.

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REFERENCES

Anonymous, 2016. *Package of Practices for Kharif Crops*. Punjab Agricultural University, Ludhiana.

Ali, A. and Aheer, G.M., 2007. Varietal resistance against sucking insect pests of cotton under Bahawalpur ecological conditions. *J. agric. Res.* **45**: 1–5.

Arimura, G., Kost, C. and Boland, W., 2005. Herbivore-induced, indirect plant defences. *Biochem Biophys Acta.* **1734 :** 91–111.

Balabaa, S.T., Zaki, A.Y. and Elshamy, A.M., 1974. Total flavonoid and rutin contents of different organs of *Sophora japonica* L. *J. Ass. Anal. Chem.* **57**: 752-55.

Balakrishnan, N., 2006. Influence of allelochemical contents in plants on the incidence of major pests of cotton. *Indian. J. Plant. Prot.* **34**: 202-05.

Brookes, G. and Barfoot, P., 2006. GM crops: the first ten years-global socio-econoic and environmental impacts ISAAA Brief No. **36.**

Butter, N.S., Vir, B.K., Kaur, G., Singh, T.H., Raheja, R.K and Kaur, G., 1992. Biochemical basis of resistance to whitfly, *Bemisia tabaci* Genn. (Aleyrodidea: Hemiptera) in cotton. *Trop. agric.* **69**: 119-22.

Carrière, Y., Ellers-Kirk, C., Biggs, R., Higginson, D.M., Dennehy, T.J. and Tabashnik, B.E., 2004. Effects of gossypol on fitness costs associated with resistance to *Bt* cotton in pink bollworm. *J. econ. Ent.* **97**: 1710–18.

Hosagoudar G.N. and Chattannavar S.N., 2009. Biochemical studies in cotton genotypes having differential reaction of grey mildew (*Ramularia areola* Atk.) *Karnataka. J. agric. Sci.* **22** : 331-35.

Ibrahim, M.H. and Jaafar, H.Z.E., 2011. Involvement of carbohydrate, protein and phenylanine ammonia lyase in up-regulation of secondary metabolites in *Labisia pumila* under various CO_2 and N_2 levels. *Molecules* 16: 4172-90.

Jindal, V. and Dhaliwal, G.S., 2009. Bases of Resistance in Cotton to Whitefly, *Bemisia tabaci* (Gennadius): Biochemical Factors. *Indian. J. Ecol.* **36**: 166-69.

Korth, K.L., 2003. Profiling the response of plants to herbivorous insects, *Genome Bio.* **4 :** 221.

Lege, K.E., Cothreen, J.T. and Smith, C.W., 1995. Phenolsic acid and condensed tannin concentrations of six cotton genotypes. *Environ. Exp. Bot.* **35**: 241-49.

Murugan, M. and Dhandapani, N., 2007. Induced systemic resistance activates defense responses to interspecific insect infestations on tomato. *J. Veg. Sci.* **12 :** 43-62.

Nair, P.M. and Vaidyanathan, C.S., 1964. A colorimetric method for determination of pyrocatechol and related substances. *Analyt. Biochem.* **7**: 315-21.

Shafique, S., Ahmad, A., Shafique, S., Anjum, T., Akram, W. and Bashir, Z., 2014. Determination of molecular and biochemical changes in cotton plants mediated by Mealybug, Wageningen *J. Life. Sci.***71**: 39–45.

Shinde, B.A., Gurve, S.S., Gonde, A.D. and Hole, U.B., 2014. Studies on resistance of cotton genotypes against jassids (*Amrasca bigutulla bigutulla* Ishida). Bioinfolet. A. Quarterly. *J. Life. Sci.* **11:** 758-62.

Swain, T. and Hillis, W.E. 1959. The phenolsic constituents of *Prunus domestica*: The quantitative analysis of phenolsic constituents. *J. Sci. Food. Agric.* **10**: 63-68.

Venkatesha, K.T., 2014. Studies on resistance to jassids (*Amrasca devastans* Dist.) in cotton (*Gossypium hirsutum* L.). *Karnataka. J. agric. Sci.* **27**: 378-426.

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Value addition of cotton fabric by using plant extract

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ABSTRACT : Value addition, a term which is commonly used to describe how a service or component can add to a product usefulness, and thus potentially to the final price charged to the customers, can enhance the quality of cotton. Features such as function, sustainability and aesthetics can help in adding the value to any textile product. This paper explains the value addition process of cotton fabric by using leaves extract of *Syzygium cumini* (L). plant which was extracted through soxhlet process and was used to develop an antibacterial and UV protective finish on cotton fabric. The finishing on cotton was given by pad dry cure process. The developed cotton fabric not only had antibacterial finish with 64.8 per cent reduction in the bacterial count for *Staphylococcus aureus* and UPF value of 37.6 which comes in the protection category of very good but was also eco friendly and aesthetically pleasing. It was concluded that such value added products can be used for different end uses which includes fashion garments, medical textiles as well as protective textiles.

Key words : Antibacterial , cotton, *Syzygium cumini* (L.), UV protection, value addition

Value addition, is a term which is commonly used to describe how a service or component can add to a product usefulness, and thus potentially to the final price charged to the consumers (Sodhi, 2017). Value added products or services are worth more because they have been improved by adding something to them. Today, textiles with desired functional and aesthetic properties are demanded by the consumers, with more value for money through different levels of comfort, durability and functionality. Also, unless any product is characterized by value addition, it is now impossible to survive in this highly competitive world market (Lokesh, 2015). Textile exports of countries like Pakistan have decreased owing largely to low value textiles products like cotton, yarn, grey fabric as reported by The Express Tribune, 2015.

Features such as function, sustainability and aesthetics can help in adding the value to any textile product. Functional textiles are engineered to meet specific performance requirements which include properties like stain and water repellency, mosquito repellent, flame retardency, odor blocks, UV absorbers, antimicrobial finishes and much more (Sodhi, 2017). The challenge is to meet all these demands without harming the environment. Thus use of sustainable raw materials and processes is a major concern to industry. Consumers are increasingly exercising their choice in favor of textile materials produced by environmentally sustainable and socially responsible methods. Companies and brands like Hustman, Arvind, H and M and KG Denim is working towards elimination of such hazardous chemicals and is committed towards environmental sustainability in their textile business practice. (Sodhi 2017). Both academic researchers and industrial product development have been intensified to seek for sustainable dyeing and finishing process, using biomacromolecules, biomaterials , plant extract, biopolymer and water free technologies. (Samanta *et al.*, 2016)

Cotton being the most favourite fiber due its inherent properties like good absorbency, comfort, light weight, soft hand, durability, easy dyeing is most preferred in summer (Gupta *et al.*, 2016). Although being the most favourite choice it lacks certain properties like UV protection as well as being a natural fiber, it offers an ideal environment for microbial growth because it retains oxygen, water and nutrients (Gupta *et al.*, 2017). With this backdrop, the present study was undertaken to add value to cotton fabric by improving different features such as function, sustainability as well as aesthetics.

MATERIALS AND METHODS

1. Selection and extraction of plant extract : An exhaustive list of plants having UV protective and antibacterial properties was prepared on review basis. From the prepared list *Syzygium cumini* (L.) was selected (Table 1) for adding value to cotton fabric. Only regenerative parts of the plant were collected from CCS Haryana Agricultural University, Hisar, because of easy accessibility. The leaves extract was prepared by using soxhlet method, where, collected leaves were washed, shade dried, grounded in powder form and subjected to hot methanolic extraction at 55-60^0 C (Table 2).

Table 1. Taxonomy of selected plant for the present study

S. No.	Plants	Scientific Name	Local name	English name	Family	Parts used
1.			*Syzygium cumini* (L.)	*Jamun*	Black plum	Myrtaceae Leaves

2. Application of *S. cumini* (L.) leaves extract on cotton fabric : The cotton fabric was treated with *S. cumini* (L.) leaves extract by using pad dry cure process. The fabric was immersed in the solution containing 7 per cent concentration of *S cumini* (L.) leaves extract, 1:20 MLR, 50 g/l resin cross linking agent, 10 g/l magnesium chloride, at pH 5 for 30 min as treatment time. Fabric was then passed between the rollers of padding mangle and then dried at 110^{0}C for 5 min and cured at 150^{0}C for 3 min in a curing chamber.

3. Assessment of aAntibacterial and UV-protective property on treated cotton fabric : Anti bacterial property of the treated fabric against gram positive bacteria (*Staphylococcus aureus)* was quantitatively determined by using

Table 2. Extraction process

ConditionsPlant	Drying of plant	Grinding	*Extraction*
Syzygium cumini (L.) (leaves)	 		

AATCC Test Method 100 and the determination of UPF of cotton fabric was done by using AATCC 183:2004 test method.

4. Consumer opinion about the treated cotton fabric : To study the consumer opinion regarding the aesthetic property, eco-friendliness and use of developed cotton fabric in different textile sectors, thirty married females in the age group of 30-45 were purposively selected from Hisar city, as respondents. Treated cotton fabric, was shown to consumers and their opinion were collected and evaluated by calculated percentage.

RESULTS AND DISCUSSION

The antibacterial and UV protective properties of treated cotton fabric was compared to respective control by calculating the per cent reduction in bacterial count as well as by studying the change in UV protection category. The data presented in Table 3 reveal that the bacterial count of control cotton fabric was 32.4×10^7 for *S. aureus*. Whereas after the treatment, the bacterial count observed was 11.4×10^7 for *S. aureus*, which indicated 64.8 per cent reduction in the bacterial count when compared to the control fabric.

The mean UVA per cent transmission of control cotton fabric was 7.70 whereas mean UVB per cent transmission observed was 8.57 and the mean UPF value was 10.9, providing no protection. After the treatment, decrease in UVA and UVB per cent transmission was observed and the mean UVA per cent transmission obtained was 3.40 whereas mean UVB per cent transmission was 2.51. The UPF value of cotton fabric after treatment with *S cumini* (L.) leaves extract improved and was observed as 37.6 UPF value, providing very good protection as shown in Table 3. .

It is unmistakably evident from the results obtained that the treated cotton fabric exhibit high antibacterial effectiveness against *S. aureus* as well as provided very good protection from UV radiations as compared to respective control.

Table 3. Antibacterial and UV protective property of treated cotton fabric

Properties	Antibacterial		Ultraviolet protection				
Cotton fabric	*S. aureus* CFU/ml	(%) Reduction	UVA (%)	**Mean UVB (%)**	UPF value	UPF Range	UPF Protection category
Control	32.4×10^7	-	7.70	**8.57**	10.9	-	No protection
Treated	11.4×10^7	64.8	3.40	**2.51**	37.6	25-39	Very good

Consumer opinion regarding treated cotton fabric : Data presented in Table 4 reveals that majority of the respondents (93.3 %) found treated cotton fabric as aesthetically pleasing. Also, majority of the respondents (96.6 %) were of the opinion that treated cotton fabric has its place in different textile sectors. This might be due to the enhanced properties of cotton which can provide comfort to the wearer and helps to lead healthy life. Results also revealed that 70 per cent of the respondents found the treated cotton fabric as eco-friendly as natural plant extract is applied on cotton instead of any synthetic chemical.

RESULTS AND DISCUSSION

Value addition of the textile or garment increases the value both by appearance and price. It attracts the customer to buy that particular product and increases the market demand. Apart from this it helps in increasing the demand of natural fibers over synthetics.

Table 4. Consumer opinion regarding treated cotton fabric

Parameters	Frequency (%)
Aesthetically pleasing	28(9.33)
Eco friendly	21 (70.0)
Use in different textile sectors	29 (96.6)

Multiple response (n=30)

Value addition can be done in different ways when it comes to textiles and depends on the end use. Printing, embroidery, finishing are some of the common methods employed. Among all these finishing is method which helps to incorporate desirable characteristics (Lokesh, 2015). In the present study, the cotton fabric treated with *S. cumini* (L.) leaves extract exhibited not only UV and antibacterial properties but was aesthetically pleasing and was considered eco friendly due to the use of natural plant extract. The results also suggested that such fabrics can be used in different textile sectors.

Cotton playing a very important role in the traditional textile and apparel industry (Yadav and Gupta, 2015) and with such treatments the horizon of use of cotton fabrics can be broadened in different textile sectors as suggested by the results of the present study. According to the Lifestyle and Retail Monitor™ Survey, more than 9 in 10 consumers would like to choose cotton over synthetics if cotton could wick moisture, regulate temperature, resist UV rays (Cotton Incorporated Lifestyle Monitor, 2015). All kinds of fibers such as natural (cotton, silk, jute, wool etc.), man made (viscose, polyester, nylon, acrylic etc.) as well as high performance speciality fibers find their usage in technical textiles with more percentage of man made fibers due to their inherent advantage of having higher strength and versatility. The current use of cotton in Indian technical textile industry is 6.8 per cent. With new advances and eco friendly properties of cotton as compared to synthetics it will find its way for different applications and industrialist should look forward to invest in cotton based technical textiles as cotton industry is the backbone of the textile sector suggested by T. Rajkumar, Chairman of Southern India Mill Association (SIMA) (Yadav and Gupta, 2015). Different segments where UV protective and antibacterial cotton based products are used and exhibit a potential of increasing market demand includes Hometech where cotton fabric is used to develop curtains, blinds, bed linen, pillow covers, towels, bathrobes etc., An article published in The Hindu, reports that with demand increasing for textile products such as home textiles in export markets such as US, those who were so far manufacturing woven grey fabrics are now getting into value added products (Kumar, 2015). Medtech is an important area of textile industry in which cotton has its prominent place due to its highly absorbent nature, naturally breathing and good aesthetic characteristics. It is majorly used in development of hygiene products, contamination control gowns, masks, wound dressing, bed spreads and many more. Another technical textile sector where cotton finds its place is Protech. Protech are textile products and related materials used in the manufacturing of protective clothing for personnel working in hazardous environment (Anonymous, 2006). People who work in agriculture tend to work many hours in the sun, so they have a greater risk for sun-induced damage which includes pre mature ageing, eye damage, skin cancer, melonoma than the general population. Location, time of the day and genetics all make a difference to the extent of possible damage (Brueggeman and Rosenthal, 2001). A study on cancer risks in a population conducted by Kachuri *et al.,* 2017 revealed that a total of 9515 incident cancer (melanoma) cases occurred in agricultural workers which were attributed to sun exposure. Such exposure of heat also leads to sweat-induced reactions, where there is too much heat and sweating followed by too little evaporation of the sweat from the skin leading to bacterial and fungal infections (Birmingham). In such conditions cotton fabrics with UV protective and antibacterial properties, developed with natural substances can reduce the fatal workplace accidents and discomforts.

CONCLUSION

It can be concluded that value addition of any textile product will help the manufacturer to increase its demand as well as will provide consumers, more value for their money. Improved characteristic of fiber like cotton will also place it in textile sectors where high performance and sustainability is required. Thus, emphasis on safer and cleaner alternatives should be made to provide comfort to not only general public but also to workers.

REFERENCES

Anonymous, 2015. Restructuring: Need to focus on value added textiles, says Dastgir. *The Express Tribune.* https://tribune.com.pk/story/947334/restructuring-need-to-focus-on-value-added-textile-says-dastgir/

Anonymous 2006. Indian Technical Textile Market. Retrieved from http://shows.nonwovens-industry.com/articles/2006/09/theindian-technical-textiles-market

Birmingham, D.J. Overview: Occupational Skin Diseases, Chapter 12- Skin Diseases. *Encyclopedia of Occupational Health Safety*, Fourth Edition. Retrieved from http://www.ilocis.org/documents/chpt12e.htm

Brueggeman, M. and Rosenthal, E. 2001. Agricultural Skin Diseases. *Rural Wisconsin Health Cooperative*. Retrieved from http://worh.org/files/AgHealth/skin.pdf

Cotton Incorporated Lifestyle Monitor. 2015. Top Performances. *Lifestyle cotton incorporated monitor.* Retrieved from http://lifestylemonitor.cottoninc.com /tag/activewear/

Gupta, V., Gupta, N. and Yadav, N. 2016. Consumer awareness and opinion regarding UV protective and antibacterial finished cotton fabrics. *Asian Jour. Home Sci.* **11 :** 202-07

Gupta, V., Chaudhary, D., Gupta, S. and Yadav, N. 2017. Environment Friendly antibacterial and UV protective finish on cotton using *Syzygium cumini* (L.) leaves extract. *Internat. Jour. Text. Fashion Tech.* (IJTFT), **7 :** 53-62.

Kachuri, L., Harris M. A., MacLeod, J.S., Tjepkema, M., Peters, P.A. and Demers, P.A. 2017. Cancer risks in a population based study of 70,570 agricultural workers: results from the Canadian census health and Environment cohort (CanCHEC), *BMC Cancer* **17:** 343. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5437486/

Kumar, R.V. 2015. Fabric Manufacturer focuses on value added products. *The Hindu*, Tamil Nadu. Retrieved from http://www.thehindu.com/news/national/tamil-nadu/fabric-manufacturers-focus-on-valueadded-products/article7376740.ece

Lokesh, K.V. 2015. Value addition finishes for Textiles. http://textilelearner.blogspot.in/2015/03/value-addition-finishes-for-textiles.html

Samanta, K.K., Basak S. and Chattopadhyay S.K. 2016. Sustainable Dyeing and Finishing of Textiles Using Natural Ingredients ad Water –Free Technologies. *Textile and Clothing Sustainability, Spinger* :99-131. Retrieved from https://link.springer.com/chapter/10.1007/978-981-10-2185-5_4

Sodhi, N.V. 2017. Value addition in textiles and clothing. Retrieved from Textile value chain. http://www.textilevaluechain.com/index.php/article/industry-general/item/296-value-addition-in-textiles-and-clothing

Yadav, N. and Gupta, V. 2015. Cotton and its perspective uses. *National Symposium "Future Technologies: Indian Cotton in the Next Decade"*, Acharya Nagarjuna University, Guntur.

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Eco-friendly production of nanolignin from cotton stalks and its application in medical textiles

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ABSTRACT : Lignin is the second most abundant renewable carbon source available on earth. It is available in plenty as a by-product from cotton agricultural field, an example cotton stalks. In this work, controlled microbial hydrolysis process was followed to produce Nanolignin from the bulk lignin extracted from cotton stalks. The ligninase secreting microorganisms were used for this purpose. The size reduction of lignin was monitored by nanoparticle size analyzer and, once the size reached below 100 nm, the samples (Nanolignin) were purified and taken for further application. Nanolignin was padded on to cotton fabrics and linen fabrics using acrylic binder and characterized by using FTIR, SEM and XRD. Colorfastness was performed to check the particle retaining ability on the fabrics after washes. The finished cotton fabrics and linen fabrics showed excellent antibacterial (as per AATCC 100-2012; 147-2016 methods), UV blocking (as per AATCC 186-2015 method) and antioxidant (as per DPPH method) properties. This work gives a new way of research to utilize cotton by-products and adding value to them to generate multifunctional medical textiles.

While synthetic polymers have replaced the traditional metals and glass based materials for diversified applications due to low cost and ease of processing, increasing environmental concerns pave way for the emergence of biopolymers. There is a great potential of the biopolymer based nanomaterials to be used in nano-medicine due to their biocompatibility and biodegradability. Lignin is the most available biopolymer next only to cellulose and constitutes 25 to 30 per cent of the non-fossil organic molecules on Earth. Its potential areas of applications include fillers in polymer composites, stabilizing agents, lubricants, coating additives, plasticizers and surfactants Nanomaterials prepared from naturally available biopolymers could potentially be harmless and benign for the ecosystem. Such environmentally biodegradable nanomaterials derived from cellulose, lignin, chitin and starch are hypothesized to support the development of eco-friendly functional nanosystem.

In lab (ICAR-CIRCOT), Mumbai, nanolignin is being extracted from cotton stalks by microbial process, high shear homogenization or ultrasonication process. For microbial process, the lignin degrading fungal isolate *Aspergillus* spp is being used. In case of cotton stalks, microbial process yields 45.3 per cent nanolignin while homogenization and ultrasonication processes yield 79.50 and 62.60 per cent, respectively.

The application of nanolignin (produced by microbial process) is demonstrated for textile applications. SEM (Scanning electron microscope), TEM (Transmission electron microscope), XRD (X-ray diffraction), DLS (Dynamic light scattering), ZETA- Potential, FTIR (Fourier-transform infrared spectroscopy), AFM (Atomic force microscopy), DSC (Differential scanning calorimetry) and CIE (International Commission on Illumination) were used to study the morphological and chemical properties of nanolignin and textiles treated with nanolignin.

Nanolignin (size: 27.5 nm ± 2.7 nm) applied onto the surface of cotton and linen fabrics by pad-dry-cure method using acrylic binder showed excellent antibacterial (as per AATCC-100 standard method), UV blocking (as per AATCC-186 standard method) and antioxidant (as per DPPH method) properties. Newer application of microbial produced nanolignin for multifunctional finishing of cotton and linen fabrics is demonstrated to generate medical / biomedical textiles.ÿþ Therefore, extraction of nanolignin from cotton stalks by a controlled microbial hydrolysis process proves to be an eco-friendly protocol having potential applications not only in conventional industries but also for textile, biomedical and environmental applications.

This project utilizing cotton byproducts and convert them in to beneficial nanolignin, which is one of important way for bolstering the rural “farmer uplift” by utilizing their agricultural byproducts (cotton stalk) and providing them the extra income.

As well as this work utilizing discarded lignin waste from paper and pulp industries and converting it to beneficial nanolignin. Therefore, nanolignin from cotton stalks by a controlled microbial hydrolysis process plays a very important role in environment that is “waste to wealth”.

Visit the following site for detail information of the respective research work. www.nanocellulose.in.

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Genetical and molecular basis of cotton leaf curl disease in upland cotton (*Gossypium hirsutum* L.)

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ABSTRACT : The present investigation comprising of six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of four crosses *viz*. GCH 3 x HS 6, GCH 3 x RST 9, H 1353 x HS 6 and H 1353 x RST 9 was conducted to study the inheritance of cotton leaf curl disease and to estimate the gene effects for the seed cotton yield and its component traits. The inheritance of cotton leaf curl disease indicated the complementary gene interaction (9:7), traits namely days to flowering, plant height, number of bolls / plant, boll weight, seed index and seed cotton yield indicated the presence of non-allelic interactions. Dominance component was significant for the characters *viz.,* days to flowering, plant height, seed index and seed cotton yield. Duplicate type of interaction was apparent for days to flower (cross IV) and plant height (cross I, II and IV). Genetic diversity between selected resistant (GCH 3 and H 1353) and susceptible (HS 6 and RST 9) parents to cotton leaf curl disease was studied in non segregating generations *i.e.* P_1, P_2 and F_1 generations of four *G. hirsutum* crosses. Twenty eight ISSR primers were used to generate DNA profile of parental genotypes and their F_1s with a view to study polymorphism/ genetic diversity. Out of twenty eight ISSR primers, twenty one primers were found as polymorphic. A total of 175 alleles were amplified unambiguously by these 28 ISSR primers, of which 127 alleles were polymorphic and ranged in size from 150-1000 bp. Inspite of per cent polymorphism, the primers showed remarkable polymorphic information content (PIC) values. The PIC value was found in the range of 0.495 to 0.907. The ISSR primer UBC 834 was found to have maximum PIC value (0.907) and was found as more informative to be used in the early screening of the germplasm lines.

Key words : Alleles, genetical, leaf curl, polymorphism, molecular, segregating

Cotton (*Gossypium hirsutum* L.) is a major fibre crop of global importance which belongs to *Malvaceae* family and domesticated independently as source of textile fiber. It is grown commercially in the temperate and tropical regions of more than 70 countries. The leading cotton producing countries are China, USA, India and Pakistan where climatic conditions suit the natural growth requirements of cotton (Meyer *et al.,* 2013).The choice of suitable breeding procedure depends upon the nature and magnitude of gene action involved in the inheritance of various characters of economic importance in the crop. The estimates of gene effects in a crop improvement program have a direct bearing upon the choice of selection procedure to improve a quantitative character. The present study was also conducted to reveal the information about inheritance pattern of cotton leaf curl disease along with gene effects for seed cotton yield and its attributing traits in upland cotton. Losses to the production of cotton due to incidence of the viral diseases is severe and among the viral diseases cotton leaf curl disease takes a heavy toll in terms of production and productivity. Therefore, development of a resistant variety to this disease is the most effective, long term, less expensive and safe method to fight against this disease and to enhance and stabilize the productivity of cotton. Research efforts to develop resistant varieties through conventional/ biotechnological approaches along with cultural and management practices are in progress for effective control of this disease. The knowledge of genetic diversity in a crop species is fundamental to its improvement. Cotton improvement through conventional breeding is time consuming, the molecular markers offer a great opportunity for crop improvement as these are more reliable and can reduce time and money required for field testing in crop improvement programs.

It was reported by Dahab *et al.,* (2013) that the knowledge of genetic relationships among the plant genotypes helps to know about the complexity present in the available germplasm and also to discover the differences in available genotypes and to build up useful conservation plans for future work. Thus, evaluation based upon the molecular markers can provide the valuable insight into the genetic structure of a plant population, which helps in the development of new and improved varieties of the crop and also this genetic diversity ensures protection procedures against diseases and pests. The characterization of germplasm with molecular markers permits a more relevant choice of the resistant / tolerant genotype.

ISSR is a PCR based simple, quick and efficient technique. It has high reproducibility and does not require radioactivity and it is useful in mapping and evolutionary biology in a wide range of crop species. Work of Khanam *et al.,* (2012) suggested that ISSR markers allow the detection of the polymorphism in inter SSR loci using the primer (16 to 25 bp long) complimentary to a single SSR and anneal at the either 3’ or 5’ end which can be di, tri, tetra or pentanucleotide as reported by Reddy *et al.,* (2002).

In order to achieve this goal, an understanding of mode of inheritance of cotton leaf curl virus disease and seed cotton yield along with genetic diversity or polymorphism is necessary for proper choice of breeding procedures.

MATERIALS AND METHODS

The present investigation was conducted in Cotton Research Area, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar in collaboration with Department of Molecular Biology, Biotechnology and Bioinformatics (MBBB) during 2013-2016.

Plant material : The plant materials comprised four genetically diverse cotton genotypes belonging to *Gossypium hirsutum* L.; two resistant to CLCuD *i.e.* GCH 3 and H 1353 and two highly susceptible to CLCuD *i.e.* HS 6 and RST 9. These four cotton genotypes were used to develop four crosses, GCH 3 x HS 6, GCH 3 x RST 9, H 1353 x HS 6 and H 1353 x RST 9. These crosses were designated as cross I, cross II, cross III and cross IV, respectively.

During *kharif,* 2013, the parents were identified and F_1 crosses were made. The F_1 and parents were raised in next season. Each F_1 was selfed to obtain F_2 generation and simultaneously backcrossed to both of its parents to produce backcross generations BC_1 (backcross to parent 1) and BC_2 (backcross to parent 2). Fresh crosses were also made to obtain the F_1 seed and all the parents were selfed to get their seeds for the next year and finally experimental material comprised of six generations *i.e.* P_1, P_2, F_1, F_2, BC_1 and BC_2 of four crosses was grown in a randomized block design with three replications during *kharif*, 2015. There were two rows of non segregating generations (P_1, P_2 and F_1), 10 rows of F_2, and 4 rows of each back cross 1 and back cross 2 generations. The length of each row was 6 m with a spacing 67.5 x 30 cm. Normal cultural practices were followed during crop season. Observations were taken during *kharif* 2015-2016. Young and actively growing leaves of cotton plants *i.e.* resistant and susceptible parents to cotton leaf curl disease and their respective F_1s of four crosses were used for DNA extraction.

DNA extraction : Total genomic DNA was isolated following CTAB method modified by Murray and Thompson (1980). All DNA samples were given RNase treatment and were further purified.

Qualitative and quantitative estimation of DNA : The quantity and quality of DNA was checked by agarose gel (0.8%) electrophoresis. The DNA was diluted to a final concentration of 25 µg/ il. A single discrete band near the wells was observed in all genotypes

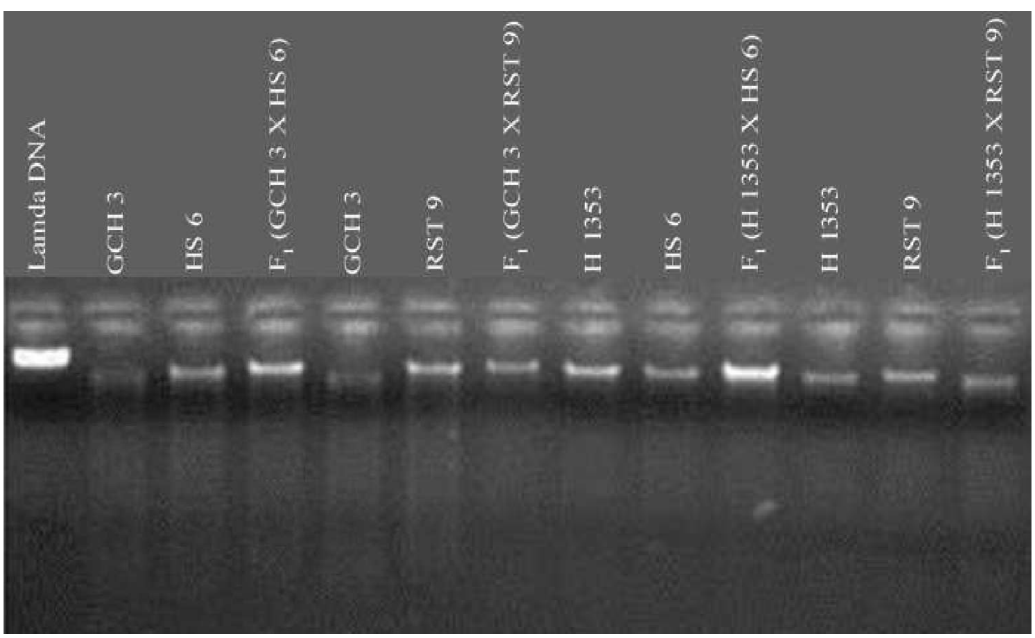

Fig 1. Isolated and RNase treated genomic DNA samples run on 0.8% agarose gelPolymerase chain reaction (PCR) amplification

("Fig.1") showing that genomic DNA was intact, of high molecular weight and free from RNA contamination.

Twenty eight random ISSR primers were screened to identify primers that were reproducible and generated the most polymorphic pattern. PCR reactions were carried out in Thermo Cycler in 10 µl reaction mixture containing 1X PCR buffer, 5 per cent DMSO, 300 µM dNTPs, 2.5 mM $Mgcl_2$, 1 U Taq DNA polymerase, 0.5 µM primer (designed by Sigma-Aldrich Pvt. Limited, India) and DNA 25 ng. PCR cycles consisted of initial denaturation at 94^0C for 5 min., 35 cycles of denaturation at 94^0C for 35 sec., annealing (as mentioned in "Table 3") for 1 min., extension at 72^oC for 1 min. and a final extension at 72^oC for 10 min. The amplification product (10 µl) was electrophoressed on 1.5 per cent agarose gel in 1X TBE buffer and stained with ethidium bromide. Bands were visualized under UV transilluminator and photographed using Bio Rad Gel Documentation system.

Observations on cotton leaf curl disease (CLCuD) : Observation on cotton leaf curl disease was recorded under field condition in each replication on all the plants of each of the non segregating generations (P_1, P_2 and F_1), backcross generations and the F_2 generation. Disease was scored on 0-6 grade (Akhtar *et al.,* 2010) depending upon the response to the cotton leaf curl virus disease.

$$Percent\ (\%)\ disease\ incidence = \frac{Number\ of\ diseased\ plants}{Total\ number\ of\ plants} \times 100$$

0= Immune

1 = Highly resistant; disease incidence (0.1–10%)

2 = Resistant; disease incidence (10.1- 20%)

3 = Moderately resistant; disease incidence (20.1 – 30%)

4 = Moderately susceptible; disease incidence (30.1 – 40%)

5 = Susceptible; disease incidence (40.1– 50%)

6 = Highly susceptible; disease incidence (> 50%)

For testing the agreement of observed frequencies with those expected upon a given hypothesis, the chi- square (÷2) test of goodness of fit was used.

Observations on economic traits : Five competitive plants from each row of non-segregating generations and 50 plants from F_2 generations and 10 plants from each of backcrosses were taken at random for recording observations on the economic characters such as days to flowering, plant height, bolls / plant, boll weight, ginning outturn, seed index, lint index and seed cotton yield.

Statistical analysis

The Chi square test of goodness of fit : For testing the agreement of observed frequencies with those expected upon a given hypothesis, the chi-square ($÷^2$) test of goodness of fit as described by Pearson (1900) was used. For carrying out this test the following formulae was used:

$$÷^2 = \sum_{i=1}^{n} (Oi - Ei)^2 / Ei$$

where,

O_i = observed frequency of i^{th} class

E_i = expected frequency of i^{th} class

For testing the significance, the $\div^2$ tabulated value was seen at n-1 d.f.

Biometrical analysis for estimation of gene effects : The "t" statistical test was applied to test the differences between parental genotypes for the characters studied before considering the biometrical analysis. The gene effects were estimated by employing generation mean analysis (Mather 1967; Hayman and Mather 1955; Jinks and Jones 1958).

Molecular data analysis

Allele scoring : The ISSR amplification profiles were scored by visual observations for parents and their F_1 generation. The presence of an amplified allele in each position was scored as 1 and the absence as 0. The size (in nucleotides base pairs) of the amplified alleles was determined based on its migration relative to standard 100 bp DNA ladder.

Polymorphic information content (PIC) : Based on the frequency of allele for each primer, polymorphic information content (PIC) was calculated, using the following formula:

$$PICi = 1- \sum_{j=1}^{n} Pij^2$$

where,

PICi is the polymorphic information content of a marker i,

Pij is the frequency of the j^{th} pattern for marker i, and

The summation extends over n patterns

Genetic similarity coefficient : Based on the 0 /1 matrix of allele scoring, genetic similarity coefficient was calculated to estimate all pairwise differences in the amplification product for parents and their F_1 generation using 'SIMQUAL' sub-program of NTSYS-PC (version 2.02) software (Numerical Taxonomy and Multivariate Analysis System program) (Rohlf, 1997). Similarity coefficients were then used for cluster analysis of parents and F_1s performed using the 'SAHN' (Sequential, Agglomerative, Heirarchial, Nested clustering method) sub program of NTSYS-PC. Dendrogram was constructed by using distance matrix by the Unweighted Pair Group Method with Arithmetic Average (UPGMA) sub program of NTSYS-PC.

The data generated from polymorphic fragments were analyzed according to the formula given below:

$$Similarity\ Coefficient = \frac{2Mx}{My + Mz}$$

Dissimilarity = 1-F

Where,

Mx = Number of shared fragments between genotypes y and z

My = Number of scored fragments of genotype y

Mz = Number of scored fragments of genotype z

Principal component analysis (PCA) was done to construct two and three dimensional diagrams for providing suitable means of testing the relationship among parents and their F_1s using the EIGEN vectors and values.

RESULTS AND DISCUSSION

Inheritance of cotton leaf curl disease : The incidence of cotton leaf curl disease during the experimental year *i.e.* 2015 was very severe under field condition particularly nearby Hisar areas, during this year no variety/ strain was observed completely immune to this disease. Even in highly resistant strains few plants showed susceptible reaction. The F_1s of four crosses had showed resistance to CLCuD which indicated that resistance is a dominant and digenically controlled trait. The expression of resistance in all (R x S) crosses revealed that there was no cytoplasmic inheritance for the expression of susceptibility to CLCuD. The dominance nature of resistance over susceptibility was further confirmed by backcrosses and F_2s, there were 2 distinct classes, *i.e.* resistant and susceptible in F_2 and backcross population. The pattern of segregation in F_2 gave a good fit to 9 resistant: 7 susceptible (Table 1) indicated the complementary type of gene action which was further confirmed by a

Table 1. Inheritance of CLCuD in upland cotton

Parent / generation		No. of plants Screened		Expected ratio Resistant	$\div^2$calculated Susceptible	PValue
Cross I (R x S): GCH 3 x HS 6						
P_1	82	80	2	-	-	-
P_2	68	0	68	-	-	-
F_1	76	74	2	-	-	-
F_2	406	240	166	9:7	1.35	0.245
BC_1	28	28	0	-	-	-
BC_2	174	135	39	3:1	0.61	0.434
Cross II (R x S):Cross GCH 3 x RST 9						
P_1	93	90	3	-	-	-
P_2	86	0	86	-	-	-
F_1	35	34	1	-	-	-
F_2	591	340	251	9:7	0.39	0.532
BC_1	54	52	2	-	-	-
BC_2	102	74	28	3:1	0.32	0.568
Cross III (R x S): H 1353 x HS 6						
P_1	109	103	6	-	-	-
P_2	104	0	104	-	-	-
F_1	51	49	2	-	-	-
F_2	706	386	320	9:7	0.715	0.357
BC_1	238	231	7	-	-	-
BC_2	174	133	41	3:1	0.096	0.756
Cross IV(R x S): H 1353 x RST 9						
P_1	79	73	6	-	-	-
P_2	71	0	71	-	-	-
F_1	80	77	3	-	-	-
F_2	624	335	289	9:7	1.66	0.205
BC_1	158	152	6	-	-	-
BC_2	164	119	45	3:1	0.52	0.470

good fit of 3 resistant: 1 susceptible ratio of backcross with susceptible parents. These results suggested that plants showed resistant reaction in the presence of dominant alleles of both the genes. Disease was expressed in those plants which had any one of the two or both the genes in the homozygous recessive state.

The breeding for cotton leaf curl disease resistance has been achieved through the assemblage of minor genes by recurrent selection and resistance depends on major genes (dominant genes) which may lose quickly because of the evolution of pathogen for these genes (Azhar *et al.,* 2010). Four types of segregation patterns in the F_2 generations were reported. A good fit for 15 (resistant):1 (susceptible), 13 (resistant): 3 (susceptible), 9 (resistant):7 (susceptible) ratios indicated digenic control of the trait with duplicate dominant, dominant inhibitory and duplicate recessive epistasis, respectively.

Estimation of epistasis : The joint scaling test of Cavalli (1952) has indicated the adequacy of simple additive-dominance model for days to flower in cross I , II and III , boll number (cross II, III and IV), boll weight (cross I, II and IV), ginning outturn (cross I, II, III and IV), 100 seed weight (cross IV), lint index (cross I, II, III and IV) and seed cotton yield in crosses I, III and IV. The observations based on three parameter model indicated the failure of simple additive-dominance model in many traits irrespective of cross which may be taken as that the observed genetic variation might not be ascribed wholly to the additive dominance gene effects for majority of the characters. By the application of six parameter model, the epistatic gene effects were found for some characters, but the type and magnitude of epistatic effects varied for character to character and cross to cross as presented in Table 2(a) and (b).

Further the significance of dominance component of gene effect (h) and its higher magnitude than the additive effect (d) indicated the scope of exploitation of heterosis for improvement of characters. Such a scope exist in the case of plant height, seed index and seed cotton yield where the estimate of dominance component (h) of gene effect has been significant and higher in magnitude than the additive gene effect (d) in the present investigation.

For those characters, where digenic model has been found as adequate, largely the characters have been observed where there has been preponderance of both ‘additive’ and ‘dominance’ components and among epistatic components mostly ‘i’ type (additive x additive) and ‘j’ type (dominance x dominance) epistasis contributed significantly towards the gene effects. Moreover, in some other situations either ‘i-type’ epistasis alone or ‘i-type’ epistasis in combination with ‘l-type’ and ‘j-type’ epistasis or all the three types of epistasis were found significantly contributing to the gene effects. It is interesting to note that ‘j’ type of epistasis alone has been reported only in boll number (cross I). Preponderance of additive x additive (i-type) epistasis suggested that such traits in the population may be improved through random mating of the selected desirable plants followed by selection. This approach will lead to the exploitation of additive (d); additive x additive (i-type) of gene effects and interactions in the populations. The high frequency of occurrence of dominance (h) and dominance x dominance

Table 2 (a). Generation mean analysis for yield attributing traits in four crosses of upland cotton

Days to flowering	Cross parameter	Cross I (GCH 3 x HS 6) Estimates± SE	Cross II (GCH 3 x RST 9) Estimates± SE	Cross III (H 1353 x HS 6) Estimates± SE	Cross IV (H 1353 x RST 9) Estimates± SE
Joint scaling test (three parameter model)					
	m	56.54** ± 0.40	57.76** ± 1.07	56.66** ± 0.47	54.63** ± 0.55
	d	2.11** ± 0.42	-0.09 ± 1.07	0.73 ± 0.44	0.32 ± 0.46
	h	0.92 ± 0.67	1.41 ± 1.86	0.22 ± 0.94	2.42* ± 1.09
	$\div^2$ **(df=3)**	**1.11**	**4.60**	**1.12**	**28.44****
Six parameter model					
	m	57.26** ± 0.34	58.68** ± 0.42	56.75** ± 0.34	57.22** ± 0.39
	d	-1.80* ± 0.88	0.66 ± 2.06	-1.23 ± 0.82	-1.06 ± 0.63
	h	-1.33 ± 2.33	-3.35 ± 5.07	1.04 ± 2.39	-7.58** ± 2.34
	i	-2.26 ± 2.23	-6.22 ± 4.45	1.17 ± 2.15	-9.42** ± 2.01
	j	0.66 ± 2.01	-1.06 ± 5.88	-1.26 ± 1.97	-4.46* ± 1.95
	l	3.20 ± 4.01	12.75 ± 9.71	-3.51 ± 4.15	16.68** ± 3.82
	Type of epistasis	-	-	-	Duplicate
Plant height		**Joint scaling test (three parameter model)**			
	m	118.93**±2.54	130.04**±3.08	144.75**±3.31	133.54**±3.08
	d	5.89*±2.59	3.96±2.63	-8.20*±2.98	-5.06±3.14
	h	2.21±4.70	-22.12**±6.34	-9.29±6.67	7.58±5.90
	$\div^2$ **(df=3)**	**25.38****	**11.19****	**19.96****	**35.71****
		Six parameter model			
	m	117.02**±1.51	120.61**±2.45	143.50**±1.81	142.44**±1.62
	d	-17.83**±4.97	-13.83**±4.13	9.83*±5.04	-5.00±6.49
	h	33.56**±12.57	-36.27**±14.82	-38.50**±14.58	-55.44**±15.71
	i	32.22**±11.64	-21.44±12.84	-13.66±12.43	-59.77**±14.51
	j	-38.33**±11.74	-30.66**±10.95	7.33±12.58	-34.66*±14.98
	l	-52.56*±22.87	48.77*±24.27	-47.66 ±26.30	82.44**±29.36
	Type of epistasis	Duplicate	Duplicate	-	Duplicateee
Boll/plant		**Joint scaling test (three parameter model)**			
	m	19.66**±1.09	18.75**±1.22	22.22**±1.09	23.53**±1.66
	d	-0.28±1.07	0.90± 1.18	-0.13±1.04	0.95±1.52
	h	-0.38±2.24	7.07**±2.60	-0.94±2.24	-0.78±3.27
	$\div^2$ **(df=3)**	**11.80****	**4.51**	**3.28**	**1.89**
		Six parameter model			
	m	28.953**±7.36	21.73**±0.63	45.03±25.46	49.62±25.65
	d	-10.73**±3.70	-3.16±3.27	-1.30±2.36	-2.03±2.67
	h	-21.61± 61	19.56**±8.18	- 97.46±102.01	-105.18±102.81
	i	-20.74±30.39	8.46±7.02	-97.80±101.98	-103.22±102.75
	j	-24.80**±7.80	-5.73±7.03	-3.66±5.26	-2.53±6.56
	l	4.74±33.31	-4.73±15.77	107.33±102.42	96.15±103.40
	Type ofepistasis	-	-	-	-

df = degrees of freedom, calculated as the number of generations minus the number of estimated genetic parameters
(*, **) indicates that the value was significant by the t-test at the 5% and 1% probability level respectively

Table 2 (b). Generation mean analysis for yield attributing traits in four crosses of upland cotton

Boll weight	Cross parameter	Cross I (GCH 3 x HS 6) Estimates± SE	Cross II (GCH 3 x RST 9) Estimates± SE	Cross III (H 1353 x HS 6) Estimates± SE	Cross IV (H 1353 x RST 9) Estimates± SE
		Joint scaling test (three parameter model)			
	m	3.137**±0.327	3.234**±0.362	1.837**±0.392	2.013**±0.371
	d	0.73±0.89	0.236*±0.093	-0.001±0.133	-0.069±0.131
	h	-0.326±0.913	-1.456±0.950	2.304±1.078	1.726±0.984
	$\div^{2}$ **(df=3)**	**5.14**	**3.80**	**9.07****	**6.40**
		Six parameter model			
	m	2.991**±0.043	2.806**±0.062	2.508**±0.055	2.612**±0.061
	d	-0.47**±0.131	0.163±0.125	0.111±0.148	-0.423**±0.123
	h	-0.256±0.362	-0.257±0.394	0.379±0.417	0.669±0.412
	i	-0.430±0.314	-0.403±0.350	1.084**±0.369	0.456±0.347
	j	-0.240±0.317	-0.146±0.311	0.224± 0.398	-0.708±0.359
	l	0.070±0.658	1.200*±0.663	-1.925*±0.742	-1.057±0.707
	Type of epistasis	-	-	-	-
Seed index		**Joint scaling test (three parameter model)**			
	m	5.58**±0.08	5.50**±0.09	5.68**±0.09	5.67**±0.09
	d	-0.54**±0.07	-0.41**±0.08	-0.36**±0.08	-0.42**±0.08
	h	0.12±0.16	-0.07±0.18	-0.41*±0.18	-0.24±0.18
	$\div^{2}$ **(df=3)**	**13.35****	**19.35****	**9.51****	**3.01**
		Six parameter model			
	m	5.70**±0.03	5.64**±0.07	5.59**±0.05	5.58**±0.08
	d	0.34**±0.10	0.11±0.13	0.33**±0.12	0.37**±0.11
	h	-0.72*±0.32	-1.31**±0.43	-1.43**±0.39	-0.57±0.43
	i	-0.52*±0.25	-1.06**±0.38	-0.98**±0.33	-0.30±0.39
	j	-0.80**±0.32	-1.05**±0.36	0.04±0.34	-0.32±0.34
	l	0.67±0.59	1.05±0.71	1.16 ±0.68	1.01±0.67
	Type ofepistasis	-	-	-	-
Seed cotton yield		**Joint scaling test (three parameter model)**			
	m	56.32**±2.30	43.00**±3.36	54.84**±3.07	50.38**±2.43
	d	-2.86±2.57	-4.93±4.88	2.96±3.76	-7.63**±2.97
	h	-37.73±31.01	-86.66±39.05	-71.85±35.73	11.96±35.20
	$\div^{2}$ **(df=3)**	**6.17**	**26.54****	**1.65**	**4.99**
		Six parameter model			
	m	59.26**±4.92	45.63**±5.03	55.07**±6.26	53.81**±7.02
	d	-10.20**±1.41	0.23±5.03	0.03±4.97	-11.53*±4.68
	h	-14.80±11.96	-60.53**±15.33	-46.14**±13.86	-9.43±14.12
	i	-18.40±10.75	-48.86**±14.06	-15.04± 12.60	-2.80±13.29
	j	-14.66±10.49	10.33±14.01	-5.86±12.47	-7.80±11.09
	l	22.93±21.84	26.13±25.52	25.71±24.27	-21.40±23.04
	Type ofepistasis	-	-	-	-

df = degrees of freedom, calculated as the number of generations minus the number of estimated genetic parameters
(*, **) indicates that the value was significant by the t-test at the 5% and 1% probability level respectively

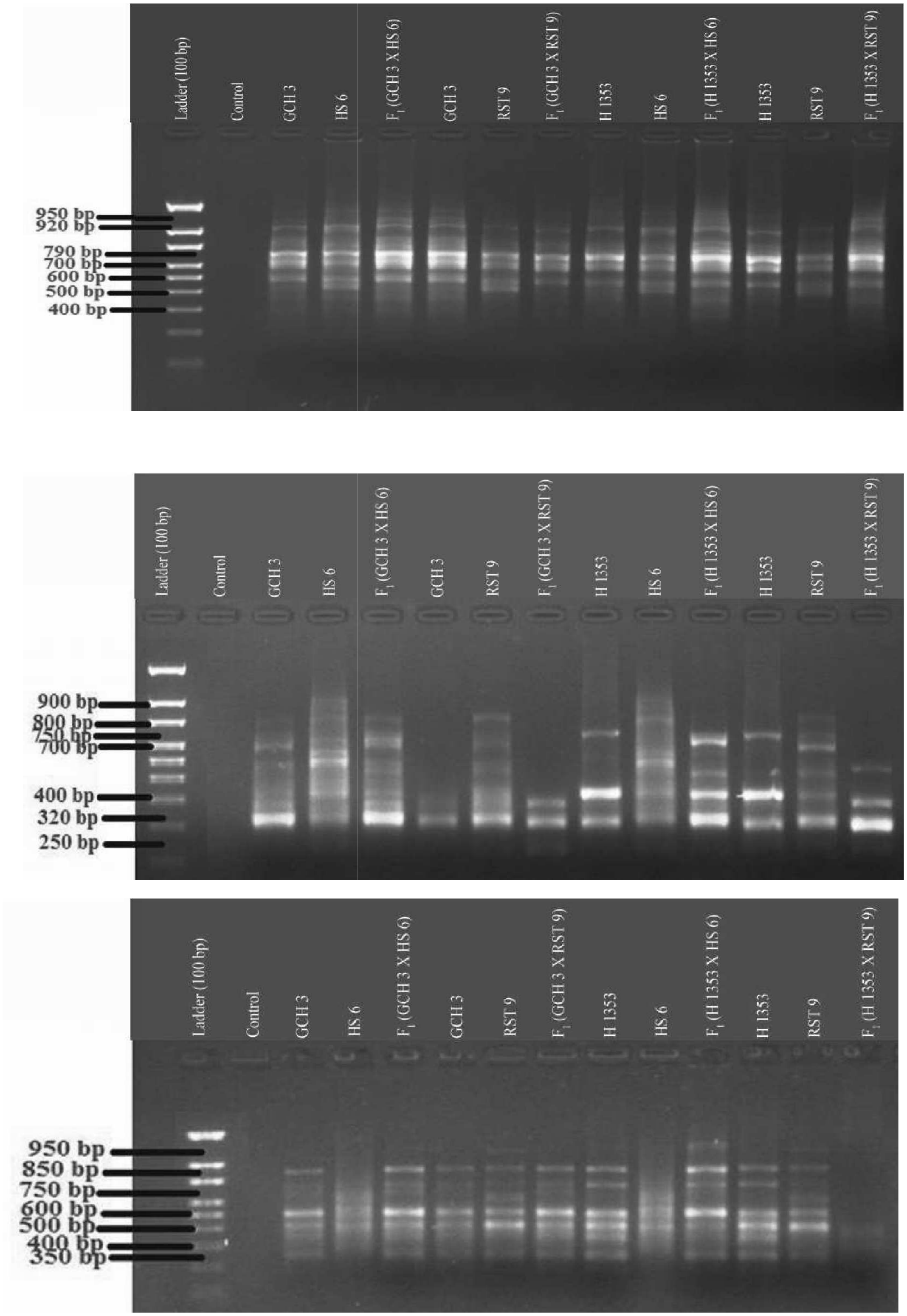

Fig 2. (a-c). Agarose gel electrophoresis pattern of PCR amplified products of parents and their F_1s, using primers ISSR 16, UBC 840, UBC 823

(l-type) gene effects and interactions may paradoxically suggest the exploitation of heterosis in cotton. However, a close examination for the sign of 'h' and 'l' type of epistasis reveal that magnitude of the two if found in opposite direction than contribution to the phenotypic mean imply thereby antagonistic effects in heterosis expression and it has been termed as 'duplicate' type of epistasis. Hence, it is difficult to improve the populations in the presence of duplicate type of epistasis.

In the present investigation analysis of variance revealed that mean squares due to generations were significant for plant height, bolls/plant, boll weight, ginning out turn, lint index, seed index and seed cotton yield in all of the four crosses. Traits like days to flower, number of bolls/plant, and boll weight directly contributed toward economic yield of seed cotton (Abbas *et al.,* 2016) and Abdullah *et al.,* (2016) also reported that the analysis of variance showed that significant differences existed among the genotypes studied. Similarly, Baloch *et al.,* (2016) studied analysis of variances which revealed that significant differences existed among the varieties for all the studied traits such as plant height, bolls / plant, boll weight, seed cotton yield / plant, and depicted the availability of substantial genetic variability among the genotypes.

Additive effects for seed cotton yield and its attributing characters were also reported (Lu and Myers, 2011; Iqbal *et al.,* 2013). Mohsen and Amein (2016) reported that seed cotton yield / plant was significantly and positively correlated with bolls/plant, boll weight, seed index and lint percentage. Ali *et al.,* (2009) found additive component fit for number of bolls, ginning outturn, seed cotton yield and plant height and in our study dominance component was found fit for seed cotton yield and plant height. More role of additive genetic effects for these parameters also reported by Basal and Turgut (2005); Ali and Khan (2007) and additive genetic effects for seed cotton yield and some other characters was also found in our study.

Molecular analysis

Amplified product visualization : The amplified PCR products, obtained through ISSRs were separated by (1.5%) agarose gel electrophoresis and visualized under UV light. The amplification pattern of selected ISSRs are presented in "Fig. 2 (a-c)".

Clearly resolved bands were scored. Molecular weights of the bands were estimated by using 100 bp DNA ladder as standards. Twenty eight ISSR primers used to generate DNA profile of parental genotypes and their F_1s with a view to study genetic diversity presented in Table 3.

A total of 175 alleles were amplified unambiguously by the 28 ISSR primers, of which 127 alleles were polymorphic (72.57%) and ranged in size from 150-1000 bp. The mean percentage of polymorphism obtained with ISSR primers in the present study was found 72.57 per cent. Similar study was also conducted in cotton by Preetha and Raveendren (2008), in which the mean percentage of polymorphism obtained with ISSR markers was 50.49 per cent, with a range of 0 per cent with (GA) 9A to 87 per cent with UBC 807. The highest values for PIC occurred with the UBC 807 primer (0.498).

Genetic relationship among parents

Table 3. DNA polymorphism in four cotton parents and their F_1s using twenty eight ISSR primers

No.	Primer	Sequence (5'-3')	Band size (bp)	Total no. of alleles	Mono-morphic alleles	Polym-orphic alleles	Polym-orphism (%)	PIC value
1.	ISSR 1	AGACAGACGC	200-800	10	3	7	70.0	0.897
2.	ISSR 14	CACACACACACAGT	530-950	6	1	5	83.0	0.790
3.	ISSR 16	CACACACACACAAG	400-950	12	3	9	75.0	0.888
4.	ISSR 24	GACAGACAGACAGACA	600-890	4	3	1	25.0	0.728
5.	ISSR 31	GAGGAGGAGGC	270-900	7	0	7	100.0	0.841
6.	HB 08	GAGAGAGAGAGAGG	300-710	5	0	5	100.0	0.778
7.	HB 10	GAGAGAGAGAGACC	250-900	6	1	5	83.3	0.824
8.	HB 12	CACCACCACGC	170-700	9	0	9	100.0	0.842
9.	17898A	CACACACACACAAC	700-900	4	4	0	0	0.750
10.	ISSR	CACACACACACACAGT	500-1000	3	3	0	0	0.551
11.	ISSR	GAGAGAGAGAGAGAGAGC	450-1000	2	2	0	0	0.50
12.	IS 5	CACACACACACAAT	350-900	4	2	2	50.0	0.720
13.	IS 15	GTGTGTGTGTGTAT	350-470	2	2	0	0	0.495
14.	UBC807	AGAGAGAGAGAGAGAGT	350-1000	11	1	10	90.9	0.882
15.	UBC 808	AGAGAGAGAGAGAGAGC	400-900	8	1	7	87.5	0.851
16.	UBC 809	AGAGAGAGAGAGAGAGG	150-500	5	2	3	60.0	0.792
17.	UBC 810	GAGAGAGAGAGAGAGAT	300-1000	11	3	8	72.0	0.881
18.	UBC 811	GAGAGAGAGAGAGAGAC	200-450	3	3	0	0	0.663
19.	UBC 816	CACACACACACACACAT	900-1000	5	1	4	80.0	0.748
20.	UBC 823	TCTCTCTCTCTCTCTCC	350-900	8	0	8	100.0	0.863
21.	UBC 825	ACACACACACACACACT	450-950	5	2	3	60.0	0.794
22.	UBC 827	ACACACACACACACACG	600-900	3	3	0	0	0.612
23.	UBC 834	AGAGAGAGAGAGAGAGYT	300-1000	13	2	11	100.0	0.907
24.	UBC 840	GAGAGAGAGAGAGAGAYT	250-900	11	1	10	90.9	0.877
25.	UBC841	GAGAGAGAGAGAGAGAYC	300-700	4	2	2	50.0	0.747
26.	UBC 849	GTGTGTGTGTGTGTGTYA	500-800	6	0	6	100.0	0.828
27.	844 A	CTCTCTCTCTCTCTCTAC	350-700	3	3	0	0	0.609
28.	844 B	CTCTCTCTCTCTCTCTGC	350-800	5	0	5	100.0	0.752

and their F_1s using ISSR primers : Inspite of per cent polymorphism, the primers showed remarkable polymorphic information content (PIC) values. The PIC value was found in the range of 0.495 to 0.907. The ISSR primer UBC 834 was found to have maximum PIC value (0.907) followed by ISSR1 with PIC value of 0.897 and minimum PIC value (0.495) was found for IS15. Clearly, it can be stated that, the ISSR primer UBC 834 with greater numbers of alleles tend to have higher PIC values and thus may be more informative.

UPGMA cluster tree analysis : The association among the different parents and their F_1s is presented in the form of dendrogram in Fig. 3. The UPGMA cluster tree analysis led to the grouping of parents GCH 3, H 1353, HS 6 and RST 9 and their F_1s into two major groups at similarity index of 0.54-0.85.

The similarity coefficient range obtained in this study is supported by the earlier genetic

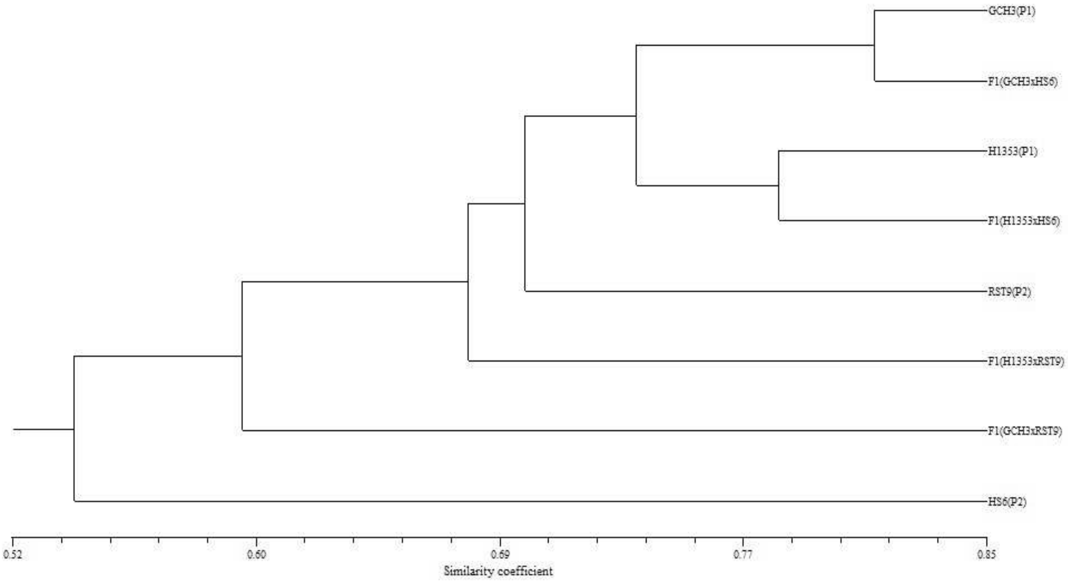

Fig 3. Dendrogram showing genetic diversity among selected parents and their F_1s using ISSR primers

diversity studies in cotton, in which range was found from 0.53 to 0.88 as reported by Noormohammadi *et al.,* (2011). Present genetic diversity study by using ISSRs, resulted similarity coefficient from 0.54 to 0.85 which fills the similarity window between cotton genotypes that was observed in earlier studies that showed similarity coefficient range from 0.185 to 0.881 as reported by Kahodariya *et al.,* (2015) and 0.77 to 0.97 as reported by Ashraf *et al.,* (2016). The dendrogram indicated that parents and their F_1s of four crosses bifurcated at similarity coefficient of 0.54 and formed two major clusters A and B. At the same similarity coefficient, parent HS 6 was clustered separately. Cluster B was further differentiated into different sub-clusters at similarity coefficient of 0.60. Similar cluster membership was found in another study of cotton by Parkhiya *et al.,* (2014) in which cluster I included only one genotype and while cluster II consisted of rest of the genotypes grouped together in their respective sub-clusters. As depicted by dendrogram parent GCH 3 and parent HS 6 were found to be more divergent at similarity coefficient of 0.54.

SUMMARY

Inheritance of cotton leaf curl disease indicated the presence of complementary gene interaction (9:7). Scaling tests revealed that additive-dominance model was fit for the characters, namely; days to flower, boll number, boll weight, ginning outturn, seed index, lint index and seed cotton yield. The traits with inadequate additive dominance model were subjected further to six parameter model. The magnitude was more for dominance component than additive component. All the three types (i, j and 1) or either of epistatic effects of them were significant for most of the cases wherein dominance x dominance (l) type of interaction was reported for days to flower, plant height and boll weight. Duplicate type of interaction was apparent for days to flower and plant height. The PIC values of ISSR markers were found in the range of 0.495 to 0.907. The ISSR primer UBC 834 was found to have maximum PIC value (0.907) followed by ISSR 1 with PIC value of 0.897 which suggested that these primers were more informative and may be used for early screening of germplasm lines.

REFERENCES

Abbas, G. H., Shahid, M. R., Mahmood, A. and Ali, Q. 2016. Characterization of plant spacing best fit for economic yield, fiber quality, white fly and CLCuV disease management on upland cotton. *J. Nat. Sci.* **14** : 12-16.

Abdullah, M., Numan, M., Shafique, S. M., Shakoor, A., Rehman, S. and Ahmad, I. M. 2016. Genetic variability and interrelationship of various agronomic traits using correlation and path analysis in cotton (*Gossypium hirsutum* L.). *Acad. J. Agric. Res.* **4** : 315-18.

Akhtar, K. P., Haider, S., Khan, M. K. R., Ahmad, M., Sarwar, N., Murtaza, M. A. and Aslam, M. (2010). Evaluation of *Gossypium* species for resistance to leaf curl burewala virus. *Ann. App. Biol.* **157**: 135-47.

Ali, M. A. and Khan, I. A. 2007. Assessment of genetic variation and inheritance mode in some metric traits of cotton (*Gossypium hirsutum* L.). *J. Agric. Social Sci.* **3** : 112-16.

Ali, M. A., Abbas, A., Younas, M., Khan, T. M. and Hassan, H. M. 2009. Genetic basis of some quantitative traits in upland cotton (*Gossypium hirsutum L*). *Plant Omics Journal* **2** : 91-97.

Ashraf, J., Malik, W., Iqbal, M. Z., Khan, A. A. and Qayyum, A. 2016. Comparative analysis of genetic diversity among *Bt* cotton genotypes using EST-SSR, ISSR and morphological markers. *J. Agri. Sci. Tech.* **18:** 517-31.

Azhar, M.T., Rehman, M. U., Aftab, S., Zafar, Y. and Mansoor, S. 2010. Utilization of natural and genetically-engineered sources in *Gossypium hirsutum* for the development of tolerance against cotton leaf curl disease and fiber characteristics. *Int. J. Agric. Biol.* **12** : 744-48.

Baloch, M., Baloch, A. W., Ansari, U. A., Baloch, G. M., Abro, S., Gandahi, N., Baloch, G. H., Baloch, A. M., Ali, M. and Baloch, I. A. 2016. Interrelationship analysis of yield and fiber traits in promising genotypes of upland cotton. *Pure Appl. Biol.* **5** : 263-69.

Basal, H. and Turgut, I. 2005. Genetic analysis of yield components and fibre strength in upland cotton (*Gossypium hirsutum* L.). *Asian J. Plant Sci.* **27**: 207-12.

Cavalli, L.L. 1952. An analysis of linkage of quantitative inheritance. In: *Quantitative inheritance (E.C.R. Reeve and C.H. Weddington eds.), HMSC, London.* **pp :** 135-44.

Dahab, A. A., Saeed, M. and Mohamed, B. B. 2013. Genetic diversity assessment of cotton (*Gossypium hirsutum* L.) genotypes from Pakistan using simple sequence repeat marker. *Aust. J. Crop Sci.* **7 :** 261-67.

Hayman, B. I. and Mather, K. 1955. The description of genetic interaction in continuous variation. *Biomet.* **11** : 69-82.

Iqbal, M., Naeem, M., Rizwan, M., Nazer, W., Shahid, M. Q., Aziz, U., Aslam, T. and Ijaz, M. 2013. Studies of genetic variation for yield related traits in pland Cotton. *American-Eurasian J Agric Env Sci* **13** : 611-18.

Jinks, J. L. and Jones, R. M. 1958. Estimation of components of heterosis. *Genet.* **43**: 223-34.

Kahodariya, J., Sabara, P., Vakharia, D. 2015. Assessment of genetic diversity in old world and new world cotton cultivars using RAPD and ISSR markers, **Ind. J. Biotech. 14 :** 511-17.

Khanam, S. A., Sham, J. L., Bennetzen, Aly, M. A. M. 2012. Analysis of molecular marker based characterization and genetic variation in date palm (*Phoenix Dactylifera* L.). *Aust. J. Crop Sci.* **6 :** 1236-44.

Lu, H. and Myers, G. O. 2011. Combining abilities and inheritance of yield components in influential upland cotton varieties. *Aust. J. Crop Sci.* **5**: 384-90.

Mather, K. 1967. Complementary and duplicate gene interactions in biometrical genetics. *Hered.* **22**: 97-103.

Meyer, L., McDonald, S. and Kiawu, J. 2013. United States Department of Agriculture, Economic Research Service Situation Outlook; Cotton and Wool Outlook, 2013 / CWS -13e/ May 14, 2013.

Mohsen, A. A. A. and Amein, M. M. 2016. Study the relationships between seed cotton yield and yield component traits by different statistical techniques. *Int. J. Agro. Agric. Res.* **8** : 88-104.

Murray, H. G., Thompson, W. F. 1980. Rapid isolation of higher molecular weight DNA, *Nuc. Acids. Res.* **8:** 4321-25.

Noormohammadi, Z., Shamee, M. H., Sheidai, M. and Alishah, O. 2011. The comparison of inter simple sequence repeat and randomly amplified polymorphic DNA markers for genetic assessment of intra-specific cotton hybrid genotypes. *Geneconserve* **42 :** 270-92.

Parkhiya, S., Gohel, K. D. R. and Mehta. 2014. Genetic diversity analysis of cotton (*Gossypium hirsutum* L.) genotypes using ISSR markers. *Int. J. App. Pure Sci. Agri.* **1 :** 1.

Pearson, K. 1900. On the criterion that a given system of deviations from the probable in the case of correlated system of variables is such that it can be reasonably supposed to have arison from random sampling. *Phil. Mag. Ser.* **5 :** 157-72.

Preetha, S. and Raveendren, T. S. 2008. Molecular marker technology in Cotton. *Bioteh. Mol. Biol. Rev.* **3 :** 32-45.

Reddy, M. P., Sarla, N. and Siddiq, E. A. 2002. Inter simple sequence repeat (ISSR) polymorphism and its application in plant breeding. *Euphytica.,* **128 :** 9-17.

Rohlf, F. J. 1997. NTSYS-PC numerical taxonomy and multivariate analysis system, Exeter Software.

ISBN-9788193678213

NHH 715 : A new *intra hirsutum rainfed* hybrid identified for central and south zone of India

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ABSTRACT : In India mostly *intra hirsutum* cotton hybrids are grown under *rainfed* conditions. As thrust of plant breeder is to develop high yielding, stable hybrid with better fibre qualities coupled with tolerance to biotic and abiotic stresses , number of efforts made for development of such hybrids with conventional breeding programme. With this attempts, Cotton Research Station, Nanded had , developed, identified and released a new *intra hirsutum* rainfed hybrid NHH 715 for central zone as well as south zone compromising eight State of India during 2016-2017 through All India Co ordinated Research Project on cotton. Across central zone of India, the newly released *intra hirsutum* hybrid NHH 715 had recorded a mean seed cotton yield of 16.78 q/ha as against 12.39 q/ha and 15.13 q/ha of zonal and local checks, respectively. The percentage increase in seed cotton yield was to the tune of 33.65 and 11.85 over both the checks. As regards to fibre properties, The test hybrid has recorded mean fibre length of 28.00 mm, fibre strength of 24.23 g/tex and Micronaire of 4.5. The oil content to the tune of 19.70 % and that of biomass upto 4.75 t/ha. The new *intra hirsutum* hybrid NHH 715 also performed better e in south zone of India. In south zone the new hybrid recorded a mean seed cotton yield of 19.08 q/ha as against 15.59 q/ha and 16.68 q/ha of Zonal and Local Checks, respectively. The percent increase in seed cotton yield was to the tune of 22.38 and 14.39 . The hybrid was found tolerant to sucking pests as well as tolerant to bacterial blight and Alternaria leaf spot diseases in south zone. Regarding fibre parameters, fibre length of 28.27 mm, fibre strength of 24.47 g/tex and micronaire of 4.40. The Oil content was observed 19.70 per cent and biomass 5.65 t/ha The hybrid NHH 715 showed higher seed cotton yield as well as quality fibre parameters in central as well as south zone of India and fulfill the requirement of textile industry and cotton growing farmers and will be true to its potential.

Key words : Cotton, fibre parameter, *Gossypium hirsutum ,* hybrid, Seed cotton yield

Central and south zones of India accounts for 66 per cent and 22 per cent of total cotton acreage in India respectively and mostly *intra hirsutum* hybrids are grown under rainfed condition Anonymous (2016). Requirement of the zone is to develop high yielding, stable hybrid having tolerance to biotic and abiotic stresses with desirable fibre qualities. Low cotton prices , increasing production costs and vagaries of monsoon are seriously challenging the cotton farmers in the country. The cotton productivity remains a major concern, which is stagnated at

Table 1. Performance of NHH 715 for Seed cotton yield during 2013-14 to 2015-16 in Central Zone under *rainfed* condition.

Year of testing	Trial Location	Seed cotton yield (kg/ha) central zone: NHH 715	Check 1 (LC)	Check 2 (ZC) (Ankur 651)	GSHH 2595	SHH 808	NHH 715 : (%) increase /decrease over: Check 1 (LC)	Check 2 (ZC) (Ankur 651)	GSHH 2595	SHH 808	CD (P=0.05)	Local Checks
2013-2014	Indore	1796	2117	1252	1934	2023	(-) 15.2	(+) 43.5	(-) 7.1	(-) 11.2	279	JKHY 3
	Akola	1562	1461	1303	1307	1561	(+) 6.9	(+) 19.9	(+) 19.5	(+) 0.1	75	PK HY 2
	Hansot	3652	2675	1736	2868	2971	(+) 36.5	(+) 110.4	(+) 27.3	(+) 22.9		G COT Hy 12
	Jalna	1946	2262	1943	2486	2402	(-) 14.0	(+) 0.2	(-) 21.7	(-) 19.0		NHH 44
	Mean	**2239**	**2129**	**1559**	**2149**	**2239**	**(+) 5.2**	**(+) 43.7**	**(+) 4.2**	**(=) 0.0**		
2014-2015	Hansod	1442	1626	1368	1328	1505	(-) 11.3	(+) 5.4	(+) 8.6	(-) 4.2	318	G COT Hy 12
	Indore	957	736	715	957	808	(+) 30.0	(+) 33.8	(=) 0.0	(+) 18.4	189	JKHY 2
	Akola	1194	1109	943	1098	990	(+) 7.7	(+) 26.6	(+) 8.7	(+) 20.6	105	PK HY 2
	Nanded	905	589	618	488	461	(+) 53.7	(+) 46.4	(+) 85.5	(+) 96.3	192	NHH 44
	Mean	**1125**	**1015**	**911**	**968**	**941**	**(+) 10.8**	**(+) 23.4**	**(+) 16.2**	**(+) 19.5**		
2015-2016	Bharauch	3139	2852	1856	3160	2718	(+) 10.1	(+) 69.1	(-) 0.7	(+) 15.5	629	G COT Hy 12
	Indore	826	701	876	1196	969	(+) 17.8	(-) 5.7	(-) 30.9	(-) 14.8	204	JKHY 2
	Akola	1593	1010	1303	1582	1249	(+) 57.7	(+) 22.3	(+) 0.7	(+) 27.5	142	PK HY 2
	Nanded	1117	1022	954	1102	834	(+) 9.3	(+) 17.1	(+) 1.4	(+) 33.9	285	NHH 44
	Mean	**1669**	**1396**	**1247**	**1760**	**1443**	(+) **19.5**	(+) **33.8**	(-) **5.2**	(+) **15.7**		
Mean over12 locations		**16.78**	**15.13**	**12.39**	**16.26**	**15.41**	(+) 10.91	(+) 35.43	(+) 3.20	(+) 8.89		

Table 2. Performance of NHH 715 for Lint yield during 2013-14 to 2015-16 in Central Zone under *rainfed* condition

Year of testing	Trial Location	Lint yield (kg/ha) central zone NHH 715	Check 1 (LC)	Check 2 (ZC) (Ankur 651)	GSHH 2595	SHH 808	NHH 715 : (%) increase /decrease over Check 1 (LC)	Check 2 (ZC) (Ankur 651)	GSHH 2595	SHH 808	CD (P=0.05)	Local Checks
2013-2014	Indore	665	735	405	681	645	(-) 9.524	(+) 64.2	(-) 2.3	(+) 3.1	JKHY 3	
	Akola	596	548	473	535	583	(+) 8.8	(+) 26.0	(+) 11.4	(+) 2.2	JKHY 2	
	Hansot	1278	907	623	1018	995	(+) 40.9	(+) 105.1	(+) 25.5	(+) 28.4	G COT Hy 12	
	Jalna	677	782	650	845	797	(-) 13.4	(+) 4.2	(-) 19.9	(-) 15.1	NHH 44	
	Mean	**804**	**743**	**538**	**770**	**755**	**(+) 8.2**	**(+) 49.5**	**(+) 4.4**	**(+) 6.5**		
2014-2015	Hansod	515	543	453	460	503	(-) 5.2	(+) 13.7	(+) 12.0	(+) 2.4	G COT Hy 12	
	Indore	344	254	252	348	271	(+) 35.4	(+) 36.5	(-) 1.1	(+) 26.9	JKHY 2	
	Akola	455	420	360	418	360	(+) 8.3	(+) 26.4	(+) 8.9	(+) 26.4	PK HY 2	
	Nanded	314	197	207	163	153	(+) 59.4	(+) 51.7	(+) 92.6	(+) 105.2	NHH 44	
	Mean	**407**	**354**	**318**	**347**	**322**	**(+) 15.1**	**(+) 28.0**	**(+) 17.2**	**(+) 26.5**		
2015-2016	Bharauch	1051	910	598	992	854	(+) 15.5	(+) 75.8	(+) 5.9	(+) 23.1	G COT Hy 12	
	Indore	273	233	304	412	303	(+) 17.2	(-) 10.2	(-) 33.7	(-) 9.9	JKHY 2	
	Akola	640	332	445	623	416	(+) 92.8	(+) 43.8	(+) 2.7	(+) 53.8	PK HY 2	
	Nanded	396	342	347	373	293	(+) 15.8	(+) 14.1	(+) 6.2	(+) 35.2	NHH 44	
	Mean	**590**	**454**	**424**	**600**	**467**	(+) 29.9	(+) 39.3	(-) 1.7	(+) 26.5		
Overall 3 years Mean		**600**	**517**	**426**	**572**	**514**	**(+) 16.1**	**(+) 40.8**	**(+) 4.9**	**(+) 16.7**		

around 500 to 550 kg lint /ha during last few years. Indian cotton breeders are expected to satisfy both the farmers , through improved yield levels and the textile mills with matching fibre quality parameters to suit their requirements. In spite of achieving record production during the past years, the textile industry faces shortage of medium staple cotton. NHH 715 a high yielding *intra hirsutum* American cotton hybrid has been recently identified for central and south zone of India cultivation under *rainfed* condition. New hybrid, NHH 715, developed at Cotton Research Station, Nanded, Maharashtra State, India, (Vasantrao Naik Marathwada Krishi Vidyapeeth,Parbhani) had given consistent performance for seed cotton yield across central zone as well as south zone under rainfed condition. Test hybrid, NHH 715 has medium staple (28.00 mm) with good fibre strength (24.23 g/tex) and micronaire (4.5) and will meet the requirement of the textile industry. Release of such a high yielding stable hybrid with desirable fibre qualities will help to improve cotton productivity and income of *rainfed* farmers.

The NHH 715 hybrid recorded superior performance for yield and fibre quality in regional and All India Co ordinate Improvement Project trials conducted during 2013-2014 to 2015-2016. This hybrid is found tolerant to sucking pests and cotton diseases such as bacterial blight, alternaria. It is found suitable for growing under *rainfed* condition. Hybrid seed

Table 3. Fibre quality parameters of hybrid NHH 715 as compaired to checks at Central Zone under rainfed condition.

Sr. No.	Test hybrids	Year	GOT (%)	Fibre quality parameters			Seed oil (%)	Biomass (t/ha)
				2.5 per cent Span length (mm)	Micro-naire value	Bundle Strength (g/tex)		
1	**NHH 715**	2013-14	36.2	28.4	4.6	21.6	19.7	6.9
		2014-15	36.2	27.2	4.2	21	-	2.6
		2015-16	35.6	28.4	4.7	30.1	-	-
		Mean	**36.00**	**28.00**	**4.50**	**24.23**	**19.70**	**4.75**
2	**SHH 808**	2013-14	34	28	4.5	20.5	18.8	3.9
		2014-15	34.1	31	3.8	20.2	-	2.3
		2015-16	32.8	29.8	4.3	30.4	-	-
		Mean	**33.63**	**29.60**	**4.20**	**23.70**	**18.80**	**3.10**
3	**GSHH 2595**	2013-14	36.5	28	4.4	20.7	18.6	4.2
		2014-15	35.7	27	4	22.1	-	1.9
		2015-16	34.8	27.8	4.1	29.9	-	-
		Mean	**35.67**	**27.60**	**4.17**	**24.23**	**18.60**	**3.05**
4	**Ankur 651 (Zonal check)**	2013-14	34.5	28.8	4.3	20.9	17.9	2.9
		2014-15	35	29.1	4.5	20.8	-	1.7
		2015-16	34.4	29.4	4.1	30.1	-	-
		Mean	**34.63**	**29.10**	**4.30**	**23.93**	**17.90**	**2.30**
5	**Local check**	2013-14	35.1	27.8	4.3	21.8	19.2	1.5
		2014-15	34.8	26.8	4	19.7	-	1.6
		2015-16	32.8	27.8	4	28.8	-	-
		Mean	**34.23**	**27.47**	**4.10**	**23.43**	**19.20**	**1.55**

production can be done by conventional method *i.e.* hand emasculation and pollination by maintaining prescribed isolation distance. Both parents can be sown at same time for seed productions as their maturity period is same.

Performance of *intra hirsutum* hybrid NHH 715 in central zone of India:

Seed cotton and lint yield: central zone of India consists of three major states *viz.,* Madhya Pradesh, Gujarat and Maharashtra. On an average of twelve locations of this zone and three years testing at three states, the test hybrid NHH 715 has recorded a mean seed cotton yield of 16.78 q/ha as against 12.39 q/ha and 15.13 q/ha of zonal and local checks, respectively (Table 1). The percentage increase in seed cotton yield was to the tune of 35.43 and 10.91 over zonal check and local check, respectively. At most of the locations, the hybrid showed statistically significant seed cotton yield over local and zonal checks under testing. Of the twelve locations the range of seed cotton yield of NHH 715 hybrid was from 8.26 q/ha at Indore location and to extent of 36.52 q/ha at Hansod location during 2015-2016 and 2013-2014 respectively . As regards to lint yield (Table 2) , the hybrid NHH 715 showed a desired productivity of 600 kg/ha which is quite good to the total averaged lint yield of India *i.e.*, 586 kg/ha during 2016-2017 (Anonymous 2016). The hybrid depicted 600 kg lint yield as compared to local check (517 kg/ha) and zonal check (426 kg/ha) and percentage increase over both to the tune of 16.1 and 40.8 respectively. Potential of lint yield per hector of NHH 715 was to the tune of 1278 kg /ha. The similar results reported for heterosis in seed cotton yield and for lint yield by several workers in cotton breedig (Khosla and Sohu ,2007; Rajmani, *et al.,* 2009;Tuteja *et al.,* 2005, 2013; Patil *et al.,* 2011,2012; Siwach *et al.,* 2016).

Fibre and other quality parameters : The fibre and other quality parameters pooled over three years, given in Table 3 revealed that the hybrid NHH 715 had given better performance than the other local and zonal check under testing in *rainfed* condition. As regards the Ginning out turn, hybrid recorded NHH 715 depicted 36 per cent. Ginning out turn as compared to local check (34.23%) and zonal check (34.63) . The hybrid NHH 715 has recorded mean 2.5 per cent span length of 28.00 mm, bundle strength of 24.23 g/tex and Micronaire of 4.5. The local check showed mean fibre length of 27.47 mm, fibre strength of 23.43 g/tex and micronaire of 4.1 and that of zonal check value was mean fibre length of 29.10 mm, fibre strength of 23.93 g/tex and Micronaire of 4.3. The hybrid NHH 715 showed Seed oil content of 19.7 per cent as compared to local check (19.2%) and zonal check (17.9%) tested during 2013-2014. The biomass value pooled over two years *i.e.* 2013-2014 and 2014-2015 showed that NHH 715 had greater biomass (4.75 t/ha) than that of local check (1.55 t/ha) and zonal check (2.30 t/ha) (Table 3).

Reaction to pests and diseases : The hybrid NHH 715 showed tolerance reaction against sucking pests *viz.,* jassid injury grade, jassids / 3 leaves, whitefly / 3 leaves done at three locations *viz.,* Nanded, Akola and Surat locations for the year 2014-2015 and 2015-2016

Table 4. Field reaction of NHH 715 to sucking pests and boll worm damage under rainfed conditions in central zone.

Item	Year	NHH 715			Zonal Check (Ankur 651)			Local Check			GSHH 2595			SHH 808		
		Nanded	Akola	Surat	NA	AK	SU	NA	AK	SU	NA	AK	SU	NA	AK	SU
Jassids	2014-2015	III	I	—	III	II	—	III	I	—	III	II	—	III	II	—
injury grade	2015-2016	I	I	II	II	II	III	II	I	II	II	I	II	II	II	III
Jassids/	2014-2015	5.1 (2.36)	3.7 (1.87)	—	6.6 (2.66)	4.9 (2.21)	—	6.7 (2.68)	3.0 (1.73)	—	6.7 (2.68)	5.2 (2.28)	—	6.5 (2.64)	4.4 (2.1)	—
3 leaves	2015-2016	6.80 (2.70)	2.50 (1.58)	3.20 (1.92)	7.50 (2.82)	3.90 (1.97)	6.90 (2.72)	7.0 (2.73)	3.10 (1.76)	5.30 (2.40)	8.00 (2.91)	2.80 (1.67)	3.50 (1.99)	10.20 (3.27)	4.10 (2.02)	7.60 (2.84)
Whitefly/	2014-2015	7.3 (2.79)	12.4 (3.52)	—	7.35 (2.8)	9.2 (3.03)	—	7.95 (2.9)	24.8 (4.96)	—	7.3 (2.79)	10.9 (3.29)	—	7.3 (2.78)	17 (4.06)	—
3 leaves	2015-2016	18.20 (4.31)	10.0 (3.24)	4.10 (2.02)	6.40 (2.62)	10.20 (3.27)	3.0 (1.73)	20.60 (4.57)	8.20 (2.94)	2.30 (1.51)	23.80 (4.89)	8.00 (2.91)	3.80 (1.95)	33.60 (5.83)	10.90 (3.37)	3.70 (1.92)
Boll	2014-2015	11.35 (19.68)	6.05 (14.23)	—	15.75 (23.38)	12.14 (20.39)	—	15.95 (23.53)	9.43 (17.86)	—	14.05 (22.01)	6.35 (14.59)	—	12.2 (20.44)	7.22 (15.58)	—
damage (%)	2015-2016	14.40 (22.26)	22.27 (28.13)	18.91 (25.75)	16.50 (23.96)	29.09 (32.63)	24.87 (29.89)	14.70 (22.54)	25.01 (29.93)	29.61 (32.94)	11.70 (19.97)	10.52 (18.51)	17.29 (24.52)	16.15 (23.68)	42.14 (40.47)	21.36 (27.45)
Locule	2014-2015	5.2 (13.18)	2.8 (9.39)	—	5.3 (13.3)	4.34 (12.02)	—	6.6 (14.87)	2.88 (9.68)	—	4.95 (12.85)	2.26 (8.64)	—	6.15 (14.36)	2.75 (9.54)	—
Damage (%)	2015-2016	4.35 (12.03)	7.16 (15.52)	11.63 (19.93)	7.10 (15.45)	9.66 (18.10)	18.70 (25.61)	4.30 (11.96)	8.49 (16.87)	20.25 (26.72)	4.15 (11.72)	3.74 (10.82)	11.41 (19.70)	5.75 (13.86)	14.61 (22.44)	15.50 (23.16)

Table 5. Reaction to various diseases under field conditions during 2013-14,2014-15 and 2015-16 in central zone.

Diseas-ereaction Natural	Year	NHH 715				Zonal check				Local check				GSHH 2595				SHH 808			
		DWD	NDD	AKL	SRT	DWD	NDD	AKL	SRT	DWD	NDD	AKL	SRT	DWD	NDD	AKL	SRT	DWD	NDD	AKL	SRT
Bacterial	2013-2014	1				1				2				1				2			
blight	2014-2015		2	2			2	2			2	2			2	3			3	3	
(Grade)	2015-2016		2	1	0		1	2	1		0	2	1		1	2	0		2	2	1
Alternaria	2013-2014	4				4				3				4				4			
leaf spot	2014-2015		2				2				2				2				2		
(Grade)	2015-2016		2		0		2		1		3		1		2		0		2		1
Grey	2013-2014	3				4				4				4				4			
mildew	2014-2015		3	3			2	0			2	0			2	0			2	2	
(Grade)	2015-2016		0	1			0	1			0	1			0	1			0	1	

Table 6 . Adaptability of NHH 715 to agronomic variables at nanded and akola locations of central zone under *rainfed* condition during 2016-2017

Particulars	Item	NHH 715	GSHH 2595
Cotton Research Station, Nanded, (VNMKV, Parbhani) location			
Plant population experiments			
Yield (q/ha)under recommended spacing	18518 plants/ha (90 x 60 cm)	1182 kg/ha	1510 kg/ha
Per cent gain or loss when sown with	Lower population :12,345 plants/ha (90 x 90 cm)	(-15.23 %)(1002 kg/ha)	(- 15.50 %)(1276 kg/ha)
	Higher population : 24,641 plants /ha (90 x 45 cm)	(+ 6.43 %)(1258 kg/ha)	(+ 4.11 %)(1572 kg /ha)
Fertilizer level experiments			
Yield (q/ha) under recommended fertilizer dose	(80:40:40 NPK kg/ha)	1165 kg/ha	1457 kg/ha
Percentage gain or loss with	Lower dose : (75 % RDF)	(- 11.42 %)(1032kg/ha)	(- 11.19)1294 kg/ha
	Higher dose : (125 % RDF)	(+ 6.78 %)(1244 kg/ha)	(+10.22)(1606 kg/ha)
Cotton Research Station, Dr. PDKV, Akola location			
Plant population experiments			
Yield (q/ha) under recommended spacing	(18518 plants/ha) (90 x 60 cm)	(1877 kg/ha)	(1874 kg/ha)
Per cent gain or loss when sown with	Lower population : (12,345 plants/ha) (90 x90 cm)	...	...
	Higher population : 24,641 plants /ha (90 x 45 cm)	(+ 5.97%)(1989 kg/ha)	(+ 18.36 %)(2218 kg/ha)
Fertilizer level experiments			
Yield (q/ha) under recommended fertilizer dose	(60:30:30 NPK kg/ha)	(1840 kg/ha)	(1931kg/ha)
Percentage gain or loss with	Lower dose : (125 % RDF)	(+ 6.36%)(1957 kg/ha)	(+ 7.72%)(2080kg/ha)
	Higher dose : (150 % RDF)	(+ 8.80%)(2002 kg/ha)	(+ 10.99%)(2126 kg/ha)

showed tolerant reaction (Table 4). The boll damage percentage and locule damage percentage of NHH 715 is also lower as compared to the local check and zonal check values screened at three locations of central zone.The field reaction for different diseases *viz.,* bacterial blight, alternarea leaf spot and grey mildew of hybrid NHH 715 showed tolerant reaction as compared to zonal and local check tested at Nanded, Akola and Surat during 2013-2014, 2014-2015 and 2015-2016 (Table 5). Similar results were reported in screening for altermaria and bacterial blight of cotton genotypes by Chattannawar, *et al.,* 2009; 2010.

Agronomic requirements : As for the agronomic requirement the hybrid NHH 715 significantly out yielded at Nanded location in spacing of 90 x 60 cm (18,518 plants/ha) over wider spacing 90 x 90 cm (12345 plants/ha) and on par in closer spacing of 90 x 45 cm (24,691 plants /ha) whereas at Akola location , the hybrid is found responsive to closer spacing of 90 x 45 cm significantly over spacing of 90 x 60 cm. Under recommended and higher fertilizer dose, the hybrid NHH 715 recorded statistically superior yield at both the locations. Hence, it should be fertilized with higher fertilizer dose of 60 : 30 : 30 NPK kg/ha. Thus, the proposed hybrid NHH 715 should be sown at 90x 60 cm at Nanded and 90 x 45 cm in Akola and fertilized with 60:30:30 NPK kg/ha in both the regions (Table 6)

Performance of *intra hirsutum* hybrid NHH 715 in south zone of India:

Seed cotton and lint yield: south zone of India consists of four major states *viz.,* Andhra Pradesh, Telangana, Karnataka and Tamilnadu. Three years testing across three states and on an average of twelve locations, the test hybrid NHH 715 has recorded a mean seed cotton yield of 19.08 q/ha as against 15.59 q/ha and 16.68 q/ha of Zonal and Local Checks, respectively. The percentage increase in seed cotton yield was to the tune of 22.38 and 14.39 over zonal check and local check, respectively (Table 7) . Lint yield of hybrid NHH 715 was observed 676 kg/ha which is excellent as compared to local check (578 kg/ha) and zonal check (535 kg/ha) and percentage increase was 16.95 and 26.35 respectively (Table 8).

Fibre parameters : The hybrid, NHH 715 has medium staple (28.27 mm) with fibre strength (24.47 g/tex) and Micronaire (4.40) as compaired to the local check with staple length of 29.27mm, fibre strength of 24.37 g/tex and micronaire of 4.3 and with zonal check showed staple length of 30.40mm fibre strength of 24.73 g/tex and micronaire of 4.17 (Table 9) . The hybrid NHH 715 showed 35.93 % ginning out turn as compared to local check 35.97% and zonal check 35.40. The hybrid NHH715 meet the requirement of the textile industry. Release of such a high yielding stable hybrid with desirable fibre qualities will help to improve cotton productivity and income of rainfed farmers.

Reaction to pests and diseases : The hybrid NHH 715 showed tolerance reaction against jassid injury grade, jassids / 3 leaves, at Dharwad and Nandyal location duritn the year 2014-2015 and 2015-2016 (Table 10). The boll

Table 7. Performance of NHH 715 for Seed cotton yield during 2013-2014 to 2015-2016 in South Zone under rainfed condition.

Year of testing	Location	Seed cotton yield (kg/ha) south zone					NHH 715 as (%) increase /decrease over				CD	Local
		NHH 715	Local Check	Zonal Check Ankur 651/ Bunny	SHH 818	ARBHH 1352	Local check	Zonal check (Ankur 651/ Bunny)	SHH 818	ARBHH	(P=0.05)	Checks
2013-2014	Dharwad	2068	1867	1740	2022	2654	(+) 10.8	(+) 18.9	(+) 2.3	(-) 22.1	523	DHH 11
	Nandyal	3265	899	1498	2804	1650	(+) 263.2	(+) 118.0	(+) 16.4	(+) 97.9	281	LAHH 5
	Kovilpatti	587	478	834	499	954	(+) 22.8	(-) 29.6	(+) 17.6	(-) 38.5	163	Malika
	Mean	**1973**	**1081**	**1357**	**1775**	**1753**	(+) **82.5**	(+) **45.4**	(+) **11.2**	(+) **12.6**		
2014-2015	Dharwad	750	1418	1150	1178	1514	(-) 47.1	(-) 34.8	(-) 36.3	(-) 50.5	220	DHH 11
	Ranebennur	2774	3374	2764	3078	3325	(-) 17.8	(+) 0.4	(-) 9.9	(-) 16.6		DHH 11
	Nandyal	3194	2019	2561	2548	2542	(+) 58.2	(+) 24.7	(+) 25.4	(+) 25.6	380	LAHH 5
	Aruppukkottai	656	302	295	870	388	(+) 117.2	(+) 122.4	(-) 24.6	(+) 69.1	62	Malika
	Perambalur	2320	2286	2404	2252	2244	(+) 1.5	(-) 3.5	(+) 3.0	(+) 3.4	88	Malika
	Mean	**1939**	**1880**	**1835**	**1985**	**2003**	(+) **3.1**	(+) **5.7**	(-) **2.3**	(-) **3.2**		
2015-2016	Dharwad	2081	1638	1928	1940	1800	(+) 27.0	(+) 7.9	(+) 7.3	(+) 15.6	482	DHH 11
	Nandyal	1379	698	642	1139	462	(+) 97.6	(+) 114.8	(+) 21.1	(+) 198.5	164	LAHH 5
	Aruppukkottai	2672	4013	1651	2729	2198	(-) 33.4	(+) 61.8	(-) 2.1	(+) 21.6	307	Malika
	Perambalur	1150	1024	1234	1148	1202	(+) 12.3	(-) 6.8	(+) 0.2	(-) 4.3	122	Malika
	Mean	**1821**	**1843**	**1364**	**1739**	**1416**	(-) **1.2**	(+) **33.5**	(+) **4.7**	(+) **28.6**		
Average mean	**over 12 locations**	**1908**	**1668**	**1559**	**1851**	**1745**	(+) 21.54	(+) 24.88	(+) 3.39	(+) 11.34		

Table 8. Performance of NHH 715 for lint yield during 2013-2014 to 2015-2016 in south zone under *rainfed* condition

Year of testing	Location	Lint yield (kg/ha) south zone NHH 715	Local Check	Zonal Check Ankur 651/ Bunny	SHH 818	ARBHH 1352	NHH 715 as % increase /decrease overLocal: Local check	Zonal check (Ankur 651/ Bunny)	SHH 818	ARBHH	Checks
2013-2014	Dharwad	724	691	626	768	1009	(+) 4.8	(+) 15.7	(-) 5.7	(-) 28.2	DHH 11
	Nandyal	1110	288	479	953	545	(+) 285.4	(+) 131.7	(+) 16.5	(+) 103.7	LAHH 5
	Kovilpatti	213	187	285	181	356	(+) 13.9	(-) 25.3	(+) 17.7	(-) 40.2	Malika
	Mean	**682**	**389**	**463**	**634**	**637**	**(+) 75.6**	**(+) 47.3**	**(+) 7.6**	**(+) 7.2**	
2014-2015	Dharwad	286	562	417	449	598	(-) 49.1	(-) 31.4	(-) 36.3	(-) 52.2	DHH 11
	Ranebennur	978	1222	947	1082	1174	(-) 20.0	(+) 3.3	(-) 9.6	(-) 16.7	DHH 11
	Nandyal	1086	646	845	892	890	(+) 68.1	(+) 28.5	(+) 21.7	(+) 22.0	LAHH 5
	Aruppukkott	289	144	129	418	167	(+) 100.7	(+) 124.0	(-) 30.9	(+) 73.1	Malika
	Perambalur	800	779	692	789	792	(+) 2.7	(+) 15.6	(+) 1.4	(+) 1.0	Malika
	Mean	**688**	**671**	**606**	**726**	**724**	**(+) 2.6**	**(+) 13.5**	**(-) 5.3**	**(-) 5.0**	
2015-2016	Dharwad	753	622	710	737	628	(+) 21.1	(+) 6.1	(+) 2.2	(+) 19.9	DHH 11
	Nandyal	502	251	234	403	171	(+) 100.0	(+) 114.5	(+) 24.6	(+) 193.6	LAHH 5
	Aruppukkottai	994	1218	610	818	707	(-) 18.4	(+) 63.0	(+) 21.5	(+) 40.6	Malika
	Perambalur	373	324	446	399	424	(+) 15.1	(-) 16.4	(-) 6.5	(-) 12.0	Malika
	Mean	**656**	**604**	**500**	**589**	**483**	(+) 8.6	(+) 31.1	(+) 11.2	(+) 35.9	
Average mean over 12 locations		**676**									

Table 9. Fibre quality parameters of hybrid NHH 715 at south zone under rainfed condition.

Sr. No.	Test hybrids	Year	GOT (%)	Fibre quality parameters: 2.5 per cent span length (mm)	Micro-naire value	Bundle strength (g/tex)	Seed oil (%)	Biomass (t/ha)
1	NHH 715	2013-2014	35.1	27.1	4.7	20.7	19.7	6.9
		2014-2015	37.2	29.2	4	22.8	-	-
		2015-2016	35.5	28.5	4.5	29.9	-	4.4
		Mean	**35.93**	**28.27**	**4.40**	**24.47**	**19.70**	**5.65**
2	SHH 818	2013-2014	36.1	29.2	4.7	22.6	18.8	5.6
		2014-2015	38.3	29.3	4.7	21.5	-	-
		2015-2016	35	28.7	4.6	30.2	-	4.4
		Mean	**36.47**	**29.07**	**4.67**	**24.77**	**18.80**	**5.00**
3	ARBHH 1352	2013-2014	36.1	27.4	4.4	22.4	18.7	3.1
		2014-2015	37.6	28.6	3.9	21.3	-	-
		2015-2016	34.7	29.4	4.5	30.2	-	2.6
		Mean	**36.13**	**28.47**	**4.27**	**24.63**	**18.70**	**2.85**
4	(Zonal check)	2013-2014	34.1	29.4	4.8	22.5	17.9	2.9
	(Ankur 651/ Bunny)	2014-2015	35.2	32.4	3.6	22.6	-	-
		2015-2016	36.9	29.4	4.1	29.1	-	4.1
		Mean	**35.40**	**30.40**	**4.17**	**24.73**	**17.90**	**3.50**
5	Local check	2013-2014	36	28.8	4.6	22.2	19.2	1.5
		2014-2015	37.9	29.3	4.2	21.1	-	-
		2015-2016	34	29.7	4.1	29.8	-	1.6
		Mean	**35.97**	**29.27**	**4.30**	**24.37**	**19.20**	**1.55**

damage percentage and locule damage percentage of NHH 715 is also lower as compared to the local check and zonal check values screened at Nadyal locations of south zone. The field reaction for different diseases *viz.,* bacterial blight, alternarea leaf spot and grey mildew of

Table 10. Field reaction of NHH 715 to sucking pests and boll damage under rainfed conditions at South Zone.

Insect name	Year	NHH 715		Zonal check (Ankur651/Bunny)		Local check		SHH 818		ARBHH 1352	
		DW	NA	DW	NA	DW	NA	DW	NA	DW	NA
Jassids	2014-2015	II	I	IV	II	IV	II	IV	I	IV	II
injury grade	2015-2016	II	I	IV	II	III	II	II	I	IV	III
Jassids/	2014-2015	14.6	13.74	13	9.35	16.6	9.58	12.8	11.49	14.2	14.65
3 leaves	2015-2016	3.4	4.45 (2.21)	8	6.95 (2.72)	6.2	6.28 (2.60)	3	6.39 (2.62)	6.8	12.06 (3.53)
Fruiting	2014-2015	7.15		3		8.1		3.79		6.75	
bodies damage (%)	2015-2016		9		15		9.5		14		12.8
Good open boll (%)	2014-2015	67		9.5		44.5		46.5		44.5	
Open boll damage %)	2015-2016		9		12.7		10		10		10.2
Locule damage (%) PBW (%)	2015-2016		13.12 (21.14)		18.76 (25.65)		13.23 (21.34)		9.36 (17.79)		12.36 (20.36)

Table 11. Reaction to various diseases under field conditions during 2013-2014, 2014-2015 and 2015-2016 in south zone

DiseaseReactionNatura	Year	NHH 715	Zonal check (Ankur 651/ Bunny)	Local check	SHH 818	ARBHH 1352
		DWD	DWD	DWD	DWD	DWD
Bacterial blight (Grade)	2013-2014	1	1	2	1	3
	2014-2015	2	4	3	4	4
	2015-2016	2	2	2	2	1
Alternarea leaf spot (Grade)	2013-2014	4	4	3	4	4
	2014-2015	4	4	4	4	4
	2015-2016	4	4	4	4	3
GreyMildew (Grade)	2013-2014	3	4	4	3	4
	2014-2015	4	4	4	3	4
	2015-2016	2	2	1	2	2
Rust (Grade)	2013-2014	4	4	4	4	4
	2014-2015	4	4	4	4	4
	2015-2016	4	4	4	4	4

Table 12 (a). Adaptability to agronomic variables at Nandyal location during 2016-2017

Particulars	Item	NHH 715	RCH 138 (Check)
RARS, Nandyal, Andhra Pradesh			
Plant population experiments			
Yield (kg/ha) underrecommended spacing	(90 x 60 cm)(18518 plants/ha)	(3147 kg/ha)	(2785kg/ha)
Per cent gain or loss when sown with	Lower Papulation(90 x90 cm)		
	(12,345 plants/ha)	...	...
	Higher papulation(90 x 45 cm)	(-11.41%)	(-2.91 %)
	(24,641 plants /ha)	(2788 kg/ha)	(2788 kg/ha)
Fertilizer level experiments			
Yield (kg/ha) under recommended fertilizer dose	(100 % RDF)(120:60:60 NPK kg/ha)	(2084 kg/ha)	(3266 kg/ha)
Percentage gain or loss with	Lower dose (125 % RDF)	(+ 81.62%)	(- 43.60%)
	(150: 75: 75 NPK kg/ha)	(3785kg/ha)	(1842 kg/ha)
	Higher dose (150 % RDF)	(+ 45.59%)	(- 4.29%) (3126 kg/ha)
	(180: 90: 90 NPK kg/ha)	(3034 kg/ha)	

hybrid NHH 715 showed tolerant reaction as compared to zonal and local check tested at Dharwad during 2013-14, 2014-15 and 2015-16 (Table 11).

Agronomic requirements : The hybrid NH 715 yielded significantly higher seed cotton yield at RARS, Nandyal, Andhra Pradesh location under recommended spacing (90 x 60 cm) over closer spacing (90 x 45 cm). The hybrid also responded well to (125%) RDF significantly which was superior over RDF (Table 12a). Whereas Agricultural Research Station, Dharwad (Karnataka State) location hybrid NHH 715 was found at par in all the populations and fertilizer doses, hence should be sown at recommended spacing of 90 x 60 cm and recommended fertilizer dose of 80: 40: 40 NPK kg/ha (Table 12b). At

Table 12 (b). Adaptability to agronomic variables at Dharwad location during 2016-2017.

Particulars	Item	HybridNHH 715	DHH 263(Check)
Dharwad, Karnataka			
Plant population experiments			
Yield (kg/ha) under	(18,518 plants/ha)	(1220 kg/ha)	(2352 kg/ha)
recommended Spacing	(90 x60 cm)		
Per cent gain or loss	(37,037 plants/ha)	(+10.66%)	(+1.40 %)
when sown with	(90 x 30 cm)	(1350 kg/ha)	(2385 kg/ha)
	Higher papulation	(-13.69%)	(-6.80 %)
	(12,345 plants /ha)	(1053 kg/ha)	(2192 kg/ha)
	(90 x 90 cm)		
Fertilizer level experiments			
Yield (kg/ha) under	(100 % RDF)	(1071 kg/ha)	(2145 kg/ha)
recommended fertilizer dose	(80:40:40 NPK kg/ha)		
Percentage gain or loss with	Lower dose : 125 % RDF)	(+ 12.89%)	(+ 6.71%)
	(100:50:50 NPK kg/ha)	(1209 kg/ha)	(2289 kg/ha)
	Higher dose (150 % RDF)	(+ 25.21%)	(+ 16.36%)
	(120:60:60 NPK kg/ha)	(1341 kg/ha)	(2496 kg/ha)

Table 12 (c). Adaptability to agronomic variables at Chamarajanagara during 2016-2017.

Particulars	Item	HybridNHH 715
Chamarajanagara		
Plant papulation Experiments		
Yield (kg/ha) underrecommended spacing	(90 x 60 cm)(18,518 plants/ha)	(1156kg/ha)
Per cent gain or loss when sown with	Lower Papulation (90 x 45 cm) (24691 plants/ha)	(+ 15.01%) (1330kg/ha)
	Higher papulation(90 x 75 cm) (14,814 plants /ha)	(-0.43%) (1151 kg/ha)
Fertilizer level experiments		
Yield (kg/ha) under recommendedfertilizer dose	(100 % RDF)(120:60:60 NPK kg/ha)	(1211 kg/ha)
Percentage gain or loss with	Lower dose: (75 % RDF) (90:45:45 NPK kg/ha)	(-14.95%) (1030 kg/ha)
	Higher dose (125 % RDF) (150:75:75 NPK kg/ha)	(+ 15.28%) (1396 kg/ha)

Chamarajanagara location , significantly higher seed cotton yield was recorded in closer spacing (90 x 45 cm) and higher fertilizer dose (125 % RDF) over recommended dose of fertilizer (150:75:75 kg/ha NPK) (Table 12c). In general, it should be sown at recommended spacing at Nandyal and Dharwad, where as in closer spacing at Chamarajanagara, It should fertilized with recommended dose at Dharwad and with higher fertilizer dose at Chamarajanagara and Nandyal as it was found response with higher dose of fertilizer.

Thus the NHH 715 hybrid recorded superior performance for yield and fibre quality in both the Zone *i.e.*, central zone and south zone hence glory of this non *Bt* hybrid may come

Table 13. Distinguishing morphological characteristics of proposed hybrid NHH 715

Sr. No.	Character	Description
1	Plant growth habit	Semi spreading
2	Plant height	100-120 cm
3	Branching (No. of monopodia)	2-3
4	Leaf lobe	3
5	Leaf colour	green
6	Leaf hairyness	medium
7	Leaf appearance	flat
8	Leaf gossypol glands	Present
9	Boll gossypol glands	Present
10	Leaf nectary glands	Present
11	Leaf petiole pigmentation	Present
12	Leaf shape	(Normal) Palmate
13	Plant stem hairyness	medium
14	Plant stem pigmentation	Present
15	Bract type	Normal
16	Petal colour	Yellow
17	Petal spot	Absent
18	Flower stigma	Exerted
19	Anther filament colour	Absent
20	Anther/pollen colour	Yellow
21	Boll bearing habit	Solitary
22	Boll colour	green
23	Boll shape (longitudinal section)	eliptical
24	Boll surface	smooth
25	Boll tip	present
26	Boll opening	open
27	Boll weight (g)	3.77
28	Seed fuzz	Sparse
29	Seed fuzz colour	Greenish Gray
30	Fibre colour	White
31	100 seed wt (g)	9.40
32	Fibre : Length (2.5 % span length) (mm)	28.00
33	Fibre : Strength (g/tex)	24.23
34	Fibre : Fineness	4.50
35	Seed oil content (%)	19.70
36	Biomass (t/ha)	4.75

back in coming years as the conversion programme of the straight varieties/hybrids initiated under public sectore. The *Bt* versions of *G. hirsutum* varieties/hybrids may helped to fulfill needs of the cultivators of the region.

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REFERENCES

Anonymous, 2016. ‘Annual Report’ All India Co-ordinated Research Project on Cotton,CICR, Coimbatore, TamilNadu.

Chattannawar, S.N., Hosagoudar, G.N., Ashtaputre, S.A. and Ammajamma, R.A. 2009. Evaluation cotton genotypes for grey mildew and Alternarial blight diseases. *J. Cotton Res. Dev.* **23:** 159-62

Chattannawar, S.N., Hosagoudar, G.N. and Ashtaputre, S.A. 2010. Evaluation cotton genotypes against Alternarial blight and bacterial blight diseases. *J. Cotton Res. Dev.* **24:** 254-67.

Khosla, G., Gill B.S. and Sohu, R.S. 2007. Heterosis and combining ability analysis for plant seed characters in upland cotton (*Gossypium hirsutum* L.*). J. Cotton Res. Dev***.** **21**: 12-15

Patil, S.A., Naik, M.R.,Patil, A.B. and Chaugale, G.R. 2011. Heterosis for seed cotton yield and its contribution characters in cotton (*G. hirsutum* L.). *Plant Archives* **11**: 461-465.

Patil, S.A., Naik, M.R., Pathak V.D. and Kumar V. 2012. Heterosis for yield and fibre properties in upland cotton (*Gossypium hirsutum* L) *J. Cotton Res. Dev.* **26**: 26-29.

Rajmani, S., Rao, Rao, C.M. and Naik , R.K. 2009. Heterosis for yield and fibre properties in upland cotton (G. hirsutum L). *J. Cotton Res. Dev.* **23**: 43-45**.**

Siwach, S.S., Jal Singh, Sangwan, R.S. and Hamid Hasan. 2016. Yield and fibre characteristics of promising strains of upland cotton (*Gossypium hirsutum* L.) under rainfed conditions. *J. Cotton Res. Dev***. 30**: 177-79.

Tuteja ,O.P., Kumar,S., Singh, M. and Kumar, M. 2005. Heterosis in single cross hybrids of Gossypium hirsutum L. *J. Cotton Res. Dev***. 19 :** 165-167**.**

Tuteja O.P., Manju Banga and Hamid Hasan. 2013. Heterosis for seed cotton yield component traits and fibre properties of American cotton (*Gossypium hirsutum* L.). *J. Cotton Res. Dev***. 27** : 184-87.

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Exploration of a combined technology package for extraction of pineapple leaf fibre – An agro waste, utilization of biomass and a future prospect for sustainable luxury textiles

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ABSTRACT : The treasure of Major natural fibres belongs to cotton, jute, wool, silk, flax, sisal and Manila hemp which are extensively used across the globe. Besides, a large large number of fibres grown in lesser quantities throughout the world have local economic importance and are consumed locally. Utilization of underexploited, unexplored natural fibres from crop waste are not only critical issues in the international scenario but are also the need of the hour in developing countries like India to search out a suitable avenue for which separate spinning system is not widely available or established. Pine apple leaf fibre (PALF) successfully tested as a base material for conveyor belts in the early eighties, could well have been the magic yarn of the day. Pineapple leaf fibre extracted from the green pineapple leaf, an agro waste reveals its immense potentiality in the field of textiles particularly due to the disposal problem after harvesting for cleaner and green environment.

PALF is well known for its silky lustre which possesses some advantageous physical and chemical properties like high tensile strength, dimensional stability, considerable resistance to heat and fire, and good dyeability while the demerits are coarseness, inextensibility. Besides, it is a low cost renewable resource and eco-friendly material. If the apparent demerits can be masked, a diverse range of products can be developed by exploiting the intrinsic properties of PALF. One of the ways of masking is blending of PALF with natural and synthetic fibres. It is felt that such binary blending will help development of textiles with better functional properties by combining positive features of the constituent fibres. Therefore, binary blending will give a wider application for production of value added diversified products which are the need of the hour.

The present paper is an endeavor to outline the complete package for extraction of PALF and utilization of the residual biomass debris from the pineapple leaf scratching machine for vermicomposting which is economically viable and remunerative for the pineapple cultivators. The paper also delineates suitable processing technique for blending of PALF with different natural and synthetic fibres for conversion into textiles using existing fibre processing system since there is no specialized spinning system available for pineapple and their possible commercial

Utilization. The PALF blended yarn has a bright future prospect for sustainable luxury textiles like fancy apparel products.

Key words : Blending, fibre properties, luxury textiles, mechanical processing, natural fibres, PALF, PALF extraction, synthetic fibres, vermicompost, yarn

Fig.1: Wardrobe of Author

Fig.2: Hackled Sliver

Fig.3: PALF Jahwar Coat

Wealth from waste is no more a slogan in 21st century but achieved successfully turning pineapple leaves into wealth which not only creates green environmental sense but also turns waste into wealth. Resource depletion and global warming have driven each industry to move toward a greener and sustainable industry. Lignocellulose, the most abundant renewable biomass is composed of cellulose, hemicellulose and lignin, as well as other minor components. Pine apple leaf fibre successfully tested as a base material for textiles in the early eighties, could well have been the magic yarn of the day. Research work on pineapple leaf fibre, an agro waste reveals its immense potentiality in the field textiles particularly technical textiles. Sufficient fibre will be available to arouse interest if the fibre is extracted commercially. Due to non availability of specialized spinning system for PALF in India, it will be much easier to promote PALF in any of the existing spinning systems provided an appropriate processing technology is developed.

Major natural fibres belongs to cotton, jute, wool, silk, flax, sisal and Manila hemp which are extensively used across the globe possess suitable processing technology and developed machinery. Besides, a large large number of fibres grown in lesser quantities throughout the world have local economic importance and are consumed locally. The pineapple plant Ananas Comosus (L) is a member of the family Bromaliaceae of the monocotyledonous, containing 1,300 species; most of which are native to tropical America. Although over nearly 90 varieties of the plants cultivated in various parts of the world, only 3 varieties, namely, Kew, Queen and Mauritius are cultivated commercially. The form of pineapple leaves varies and depends on the position of the stem and age.

According to the data available, Pineapple fibre can be profitably produced in Tripura as well as Siliguri in West Bengal, where extensive pineapple farming takes place. In India, Pineapple leaves are never cut off, and are cleared when the plants naturally shed them. As a result, fewer pineapple plants are grown in India, as the leaves cover a lot of space. In countries like Brazil where extensive pineapple farming is done the leaves are cut away to make space for more plants. "We have gone through the science of it- Interestingly, cutting away of the leaves does not harm the plant and in fact helps it grow bigger fruit, as the leaves normally draw away a lot of the nourishment" says Dr. S. K. Dey, Senior Scientist of ICAR-CIRCOT, Mumbai. Indian farmers mostly throw away the leaves. Research on plantation has established that the leaves can be cut three times a year, without harming the harvest and suitably designed industry for pineapple leaf fibre, can run the year round on these supplies.

The outer, long leaves are preferred for fibre. In the manual process, they are first decorticated by beating and rasping and stripping, and then left to ret in water to which chemicals may be added to accelerate the activity of the microorganisms which digest the unwanted tissue and separate the fibres. Retting time has been reduced from 5 days to 26 hours. The retted material is washed clean, dried in the sun and combed. In mechanical processing, the same machine can be used that extracts the fibre from sisal. Estimating 22 leaves/kg, 22,000 leaves would constitute one ton and would yield 22-27 kg of fibre.

A graphical presentation of green leaves, dried leaves and moisture content of the leaves are shown in Fig.4. A research work on length and weight of 50 young pineapple leaves reveal that average length is 112.8 cm and average weight is 70 g. The coefficient of variation of length and weight is 18 and 14 per cent, respectively. The average shrinkage of the

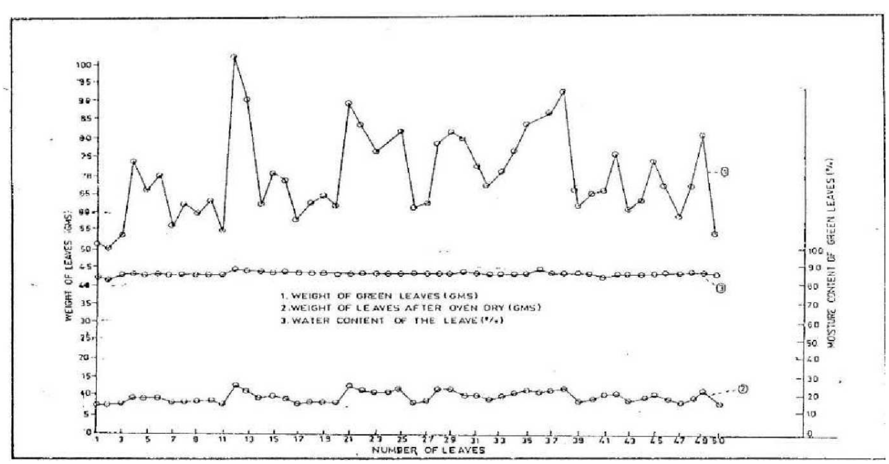

Fig. 4. Weight of Green Leaves with Oven Dry leaves and water content of PALF

length of the leaves is 1.77 per cent on drying at 110° C for 2 h whereas the weight loss is 86 per cent which clearly indicates that Pineapple leaves contain 86 per cent moisture.

In 2008, India produced 1.2 million tonnes of pineapple and the major pineapple producing states in India are West Bengal (23%), Assam (16%), Karnataka (12%), Bihar (11%), Tripura (10%) Kerala (8%), Meghalaya (7%), Manipur (6%). In India, there are around 80,000 hectares of land under pineapple cultivation and given the average yield of around 2 tonnes of fibre per hectare, the total potential for production of pineapple fibre in the country is

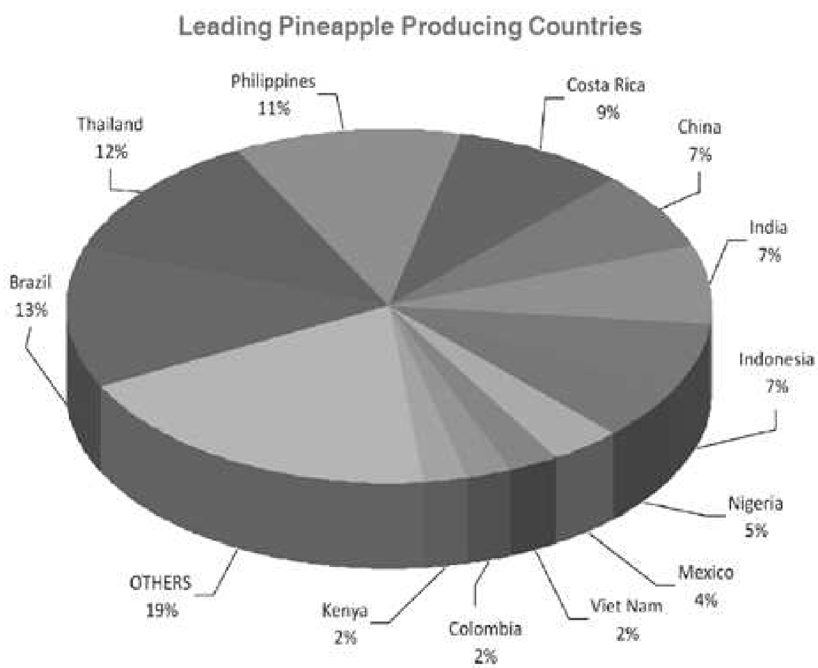

Fig.5. Pineapple Cultivation Area : 896,000 hactre Global production : 19 Million tonnes

Pineapple Plant

Pineapple leaf fibre

PALF Sliver

Fig.6.

around 1,60,000 tonnes. There is huge potential for pineapple fabric, given its diverse uses and eco-friendly properties. The warp and weft of the fabric made from pineapple fibre makes it ideal for furnishings, twines, threads, decoratives and also for stitching necklaces and sewing shoes. Cover spun yarns using yarns spun from PALF and other blends spun on cotton and jute spinning system were found suitable for production of curtains, bed spreads, carpets, furnishing fabrics, towels etc. using chemically treated PALF, needle punched felts are made for use as geo-textiles for earth works like erosion control of the slopes of river banks. Industrial products like V-belt cord, conveyor belt cord, light weight duck cloth etc. can also be manufactured.

The philosophy of blending between two fibres depends on two basic principles which apparently appear to be a bit contradictory.

1. PALF may be blended with cheaper fibres so that a cheaper product mix becomes feasible. In this category, blending of ramie with jute, ramie, Mesta, banana, Roselle hemp appear to be worth pursuing.
2. PALF is often blended with synthetic fibres to produce diversified blended fabrics which are expected to fetch higher prices/unit weight of ramie and consequently higher profitability.

Vermicomposting is a simple biotechnological process of composting using certain efficient species of earthworm. This is a mesophilic process, mediated by special types of earthworms and microorganisms. The process is faster than common composting, because the substrate materials pass through the earthworm gut where transformation takes place. The resulting earthworm manure is rich in microbial activity and plant growth regulators and fortified with pest repellence attributes as well. Earthworms can consume the organic mass of the pineapple leaf residue to convert them into the vermicompost.

Since no information on specialized spinning system for pineapple leaf fibre in India is available, it will be much easier to promote pineapple leaf fibre in any of the existing spinning systems provided an appropriate processing technology is developed. The present paper is an endeavor for the extraction of fibre from pineapple leaf agro-waste, utilization of residual biomass debris obtained during extraction of PALF through vermicomposting for additional income generation of pine apple growers and finally the important methods available for the development of technical textiles from pineapple leaf fibre with an appropriate processing technology in jute, cotton, semi-worsted and flax system.

MATERIALS AND METHODS

Pineapple leaf fibre used in this investigation was received from khadi and village Industries Commission. Jute fibre (*Corchorus olitorious*) TD 3 grade was used for blending in conventional jute spinning system whereas Indian cotton was used in cotton spinning system. Chokla variety of coarse Indian wool was used in semi-worsted processing system, 120mm long,6 denier Polypropylene staple fibre from Neomar Ltd, Baroda and Acrylic fibre (non-shrinkable) top of 3 denier and 120mm length from Indian Petrochemical corporation Ltd, Baroda.

Chemical constituents of fibre : Chemical constituents of pineapple leaf fibre, *viz.,* á -cellulose, pentosan, lignin, fat and wax, pectin, nitrogenous matter, ash content, were determined following TAPPI standard methods.

Physical properties of fibre : Physical properties of pineapple leaf fibre, jute cotton viz, tenacity, fineness, extension at break were determined following standard procedures for comparative study.

Vermicomposting from pineapple leaf residual biomass : Cement tanks of 8' x 4' x 2.5' were used for vermicomposting from organic residues of pineapple leaf after scratching semi-dried pineapple leaf debris were mixed with cattle dung@100kgs/ton of pineapple leaf waste and used for preliminary bed preparation. This organic residue was allowed to decompose for one month, covering surface with dry grass and leaves for mulching before inoculation of mature earthworm species. African night crawler (*Eudrilus engeniae*) @100 in number/square metre area on the bed was inoculated and then covered with fresh pineapple scratched leaf residue. This process was allowed to continue for another 45 days. Water was regularly sprayed on the composting beds to keep the earthworm alive and in action. Water was stopped 3-4 days before harvesting *i.e.* when the biomass lump becomes brittle and brown in colour for surface drying and moving the earthworm to penetrate inside. Dry compost was collected from the surface grinded and sieved before packing as ready vermicompost.

RESULTS AND DISCUSSION

Pineapple leaf fibre is multi cellular with an average ultimate cell length of 5 mm. The fibre is lignocellulosic in nature, like most other natural vegetable fibres having low lignin and a high a cellulose (Table 1) content indicating their potential as raw material in the cellulose product industry as well as their utility in the textile industry.

Normally, the fibre is as fine as the finer quality jute, although about ten times as coarse as cotton. Unlike jute, its structure is without mesh, filaments are well separated and it is two and a half times more extensible with superior bundle strength and L/B ratio. Both the flexural and torsional rigidity of pineapple leaf fibres are comparable with jute fibres of less rigid quality.

PALF is well known for its silky lustre which possesses some advantageous physical and chemical properties like high tensile strength, dimensional stability, considerable resistance to heat and fire, and good dyeability while the demerits are coarseness, inextensibility. Besides, it is a low cost renewable resource and eco-friendly material.

Normally, the fibre is as fine as the finer quality jute, although about ten times as coarse as cotton. Unlike jute, its structure is without mesh, filaments are well separated and it is two and a half times more extensible with superior bundle strength and L/B ratio[2]. Both the flexural and torsional rigidity of pineapple leaf fibres are comparable with jute fibres of less rigid quality. An interesting characteristic was observed in the case of pineapple leaf fibre and yarn when their tensile properties were studied in wet condition. The bundle strength of pineapple leaf

Table 1. Physical and chemical properties of PALF, cotton and jute fibre

Physical Properties		Pineapple leaf fibre	Jute	Cotton
I Ultimate cell	Length (mm)	3-9	0.8-6.0	15-60
	Breadth(10^{-3} mm)	4-8	5-25	15-20
	L/B ratio	450	110	1300
II	Gravimetric fineness (tex)	1.54	1.25-5.0	0.10-0.30
	Tenacity (gm/tex)	50	35-50	20-45
	Extension at break (%)	2-6	1.0-2.5	6.5-7.5
	Modulus of torsional rigidity(x 10^{10}dyne cm^{-2})	0.36	0.25-1.30	0.8-1.20
	Flextural rigidity(dyne cm^{-2})	3.8	4.0-6.0	0.30-1.0
	Transverse swelling in water (%)	18-20	20-22	20-22
III Bundle	Tenacity (g/tex)	26.0	13-31	-
	Density (g/cc)	1.48	1.45	1.55
	Moisture Regain at 65 per cent Relative humidity	11.8	36.0	24.0
Chemical composition				
	a-Cellulose	70	60.5	92.89
	Hemicellulose	24.3	21.2	2.67
	Lignin	4.5	13.3	0.54

fibre decreases by 50 per cent when in a wet condition but the yarn strength increases by about 13 per cent. A detailed research reveals that the frictional property of pineapple leaf fibre is very high in the wet condition and it predominates over the fall in tensile strength of the fibre so as to increase the wet strength of the yarn.

Different stages of blending process : The development of blended yarn from PALF with natural and synthetic fibres can be achieved in the three stages of processing as given below.

1. Blending at carding or drawing.
2. Blending at spinning and
3. Union blending *i.e.* at fabric stage.

BLENDING AT CARDING OR DRAWING

Jute spinning System : The processing technology of pineapple leaf fibre in jute, cotton, semi-worsted and flax systems as well as to compare performance, research work was undertaken at Jute Technological Research laboratories which later on renamed as National Institute of Research on Jute and Allied Fibre Technology, Kolkata.

Performance of jute/pineapple leaf fibre on jute spinning system : When the golden fibre blends with pineapple, a magic yarn is born. The fibre is best used as decorative material. Firstly, the natural colour is creamy white hence unlike jute it does not need bleaching. We have tried various combinations of the fibre at our pilot plant and blended it with jute and synthetic material. When blended with synthetic material, the product is an extra fine material. The filaments of pineapple leaf fibre, being stronger and finer than jute, could be successfully spun to a fine, strong yarn in jute machinery. Some special techniques were developed for processing pineapple leaf fibre in jute machinery. PALF was softened with 15 per cent oil water emulsion leading to an oil application of 1 per cent on the weight of the fibre, binning for 24 hours and stapling the fibre to 20 cm. The conventional carding system used in processing jute being unsuitable for processing pineapple leaf fibres , cards with higher pin density were necessary for better filamentation of the fibre. Thus, a jute breaker card and a flax finisher card with progressively higher pin density were used as first and second cards, respectively, instead of conventional breaker and finisher cards. To avoid nep formation as far as possible, the speed ratio and setting between the cylinder and worker rollers of the first card were changed. The optimum twist factor in the case of pineapple leaf fibre yarn was found to be of the order of 24-27 "tex, tpcm units in yarns of 70 to 170 tex. It can work wonders with jute. If pineapple fibre is blended with jute up to 20-25 per cent fine yarn of linear density of 69 tex or less can be created. This is very difficult to achieve with Indian jute alone.

Blending of pineapple leaf fibre with jute improves the quality of the blended yarn. Thus, 10-15 per cent pineapple leaf fibre in blend can produce a finer yarn which cannot be produced from jute alone. This findings suggests that pineapple leaf fibre may be used in the jute industry with consequent improvement in the quality of yarns and with the distinct possibility of making curtains and other furnishing fabrics, table mats etc, of the fibre alone or in blends with jute, or for the production of stronger twines.

Table 2. Performance of jute/pineapple leaf fibre on jute spinning system

Pineapple leaf fibre (%)	Long reed jute (%)	Stapled jute (20Cm)(%)	Yarn linear density(Tex)	Spinning breaks/ spindle	Yarntenacity (g/tex)	
					Dry	Wet
-	-	100	79	31	5.2	4.7
5	-	95	77	11	4.8	4.6
10	-	90	77	12	5.1	4.5
15	-	85	76	2	7.1	5.2
20	-	80	78	10	7.0	5.6
-	100	-	69	4	8.3	7.4
5	95	-	80	3	8.3	8.0
10	90	-	66	4	8.9	7.4
15	85	-	66	2	7.8	6.3
20	80	-	72	2	8.7	8.6
100	-	-	73	2	11.1	13.5

It is evident from Fig.7 that Pineapple leaf fibre – jute blended yarn follows the Hamburger theory. Similar trend is observed in both case.

Tossa jute of TD_2 to TD_7, White jute of W_2 grade and Mesta fibre of middle and bottom were selected to investigate the blending behavior on jute processing system by Ghosh *et al.,* (1982).

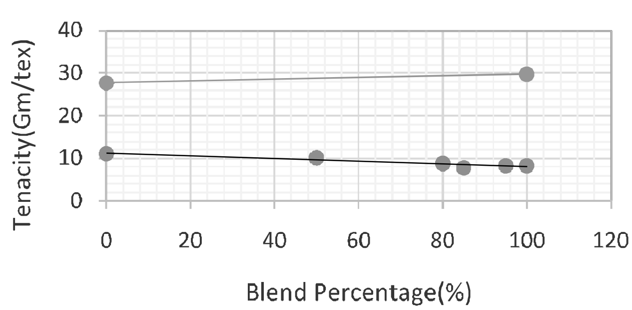

Fig 7. Change of Yarn Tenacity with Blend Composition

The PALF and jute were separately processed in the breaker and finisher jute carding machine. The slivers of PALF and jute were blended in the proportion of 20:80 at Mackie’s first drawing machine. Yarns of two linear density of 207 and 276 tex were spun in Mackie’s slip draft spinning machine from blends as well as control fibre. It reveals from the results that the mechanical properties like tenacity, extensibility and regularity of PALF yarns of two linear density are superior to that of jute yarns. Addition of 20 per cent PALF in the blend, a significant

Table 3. Performance of PALF jute blended yarns over jute yarn

S. No	Particulars	Yarn tex	Fibre		
			Tossa	White	Mesta
1	Improvement of strength of the blended yarns over control jute yarns (%)	207 276	2-18 1-13	13 10	14-29 17-20
2	Improvement of extensibility of the blended yarns over the control jute yarns	207 276	0.54 6-18	33 13	50-85 27-38

improvement of strength and extensibility was noticed in all cases. Hence, it indicates that PALF and jute fibre blending is beneficial to improve the quality of jute yarn for development of quality jute product compared to the conventional one.

Jalil *et al.,* reported that physical properties of jute PALF blended yarn (5 and 7 lbs/spy) of 70:30 and 80:20 respectively are better than those of 100 per cent jute yarn while there is no significant surface appearance properties like color strength (K/S value) and whiteness, yellowness and brightness indices of the blended yarns.

PALF Ramie blended yarn: PALF and ramie yarns spun in dry and wet spinning systems are comparable but wet spun yarns reveal better performance than dry spun yarns dur to better inter fibre friction in the wet spinning system. By gradual increase in the percentage of PALF in the blend, a gradual decrease in tenacity of the blended yarn has been observed. And this may be due to the difference of fineness of the two fibres.

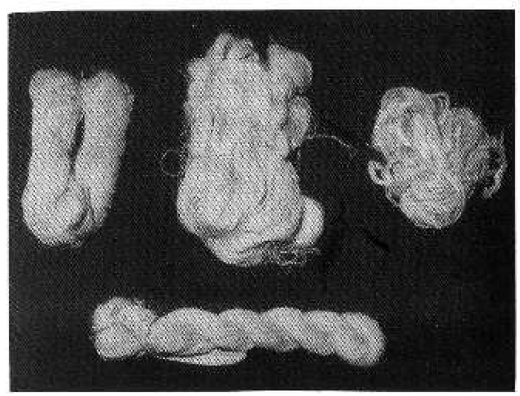

Fig. 8 Blended yarnd from PALF

Fig 9. Jawhar Coat from Ramie-PALF

PALF viscose blended yarn : 100 per cent viscose yarn spun in jute spinning system shows higher tenacity for wet spinning and lower extension compared to dry spinning. Gradual increase of PALF in the blend brings about gradual improvement in the tenacity of the blended yarns due to higher strength of PALF. The wet spun blended yarn from PALF viscose show better performance than corresponding blended yarns spun on the dry spinning system.

PALF polypropylene blended yarn : Binary blending of PALF –Polypropylene for its use in sophisticated area of textiles, Polypropylene fibre of 15 denier and 120 mm length was used. Both PALF and Polypropylene fibres were processed separately in Flax Finisher card with the developed technology of processing the above fibres and a linear density of 138 tex was spun with 5.5 T.P.I in both dry and wet spinning system. Binary blending of the carded material was achieved at Mackie's First Screw Gill Drawing frame with a blend proportion of 75:25, 50:50 and 25:75. No difficulty was encountered during spinning of blended yarn and control yarn.

The performance of PALF polypropylene blended yarns in Table 4 reveal that 100 per cent PALF yarn is better than polypropylene yarn though latter is stronger than the former. Probably low cohesiveness of P.P fibre in the yarn

Table 4. Performance of PALF ramie blended yarns

Blend composition	Dry spinning		Wet spinning	
	Tenacity(gm/tex)	Br. Elongation(%)	Tenacity(gm/tex)	Br. Elongation(%)
100(%) ramie	17.1 (28.0)*	2.1	19.4 (23.0)	2.1
75(%) ramie:25(%) PALF	16.8 (25.00	2.1	19.5 (22.0)	1.6
50(%) ramie:50(%) PALF	14.9 28.0)	2.1	20.0 (21.0)	2.0
25(%)ramie:75(%) PALF	14.6 (19.2)	1.9	19.2 (21.0)	1.9
100(%) PALF	17.1 (25.0)	2.3	20.4 (17.0)	2.3

*Figure in the parenthesis indicate CV (%)

Table 5. Performance of PALF Viscose blended yarns

Blend composition	Dry spinning		Wet spinning	
	Tenacity(gm/tex)	Br. Elongation(%)	Tenacity(gm/tex)	Br. Elongation(%)
100(%) Viscose	7.4 (25.0)*	8.7	9.0 (26.0)	7.8
75(%)Viscose:25 (%) PALF	7.8 (20.0)	2.9	9.0 (17.0)	3.7
50(%)Viscose:50 (%) PALF	9.0 (19.0)	2.4	11.7 (19.0)	3.3
25(%)Viscose:75 (%) PALF	13.4 (24.0)	2.4	17.0 (18.0)	2.6
100 (%) PALF	17.7 (29.0)	2.8	13.7 (17.0)	2.8

*Figure in the parenthesis indicate CV (%)

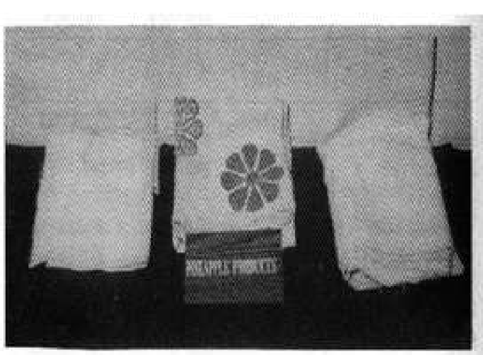

Fig. 10. Variety of Clothes made from PALF

is responsible for poor performance of the yarn. The performance of all blended yarns spun on wet spinning systems is better compared to dry spun yarn. The strength characteristics of all blended yarns, spun on dry and wet spinning systems show a downward trend up to 50 per cent blend proportion. This indicates that there is no homogeneity of blending due to unequal elongation characteristics of the PALF and Polypropylene fibre. A blend of PALF with polypropylene spun on jute system can give an acceptable apparel fabrics.

Table 6. Performance of PALF polypropylene blended yarns

Blend composition	Dry spinning		Wet spinning	
	Tenacity(gm/tex)	Br. Elongation(%)	Tenacity(gm/tex)	Br. Elongation(%)
100(%)polypropylene	12.7 (39.0)*	18.2	13.2 (33.0)	21.4
75(%)polypropylene:25 (%) PALF	8.6 (32.0)	15.1	8.8 (37.0)	15.6
50(%)polypropylene:50 (%) PALF	7.9 (25.0)	7.4	8.2 (26.0)	6.5
25(%)polypropylene:75 (%) PALF	10.0 (23.0)	2.8	11.8 (23.0)	5.1
100 (%) PALF	15.8 (23.0)	2.5	16.4 (24.0)	4.4

*Figure in the parenthesis indicate CV (%)

PALF acrylic blended yarn

Optimum twist factor of yarns : The optimum twist factor of PALF, acrylic and PALF/ acrylic blended yarn were evaluated in jute spinning machinery with the technical know-how developed to process this special natural fibre. There was no difficulty encountered to process acrylic top in jute screw gill drawing, roving and rove spinning frame. The carded slivers of PALF and Acrylic top were blended at first drawing stage in the blend ratio of 50:50 and processed in three passage of gill drawing frame (Mackie). Liner density of 84 tex were spun from 100 per cent PALF, 100 per cent Acrylic and 50:50:: PALF/acrylic blend with a varying twist factor ranging from 6-12 (Jute system). The tenacity of different yarns with varying twist factor was plotted graphically in Fig.1 to evaluate optimum twist factor. It is observed from the figure that the optimum twist factor on the basis of maximum strength of the above three yarns are achieved as follows.

PALF yarn 11.07, Acrylic yarn 10.28 and PALF/Acrylic (50:50) Yarn -9.49

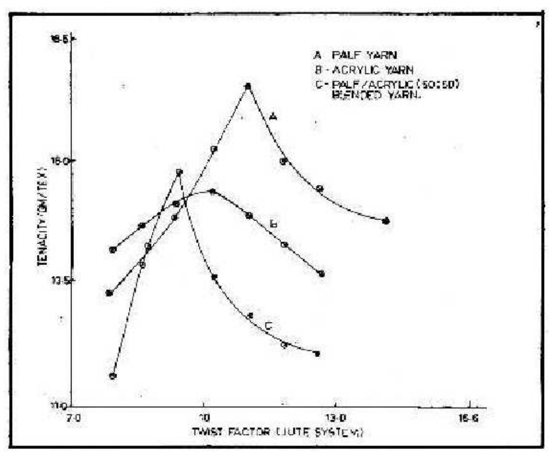

Fig 11. Twist vs. Tenacity Curve

Optimum stage of blending of PALF and acrylic fibre : PALF: Acrylic:: 50:50 blended yarns having linear density of 84 tex with a T.P.I of 7.5 were developed in jute spinning system in dry and wet spinning conditions. Four blended yarns were spun by blending PALF and acrylic at four different stages of jute processing *viz.*, carding and three drawing frames. The performance of the blended yarns was studied to evaluate the optimum stage of mechanical processing for binary blending of PALF and acrylic.

It reveals from Table 7 that the performance in respect of strength and regularity properties was better when blended at carding stage compared to blending at drawing stages. The probable reason may be that in carding stage of blending, the fibres might have got scope to mix intimately to make a homogenous mixture of fibres so that each fibre component contribute their own share proportionately in the yarn structure which ultimately helps to achieve a good quality yarn blended at carding stage. During wet spinning, yarn strength increases considerably. This can be attributed to the higher wet strength of PALF and increase of fibre friction on wetting. A similar increase of yarn strength due to wetting was observed by Lawson et al and Chakraborty et al while studying the properties of cotton and pineapple leaf fibre respectively.

The PALF yarn is superior in strength but inferior in extension value, and is more irregular than all acrylic yarns, and the same yarn spun in wet condition follows same trend but wet spinning helps to increase strength and extension properties of the yarns. The packing co-efficient of the dry spun acrylic yarn is higher

Table 7. Performance of PALF-Acrylic (50:50) blend at different stages of jute processing

S. No	Stage of blending	Nominal linear density (Tex)	Actual linear density (Tex)	Tenacity(Gm/tex)		Breaking Extension (%)	
				Dry Spg	Wet Spg	Dry Spg	Wet Spg
1	Carding	84	81	15.93 (21)*	20.07 (20)	3.05	3.50
2	First drawing	84	92	12.37 (17)	12.55 (17)	3.52	3.50
3	Second drawing	84	93	10.54 (33)	12.15 (20)	2.84	3.50
.4	Third drawing	84	89	9.25 (39)	11.37 (17)	1.83	4.12

* Figure in the parenthesis indicate CV (%)

Table 8. Effect of blend composition on yarn quality dry spun yarn

Property	Proportion of acrylic in the blended yarn (%)						
	0	17	33	50	67	83	100
Fibre linear density (Denier)	24		3				
Yarn linear density	132	141	139	133	155	156	145
Diameter μ (x 10^{-4}cm)	0.34	0.35	0.40	0.39	0.48	0.50	0.40
Tenacity (gm/tex)	16.86*	12.78	12.69	12.37	12.17	12.12	10.97
	(32.59)	(25.96)	(22.25)	(21.04)	(17.16)	(16.42)	(15.07)
Breaking elongation (%)	1.20	2.70	2.81	3.52	3.56	5.55	6.82
Weight C.V(%) on 2^3 cut length	26	18	15	18	13	12	8
Packing Co efficient	0.63	0.63	0.61	0.57	0.52	0.41	0.85

*Figures in the parenthesis indicate C.V (%)

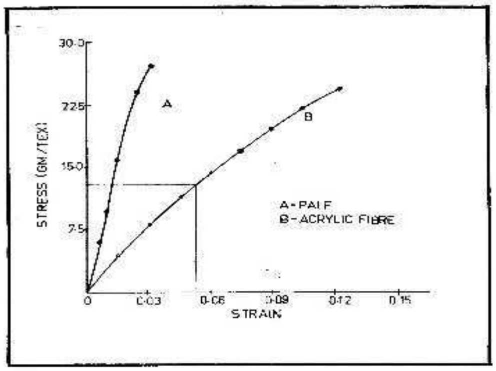

Fig 12. Stress *v/s.* strain curves of PALF and Acrylic fibres

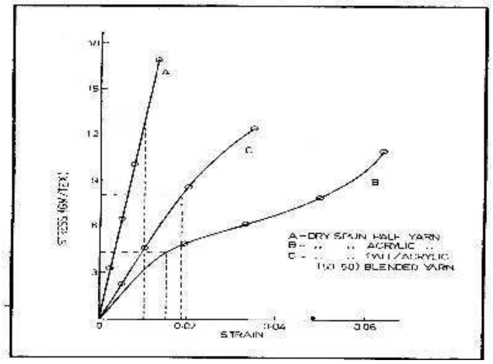

Fig. 13. Tensile characteristics of dry spun yarn

than that of the dry spun PALFs yarn but it reverses with wet spun yarn. With the inclusion of PALFs from low to high proportion in PALF acrylic blend, there is a marked improvement of strength of the blended yarn at the initial stage, but later on, the improvement is insignificant. The extension property of the blended yarn gradually improves with acrylic fibre from low to high proportion in the blend. Optimum blend composition of PALF/Acrylic yarn is 67/33 because at this ration the strength of the blended yarn is higher than that of the acrylic yarns and its extension and regularity higher than, the PALF yarn.

Wet spinning technology : Wet spinning brings about improvement in short-term weigh irregularity of the yarns resulting in better regularity of yarn diameter. This is chiefly due to better control of fibres in the drafting zone of the spinning frame during wet spinning. The diameter of wet spun PALF yarn of equivalent linear density is lower and its packing coefficient is also higher than that of the dry spun one. The tenacity of the wet spun yarn (Fig.4) is higher than that of the dry spun one as the regularity of wet spun yarn is better and the higher packing coefficient is expected to generate transverse pressure during tensile loading. The strength C.V (%) of wet spun yarn was also lower compared to dry spun yarns. There was no significant difference in breaking elongation of dry and wet spun yarns.

The fineness or linear density of PALF and acrylic are different which are presented in Table 8. The average fineness and tenacity of the indigenous PALF were 2.67 tex and 271.84 mN/tex, respectively. Acrylic fibres in this experiment were100 mm staple length with a fineness of 0.33 tex. The higher fineness of acrylic fibre improves the spinnability of blended yarn and also results in a more regular yarn by providing more numbers of fibres per yarn cross section. The stress strain curves of PALF and acrylic (Fig 12) reveals that PALF is almost linear but that of acrylic is non-linear. It is evident from the stress-strain curves that strength and modulus of PALF fibre is much higher compared to acrylic fibre. But on the contrary the elongation percentage of acrylic is much higher than PALF. The wide difference of PALF and acrylic will have effect on the tensile properties of the blended yarn.

(S_a - Breaking tenacity of PALF; S_b– Breaking tenacity of acrylic; and $S_{b/a}$ – specific stress of acrylic at breaking strain of component PALF)

The performance of development of PALF

Table 9. Effect of blend composition on yarn quality wet spun yarn

Property	Proportion of acrylic in the blended yarn (%)						
	0	17	33	50	67	83	100
Fibre linear density (Denier)	24		3				
Yarn linear density	132	141	139	133	155	156	145
Diameter μ (x 10^{-4}cm)	0.32	0.35	0.36	0.40	0.49	0.49	0.43
Tenacity (gm/tex)	21.40*	15.15	13.44	11.85	11.96	12.76	14.92
	(31.68)	(23.21)	(18.75)	(17.68)	(17.58)	(12.46)	(9.73)
Breaking elongation (%)	1.39	2.84	3.79	4.09	4.72	10.46	14.92
Weight C.V(%) on 2^3 cut length	28	19	18	16	14	14	14
Packing Co efficient	0.79	0.83	0.71	0.58	0.47	0.48	0.52

*Figures in the parenthesis indicate C.V (%)

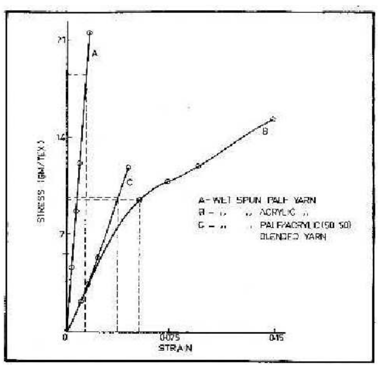

Fig.14. Tensile Characteristics of Wet Spun Yarn

yarns in flax wet spinning system and conventional jute spinning system which is dry reveals that wet spinning technology generally adopted in flax system brings about improvement in weight irregularity of the yarn resulting in better regularity of yarn diameter. This is mainly due to better control of fibre in the drafting zone during wet spinning

The diameter of wet spun PALF yarn of equivalent linear density is lower and its packing

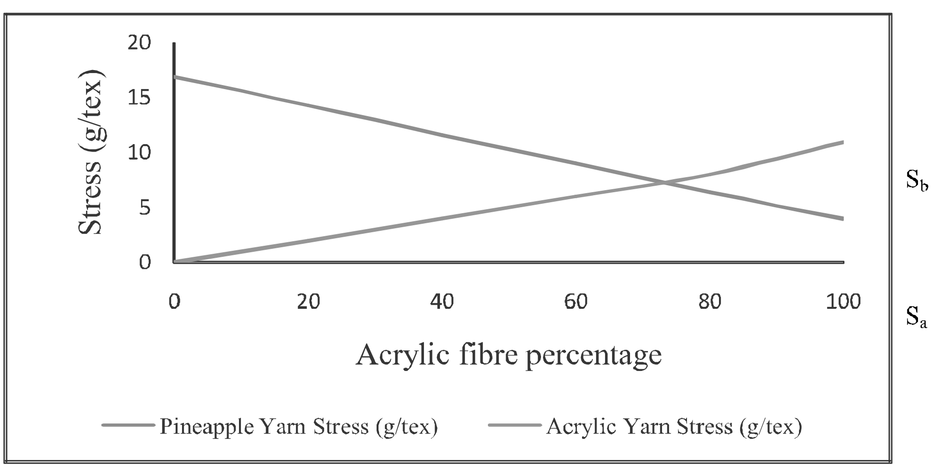

Fig.15. Prediction of Strength of Blended Yarns

Fig.16. PALF-Acrylic blended yarn

Fig.17. Jawhar Coat from PALF-Acrylic

co-efficient is also higher compared to dry spun PALF yarn in jute system. Hence the tenacity of wet spun PALF yarn in flax system is higher than that of the dry spun one of the jute system because better regularity and higher packing co-efficient is expected to generate higher transverse pressure during tensile loading. Labile gummy matter inherent in the fibre surface gives a better inter-filament frictional property in hot water which is the reason for better working in wet spinning system.

PALF yarns from both systems are superior in strength compared to cotton yarns of equivalent linear density but in case of regularity the result is reversed. This may be due to low fineness value of cotton fibre compared to PALF and also for the reason of better fibre control in short fibre processing machinery over long fibre machinery.

Table 10. Performance of PALF and cotton yarn

Particulars	Palf yarn		Cotton Yarn
	Jute system	Flax system	
Linear Density(Tex)	85.10	82.14	84.0
Weight C.V on 25 Yds (%)	8.29	7.16	5.0
Uster fineness (U%)	29.50	27.50	21.50
Average diameter(cm)	0.333(17.42)*	0.311(19.94)	-
Breaking stress(gm/tex)	17.33(27.84)	19.81(23.56)	7.5(8.0)
Breaking strain(%)	8.8	8.2	-
Packing coefficient	0.65	0.72	-

*(Figure in the parenthesis indicate C.V (%.)

The PALF plied yarns generated from flax wet spinning system are superior to plied yarns from conventional jute spinning system in respect of u(%)weight and diameter irregularity The breaking stress of PALF plied yarns in both the system are comparable. It is interesting to mention here that PALF yarn from jute spinning system with high irregularity and low strength compared to yarn from flax system improves considerably when plied It is reflected in the tensile property of plied PALF yarns in both the system of equivalent linear density. The packing co-efficient of PALF plied yarns improves

Table11. Performance of PALF and Cotton Plied Yarns

Experiment	Ply yarn (Tex)	Tenacity (gm/tex)	Elongation (%)	Threads /cm of ply yarn	Weight C.V on 25 yds (%)	U (%)	Diameter (mm)	Packing coefficient	Remarks
PALF spun in flax wet spinning system	30,803.00	20.52 (11.31)	13.33 (10.88)	3.50	2.56	13.25	0.09 (11.64)	0.43	
PALF spun in jute system	30,803.00	19.20 (19.51)	11.00 (16.41)	3.57	4.24	16.00	0.09 (19.78)	0.45	
Cotton yarn	30,803.00	15.20 (6.01)	8.60 (3.60)	3.96	-	-	-	-	
PALF spun in 30,834.00 flax wet spinning system	18.86	11.90 (14.95)	3.00 (18.86)	2.89	13.00	0.10	0.41 (9.84)		
PALF spun in jute system	30,834.00	20.35 (14.92)	12.23 (20.35)	3.00	2.53	15.50	0.10 (13.24)	0.47	
Cotton yarn	30,834.00	15.28 (6.49)	11.90 (9.97)	3.99	-	-	-	-	
PALF spun in flax wet spinning system	30,895.00	19.30 (10.58)	12.30 (19.30)	2.50	2.75	12.25	0.11 (9.08)	0.49	Twisted In wet state
PALF spun in jute system	30,895.00	19.51 ((15.56)	13.27 (19.51)	2.50	2.85	14.00	0.12 (14.70)	0.39	
Cotton yarn	30,895.00	17.41 (5.73)	9.80 (5.71)	2.87	-	-	-	-	
PALF spun in flax wet spinning system	31,017.00	17.00 (9.26)	13.30 (17.00)	2.00	1.85	12.00	0.13 (7.69)	0.49	Twisted In wet state
PALF spun in jute system	31,017.00	18.47 (11.57)	14.03 (18.47)	2.27	2.28	11.80	0.16 (12.93)	0.36	
Cotton yarn	31,017.00	15.77 (4.97)	13.80 (5.29)	2.79	-	-	-	-	

(Figure in the parenthesis indicate C.V (%.)

significantly when the yarns are twisted in wet state in case of 8 ply and 12 ply in flax system.

The PALF plied yarns generated from flax wet spinning system are superior to plied yarns from conventional jute spinning system in respect of u (%), weight and diameter irregularity. The breaking stress of PALF plied yarns in both the system are comparable. It is interesting to mention here that PALF yarn from jute spinning system with high irregularity and low strength compared to yarn from flax system improves considerably when plied It is reflected in the tensile property of plied PALF yarns in both the system of equivalent linear density. The packing co efficient of PALF plied yarns improves significantly when the yarns are twisted in wet state in case of 8 and 12 ply in flax system.

The tensile property of PALF yarns of both the system are superior to cotton plied yarns.

Table 12. Performance of PALF and cotton duck cloth

Particulars	PALF industrial fabric	Cotton industrial fabric
Cloth weight(gm/m^2)	960	960
Count of warp yarn(Tex)	8/84	5/84
Count of weft yarn(Tex)	5/84	6/84
Warp thread/10cm	74	91
Weft thread/10 cm	58	55
Crimp in warp yarn(%)	14.7	22.0
Crimp in weft yarn(%)	5.6	3.0
Breaking strength, Warpwise (kgs)	154	134
Breaking strength, Weftwise (kgs)	93	8.5
Breaking elongation, Warpwise (%)	18.9	28.2
Breaking elongation, Weftwise (%)	8.1	8.5
Thickness(mm)	1.57	1.60

The elongation property of PALF plied yarns are either better or comparable to cotton plied yarns. The lower strength C.V (%) values of cotton plied yarns indicate its superiority over PALF plied yarns but it may not create any hindrance while converting 5/84 and 8/84 tex yarn into PALF industrial fabric.

The higher strength of PALF compared to cotton has been reflected in case of single and plied PALF yarn and this has also been reflected in the newly designed and developed PALF industrial fabric .The tensile strength of developed industrial fabric from PALF is higher than that of the industrial fabric from cotton in both directions. The elongation property of the new fabric is comparable with that of cotton fabric in weftwise direction. Though the value in warpwise direction is lower it may not have any adverse effect on the actual end use of the fabric. The thickness value of the developed PALF industrial fabric are comparable with cotton .The crimp (%) in both the directions of PALF fabric are different from cotton and this is due to the difference in the manufacturing techniques of both the fabrics.

Short staple cotton spinning system : An attempt was made to blend pineapple leaf fibre with cotton in cotton spinning system in a commercial mill. Pineapple leaf fibre was first stapled to 32 mm, opened in a single opener machine, blended with Indian cotton in two proportions (i) 67 per cent cotton: 33 per cent Pineapple leaf fibre and (ii) 80 per cent cotton:20 per cent pineapple leaf fibre and yarn of a coarse count 14^s spun. The performance of the blended yarns showed that on increasing the proportion of pineapple leaf fibre in the blend, the count

Fig.18. Duck cloth from PALF

Fig.19. Conveyor belt

strength product and regularity deteriorated and a higher percentage of droppings of fibre was noticed in the blow room and carding machine. Thus, some pre-treatment of the pineapple leaf fibre for softening was envisaged. In the next stage, pineapple leaf fibre was subjected to chemical and microbial treatments along with a conventional softening treatment with water alone. Of various pre-treatment's undertaken, softening pineapple leaf fibre for 2 days in water, followed by a suitable chemical treatment in a boiling solution of sodium hydroxide of 1 per cent (w/w) concentration, produced an appreciably stronger and finer fibre. The softened pineapple leaf fibre, in a blend proportion of pineapple leaf fibre: cotton of 70/30, was again processed through a commercial cotton mill, producing yarn as fine as 22^s cotton count (27 tex). In this case improvement on enhanced droppings was achieved during processing, allowing a higher proportion of pineapple leaf fibre in the blend. However, the blended yarn was of lower strength than all cotton yarn because of less cohesiveness of coarse pineapple leaf fibre in the blend. Yarns thus produced have potential in the production of coarser fabric or may be channelled into the rural sector for cottage industrial uses.

Spinnability of PALF improves after chemical treatment which was not achieved from cotton/raw PALF (67:33) blend composition. It is clear from the Table-3 that the Spinnability increased from 14^s to 22^s with higher blend composition of PALF: Cotton:: 70:30.Yarn performance indicates that the C.S.P of the blended yarn is lower compared to cotton yarn. The cohesiveness of chemically treated PALF

Table 13. Performance of PALF : cotton blended yarns on short staple spinning system

Particulars	Blended yarn from Chemically treatedPALF/Cotton(70:30)		Yarns from 100 per cent cotton	
	14^sCount	22^sCount	14^sCount	22^sCount
Actual linear density(Count)	13.78 (5.45)	22.55 (6.16)	13.81(4.15)	21.98 (5.25)
Breaking stress (Gm/tex)	7.36 (19.36)	7.88 (13.43)	8.18 (16.25)	10.84 (13.01)
Breaking strain (%)	3.73	3.15	-	-
Actual T.P.I	25.93	30.87	26.50	32.00
Lea strength(kg)	32.93	18.53	37.82	29.75
C.S.P	997.7	920.0	1149	1438
U(%)	25.5	28.5	14.0	15.5
Breaks /100 spindle Hour	16	15	18	14

needed higher twist multiplier than normal cotton yarn of same count.

An attempt to spin Pineapple leaf fibre with cotton by Sreenathan *et al.,* (1990) of Cotton Technological Research Laboratories, Mumbai reveals that various pre-treatment of pineapple leaf fibre with organic solvents followed by sodium hydroxide was promising. Pineapple is coarse like jute. To upgrade the spinning potential without much loss in fabric strength, the best blend composition is 20:80 pineapple: cotton. Sreeenathan *et al.,* (1990) opined that there is a good potential of this fibre in a coarser range of counts for producing upholstery fabrics. Wall hangings etc. in the handloom sector. 20:80 pineapple: cotton blended yarn can conveniently used to produce denim and other type of fabrics.

Semi worsted spinning systems : PALF were blended with Chokla variety of coarse Indian Wool at Central Sheep and Wool Research Institute, Avikanagar, Rajasthan, a sister concern of Indian Council of Agricultural Research. Yarns of nominal linear density of 138 tex were spun on the semi-worsted spinning system by varying the blend proportion of PALFs.

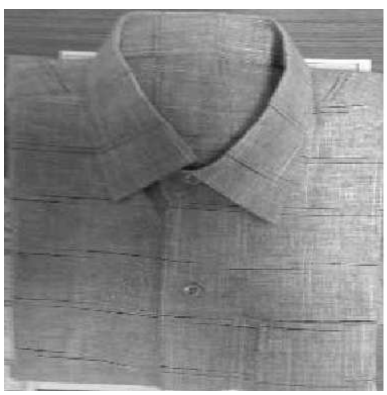

Fig. 20. PALF cotton blended shirt

Table 14. Yarn characteristics of blended pineapple yarn

Property	Control V.797	Blend (80%) V 797/(20%) Pineapple fibre
Actual count	11.4	11.9
Actual strength (lbs)	153.8	113.2
Corrected CSP	1810	1324
Single thread strength (g/t)	11.9	10.6
Elongation at break (%)	9.7	9.2
CV (%) of breaking strength	11.5	17.8
U(%)	16.8	20.3
Thin place/100 metre (M)	8	45
Thick place/100 metre	30	50
Neps/M	46	86

Table 15. Strength of pineapple blend fabric

Particulars	Warp way		Weft way	
	Load (Kg)	Elong-ation (%)	Load (Kg)	Elong-ation (%)
100(%) V797(Control)	30.2	13.2	50.2	10.8
20(%) Pineapple/80% V797	32.8	11.9	49.0	9.9

Blending of PALFs by 25 per cent could bring about a sharp drop in breaking elongation of yarns and blending by 50 per cent results a sharp increase in tenacity of blended yarns. Besides, by blending PALF with wool at 25:75,the bulk resilience of yarn decreased only by 10 per cent as compared to all wool yarn. The blended materials of PALF wool, all PALF and all wool were processed separately on the semi worsted spinning systems.

Table 16. Performance of PALF wool blended yarns (Linear density-138 tex)

Spinning system	Blended proportion (PALF: Wool)	Tenacity (gm/ tex)	Breaking elong- ation(%)	Packing Co- efficient
Semi worsted system	0:100	4.48	15.11	0.3219
	25:75	4.94	4.04	0.4455
	50:50	7.99	3.58	0.5221
	75:25	10.97	2.97	0.5476
	100:0	13.71	3.74	0.5688

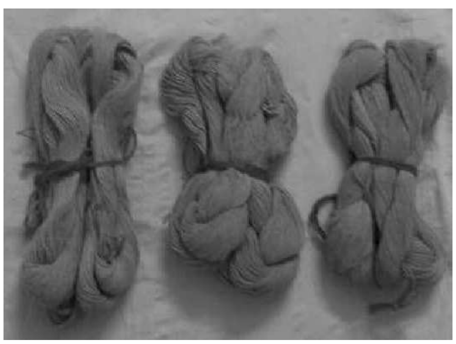

Fig.21. PALF-Chokla blended yarn

The performance of PALF-Wool blended yarn was studied as it is shown in Table 16 which indicates that inclusion of PALF from low to high proportion in PALF-wool blended composition, shows gradual improvement of strength property of the blended yarn whereas its extension property is reversed. This is due to high strength and low extension property of all PALF yarn over all wool yarn. The optimum blend composition of PALF-wool may be considered as 75:25 because in this blend composition, the strength and extension characteristics of the blended yarn are higher than all wool and all PALF yarn respectively.

Performance of Pine apple leaf fibres in Jute and Worsted spinning by Palit et al reveals that for every (1%) addition of PALF, the strength of jute/PALF blended yarn increases by about (38%).Polyester/wool/PALF blended yarns (45%/ 45%/10%) spun on worsted spinning system are inferior to polyester/wool yarn(50%/50%) in major tensile characteristics.

Eri silk spinning systems : Latest finding reveal that pineapple leaf fibre was successfully processed and blended with red eri available in north eastern region only using Chinese silk processing facilities available at Fabric plus, Guwahati. Red eri and softened pineapple leaf fibre were processed through the sequence as follows:

Floss Cutter – First Circular Dressing – Second Circular Dressing – Third Circular Dressing – First Spreader – Second Spreader – Slivering – First Drawing-Second drawing – Third Drawing- Roving – Ring spinning – Winding – Twisting – Conditioning – Singeing – Package.

Finer linear density of PALF: Red Eri blended yarn reveals its immense potentiality to be used in the field of Luxury textiles. Finest blended yarn could not be spun except this spinning system. The mechanical properties of the blended yarn were up to textile quality.

BLENDING AT YARN STAGE

Composite yarns for technical textiles from natural fibres based on friction spinning technology : DREF friction spinning can be used

Fig 22. ERI-PALF Blending Sequence

to produce core-sheath structured yarns. Composite yarn samples were spun on a DREF 3000 Friction spinning machine installed at CIRCOT, Mumbai.

DREF 3000 is a core-sheath type mechanical aerodynamic spinning process in which the spinning is effected by the rotation of two perforated spinning drums in the same direction, aided by air-suction in the yarn formation zone. PALF spun yarns were fed to the rotating drums axially as core along with a small portion of cotton fibres drafted from a sliver and aligned along the yarn axis. The core yarn was false twisted by the torque generated due to the rotation of the spinning drums. For the sheath fibres, cotton slivers were fed to a rotating carding drum, fibre were separated and deposited on the false twisted core surface and wrapped helically over the core. The sheath content in yarn was varied so as to fully envelope the core in each case of spinning. The spinning parameters used on DREF 3000 machine was as follows: Spinning drum speed 2500 rpm; Carding drum speed 5000 rpm; inlet speed 1.35 m/min; main suction fan speed 2600 rpm and delivery speed 150 m/min.

Union blending at fabric stage : Further, the composite yarns were converted into fabric on a sample loom. A suitable duck fabric could

Table 17. Physical properties of DREF 3000 spun composite yarns

Yarn Type Properties	PALF yarn(100%)	PALFCore Cotton sheath	3 ply PALF yarn	3 plyPALF Core cotton sheath
Actual Linear density (Tex)	257	395	815	957
Yarn Diameter (mm)	0.83(29.0)	1.43(14.3)	1.47(15.4)	1.78(8.95)
Bulk density(g/cc)	0.47	0.24	0.48	0.38
Packing fraction	0.32	0.16	0.32	0.26
Specific volume(cc/g)	2.10	4.06	2.08	2.59
Increase in sp. volume (%)	-	93.1	-	24.9
Increase in diameter (%)	-	72.3	-	21.1
Sheath material (%)	-	35.0	-	14.8

be produced from composite yarn made from 3 ply PALF yarn as core and cotton as sheath. Such composite yarn was about 25% more bulky than the control 3Ply PALF yarn resulting in lighter fabric with better cover.

Future prospect and economics of PALF in India : Globally, India holds the top position in of jute and cotton, 5th in wool and 7th in pineapple. The global annual production of natural fibres in 2013 is approximately 33 million tonnes. At present pine apple cultivation in India is 1,09,880 ha with annual production of 1,736,740 tons. After harvesting the fruit, the plants are uprooted from soil and either burnt or kept in the field for natural degradation. Assuming an average plant density of 30,000/ ha, it was estimated 40 matured leaves out of 80-100 leaves/plant annually with an average weight of 70 gm and 50-60 cm length and 2.5 per cent fibre yield, India having a potential for producing around 5.29x 10^6 tonnes of pineapple leaves per anum from pineapple cultivation.

As per Focus Fibre Focus state approach by Ministry of Textiles, Govt of India, Pineapple of Tripura State in NER was chosen for this activity to promote pineapple fabric in India. Although a huge amount of fibre can be generated but in the current Trade it appears negligible due to unawareness in farming sector. Pineapple is suitable for blending with silk to fetch high value addition in textiles. It is assumed that adulteration is done at 1/3 rd price of Indian raw silk prices in India considering 1 kg of indigenous Pineapple leaf fibre around Rs.200/ -, it is a worth of 105.80 crores ,showing the potential of PALF, an agro waste as an additional income for the cultivators of modern India.

Table 18. Mechanical properties of DREF 3000 spun composite yarns

Yarn Type Properties	PALF Yarn(100%)	PALFCore CottonSheath	3 ply PALFYarn	3 plyPALF Core Cotton Sheath
Actual Linear density (Tex)	257	395	815	957
Br. load (N)	45.5(11.6)*	43.7(11.8)	147.6(11.7)	147.2(7.13)
Br. tenacity (cN/tex)	17.7(11.6)	11.1(11.8)	18.1(11.7)	15.4(7.13)
Br.elongation(%)	2.48(29.5)	2.47(6.99)	3.26(9.14)	3.82(19.1)
Energy at break(mJ)	174.2(16.6)	277.7(16.3)	1104.0(18.1)	1597.0(39.2)
Sp.work of ruptutre(mJ/tex-m)	1.13(16.6)	1.17(16.3)	2.26(18.1)	2.78(39.2)

*Figures in the parenthesis indicate CV percent

Average moisture content in vermicompost cast was 50 per cent and the pH was 7.0.It is observed that the vermicompost contain more nitrogen, phosphorus and potassium almost at per and less C:N ratio than other compost although it is likely to vary with pineapple leaf biomass residue used for vermicomposting. Pineapple leaf residue vermicompost contains 1.0-1.2 per cent nitrogen,0.3-0.4 per cent phosphorus and 0.4-0.5 per cent potassium which indicates that that pineapple leaf debris vermicompost is rich enough in NPK and will be suitable for agriculture.

Earthworms are invertribates and are of two types (i) burrowing type and (ii) non-burrowing

Table 19. Properties of fabrics developed from composite yarn

Fabric type properties	Duck fabric (3 ply PALF yarn core and cotton sheath composite yarn)
Linear density of warp(Tex)	957
Linear density of weft(tex)	957
EPI (EPcm)	7 (3)
PPI (PPcm)	11 (5)
Area density(gm/m^2)	744

type. The non-burrowing types live in upper layer of soil surface and consume 10 per cent soil organic matter and 90 per cent added organic matter, whereas the burrowing type live deep in soil and depend 90 per cent on soil organic matter and 10 per cent on added organic matter. The non burrowing type has been used for vermicomposting from pineapple leaf scratching debris. Generally, microbial population initially increases in compost beds when organic matter is actively decomposing and then gradually decreases in number and reaches to an equilibrium when easily decomposable organic materials are exhausted (Table 21). It is also important that the microorganisms face competition for organic matter from earthworms in vermicompost beds. Moreover, earthworm inevitably consumes soil microbes during ingestion of the organic substrate and extracts nitrogen from microbes especially from microbes. This may be the reason for less number of fungi in vermicompost samples. Bacteria might have multiplied fast again in vermicompost so long the sufficient moisture is there, pH and temperature show a profound role in controlling microbial population in vermicomposting.

Table 20. Performance of All PALF, and PALF/PP blended fabrics

Sample No	1	2	3
Warp	All PALF yarn	All PALF yarn	All PALF yarn
Weft	All PALF yarn	ALL PP Yarn	PALF/PP(50:50) blended yarn
PALF/PP in fabric	100:0	55:45	78:22
Warpwise strength	108	113	102
Weftwise strength	112	232	118
Strength CV (%) warpwise	12	9	6
Strength CV (%) weftwise	14	6	11
Warpwise extention (%)	5.1	5.8	4.7
Weftwise extention (%)	8.2	21.7	6.5
Extension CV (%) warpwise	15	16	15
Extension CV (%) weftwise	8	9	13
Fabric stress (g/tex)	60	64	58

Table 21. Microbial population in Vermicomposting samples

Sample	Viable bacteria/g	Viable fungi/g	Viable actinomycetes/g
Partially decomposed substrate	69×10^6	11×10^4	2×10^4
Vermicompost	54×10^6	8×10^4	1×10^4

Banik's work[19] on vermicomposting reveals that 0.68 tons of vermicompost is formed from 1.5 tons of pineapple leaf scratching residues. This is obtained from 8 tons of fresh harvested agro-waste leaves after harvest of pineapple fruit from 1 ha of land under pineapple cultivation. The present Indian market price of vermicompost is approximately Rs.6/kg and Pineapple leaf fibre is Rs.25/kg. Assuming average availability of 8 tons of pineapple leaf from one ha of land, the fibre yield@ 2.5 per cent is found to be 200 kg under pineapple cultivation. Thus an extra income from pineapple leaf fibre is Rs.5000/- and from vermicomposting is Rs.4080/-, *i.e.* Rs.9080/- from one ha of land from the integrated system of waste management. The payback period for pineapple leaf scratching machine is 4.5 years with 39.57 break-even point. Accordingly, the combined technology can be adopted by all the pineapple growers for additional income.

The cultivators are not showing much interest for extraction of PALF due to various techno-economic reasons like lack of efficient decorticator, and apparently low fibre yield. Lack of awareness in the cultivators and common people about PALF is another retarding factor.

CONCLUSION

Investigation on pineapple leaf fibre clearly indicate that the agro waste can be suitably processed into useful products. Pineapple leaf fibre had already been proved to be a useful raw material for good quality paper. Development of appropriate processing technologies for generating yarn with improved properties can widen the application of this agro waste. The extractor can effectively be used to extract the fibre from the agro waste of pineapple leaves and the residual sludge obtained after scratching the leaves can be used for vermicomposting successfully. Investigation on pineapple leaf fibre clearly indicate that the agro waste can be suitably processed into useful products. Pineapple leaf fibre had already been proved to be a useful raw material for good quality paper. Development of appropriate processing technologies for generating yarn with improved properties can widen the application of this agro waste. The integrated technology for the extraction of pineapple leaf fibre and the vermicomposting altogether becomes remunerative to pineapple cultivators which can be adopted by all pineapple growers not only for additional income but also proper utilization of wastes particularly agricultural wastes which is an important factor in planning the economic progress of a developing country like India.

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REFERENCES

Banik, S, Nag, D and Debnath, S. 2011. "Utilization of pineapple leaf agro-waste for extraction of fibre and the residual biomass for vermicomposting" *Ind. Jour. Fib. Tex. Res.,* **36 :** 172-77.

Chakraborty A. C., Sinha M. K. and Ghosh, S. K. and Das, B.K, 1978. *Ind. Textile J,* **88 :** 95.

Dey, S.K, 2017. Exploration of Indigenous Pineapple-acrylic blend-A Future prospect for sustainable luxury textiles, *J. Archit Eng Tech.*, **6 :** 2.

Dey, S.K, 2016. Performance of binary blends of Indigenous Ramie-acrylic, *J. Text Sci Eng* **6 :** 5, DOI: 10.4172/2165-8064, 1000277.

Dey, S.K, 2013. Processing technology for the utilization of pineapple leaf fibre (PALF) - An Agro-waste, *"Diversification of Jute and Allied Fibres: Some Recent Developments*, NIRJAFT, I.C.A.R, Kolkata, 239-250.

Dey, S.K. and Satapathy, K. K., 2013. "A combined technology package for extraction of pineapple leaf fibre - An Agrowaste, Utilization of biomass and for application in Textiles", *9Th People Technology Congress,* Kolkata.

Dey, S. K. and Bhattacharyya, S. K. 2005. "Magic yarns from ramie and pineapple- *A new dimension in 21st century", 20th Indian Engineering Congress*, p 69.

S. K. Ghosh, S. K. Dey and S. K. Bhaduri, 1982. "Processing of chemically treated Pineapple leaf fibre in cotton machinery", *Text Trends,* July, 1.

S. K. Ghosh, S. K. Dey and A. Ghosh 1989. "Pineapple leaf fibre/Wool blend in semi-worsted processing", The *Ind Text Jr*, April, 152

S. K. Ghosh, M. K. Sinha, S. K. Dey and S. K. Bhaduri, 1982. "Processing of pineapple leaf fibre in Cotton Machinery", *Text Trends,* **14 :** 49.

Dey, S.K., Nag, D and Das, P. K. New Dimensions of Pineapple leaf Fibre-An agrowaste for Textile Applications, *"New Technologies for rural development having potential of commercialization"* Allied Publishers Pvt. Ltd, New Delhi, 115-127, ISBN: 9788184244427

Dey, S.K., Nag, D and Das, P. K. 2009. *New Technologies for rural development having potential of Commercialization,* Allied Publishers Pvt Ltd., New Delhi, 115-27.

Ghosh, S.K, Dey, S.K, and Ghosh, A, 1987. *Manmade Textiles India*, October, 485.

Doraiswamy, Indra and Chellamani, P, 1993. Pineapple leaf fibres, Textile Progress, Vol 24, No 1.

Ghosh, S. K, Sinha, M. K and Dey, S. K. 1979. "Utilization of pineapple leaf fibre in Textile sector", *Text Ind Trade Jr,* **17 :** 114.

Ghosh, S. K, Dey, S. K and Ghosh, A. 1989. "Pineapple leaf fibre/Wool blend in semi-worsted processing", *The Ind Text Jr*, April, p 152

Ghosh, S. K, Dey, S. K, Sinha M. K. and. Ghosh, R. N, 1982. "Pineapple leaf fibre in conveyor belting", The *Ind Text Jr*, April, p 65.

Ghosh, S. K. and Dey, S. K. 1983. "Designing an industrial fabric from pineapple leaf fibre", *Jr Inst of Engrs*, December, p 16.

Ghosh, S.K and Dey, S.K, 1988. *Jour. Tex. Asso.,* 167-71.

Hamburger, W.J, J. 1949. *Text. Inst*, **40 :** 700

Layak Suman, 1997. Telegraph, October 3.

Lawson, R, Ramey, H.H and Krowki, R.S, 1976. *Text. Res. J*, **46 :** 715.

Jalil Mohammad Abdul, Sinha, Rabindra Chandra, Mahabubzzaman, A.K.M, Hossain, Md. Milon and Idris, Mohammad Arafat, 2016. Research Journal of Textile and Apparel, ISBN:10.1108/RJTA-19-03-2015-B002.

ISI Handbook of Textile Testing, Quantative Chemical Analysis of Binary Mixtures of Acrylic and certain other fibres, Method I.S:3421, p.430, 1966.

Indian Horticulture Database, 2014.

Mukhopadhyay, S.N, 1980. *Ind. Text. J,* **12 :** 25.

Palit, S, Chakraborty, T.N, Sarkar, A, Doraiswamy, I and Chelamani, P, 1992. Performance of PINEAPPLE LEAF FIBRES(PALF) IN JUTE & WORSTED SPINNING SYSTEMS, Textile Trends, pp 33-38.

Siti Asia binti Yahya and Yusri Yusof, 2013. *Adv. Mat. Res.,* **701 :** 430-34.

Sinha M. K. and Ghosh, S. K. 1977. “Processing of pineapple leaf fibre in jute machine”, The *Ind Textile Jr*, December, p 105.

I. N. Ghosh, N. L. Debsarkar, A. Day and B. C. Mitra,1999. “Some studies on pulping characteristics of jute and other allied non-wood plant fibres for paper manufacture in the Handmade paper mills”, IPPTA, **11 :** 1

Sawakhande, K. H, Iyer. V and Srinathan. B, 1987, *Ind Text Jour.,* **98 :** 64.

Srinathan. B, Iyer. V and Sawakhande, K. H, 1990, *Ind Text Jour.*, 46.

Yoshinavi Kobayashi and Ryukichi Matsuo, “Chemical and enzymatic pulping of the decorticated pineapple leaf fibre and some physical properties of its paper, *Cellulose Chem. Tech.,* **11 :** 487-99.

Yusri Yusof, Siti Asia Yahya and Anbia Adam, 2014. *Jour. Adv. Agri. Tech.* **1 :** 161-64.

Contd. pp. 6

Extra long staple diploid cotton (G.*arboreum*): Retrospect, present status and strategies

Pradesh) Karangani 2 and Karangani 5 (Tamilnadu) fo *G. arboreum* and Dharwad 1, Dharwad 2 (Karnataka), Wagad 5, Digvijay (Gujarat) of *G. herbaceum* (Deshpande *et al.,* 2004) .

Efforts were made to improve the yield potential and to some extent fibre properties and ginning outturn of these diploids by adopting conventional breeding methods. This has resulted into upgrading yield potential from 300 to 700 kg/ha, ginning outturn from 32 to 40 per cent, fibre length from 19.0 to 23 mm and spinning potential from 10^s to 20^s count. This mainly includes the varieties like PA 32, AKH-4, Y 1 (Maharashtra), CJ-73 (Gujarat), Karangani-1 (TamilNadu), Veena (Andhra Pradesh) of *arboreum* and Vijay, Digvijay (Karnataka), BD 8 (Gujarat) of *G. herbaceum.* The north zone *arboreum* were and are still inferior having fibre length ranging from 15 to 19 mm and spinnable for 0 to 10^s count.

Fibre qualities of all these varieties were still inferior compared with tetraploid American cotton. Therefore, concentrated efforts were continued by the breeders to improve the yield and fibre quality parameters of diploid cotton till that period, main competition for diploid cotton was straight varieties of American Cotton. Inspite of this, the genetic potential of diploids still remain unexploited suggesting formulating strong breeding strategies for its genetic enhancement to avoid further erosion of this species having tolerance to biotic and abiotic stresses for the benefit of farmers of India. Later on, again with the introduction of *intra hirsutum* hybrid cotton in India by Dr. C.T. Patel during 1970, the competition of diploid cotton survival was became more challengeable.

Development and release of long staple varieties of *desi* cotton (1993 to 2003) : Strenuous efforts was made by Indian cotton breeder particularly at Parbhani (Maharashtra), Surat (Gujarat), Khandawa (Madhya Pradesh) and Mudhol (Andhra Pradesh) to improve the productivity and fibre qualities of diploid cotton (*G. arboreum*) bring them to the level of tetraploid cotton during the year 1993-2003. These efforts resulted in the development of G. *arboreum* varieties like PA 255, PA 402 (from Maharashtra); MDL 2463 (from Andhra Pradesh) and DLSA 17 (from Karnataka) having high productivity and superior fibre qualities at par with tetraploid cotton. The yield potential of these varieties is upto 1400 kg/ha, fibre length ranged

Table 5. Fibre properties of qualities *arboreums* in comparison with varieties of *hirsutum* cotton

Strain	Ginning outturn (%)	2.5 per cent span length (mm)	Fibre strength (g/tex)	Micro-naire	Unifo-rmity ratio (%)	Elon-gat-ion (%)
PA 402	37.0	25.3	21.1	4.65	48	6.2
MDL 2463	37.3	26.5	22.8	4.20	48	5.9
DLSA 17	36.3	26.3	22.4	4.70	49	5.5
PA 255	36.9	27.4	21.5	4.50	48	5.5
Checks						
LAC	35.1	26.4	21.7	4.60	49	5.9
LHC	38.0	25.7	20.1	3.75	47	5.5
LHHC	34.2	27.1	22.0	3.85	48	6.1
Bunny	36.3	28.7	22.3	3.75	44	5.7

from 26-28 mm, ginning outturn form 37 to 38 percent and spinning potential upto 30[s] count. Yield and fibre parameters of these varieties are presented in Table 4 and Table 5 respectively.

As a result of releasing four quality *arboreums viz.,* PA 255, PA 402, MDL 2463 and DLSA 17 under network Project NATP (RCPS-7) and Technology Mission on Cotton (MM 1.2), the further erosion of diploid species were ceased and slowly hope of ray was bloomed for increasing area under diploid cotton. During 2003 onwards, such type of quality material was available in the market to compete with *hirsutum* varieties/ hybrids to some extent. All these newly developed quality *arboreum* varieties were suitable for modern textile industries. At this critical juncture, *Bt* cotton technology was introduced in the country during 2002, and this was the

Table 6. Performance of PA 528 in various trials conducted during 2007-2008 to 2012-2013 in central zone

Particular	Year of testing	No. of trails	PA 528	PA 255 (Check)	PA 402 (Check)	NH 615 (Check)	PHH 316/ NHH 44 (Check)
Preliminary Station trial	2007-2008	1	1344	1101	1041	1169	1047
Advance Multilocation varietal trail	2009-2010 to 2012-2013	15	1437	1219	1183	1159	1185
State Multilocation varietal trial	2009-2010 to 2011-2012	9	1459	1286	1284	-	-
TMC trials	2008-2009 to 2011-2012	4	1806	1530	1487	1397	-
AICCIP Project trials	2007-2008 to 2008-2009	3	1576	-	1628	-	-
Weighted mean	**32**	**1499**	**1278**	**1286**	**1207**	**1174**	
Per cent increase over		**-**	**17.29**	**16.56**	**24.19**	**27.68**	

Table 7. Summary data of PA 08 in different trials conducted during 2003-2004 to 2011-2012 in Marathwada region

Particular	Year of testing	No. of trails	PA 08	PA 255 (Check)	PA 402 (Check)	Check PH 368/ NH 615	PHH 316/ NHH 44 (Check)
Preliminary station trials	2004-2005 to 2005-2006	2	1433	1271	1120	-	-
Advance multilocation varietal trial	2006-2007 to 2011-2012	18	1331	1190	1181	1146	1117
State multilocation varietal trials	2008-2009 to 2009-2010	6	1543	1374	1386	-	-
NATP / TMC trials	2003-2004 to 2007-2008	4	1573	1244	1237	1184	-
AICCIP project trials	2006-2007 to 2008-2009	6	1533	-	1312	-	-
Weighted Mean	**36**	**1435**	**1236**	**1240**	**1151**	**1117**	
Per cent increase over		**-**	**16.10**	**15.72**	**24.67**	**28.46**	

Table 8. Fibre and full spinning report of PA 528 in comparison with PA 402 received along with oil content (%)

Particular	PA 528	PA 402
2.5 per cent span length (mm)	26.3	24.9
Uniformity ration	49	49
Micronaire	4.8	5.1
Fibre strength (g/tex)	18.4	19.4
Elongation (%)	4.9	4.9
Maturity (%)	83	82
CSP count	1989	1998
Neps / km	638	506
Oil content (%)	18.98	17.30

main setback for *Desi* cotton. This shock was still continued and at present area under diploid cotton was completely wiped out and ceased to the extent of 2 to 3 per cent only.

Breeding strategies for increasing fibre properties of *Desi* cotton (2004-2005 to 2015-2016)

I. Conventional breeding : Conventional breeding methods *viz.,* introduction, selection, hybridization followed by pedigree method, backcross method and multiple crossing are not sufficient and efficient. Adoption of non conventional approaches like introgession and aid of biotechnological techniques for development of transgenic cotton is needed for *hirsutisation* of diploid cotton.

The conventional breeding approaches helped in improving spinning potential of diploid cotton from 10^s to 30^s count (Qureshi and Rao, 1973; Niles, 1980; Rao *et al.,* 2004; Khadi *et al.,* 2004). For further uplifting of spinning potential above 40^s count, improvement in fibre strength along with fibre length and micronaire suitable for high speed spinning is prime requirement to fulfil present demand of modern textile industries. It is therefore necessary to bread the *Desi* cotton varieties having superior fibre length (26-30 mm), high fibre strength (25-30 gm/tex) and fine micronaire (3.82 to 4.0).

During last three decades most of the research centres practically neglected their focus of research from diploid cotton. However, concentrated efforts were continued at Parbhani centre which was established during 1918 exclusively for the improvement of *Desi* cotton with a main objective of genetic improvement of *desi* cotton by adopting conventional and introgression breeding work (Deshpande *et. al.*, 2001, 2004(a) ,2004 (b) and 2007; Ansingkar and Pawar 1992).

As a result of exhaustive testing of more than eighty breeding trials during 2004 to 2013, two quality *arboreum* varieties of *Desi* cotton has been released for commercial cultivation in the state of Maharashtra. As a result of exhaustive testing's for more than ten years, two long linted varieties of G. *arboreum viz.*, PA 08 and PA 528 were released for commercial cultivation for Maharashtra state by Vasantrao Naik

Table 9. Fibre and full spinning report of PA 08 in comparison with PA 402 received along with oil and gossypol content (%).

Particular	PA 08	PA 402
2.5 per cent span length (mm)	26.9	27.0
Uniformity ration	50	51
Micronaire	4.4	5.4
Fibre strength (g/tex)	22.9	20.6
Elongation (%)	5.6	5.4
Maturity (%)	83	82
CSP count	2217	2052
Neps / km	393	423
Oil content (%)	21.17	19.20
Gossypol content in seed	0.7484	2.1432

Standard CSP for 30s count: 2116

Table 10. Performance of newly developed quality *arboreums* having high yield coupled with superior fibre qualities

Name of strain	Seed cotton yield (kg/ha)					**Mean**	Per cent increase over				Mean GOT (%)	Mean staple length (mm)	Fibre parameters (HVI mode)		
	2012-2013 (03)*	2013-2014 (04)	2014-2015 (3)	2015-2016 (02)	2016-2017 (04)		PA 402	PA 08	NH 615	NHH 206			UHML (mm)	Mic (µg/inch)	Str (g/tex)
PA 740	1195	1859	1253	1150	-	**1423**	24.39	21.05	37.19	29.20	36.01	28.10	**27.8**	**4.85**	**26.8**
PA 741	1192	1546	1226	-	-	**1344**	17.44	14.29	29.52	21.98	33.41	27.15	-	-	-
PA 785	1096	1765	1302	1032	-	**1360**	18.84	15.65	31.07	23.43	36.35	28.00	-	-	-
PA 809	-	-	1381	1020	862	**1140**	-0.34	-3.02	9.91	3.51	35.03	27.93	33.7	4.1	29.6
PA 810	-	-	-	-	890	**890**	-22.22	-24.31	-14.22	-19.22	36.06	29.10	32.7	4.1	29.4
PA 812	-	-	1426	1126	1014	**1176**	2.79	0.03	13.37	6.77	35.48	14.40	32.2	4.8	29.7
PA 835	-	-	-	-	960	**960**	-16.10	-18.35	-7.47	-12.86	37.83	-	32.5	4.9	27.8
PAIG 380	-	-	-	-	895	**895**	-21.78	-23.88	-13.73	-18.76	37.51	-	33.1	4.3	31.6
Checks															
PA 402	1054	1393	1314	1060	878	**1144**	-	-	-	-	36.76	25.93	27.2	5.1	28.5
PA 08	1062	1541	1085	1152	976	**1176**	-	-	-	-	36.29	26.85	30.5	4.9	28.9
NH 615	884	1318	926	1041	954	**1038**	-	-	-	-	37.90	28.08	29.5	4.1	27.5
NHH 206	-	1388	982	1030	941	**1102**	-	-	-	-	38.56	27.25	29.1	4.1	27.2

Number of locations

Marathwada Krishi Vidyapeeth, Parbhani during 2012 and 2013, respectively. On the basis of mean of 32 trials conducted across Marathwada region, the strain PA 528 recorded 16 and 17 per cent higher seed cotton yield over check PA 402 and PA 255, respectively, whereas, on an average of 36 trials conducted across Marathwada region, the variety PA 08 recorded 16 and 15 per cent higher seed cotton yield over checks, PA 255 and PA 402, respectively (Table 6 and 7). The fibre properties of PA 528 and PA 08 in comparison with local check, PA 402 are presented in Table 8 and 9.

II Introgression breeding : Earlier, the interspecific hybridization was mostly adopted for overall genetic improvement and to transfer insect, pest and disease resistance of diploid G. *arboreum* into tetraploid *G. hirsutum* (Ganeshan 1947, Meyer, 1952, Stewart, 1995). Attempts to introgress favorable traits like big boll size and fibre length of cultivated tetraploid *G. hirsutum* into cultivated diploid *G. arboreum* were limited. Such introgression breeding has been underway at Parbhani (Deshpande *et al.*, 1992 and Deshpande and Baig., 2002), Dharwad (Kulkarni *et al.*, 2002, 2003) and at China. With a view to

Table 11. Performance of Extra Long Staple cultures of G. *arboreum* developed through conventional /introgression breeding method.

Name of entry	Fibre parameters (HVI Mode)								
	UHML (mm)			Mic (µg/inch)			Tenacity 3.2 mm (g/tex)		
	2015	2016	**Mean**	2015	2016	**Mean**	2015	2016	**Mean**
Conventional culture									
PA 801	-	30.7	**30.7**	-	5.0	**5.00**	-	29.6	**29.60**
PA 805	-	30.0	**30.0**	-	4.8	**4.80**	-	31.2	**31.20**
PA 806	30.9	-	**30.9**	4.3	-	**4.30**	24.3	-	**24.30**
PA 808	30.1	32.0	**31.05**	5.0	4.7	**4.85**	29.7	34.1	**31.90**
PA 809	32.4	33.7	**33.05**	4.3	4.1	**4.20**	31.6	29.6	**30.60**
PA 810	34.4	32.7	**33.55**	5.0	4.1	**4.55**	24.9	29.4	**27.15**
PA 811	-	31.5	**31.50**	-	4.6	**4.60**	-	25.8	**25.80**
PA 812	30.8	32.2	**31.50**	4.7	4.8	**4.75**	25.3	29.7	**27.50**
PA833	30.0	-	**30.00**	5.0		**5.00**	26.9	-	**26.90**
PA 835	32.0	32.5	**32.25**	5.1	4.9	**5.00**	28.0	29.8	**28.90**
PA 837	31.0	30.7	**30.85**	5.1	4.8	**4.95**	26.3	29.3	**27.80**
PA 838	30.2	30.0	**30.10**	4.9	5.0	**4.95**	23.6	25.1	**24.35**
PA 839	31.2	33.0	**32.10**	4.2	4.5	**4.35**	24.6	28.3	**26.45**
PA 840	-	32.2	**32.20**	-	5.5	**5.50**	-	23.2	**23.20**
PA 841	-	30.2	**30.20**	-	4.6	**4.60**	-	27.6	**27.60**
PA 847	-	31.3	**31.30**	-	4.6	**4.60**	-	4.6	**28.80**
Introgressed cultures									
PAIG 375	30.7	29.3	**30.00**	5.0	4.3	**4.65**	27.3	24.4	**25.85**
PAIG 377	30.9	32.1	**31.50**	4.9	4.3	**4.60**	24.8	28.2	**26.50**
PAIG 378	32.4	29.4	**30.90**	4.7	4.6	**4.65**	29.1	26.7	**27.90**
PAIG 379	31.0	30.6	**30.80**	4.6	4.4	**4.50**	23.7	25.1	**24.40**
PAIG 380	30.7	33.1	**31.90**	5.1	4.3	**4.70**	26.9	31.6	**29.25**
PAIG 381	30.8	-	**30.80**	4.7	-	**4.70**	23.1	-	**23.10**

bring this G.*arboreum* species *at par* with tetraploid *hirsutums* for productivity and fibre qualities, It was thought to adopt interspecific hybridization for introgressing favorable traits like big boll size and fibre properties of *G. hirsutum* into *G.arboreum.*

Methodology adopted for introgression : The introgression work was initiated at Parbhani during 1990 .Owing to limitations at ploidy level for interspcecific transfer of quality traits from *G. hirsutum* (2n=52) in *G.arboreum* (2n=26), polyploidy was induced in *G. arboreum* variety PA 85/85 by colchicine treatment. The 4n *arboreum* (autotetraploid) so obtained was then crossed with G. *hirsutum* variety NH 239 to produce interspecific F_1 having 2n=4x=52 chromosome. The ovary of interspecific F_1 was abortive. The fertile pollen source (27.67%) from this interspecific F_1 was used for further introgression of favourable genes of G. *hirusutum* into G. *arboreum*. The interspecific F_1 was backcrossed with original autotetraploid 4n *arboreum* to produce fertile backcross F_1 of 4n *arboreum* x interspecific F_1 (4n *arboreum* x G.*hirusutum).* From segregating population of this backcross F_1's more than 250 introgressed lines having big boll size (3.0 to 3.5 gm) superior fibre length (25 to 30 mm) and high fibre strength (22 g/tex to 28 g/tex) have been identified.

The *inter se* mating amongst the transgressive seggregants having big boll size and high fibre qualities derived from introgressed material may help in further improvement of both diploid species. Thus, the introgression through interspecific hybridization helped in creating tremendous unexpected potential variability which can be tapped by Indian cotton breeders for genetic improvement of the species in question.

The first introgressed variety PA 402 (Vinayak) was released for commercial cultivation in Maharashtra during 2003 (Deshpande *et al.,* 2004c). The newly developed extra long staple culture PAIG 380 from introgressed population may be evaluated for yield and fibre quality parameters on multi-locations and may be used as a source in breeding program particularly for improvement of fibre quality parameters.

Discovery of extra long staple *arboreums* coupled with high yield at Parbhani (2015-2016 to 2016-2017) : The process of selection of *Desi*rable seggregants specially superior fibre length is still continued at Vasantrao Naik Marathwada Agricultural University, Parbhani. During 2015-2016 to 2016-2017, more than 300 strains were tested for yield and fibre quality parameters at Parbhani and Nanded. The *Desi* cotton variety PA 740 has been released specifically for excellent fibre qualities coupled with high yield for south zone under AICCIP. The details of yield and fibre quality parameters are presented in table 10. Five strains *viz.,* PA 809, PA 810, PA 812, PA 835 and PAIG 380 recorded excellent fibre properties (UHML 32.2 to 33.7 mm, Mic , 4.1 to 4.9 ug/inch and strength, 27.8 to 31.6 g/tex) (Table 11). Similarly, fibre quality parameters of newly developed cultures having extra long staple coupled with fine micronaire and high strength are presented in Table 11, in which twenty two strains recorded more than 30.0 UHML (mm). On an average of two years, two strains *viz.*, PA

809 and PA 810 recorded more than 33.0 mm UHML, fine micronaire (4.2 to 4.5 ug/inch) and excellent fibre strength (above 29 g/tex).

During 1950's, the staple length of local varieties *viz.,* Bani, Gaorani 6, Gaorani 12, Daulat was in the range of 20.0 to 21.5 mm (Table 3.). Therefore, it will take nearly 100 years to increase staple length of *Desi* cotton (G.*arboreum* L.) from 20-21 mm during 1918 to 32-33 mm during 2016-17, this clearly indicates that nearly one decade is required to increase one mm in fibre quality of *desi* cotton apart from genetic improvement in yield, ginning outturn, duration and resistance for pests and diseases. This is a classical example of breeding work done by cotton breeders exclusively through conventional breeding in India.

This is the beginning of new era of extra long staple *desi* cotton, which was the dream of cotton breeders. These extra long staple cultures may play important role in developing *desi* cotton brand of the country. There is strong need for advocating proper agronomical recommendation along with pest and disease control measures to spread these cultures on large scale and replace area under tetraploid transgenic cotton at least to the extent of 20-25 per cent to maintain proper species balance for sustainability of cotton cultivators, otherwise in coming years these diploid species will become part of museum.

Promotion of *desi* cotton varieties to ensure profitability and sustainability in Indian cotton production systems : *Desi* cotton species *Gossypium arboreum* originated in India and is being cultivated over thousands of years in the country.

Advantages with *desi* varieties:

1. Tolerant to drought and water logging
2. Tolerant to insect pests, diseases and immune to the leaf curl virus
3. Highly suitable for *rainfed* conditions especially for light, marginal and saline soils.
4. Ideal to combat effects of climate change
5. Requires less fertilizer and least chemical interventions.
6. Highly suitable for organic cultivation systems.
7. Low cost of production for sustainable yields.
8. Endowed with excellent ginning percentage of about 38 to 40 per cent.in comparison to 32-33 per cent with American cotton hybrids.
9. *Desi* varieties produce fibres of high maturity and least fibre neps.
10. Fabric made from *desi* varieties gives higher values for dye uptake and air permeability.

Disadvantages of *desi* cotton :

- Smaller boll size and lack of compact bolls resulting in cotton shedding.
- Tall and lanky plant type with more number of monopodia particularly in *herbaceums.*
- Late in maturity (180-210 days) particularly *herbaceums.*
- Non-availability of CMS source for cheap hybrid seed production.
- Non availability of long linted CMS lines.
- Small and delicate flower structure difficult for hybrid seed production by conventional methods.

Alternative strategies to mitigate the existing uncertainty with the declining efficacy of the *Bt* cotton hybrids on the pink bollworm and the American bollworm. Currently India's cotton area is saturated with the *Bt* cotton hybrids which need irrigation and intensive use of fertilizers and chemical pesticides to obtain higher yields. Majority of the *Bt* cotton hybrids are susceptible to drought, water logging, saline soils, sucking pests, cotton leaf curl virus disease and several other biotic stress factors. These factors make the current production systems unsustainable because of high production cost and intensive chemical interventions which cause serious harm to ecology and environment.

In view of the above predicament, the following strategies are suggested for consideration:

1. Varieties of *desi* cotton shall be promoted in the country to ensure high yields with low cost of production and least chemical intervention.
2. *Desi* cotton varieties with superior long staple fibre qualities of 27 to 32 mm suitable for high speed machines of the modern textile industry shall be tested in multi-location field trials across the country to assess their suitability to various ecological conditions. Notified varieties with superior fibre staple length of more than 27 mm, such as G. Cot. Hy DH 9 (fibre length of 31 mm); Pha 46 (29 mm) Parbhani Turab (28 mm); K-11 (28 mm); DLSA 17 (27.5 mm); PA 183 (27mm); ADB 332(27mm); PA 402 (27mm); NA 48 (27) and Phule JLA 794 (27 mm) may be tested for advanced agronomical trials particularly for spacing and fertilizer dose.
3. *Desi* cotton varieties of short and medium staple fibre shall be promoted through subsidized seed production and seed availability.
4. Efforts shall be intensified to develop *desi* cotton based organic cotton cultivation systems for different agro-ecological zones in the country.
5. Minimum support price shall be determined separately for *desi* cotton fibres of short, medium and long staple properties to encourage their use. The support price may be fixed appropriately in excess of the MSP of corresponding staple length categories of the American cotton species and also additionally include a separate premium price for higher ginning percentage.
6. Promotional efforts shall be taken up by extension agencies in all cotton growing regions of the country to highlight the advantages of *desi* cotton through field demonstrations and advertisements.
7. A special scheme on *desi* cotton procurement may be launched by the Cotton Corporation of India.
8. The textile industry to launch a special drive on 'Make in India; specialty fabric made from *desi* cotton fibres.
9. National campaigns shall be launched to promote products such as 'surgical cotton, absorbent cotton, denims and technical textiles made from short staple non-spinnable *desi* cotton fibres.
10. Biodiversity of *desi* cotton germplasm shall be legally protected through Geographical Indicators, PPV-FRA and other registration processes.

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REFERENCES

Anonymous 1961 . Central *arboreum* cotton in India – A monograph. Indian Central Cotton Committee Publication Bombay. 161 p.

Anonymous 2016. *"Annual Report"*- All India Coordinated Research Project on Cotton- 2016-17.

Ansigkar A.S. and Pawar K.P. 1992. Retrospect and prospect of *desi* cotton for productivity in relation with hybrids in Maharashtra in : *Proceedings of the first Vasantrao Naik Memirial National Seminar on 'Cotton Development'* -5-6 Dec., Nagpur

Deshpande L. A. , Kokate R.M., Kulkarni U.G. and Nerkar Y.S. 1992. Cytomorphological studies in induced tetraploid *G. arboreum* x *G. hirsutum* L. *Proceedings of the first Vasantrao Naik Memirial National Seminar on 'Cotton Development'* -5-6 Dec., Nagpur. pp 38-47

Deshpande L.A., Narula A.M. and Baig K.S. 2001. Can newly developed quality *desi* cotton (G. arboreum) substitute *hirsutum*? In proc. Sustainable cotton production to meet the future requirement of industry by DOCD. Mumbai. India. October, 3-4,2001 pp 55-74.

Deshpande, L. A. And Baig K. S. 2002. Interspecific transfer of favourable genes from *G. hirsutum* into *G. arboreum* and cytomorphological studies of introgressed genotypes. *In Proc. Of 12th Australian plant Breedig conference held at Pearth, Auatralia* on 17th to 20th September, 2002.

Deshpande L. A., Baig K.S.,Kulkarni V.N.,Matishchandra and Kakde S.S. 2004 a. Strategies to improve cultivated diploid- Perspective. International Symposium on *'Strategies for sustainable cotton production-A global vision' 1 Crop Improvement* ,23-25 November, 2004.University of Agricultural Sciences, Dharwad, Karnataka (India), pp 25-30.

Deshpande L. A., Baig K.S. and Kakade S.S. 2004 b. Development of quality diploid cotton varieties in India and their role in sustainable cotton production. Lead papers of National Symposium on *'Changing World Order-cotton Research, Development and Policy in Context' at Acharya N.G. Ranga Agricultural University, Hyderabad*, August 10-12, 2004.pp 32-39.

Deshpande L.A., Baig, K. S., Kulkarni V.N., Kakde S.S. and Matishchandra. 2004 c . PA 402 (Vinayak)- First introgressed *G. arboreum desi* cotton cultivar bred and released in India. *In Intrenational Sypmosium on 'Strategies for Sustainable cotton Production- A Global Vision" I Crop Improvement*, 23-25, Nove. 2004, University of Agricultural Sciences, Dharwad, Karnataka (India). pp 310-13.

Deshpande L.A., Baig K. S., Kulkarni P.J. and Pole S.P. 2007. Quality *desi* Cottons (*G. arboreum*) : Better substitute for American Cottons (*G. hirsutum*) cotton in Andhra Pradesh. Acharya N. G. Ranga Agricultural University, Hyderabad. Pp 125-36.

Hutchinson J.B., Silow R.A. and Stephens S.G. 1947. The evolution of *Gosspium*. Oxford Univ. Press. London.New York.

Ganeshan D. 1947. Interspecific hybridization in Cotton. *In Proc. Third conference on cotton growing problems in India (ICCC).* pp. 80-86.

Khadi B.M., Kulkarni,V.N., Katagari, L.S. and Mahantashivayogayya K. 2004. Development of cotton hybrids in India and their role in increasing cotton production. *In : Chauhan M.S. and Saini R.K. Eds. Book of papers of National Symposium on changing world order Cotton Research Development and Policy- In context held on* 10-12 August, 2004. Pp 40-48.

Kranthi K. R. 2016. Historical perspective of Indigenous cotton. *National workshop on Indigenous (Desi) Cotton in India,* 28-30, November,2016, Nagpur, India. pp 5

Kulkarni V.N. , Khadi B.M. and Sangam V.S. 2002. Pre breeding efforts for low gossypol seed and high gossypol plan in *G. herbaceum* L. Cotton utilising *G. austral* Mueller. *Curr. Sci.* **82 :** 434-39.

Kulkarni V.N. , Khadi B.M., Deshpande L.A. and Srinivasas 2003. *Hirsutization* of cultivated diplod cotton. *Abstracts of 3rd world cotton conference.* Cape Town, South Africa 2003, 9-13 March, C 29-3.

Meyer, J.R. 1952. Species, the raw material for future cotton. Missi Agril. Expt. Station.,pp. 172.

Niles G.A. 1980. Plant breeding and improvement of cotton plant. Out look on Agriculture.**10**: 152-58

Qureshi, M.R.H. and Rao, N.G.P. 1973. Breeding gaorani cottons (G. *arboreum* race *indicum*) of a new plant architecture, larger yield and superior fibre attributes, *Indian J. Genet.* **34 A** : 849-59

Rao, N.G.P., Deshpande, L.A. and Khadi, B.M. 2004. Improvement of Asiatic Cottons in India. *International Cotton Genome Initiative, ICGI 2004 workshop.* Souvenir pp. 48-53.

Sikka S.M., Arjan Singh, Avtar Singh, Gadkari P.D.,R. Balsubramanyam, Iyengar N.K., Sawhney K., Bedarkar V.K., Patel G.B., Pandya P.S., Paranjpe V.N. and Panigrahi N.S. 1961. Cotton In India- A Monograph, Indian Central Cotton Committee, Bombay.

Stewart, J.M.C.D. 1995 . Potential for crop improvement with exotic germplasm and genetic engineering. In Challenging the future. *Proc. World cotton research conf.* I. Brisbane, Australia. February 14-17, 1994. pp. 313-27.

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