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PREFACE

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 thirteen 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.

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 worldwide 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.

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 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 research papers included in the **"Book of Oral Presentations"** are related to **"Crop Improvement, Biotechnology and Post Harvest Technology", "Crop Production, Mechanization and Economic Development" and "Crop Protection and Biosafety"** which were the theme areas of the symposium. Present compilation on **"Future Technologies : Indian Cotton in the Next Decade"** is a compendium of holistic advancements and other relevant information related to cotton covering different disciplines. We hope that the information contained in this "Book of Papers" 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 for 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, 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 farmers.

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Book of Oral Presentations on "Future Technologies : Indian Cotton in the Next Decade"

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Cotton in Gujarat - A review

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Cotton has been the king of apparel fibre. It has played a vital role in the history of mankind and civilization. Due to its importance in agricultural as well as industrial economy, it is also called as "white gold".

Inspite the incoming of synthetic fibres, cotton still holds an outstanding position. It is a chief cash crop in several parts of the country and plays a vital role in national economy. Gujarat is one of the main cotton producing states in India. It covers about 25 lakh hectares area under cotton, producing 100 lakh bales of lint, about 34 lakh tonnes of cotton seed and 60-65 lakh tonnes of stalks aggregately valued at about 16000-18000 crores of rupees. On the national basis, the state contributes about 39 per cent of the total cotton produced in the country from 26 per cent of the area under cotton. The average yield of lint/ha in the state was 609 kg against 485 kg of the country in the year 2008-2009.

History and development of the crop : The exact period when cotton fibre was used first is not known. Archaeological excavations of about 300 BC in Indus river valley and *Riguweda* hymns written about 15 centuries BC revealed use of cotton fibre. Marco Polo mentioned the cultivation of tree cotton in Gujarat in about 1290 AD. Cotton has been grown in this country since time immemorial and history, recorded and unrecorded, bears witness to the claim that this fibre is indigenous to this country, particularly the Asiatic types *G. arboreum* and *G. herbaceum*. However, attempts to put cotton growing on a scientific basis and introduce the New World species, *G. hirsutum* into this country date back to the middle of the eighteenth century. The area, now forming the State of Gujarat, figured prominently in these early attempts at the introduction of American Cotton, but repeated trials at Surat and Bharuch, however, failed to yield encouraging results. Nevertheless, efforts at selection of improved strains from the existing mixture were pursued with vigour in the state and in course of time, Fletcher made a real breakthrough with the isolation of the famous strain, 1027 ALF from a cross between Kumpta and Goghari, suitable for cultivation in the Surti tract. In 1919-20 an area of about 6000 acres in Gujarat tract was sown with the selection 1A and this could fetch a premium of ' 22 to 75 per candy over the Surat cotton. The establishment of the Indian Central Cotton Committee in 1921 gave the much needed impetus to cotton work in the state. As a result of the work carried out here for the control of bollworm, an effective plant puller was designed and employed for uprooting cotton plants at the end of the season to minimize over wintering of the pest. The first textile mill in Gujarat was set up in Bharuch in 1843, providing further fillip to cotton cultivation in the state.

The soils, suitable for cotton cultivation in Gujarat vary from the sandy soils of Kutch and the alluvial soils of Ahmedabad and Kheda districts to the black cotton soils of Central and Southern Saurashtra regions. The rainfall is moderate (50 to 125 cm) and the maximum temperature during the growth period may lie between 38° to 41°C.

Gujarat has long been known for the fine *G. herbaceum* cotton, it had been growing from the days of yore. The famous muslins of ancient India, probably, owed their origin to these types of cottons. The cottons known as Oomras to the trade included *G. arboreum* cottons or bengalense or indicum origin grown in the Mathio tract of Gujarat, possessing coarse loamy soils, called "gorat". These are grown in June-July and harvested in the months of October to December. The earlier cotton of this region, known as Mathio (due to resemblance of its leaves to those of math, (*Phaseolus aconitifolius*) was, in fact, the Khandesh Jadi Mixture. This along with the *G. herbaceum* cotton Wagad used to be called Dholleras by the trade, after the name of the port in Kathiawar through which it was shipped. A scheme for the improvement of the Mathio cotton was initiated at Amreli in 1937. Trials were laid out with early strains of Wagad (*G. herbaceum*) and some improved *G. arboreum* strains like N. Roseum, Jarilla, Benilla, Verum and Cawnpore 520. Of these, Cawnpore 520 was found suitable and distributed for cultivation in 1942. Further, selection work in the local material led to the release of variety, Pratap in 1945. This possessed a better ginning outcome, fibre length and spinning capacity, than the local cotton under cultivation. Simultaneously, work on crosses of Cawnpore 520 with Jarilla and Pratap as well as those of Pratap with the Madras, *G. arboreum* Karunganni was in progress and this eventually resulted in the isolation of CJ 73 from the cross, Crawnpore 520 x Jarilla and this, which proved superior to Pratap, was released for general cultivation in the region in 1958-59 under the popular name, Sanjay.

The early *G. herbaceum* cottons grown in the state were Wagad, Bharuch and Surat. These were grown under rainfed conditions in the black soils, alluvial soil or red laterites. The sowing was done in June to August and the crop harvested in the months of January to March. Lalio cotton of North Gujarat and South Kathiawar used to suffer from frost attack often due to late maturity. A solution to this problem resulted from the introduction of the early maturing (hence frost escaping) Mathio (*G. arboreum*) cotton in South Kathiawar, and the closed boll type Wagad and some improved Bharuch types in North Gujarat. Similarly, Goghari, a high ginning poor quality G. herbaceum cotton of Middle Gujarat was also replaced by name improved Broach type.

The early *G. herbaceum* cottons grown in the state were Wagad, Bharuch and Surati locals. These were grown under rainfed conditions in the black soils, alluvial soil and red laterites. The sowing was done in June to August and harvested in the months of January to March. Lalio cotton of North Gujarat and South Kathiawar used to suffer from frost attack often due to late maturity. A solution to this problem resulted from the introduction of the early maturing (hence frost escaping) Mathio (*G. arboreum*) cotton in South Kathiawar and the closed boll type Wagad and some improved Bharuch types in North Gujarat. Similarly, goghari, a high ginning, poor quality *G. herbaceum* cotton of Middle Gujarat was also replaced by some improved Bharuch types.

The earliest cotton of South Gujarat was Surti local (also called Surti- Bhroach). Work on the improvement of G. herbaceum cottons was being pursued at the Government Agricultural Research Station at Surat, established long back in 1896. I A Long Boll, released in 1919 which succeeded Surti Local, was a selection from the same, possessing four per cent higher ginning percentage. This in time, yielded place to 1027 ALF evolved at Kirkee Farm from a cross between Goghari and Kumpta made in 1901. This cotton which was released in 1923 displayed a higher length and fineness, but suffered from a lower ginning percentage. This was corrected by backcrossing 1027 ALF with the higher ginning per cent, 1A Long Boll, and a new variety Suyog resulted. This variety, released in 1945, however, was found to be late maturing and susceptible to wilt attack as well as drought conditions. Then followed Vijalpa, in 1951, combining a higher yield, earliness, and wilt resistance, and Sujay (3943), a dwarf, high yielding variety from the cross (RF. Dwarf x 2334) in 1971.

Cotton improvement work started in earnest at Bharuch (Middle Gujarat) with the establishment of a Research Centre there in 1926. The variety BD 8 was given out in 1936. As a result of intensive work on hybridization with Comilla (*G. arboreum* race cernuum) and Wagale (*G. arboreum* race burmanicum) and Goghari selections, a variety named Vijay was evolved in 1943 from the cross, (BD 8 x Goghari A 2). Back crossed to BD 8. This variety, possessing wilt resistance, higher ginning percentage and better fibre quality found favour in the whole of Middle Gujarat and parts of South and North Gujarat. This was followed by the most popular variety, Digvijay released in 1956. Digvijay was evolved from the cross (Vijay x 1027 ALF) x Vijay. Then came G.Cot.11, a high yielding, early maturing variety evolved from the cross (3200 x EP 2) has been released in 1979. subsequently a high yielding early maturing variety G.Cot.17 evolved from the cross (1762 x Yerli 197-2) was released in 1995 for middle Gujarat cotton zone. This was totally replaced by G.Cot.23 released in 2000. This variety a cross of 625 BB x GBhv 41 became very popular not only in Middle Gujarat but in Wagad zone as well. Most recently a variety G.Cot.25 has been released in 2010 for whole Gujarat.

Another important cotton of Gujarat was Wagad, named after an area in Kutch in which probably it was grown first. This cotton, bearing indehiscent bolls, owes its origin to the perennial, closed-boll types of Baluchistan. As a result of selection in the local material carried out at the Cotton Research Station, Viramgam (established in 1922), the cotton Wagad 8 was isolated in 1933. This recorded an increase of 11 per cent in yield and 4 per cent in ginning percentage over the local, but had poor lint quality. Hybridization of Wagad 8 with 1027ALF and segregate 22-3-1-3 from Surat gave rise to the varieties Wagotar (in 1943) and Kalyan (in 1947). Crosses of Wagad with closed-boll types from Iran and USSR proved useless. Of the two mentioned above, Kalyan proved superior and more acceptable and this spread to the western part of the Wagad tract and Western part of North Gujarat. This was released for general cultivation in 1947. Further march in the direction improvement led to the evolution of V 797 from the cross (Kalyan x Vijay) x Kalyan. This was released for general cultivation in 1966 and found a congenial home in the medium black soils of Amadavad, Mehsana and Banaskantha as well as in Junagadh, Kutch and Surendranagar districts. This is extensively grown even today in Wagad region. To satisfy the demand of this area for open boll type, due to increased labour rates for shelling, a new variety G.Cot.13, evolved from the cross (Kalyan x 1802) had been released in 1981, followed by G.Cot.21 in 1998 which made increase in wide area in the state. Most recently a semi open variety Anand *desi* cotton 1 has been accepted for release due to bigger bolls and earliness.

Due to the textile revolution in Great

Britain, the then East India Company attempted to introduce American cotton for cultivation in India during the 18th century. This cotton was grown on experimental basis on cultivators' fields in Gujarat from 1797 to 1873 with no success. Hence, the major efforts were made to improve the indigenous cottons, particularly after the establishment of research station at Surat in 1896. However, the systematic research work on cotton was started in 1904 at the station for the first time in country. In addition to the improvement of indigenous cotton the attempts were made to combine the fibre quality of American cotton. *G.* hirsutum with the general adaptability of Asiatic cottons, *G. herbaceum* and *G. arboreum,* as the American cottons failed to adapt in Gujarat conditions. Systematic interspecific hybridization work was started in 1925 involving *G. arboreum, G. herbaceum* and *G. hirsutum* which was intensified in 1938 under the scheme for interspecific hybridization in cotton. The two economically successful varieties that resulted were 170-Co.2 (Deviraj) and 134-Co-2-M (Devitej). These were the commercial varieties, developed at Surat from crosses, involving Asiatic and American cottons and were released for cultivation in 1951-1952. Further work in this direction led to the evolution and release of the extra long staple strain Gujarat 67 in 1963. This replaced Devitej entirely and Deviraj partly. However, Deviraj continued to enjoy popularity with the cotton growers, because of its greater adaptability and resistance to moisture stress.

The entire research work has been strengthened from time to time particularly from 3rd FYP when work on various disciplines, particularly agronomy and plant protection besides breeding work was strengthened. Inception of All India Coordinated Cotton Improvement Project gave it a further boost.

In 1974, the new short branched, sympodial type, IAN 579(188) was released as G.Cot.100. However, these rapidly yielded place to the famous, hybrid Hybrid 4, blazing a new trail in cotton cultivation, that became the rage of the country. The cross (Co.2 x Tomentosum) repeatedly back-crossed to G. hirsutum, made and stabilized at Surat gave highly hairy "Cotom" types. One of such "Cotom" types was crossed with Indore 2 at Indore and the stabilized material from this gave CTI types. CTI types yielded the selection, KW 66-2096 at Indore/ Khandwa and from this the variety G.Cot.10 was isolated at Surat. This amazing variety released for general cultivation in 1974 has found a congenial home, not only in several other states in the country, but also neighbouring Burma. "Cotom" type has also given rise to the locally adopted variety "Khapatia" which has obtained recognization as G. Cot.12 (1981). This was followed by G.Cot.14 (1986) and G.Cot.18 for Saurashtra region. In the mean time a drought tolerant variety G.Cot.16(1995) was released for rainfed tract of Middle Gujarat. Most recently a high yielding variety G.Cot.20 (2008) has been released from Surat for irrigated areas of whole state.

Cotton research station, Surat has been a trail blazer for its reach achievement. Though intra and inter- specific hybrid variety development work has both in progress in the State since the advent of the second quarter of the century, real success came only in 1967-68, when Gujarat shot into world fame with the launching of the World's first commercial hybrid from Surat. Hybrid 4 (1971) is an intra hirsutum cross between the extra long staple variety, Gujarat-67 and American Nectariless, an exotic variety from U.S.A. This is truly remarkable cotton combining an extraordinary productivity with excellent quality. Its range of adaptability, too, is outstanding, leading to its finding favour with farmers, over more than half the country. This hybrid was landmark in the history of cotton and proved to be harbinger for other researchers in the country and abroad. This fired the imagination of the breeders elsewhere and several cotton hybrid followed in its wake.

An even more remarkable hybrid was the high yielding, early maturing G.Cot.Hy 6 released in 1980 which found favours from the growers beyond the borders of Gujarat from spinners across the country. An entirely new approach in cotton cultivation was introduced with the release of perennial budded cotton variety G.Cot.101 in 1977 for adivasi farmers in backward areas. A short duration early maturing hybrid G.Cot.Hy 8 suitable for double cropping and rainfed cultivation was released in 1988. Concurrent efforts illuminated in the release of first ever desi hybrid G.Cot.DH 7 in 1984 which had high yield potential, tolerance to pests and diseases coupled with earliness. This was another feather in the cap of this station. In fact it proved to be trend setter for desi hybrids in the country. In 1989, the first ever extra long staple desi cotton hybrid G.Cot.DH 9 was released. The pace of introduction of newer technologies and hybrid has constantly been on move. A short duration early maturing hybrid G.Cot.Hy 8 suitable for double cropping and rainfed cultivation was released in 1988 and was popular amongst farmers from Punjab to Pondicheri. Than a new intra hirsutum hybrid G.Cot.Hy 10 with high yield potential giving continuous flush was released in 1995. This was followed by a new versatile hybrid G.Cot.Hy 12 in 2005 suitable for both rainfed and irrigated condition. Efforts for developing ELS hybrid finally culminated with the release of G.Cot.102 in 2002. Simultaneously, the first GMS based intra arboreum hybrid G.Cot.MDH 11 was also released in 2002. Recently a new intra hirsutum hybrid G.Cot.Hy 10 with high yield potential giving continuous flash has been given to farmers for cultivation in 1995. The pace of introduction of newer technologies high yielding varieties and hybrids has constantly been on move. Some of the finest material with desired quality traits and tolerance to biotic and abiotic stress is in pipeline to see the light of the day. The result and impact is appealing. The average productivity in the state has touched 368 kg/ha despite only about 27% cotton area being irrigated in the state.

Since introduction of *Bt* cotton in India in 2002, upto 2012 there was a dominancy of private sector and in the *Bt* seed industry. But,, Navsari Agricultural University break the ice and introduced first public sector *Bt* hybrid *i.e.* G.Cot.Hy 6 (BG II) and G.Cot.Hy 8 (BG II) which was followed by G.Cot.Hy 10 (BG II) and G.Cot.Hy 12 (BG II) in 2015.

Future challenges : Due to introduction of Bt cotton and favourable season and crop condition since last ten years, Gujarat occupied the highest position in cotton production and productivity at National level. Due to *Bt era*, in some area the socio-economic level of cotton growers was boosted up. But, at the same time the threatening issues are emerging in cotton cultivation. Mealybug havoc after 3-4 years of *Bt* introduction in Gujarat was noticed and was tackled very well. Thereafter, pink boll worm(PBW) issue became headache for cotton researchers as well as growers. The state and central government compelled to address the issue. Besides this, illegal *Bt*, avoidance of refugee crop, abnormalities in cotton morphology are the major issues in cotton cultivation and in coming years there may possibilities of new unknown issues in cotton cultivation.

Resurgence of *desi* cotton – A status of past, present and future

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ABSTRACT : Cotton is a commercial crop used for its fibre in textile industries. Cotton belongs to the family Malvaceae, the genus name is *Gossypium*. Species of cotton broadly classified into old world cotton (diploid 2n=2x=26) and new world cotton (tetraploid2n=4x=52). Old world cotton consists of two distinct species namely *Gossypium arboreum* (*karunganni/ nadan* cotton) and *Gossypium herbaceum*(*uppam* cotton),these two species of diploid cotton broadly known as *desi* cotton (native species) or Asiatic cotton. After the American civil war, British government introduced the *Gossypium hirsutum* to India and other colonized countries to cater the need of textile industries of England. At the time of independence, *desi* cotton occupied 98 per cent area (2.79 mha of *arboreum* and 1.39mha of *herbaceum*) and American cotton shared only 2 per cent (0.14mha). During 2000 the area of *arboreum* reduced to 1.46mha and *herbaceum* to 0.95mha due to increase in area under hybrids (3.64mha) and *hirsutum* (2.48mha) cotton. Since the introduction of Bt cotton area under *desi* cotton has been reduced to less than 1 per cent. *Desi* cotton known for its ability to grow in marginal environment especially *herbaceum* prefers to grow in coastal region. *Desi* cotton possesses resistance to range of insect pests namely hoppers, white flies, thrips and aphids. *Desi* cotton almost exhibits immune to the vector borne leaf curl virus. Due to short, coarse and weak fiber traits make them unsuitable for modern machine textile industries. However during 17-18th century, *desi* cotton was being spun by handcrafters, the cloth was so fine *e.g.* Dhaka muslin (Dhaka *malmal*). Machine and electrospinning needs high strength fibre, this property lacks in *desi* cotton. In spite of poor fibre traits, these short stable cotton used for denim, upholstery and surgical cloths. Recent past the trend is reversing, the demand for short stable cotton is 2% however the production is 1%; this makes a lot of hope for increasing the area of *desi* cotton. Concentrated varietal improvement resulted in the release of long linted variety like PA-255 (Parbhani), DLSA 17 (Dharwad), MDL2463 (A.P) and Jawahar Tapti of arboreum cotton with fine fibre qualities created a hope to satisfy the requirements of textile industry. Recent havoc of whitefly and leaf curl incidence in *hirsutum* demands a hardy genotype; by the virtue of above facts the true resurgence of *desi* cotton is not far away.

Key words : *arboreum*, *desi* cotton, *herbaceum*

Mankind attained full civilization after started wearing the cloth; in particular cotton revolutionized a complete civilization by means of giving different products from lint to yarn. Since then Cotton has been known as cash crop mainly for its fibre values in textile industries. Cotton belongs to the family Malvaceae, the genus name is *Gossypium*. Species of cotton broadly classified into old world cotton (diploid 2n=2x=26) and new world cotton (tetraploid2n=4x=52). Old world cotton consists of two distinct species namely *Gossypium arboreum* (*karunganni/ nadan* cotton) and *Gossypium herbaceum*(*uppam* cotton),these two species of diploid cotton by and large known as *desi* cotton (native genotype) or Asiatic cotton.

Origin : Both *arboreum* and *herbaceum* species are the lineage of A genome, possible speciation occurred between these species leads to formation of A_1 genome (herbaceous) and A_2 (*arboreum*) species. Two hypothesis exists for speciation of *arboreum*;(i) domestication occurred separately between these two species in parallel and diverged as distinct species before human interference(Fryxell,1979)(ii) there is no ancestor for *arboreum*, it was believed that 5000 years back, *arboreum* was evolved from the existing *herbaceum*(Hutchinson,1959). Cytologically the specie *arboreum* differs from *herbaceum* by a reciprocal translocation (Gerstel and Sarvella,1956).

Genome size : All diploid species are believed to be originated from a common ancestor and divereged as eight different (A to K) species. However, *G. arboreum* (A_2) and *G. raimondii* (D_5) are the putative donor species for the A and D chromosome groups, respectively. *G. arboreum* (1,746 Mb/1C) has a genome size that is twice that of *G. raimondii* (Li *et al.,* 2014). Molecular analyses revealed that divergence of *G. arboreum* and *G. raimondii* from their common ancestor is approximately 2 - 13 million years ago, (Wikstrom *et al.,* 2001).

Races of *arboreum* : *Gossypium arboreum* grouped into five races namely *indicum, bengalense, cernum, burmanicum, sinense and soudanense*. Indus valley believed to be the site of origin though there is no clear cut ancestor of *arboreum* exists. *G. arboreum* species well spread across the Indian Subcontinent. Race *indicum* found in peninsular region of India (Andhra Pradesh and Tamil Nadu), high quality cotton crop as an annual and wild form also found in this region. Genetically race *indicum* is more closely related to *herbaceum* than other races of *arboreum*(Sillow,1944). Race *indicum* has been called as *Karunganni* in Tamil Nadu; *Gaorani* in Maharashtra, Karnataka and Andhra Pradesh, *Mathio* in Gujarat. Remnants taken from Mohenjo Daro (3000-2700 BC), lint traits resembled to *arboreum*(Gulati and Turner,1928). Race *indicum* further moved towards east (north eastern states) and formed as perennial with long dropping linted bolls called as race *burmanicum*(Dacca). At the same time race *indicum* moved towards African side through Arabian plains diverged as separate race *soudanense*(*senaar* tree cotton). Race *burmanicum* moved through yellow river basin of China became annual in nature emerged as distinct race *sinense*. Race *burmanicum* which developed frost tolerance capacity set aside as distinct annual race *bengalense*(*Oomura* or *Bengaldeshi* cotton), which become commercial crop of North India. *Comilla* is vernacular name of the race *cernum* found at Assam hills and Bangladesh (Hutchinsion,1954 & Sillow,1944).

Races of *herbaceum* : *Gossypium herbaceum* grouped into four races namely *africanum, acerifolium, persicum, kuljianum,* and *wightianum*. Unlike *arboreum*, *herbaceum* race *africanum* is putative ancestor for all the modern races. Southern part of the African continent is believed to be the home for the race *africanum*. *G. herbaceum* race *africanum* was found in the form of xerophytic(open vegetative type) in African continent, this race is much similar to the species *arboreum* race *indicum* found in Western India (Braak, 1947).The most primitive type of the cultivable form of *herbaceum* is perennial similar to race *acerifolium* found from Mekran in Baluchistan, through Arabia and across the Sahara to West Africa(Ansari,1941& Hutchinson,1949). *Herbaceum* race had undergone climatic stress across different geographic regions and adopted into various racial forms such as *persicum, Kuljianum, wightianum*. Through traders, race *africanum* moved via Indian Ocean route and reached to the Arabia, where the domestication of *herbaceum* occurred. From Arabia, perennial raced called *acerifolium* moved towards North Africa. Perennial race *africanum* further moved towards Iran region where they adopted to a prolonged cold winter and short summer duration resulting into annual race *persicum*(Levant cotton). *G.herabceum* moved further towards north region of India and underwent habituation of hot, short summer and long winter climate emerged as new race *kuljianum*. Crop domestication of *G. herbaceum* annual race at Western India distinctly formed as new race *wightianum*(*Waghad, Kalyana, Jayadhar*)(Hutchinsion,1954 & 1959).

Ecological and geographical distribution of *desi* cotton in India : India having wider geographic region with different climatic zones, here both *arboreum* and *herbaceum* grows; whereas in particular area there is an introgression of two species also found. *G. arboreum* race *bengalense* found in North India and in some parts of the Pakistan, these races are short and very coarse fibre with long maturity. G. *arboreum* race *indicum* found in both North and South India, towards down south, it is called as *Karunganni* in Tamil Nadu suitable for very harsh environment; *Mungari* in Karnataka as it sown by early monsoon on set, *Mathio* in Gujarat. However, *Pundro* cotton in Andhra Pradesh possesses fine fibres. Mixed race of *indicum* and *bengalense* found in central India suited for rain-fed condition; *Gaoran*i is mainly grown over Maharashtra state. G*. arboreum* race *cernum* is a big boll type called as *Gharo* cotton in Assam and Bengladesh(Despande *et al.,*2004).

In case of *G. herbaceum*, race *wightianum* called as *uppam* cotton in Tamil Nadu, as it grows along the sea shore region of Bay of Bengal. In Karnataka, it was sown by late after onset of monsoon called as *Hingari*. *Dhummad* cotton in Junagadh and Kathiawar region of Gujarat, *dhummad* is a closed boll type as it requires high labour for ginning. *Wagad/Kalyan* type possesses open boll type which grown in Rajasthan and parts of Gujarat. *Jayadhar* is grown at rainfed tracts of Northern Karnataka (Kulkarni *et al.,*2009; Despande *et al.,*2004 & Narula *et al.,*2001).. Gujarat is the major state growing *G.herbaceum* cotton under three different situations: (i) In the Ghed area, where sea water intrudes and the water is brackish (ii)In the coastal desert sands with salinity and drought (iii)In the inland black cotton soil where salinity and drought are major problems. Form of *G. herbaceum* race *wightianum* found growing mixed with *G. arboreum* race *bengalense* in Western India(Dhummad x Mathio), and with *G. arboreum* race *indicum* in Southern peninsular India(*Mungari* x *Hingari*). Occasionally crossing between these two species occurred and fertile F_1 also been produced, however, there were a heavy breakdown noticed in F_2. It reinforces the species isolation between these two species (Silow, 1944).

Virtues of *desi* cotton

- Possesses resistance to range of insect pests namely hoppers, white flies, thrips and aphids.
- It is having resistance towards various diseases especially it shows immune to the vector borne leaf curl virus (CLCv)
- It is highly suitable to rainfed ecosystem being drought tolerant crop
- It is suitable for sustainable crop production
- It requires less cost of cultivation(low or no cost of crop protection)
- It is known for its ability to grow in

marginal environment especially *herbaceum* prefers to grow in coastal region

- Natural colour cotton such as Brown linted varieties *G.arboreum*, namely, Cocanada-1 and Cocanada-2 suitable for manufacturing of ecofriendly cloths

Infirmness of *desi* cotton

- Poor fibre quality (less strength and length) and coarse fibre properity of desi cotton unsuitable for modern day electrospinning
- Poor plant architecture (Smaller boll size and open boll type results in cotton shedding)
- Small flower hinders manual hybrid seed production unlike tetraploids
- More number of monopodia with lanky, tall plant type (*herbaceum*)
- Very longer duration of maturity (180-210 days in *herabceum*)
- *Herbaceum* genotypes are more susceptible to grey mildew than *arboreum*

(I) ***Arboreum* cotton Improvement**

Genetic potential of *arboreum* cotton (Deshpande *et al.,* 2004 & Kulkarni *et al.,* 2009)

Desi cotton by its inherent potential has the coarse fibre, less fibre length (<20mm) and poor spinnability (10s), with concentrated breeding efforts at different AICCIP centres namely Parbhani, Bharuch and Dharwad resulted in development of long linted *arboreum* with higher fibre length from 26 to 28mm, ginning out turn from 37 to 38 per cent, spinnability from 10s to 30s and yield increased from 300 kg/ha to 1400 kg/ha(Table.1).

Heterosis breeding : Crossing between *arboreum* lines with *herbaceum* genoytpes produced high yielding hybrids which outperformed over tetraploid hybrids in rain-fed eco system. Hybrids namely G.cot Dh 7, G.cot Dh 9, DDH 2 and PHA 46 were produced through interspecific hybridizing among diploid species. However, manual hybrid seed production was very tedious because of tiny flower nature. Genetic Male Sterility (GMS) had been exploited by using the sources GMS1, GMS 2 and GAK 423. Hybrids *viz.,* AAH1, AKDH7 and G. cot MDH 11 were produced employing GMS. These GMS based hybrids were not popular because of its short fibre and poor spinnability(Meshram and Wadodkar,1992). There is no CMS source available for exploiting heterosis(Khadi *et al.,*2004).

Ideotype breeding : Ideal plant type is called as ideotype, based on optimum plant architecture effort has to be oriented towards development of such a prototype plant is known as ideotype Breeding. In general, *arboreum* genotype possesses tall, lanky plant with weak stem; selection in such genotypes focuses on semi dwarf plant type with stiff, strong stem (Sing

Table 1. Important varieties of *arboreum*

Varieties	Yield	Fibre Length	Spinnability
G12,G22,G46 (Maharashtra);Maljari, Zarilla(Madhya Pradesh); K2,K5(Tamil Nadu)	300kg/ha	21-22mm	10-20s
PA 32, AKH 4, Y1 (Maharashtra),CJ 73 (Gujarat), K1(Tamil Nadu), Veena (Andhra Pradesh)	700kg/ha	23mm	20s
PA 255, PA 183(Parbhani Turab), AKA 8401(Maharashtra); MDL2463(Andhra Pradesh)	1400kg/ha	26-28mm	30s

and Narayanan, 1999).

Hirsutization of *arboreum* : Introgression of *hirstum* lines with *arboreum* background is called hirsutization of *arboreum*, resulting lines possess long lint. Parbhani and Dharward centers produced long linted *arboreum* lines *viz.,* PA402 and DLSa17 respectively (Despande *et al.,*2004; Kulkarni *et al.,*2002&2009).

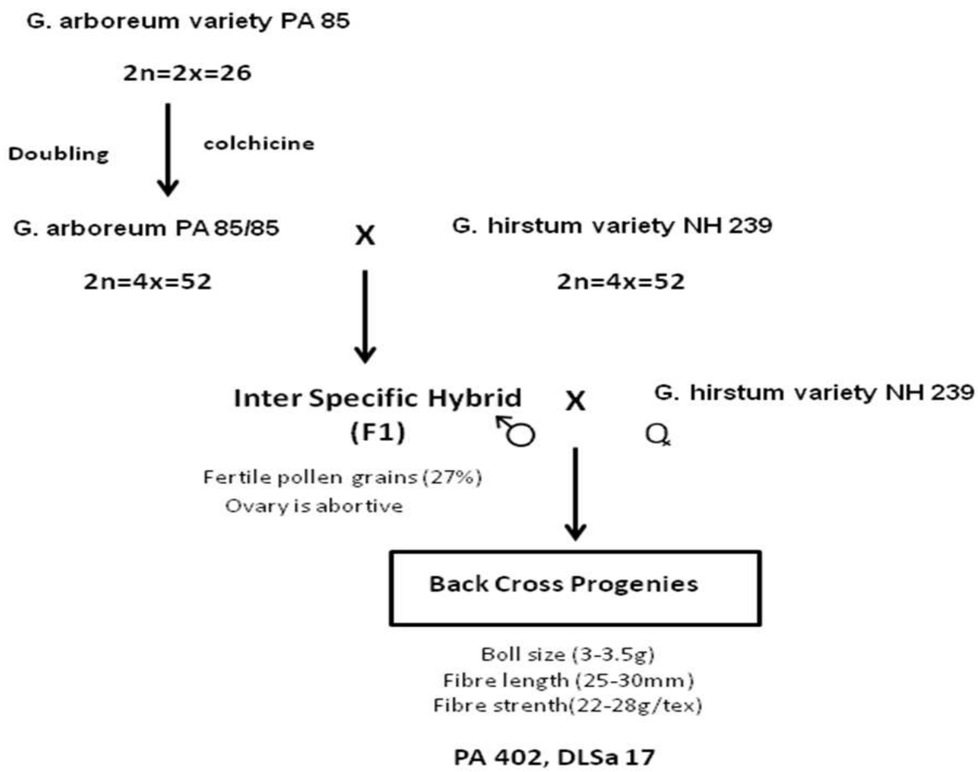

Fig 1. Hirsutization of arboreum cotton

(II) ***Herbaceum* cotton improvement**

Three distinct *G.herbaceum* territory have emerged for herbaceum growing namely *Wagad, Surti* (or) *Bharuchi* and *Kumpta* . *Surti/ Bharuchi* and *Kumpta* are fully open boll and named after parts of Surat and Bharuch of Gujarat. *Wagad* on the other hand is closed boll type, it has to be picked as such from plant and opened manually. Vagad is a place in Kutch region of Gujarat where it was first grown, hence the name *Wagad* derived. *G. herbaceum* Improvement started in 1896 at Surat and later it was strengthened at Dharwad (1904) in Karnataka; Bharuch (1913) and Viramgam (1922) in Gujarat.

Genetic potential (Narula *et al.,* 2001)

Three criteria are being considered as hall mark in *herbaceum* improvement viz., 1. High seed cotton yield, 2.high ginning out turn and 3. Early maturity. With this yard stick different breeding methods namely Selection, Pedigree method, Back Cross method, Mutation Breeding and Heterosis breeding were employed for the improvement of *herbaceum* cotton(Table.2). Concentrated efforts on *herbaceum* breeding yields into the development of many important varieties among which Digvijay (1956), V 797 (1965) and G. Cot 13 (1981) in Gujarat and Jayadhar (1950), Suyodhar (1963) and DB-3-12 (1983) in Karnataka (Table 3). Narula *et al.,*2001 had reviewed the *herbaceum* improvement in detail. Here below the brief account of their review.

G.herbaceum cotton genotype RAHS 14 was found to be saline tolerant, high yielding, early and well adapted at many locations. This genotype could be promoted in coastal areas of peninsular India for enhancing cotton productivity and income of farmers, especially under severe salinity stress conditions. The high yield potential of *G.herbaceum* varieties namely DB.3-12, G.Cot. 13 and G.Cot.21 could be demonstrated at several locations even under adverse situations in marginal soils. A promising strain of *G. herbaceum* – RAHS 131 has been identified under marginal conditions with a yielding ability of 500-800kg/ha in coastal areas. *G.herbaceum* genotypes namely RAHS 14, RAHS 119, RAHS 131 and hybrids G.Cot.DH.7 and G.Cot.DH.9 yielded around 600-900kg/ha in highly saline areas of Ankola, wherein sea water intrusion was seen and consequently, crops like green gram and black gram failed(Anonymous, 2003).

Ideotype breeding : In case of herbaceum genotype in nature of producing bushy and high number of monopodia(5-6) and late in maturity, ideotype focuses on open plant type, more number of sympodia with few monopodia(1-2).

(III) **Technology Mission on Cotton**

Under the umbrella of Technology Mission on Cotton (TMC), improvement of desi cotton genotypes has been undertaken in phased manner with different objectives.

Technology Mission on Cotton Mini Mission - I : Programmes in phase - I : TMC MM1.1 aimed at development of diploid cotton cultivars with high fibre quality. North Indian diploid cottons were improved (High yielding with low fibre quality) into long linted genotypes by means of shuttle breeding employing long linted diploids of south Indian genotypes introgressed into northern Indian lines with help of off season nursery. In this programme centres namely Parbhani, Hissar, Ludhiana, Sriganganagar, Dharwad and Coimbatore were involved (Anonymous, 2007).

Technology Mission on Cotton Mini Mission - I : Programmes in phase - II : TMC MM1.1 aimed at development and promotion of medium and long linted diploid cottons**.** The project is launched for development and promotion of desi cotton with high fibre qualities suitable for rain-fed cultivation to strengthen the economy of marginal cultivars. Centers namely

Table 2. Breeding strategies employed for *G. herbaceum* improvement (Narula *et al.,*2001)

Method	Varieties developed
Selection from local	1 ALB, Dharwad-1, Dharwad-2, Wagad-8, BD-8.
Pedigree method	Jayawant, Suyog, Jayadhar, Suyodhar, Raichur-51, G. Cot 11, G. Cot 13, G. Cot 17, G. Cot 21, G. Cot 23.
Back cross method	Wagoter, Kalyan, Vijalpa, Vijay, Digvijay, V 797
Mutation Breeding	DB-3-12
Heterosis Breeding	GDH-7, GDH-9, Pha 46, MDCH-201; DDH-2.

Table 3. List of *G. herbaceum* varieties released in India (Narula *et al.,* 2001)

S.	Variety (year of release)	Pedigree	Area of adaptation	Remarks
1.	Dharwad 1 (1918)	Selection from Kumpta local	Karnataka	Wilt susceptible
2.	1 ALB (1919)	Selection from Surat local	South Gujarat.	High yielding and high GOT but was discontinued in favor of 1027 ALF
3.	Dharwad 2	Selection from Kumpta local	Karnataka	Wilt tolerant
4.	1027 ALF (1923)	Goghari x Kumpta	South Gujarat.	Snow white quality cotton.
5.	Jayawant (1930)	Dharwad 1 x Dharwad 2	Karnataka	Susceptible to late rains.
6.	Wagad 8 (1933)	Selection from Wagad local	North Gujarat	Spinning value was lesser than local.
7.	BD 8 (1938)	Selection from Bharuch local	Central Gujarat	Wilt tolerant
8.	Wagotar (1942)	(Wagad-8 x 1027 ALF) x Wagad-8.	North Gujarat	High GOT but drought susceptible.
8.	Vijay (1943)	(BD-8 x GA-26) x BD-8	Central Gujarat	Had irregular spinning though had high GOT and abiotic tolerance.
9.	Suyog (1945)	1027 ALF x 1 ALB	South Gujarat	Late and susceptible to drought.
10.	Kalyan (1947)	(Wagad 8 x Surati-22-3-1-3) x Wagad 8.		North Gujarat Immense flowering potential to tide over unfavorable weather.
11.	Jayadhar (1950)	KFT (12-2-5 x IA 14-3)	Karnataka	Wilt tolerant with an ability to withstand dry spells. Still covers around 0.1 m ha.
12.	Vijalpa (1952)	(Vijay x 1027 ALF) x Vijay	South Gujarat	-
13.	Digvijay (1956)	Vijay x (Vijay x 1027 ALF)	Central Gujarat	Still occupies around 0.1 m ha, preferred highly by the millers due to high spinnability.
14.	Suyodhar (1963)	(Jayadhar x Suyog) x KFT-12-2-5.	Dry belt of North Karnataka	Suited to low rainfall areas.
15.	V 797 (1966)	(Kalyan x Vijay) x Kalyan	North Gujarat	Closed boll, tolerant to wilt and fast winds.
16.	Raichur-51 (1968)	RK-19 x NS-12	North Karnataka.	Suitable for low rainfall.
17.	Sujay (1971)	Dwarf mutant x 2324	South Gujarat	Good combiner, parent of GDH-7
18.	G. Cot 11 (1979)	3200 x EP2	Central Gujarat	Early and high yielder than Digvijay but low boll weight.
19.	G. cot 13 (1981)	Kalyan x 1802	North Gujarat	First semi open boll variety for North Gujarat.
20.	Renuka(DB-3-12)(1983)	Mutant of Western 1	North Karnataka	Earliest among all the released varieties of herbaceum.
21.	G. Cot 17 (1995)	1762 x Yerly 197-3	Central Gujarat	Has high GOT, tolerant to wilt but smaller boll size.
22.	G. Cot 21 (1998)	1502E (G. Cot 13 x 4011D)	North Gujarat	Semi open boll variety that recorded 25% increase in yield after 1965 in Wagad area.
23.	G. Cot 23 (2000)	625BB x GbBhv-41	Central Gujarat	Big boll variety having good boll opening.

Bharuch, Banswara and Dharwad were concentrated on *herbaceum*. Centres *viz.,* Sirsa, Ludhiana, Hisar, Nagpur, Sriganganagar, Parbhani, Khandwa, Rahuri, Akola, Mudhoi and Kovilpatti were on *arboreum*(Anonymous, 2012).

Technology Mission on Cotton Mini Mission - I : Programmes in phase - III

TMC MM 1.4 launched with objective of evaluation of genotypes for surgical cotton. This project focuses on surgical cotton (absorbent cotton) production. Coarse textured lint with short fibre length of *arboreum* cotton can be easily arranged into layers for surgical purpose. Demand for surgical cotton is growing at the rate of 10% per annum across the world. Centres *viz.,* Nagpur, Coimbatore, Sirsa, Akola, Nanded, Dharwad, Faridkot, Jalgaon and Hissar are involved in this project (Anonymous, 2013).

Status of *desi* cotton : After the American civil war, British government introduced the *Gossypium hirsutum* to India and other colonized countries to cater the need of textile industries of England. At the time of independence, *desi* cotton occupied 98 per cent area (2.79 mha of *arboreum* and 1.39mha of *herbaceum*) and American cotton shared only 2 per cent (0.14mha) (Santhanam,1997). In 1960s, *arboreum* strains AK 235(Maharashtra and Madhya Pradesh) and the improved *Gaorani* in Southern Maharashtra and Northern Andra Pradesh were predominant in cultivation. While in *herbaceum* Jayadhar(Karnataka) and V797(Gujarat) were leading cultivars(Santhanam,2004). During 2000 the area of *arboreum* reduced to 1.46mha and *herbaceum* to 0.95mha due to increase in area under hybrids (3.64mha) and *hirsutum* (2.48mha) cotton. Since the introduction of Bt cotton; area under *desi* cotton has been reduced to less than 1 per cent (Table 4) (Kranti, 2015 & Narayanan *et al.,* 2014).

Table 4. Area and Production of Desi cotton in India

Years	*G. arboreum*		*G.herbaceum*	
	Area (m ha)	Production (m ton)	Area (m ha)	Production (m ton)
1947-1948	2.79	0.253	1.39	0.109
1989-1990	1.28	0.217	0.98	0.130
2013-2014	1.17	0.129	0.58	0.064

Desi cotton known for its ability to grow in marginal environment especially *herbaceum* prefers to grow in coastal region. Coastal agricultural system in the States of Karnataka, Gujarat, Andhra Pradesh and Tamil Nadu are suitable for growing *G.herbaceum* cotton. Thus, *G.herbaceum* cotton can be introduced in problem soils in coastal agricultural eco-system for its rejuvenation and prosperity. *Desi* cotton possesses resistance to range of insect pests namely hoppers, white flies, thrips and aphids. *Desi* cotton almost exhibits immune to the vector borne leaf curl virus. Due to short, coarse and weak fiber traits make them unsuitable for modern machine textile industries. However during 17-18th century, *desi* cotton was being spun by handcrafters, the cloth was so fine *e.g.* Dhaka muslin (Dhaka *malmal*). Machine and electrospinning needs high strength fibre, this property lacks in *desi* cotton. In spite of poor fibre traits, these short stable cotton used for denim, upholstery and surgical cloths. Recent past the trend is reversing, the demand for short stable cotton is 2% however the production is 1%; this makes a lot of hope for increasing the area of *desi* cotton.

Future strategies

- *Desi* cotton possesses resistance to

sucking pests' offers ecofriendly crop due to less or no spray of pesticides.

- Diploid cotton exhibits tolerance towards abiotic stress like drought, their capacity to grow in rainfed condition offers unique solution to climate change.
- *G.herbaceum* has special adoptability to grow in marginal environment in particular towards costal saline area; paves the way for answer to problem soils.
- Both *arboreum* and *herbaceum* are having the potential for organic cotton production in the rainfed ecosystems. This organic cotton fetches higher revenue from export point of view.
- Recent incidence of whitefly menace in Northern India reveals that desi cottons are better tolerant towards such a pest.
- *Desi* cotton exhibits almost immune reaction to leaf curl disease in contrast teteraploid cottons are highly susceptible to CLCV.
- Breeding programme to improve the fibre quality of *desi* cotton is necessary to crab the textile value of its fibre.
- Breeding for ideal plant type in both *herbaceum* and *arboreum* is needed to tap the potential for input responsible crop production in irrigated condition.
- Screening for resistance to Grey mildew and Alternaria blight is needed to identify the genetic stocks for disease tolerance.
- Brown linted varieties *G.arboreum*, namely, Cocanada-1, Cocanada-2 could be exploited for natural colour yarn. This natural coloured cotton gives solution to dye effluent menace.
- Breeding to produce glandless seed with glanded plant part for low gossypol cotton seed oil.
- Modern biotechnological tools such as molecular marker and genetic transformation techniques could be employed for improving fibre quality traits of *desi* cotton.

REFERENCES

Anonymous. 2003. Prospects of *herbaceum* cotton cultivation for improving agricultural output of coastal agro ecosystmes. In: N.Gopalakrishnan, K.N.Gururajan, S.E.S.A.Khader, U.G.Patel, S.S.Patil, T.S.Raveendran, S.Thirumeni and J.S.V.Sambamurthy(Eds), T.P.Rajendran, CICR,RS, Coimbatore.

Anonymous.2007. TMC Programmes in Phase – I, TMC Mini Mission 1.1. Annual Report, CICR, Nagpur.

Anonymous.2012. TMC Programmes in Phase – II, TMC Mini Mission 1.1. Annual Report, CICR, Nagpur.

Anonymous.2013. TMC Programmes in Phase – III, TMC Mini Mission 1.4. Annual Report, CICR, Nagpur.

Ansari, M. A. A. 1941. Survey of cottons of Baluchistan. *Indian. J. Agric. Sci.,* **11:** 59.

Braak, C. 1945. On the Climate of and Meteorological Research in the Netherlands Indies. In Science and Scientists in the Netherlands Indies. Board for the Netherlands Indies, Surinam and Curacao.

Deshpande, L.A., K.S. Baig, V.N. Kulkarni, Matishchandra and S.S. Kakde. 2004. Strategies to improve cultivated diploids – Perspective. In: B. M. Khadi, I.S. Katageri, S.S. Patil, H.M. Vamadevaiah, B.R. Patil and S.M. Manjula (Eds), Proceedings of 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.

Fryxell, P.A. 1979. Natural History of the Cotton Tribe, College Station, Texas A&M University Press.

Gerstel, D. U and P.A. Sarvella 1956. Additional Observations on Chromosomal Translocations in Cotton Hybrids, *Evolution,* **10 :** 408-14.

Gulati, A.N and A.J. Turner. 1929. A note on early history of cotton. *Journal of the Textile Institute, Transactions,* **20:** 1-9.

Hutchinson, J.B. 1954. New evidence on the origin of the old world cotton. *Heridity,* **8:** 225–41.

Hutchinson, J.B. 1959. The application of genetics of cotton improvement. Cambridge University Press, Cambridge.

Khadi,B.M., V.N.Kulkarni, M.S.Bisankoppa and H.M.Vamadevaiah. 2004. Introgression derivatives from *Gossypium arboreum* (A2) and *G.hirsutum* (AD1) serve as source to identify 'D' genome genes – A study. Book of Abstracts of International Cotton Genome Initiative 2004, Hyderabad, India. 10–13 October, 2004, pp. 85.

Kranti, K.R.2015. Desi Cotton - Returns?. *Cotton Statistics & News.,* **15 :** 1-4.

Kulkarni, V.N. 2002. Hirsutisation of *G. arboreum* cotton and genetic emendation of *G. hirsutum* for sucking pest resistance. *Ph. D. Thesis* submitted to University of Agricultural Sciences, Dharwad, India.

Kulkarni,V.N., B.M. Khadi, M.S.Maralappanavar, L.A.Deshapande and S. S. Narayanan. 2009. The Worldwide Gene Pools of *Gossypium arboreum* L. and *G. herbaceum* L. and their Improvement; In: Genetics and Genomics of Cotton, Plant Genetics and Genomics: Crops and Models 3, A.H. Paterson (ed.), Springer Science &Business Media, LLC.pp69-97.

Meshram, L.D. and M.B.Wadodkar.1992. Male sterility in Asian cotton *Gossypium arboreum.*L., *Hybrid cotton newsletter.,* **2 :** 3.

Narayanan,S.S., Parchuri Vidyasagar and K. Srinivasu Babu.2014. Cotton Germplasm in India — New Trends; In: World Cotton Germplasm Resources Edited by Ibrokhim Abdurakhmonov.pp.87-118.

Narula, A.M., Acharya, S., Khadi, B.M. and Kulkarni, V.N. 2001. *Gossypium herbaceum* cotton in India. Directorate of Cotton Development, Department of Agriculture and Cooperation, Mumbai, India.

Santhanam, V. 1997. Agri-history of Cotton in India-An Overview; In: Asian Agri-History, **1 :** 235-51.

Santhanam, V. 2004. Emerging trends in conventional breeding for cotton improvement, In: B. M. Khadi, I.S. Katageri, S.S. Patil, H.M. Vamadevaiah, B.R. Patil and S.M. Manjula (Eds), Proceedings of 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. 1-4.

Sillow, R.A. 1944. The genetics of species development in the Old World cottons. *Journal of Genetics*, **46 :** 62-77.

Singh, P. and S.S.Narayanan. 1999. Cotton Improvement Procedures, In: Hand Book of Cotton in India, Sundaram V. , Basu A K., Krishna Iyer K R., Narayanan S S., Rajendran T P (Eds): Indian Society for Cotton Improvement, Mumbai, pp.41- 56.

American cotton genotype Phule Yamuna (RHC 0717) : Potential for central zone of India.

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ABSTRACT : The overall mean performance indicated that genotype Phule Yamuna RHC 0717 (1911 kg/ha) recorded 33.96 per cent and 19.96 per cent higher seed cotton yield than the zonal check LRA 5166 (1427 kg/ha) and local check (1593 kg/ha), respectively. The RHC 0717 was adjudged as the best entry in the twenty one trials out of thirty trials conducted at different locations in respect to yield and yield attributing characters. Likewise, this variety performed excellent fibre properties *viz.* Ginning percentage (34.5), long fibre length (27.85 mm), average fibre strength (23.23 g/tex), average micronaire (4.5), excellent uniformity ratio (51) and very good maturity (>81); which were suitable for medium stable cotton. The variety showed disease free reaction to grey mildew, resistant to BLB, moderately resistant to ALB and tolerant to sucking peats and bollworm. Therefore, this genotype is recommended under the name 'Phule Yamuna' for commercial cultivation in irrigated tract of central zone of India comprising Maharashtra, Madhya Pradesh and Gujarat state.

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

Cotton is the world's leading natural fibre crop and it is a cornerstone for textile industries worldwide. 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). The cultivated tetraploid species *G. hirsutum*, also referred to as 'upland cotton' accounts for about 95 per cent of the global cotton production. Consequently, a great majority of worldwide cotton breeding programme have been focusing on improving upland cotton. With the increasing global demand for textile products, intense competition from synthetic fibre and textile industry's modernization, the need for higher yielding upland cotton cultivars with improved fibre quality has never been more critical (Vindhiyavarman, 2015).

India continued to maintain the largest area under cotton and second largest producer of cotton next to China with 35.29 per cent and 24 per cent of world cotton area and production, respectively. India also sustained the position of being the second largest consumer and exporter of cotton (Anonymous, 2015).

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 parent in crossing programme by the breeders for creating genetic variability.

MATERIALS AND METHODS

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 lower than *barbadence* cotton. Development of such a high yielding stable genotype with desirable fibre qualities will help to improve cotton productivity and income of farmers in Maharashtra, Gujarat

Table 1. Detailed DUS description of Phule Yamuna (RHC 0717) with checks

SN	Characteristics as per National Test Guidelines (DUS)	Phule Yamuna (RHC 0717)	LRA-5166	Phule-688
1.	Hypocotyl : Pigmentation	Present	Present	Present
2.	Leaf : Colour	Green	Green	Green
3.	Leaf : Hairiness	Medium	Medium	Medium
4.	Leaf : Appearance	Flat	Flat	Flat
5.	Leaf : gossypol glands	Present	Present	Present
6.	Leaf : Nectaries	Present	Present	Present
7.	Leaf : Petiole Pigmentation	Present	Present	Present
8.	Leaf : Shape	Normal	Normal	Normal
9.	Plant : Stem Hairiness	Medium	Strong	Medium
10.	Plant : Stem Pigmentation	Present	Present	Present
11.	Plant : Height	Medium (110-120)	Medium (104.80)	Tall (110-120)
12.	Plant : Growth Habit	Semi-spreading	Semi-spreading	Semi-spreading
13.	Bract : Type	Normal	Normal	Normal
14.	Flower: Time of 50 % Flowering	**Medium (55-60)**	Late (67)	Medium (55-60)
15.	Flower : Petal colour	**Yellow**	Cream	Cream
16.	Flower : Petal Spot	Absent	Absent	Absent
17.	Flower : Position of Stigma	Exerted	Exerted	Exerted
18.	Flower : Filament Colour	Absent	Absent	Absent
19.	Flower : Pollen colour	**Cream**	Yellow	Yellow
20.	Flower: Male sterility	Absent	Absent	Absent
21.	Boll : Bearing habit	Solitary	Solitary	
22.	Boll : Colour	Green	Green	Green
23.	Boll : Shape Longitudinal Section	Ovate	Ovate	**Elliptic**
24.	Boll : Surface	Smooth	Smooth	Smooth
25.	Boll : Prominence of Tip	Pointed	Pointed	Blunted
26.	Boll : Opening	Open	Open	Open
27.	Boll : Weight	3.5-4.0	3.0 – 3.5	4.1-4.5
28.	Seed: Fuzz	Medium	Medium	Medium
29.	Seed : Fuzz Colour	Grey	Grey	Grey
30.	Seed Index	Medium (8.35)	Small (6.87)	Medium (9.74)
31.	Ginning %	Medium (34)	Low (27.67)	Medium (37)
32.	Fibre : Colour	White	White	White
33.	Fibre : Length (SL)	Med. long (26-27)	Medium (26.4)	Medium (26-27)
34.	Fibre : Strength S (3.2m)	Medium (22-23)	Medium 22.2	Medium (22-23)
35.	Fibre : Fineness (MIC)(Micronaire Value)	**Medium (4.8)**	Fine (3.9)	Fine (3.2)
36.	Fibre : Uniformity Ratio (UR)	Good (51)	Good (48)	Good (50)
37.	Fibre: Maturity (%)	84	84	83

Table 2. Performance of Phule Yamuna (RHC-0717) in comparison with checks over seasons for 15 locations in station, Multi Location and Coordinated Varietal Trials.

Yield and quality characters	Culture/ checks	Station trial (2008-2009)	MLT 2009-2010	MLT 2010-2011	MLT 2011-2012	MLT 2012-2013	MLT 2013-2014	Br-02a IET (2010-2011)	Br-03a PVT (2011-2012)	Br-04a CVT (2012-2013)	Mean	Increase over (%)
Seed cotton yield (kg/ha)	**RHC 0717**	2107	2251	1996	2399	1484	1418	1345	1930	2268	**1910.89**	-
	LRA 5166	1578	1272	1316	-	-	-	1057	1287	2049	1426.50	**33.96**
	Phule 0688	1674 #	1748	1433	2253	1212	1298	1330	1721	1748	1592.88	**19.96**
Lint yield (kg/ha)	**RHC 0717**	748	717	681	797	712	536	455	662	789	**677.44**	-
	LRA 5166	576	396	470	-	-	-	365	439	738	497.33	**36.22**
	Phule 0688	607 #	588	494	847	530	450	449	563	611	566.50	**19.58**
GOT (%)	**RHC 0717**	35.48	31.86	34.12	33.20	34.07	37.81	33.7	34.6	35.1	**34.44**	-
	LRA 5166	36.50	31.16	35.73	-	-	-	35.2	33.8	36.3	34.78	**-0.99**
	Phule 0688	36.28 #	33.62	34.50	37.61	33.23	34.70	34.3	32.0	34.9	34.36	**0.23**
Bolls /Plant	**RHC 0717**	33.0	43.0	39.0	46.0	49.0	42.7	27.2	24.0	35.7	**37.73**	-
	LRA 5166	31.0	36.0	31.0	-	-	-	23.9	18.0	34.8	29.12	**29.59**
	Phule 0688	28.6 #	37.0	34.0	43.0	44.0	43.0	28.8	23.0	31.2	35.50	**6.29**
Boll weight (g)	**RHC 0717**	3.19	3.5	4.2	3.40	4.47	4.07	2.9	4.1	3.6	**3.71**	-
	LRA 5166	3.28	3.4	5.7	-	-	-	3.2	4.0	3.5	3.85	**-3.44**
	Phule 0688	3.46 #	3.3	5.1	3.60	4.20	4.13	3.3	4.4	3.6	3.95	**-6.05**
2.5 per cent Span length (mm)	**RHC 0717**	28.1	27.9	27.9	26.9	28.9	29.5	26.8	27.3	27.3	**27.84**	-
	LRA 5166	30.2	29.1	29.7	-	-	-	30.5	29.7	24.8	29.00	**-3.98**
	Phule 0688	29.1 #	27.2	28.6	27.0	27.6	28.6	29.3	27.0	27.5	27.85	**-0.02**
Micronaire	**RHC 0717**	3.8	4.5	4.7	4.6	3.8	4.4	4.6	5.0	5.1	**4.50**	-
	LRA 5166	3.9	3.6	4.3	-	-	-	4.4	4.1	4.8	4.18	**7.57**
	Phule 0688	3.9 #	3.7	4.4	3.8	4.0	4.4	4.4	4.6	4.8	4.26	**5.57**
Bundle strength (g/tex)	**RHC 0717**	26.1	27.5	23.3	22.2	20.3	21.6	23.6	23.1	21.4	**23.23**	-
	LRA 5166	25.7	28.3	23.1	-	-	-	24.1	27.7	22.0	25.15	**-7.62**
	Phule 0688	22.3 #	25.4	22.1	23.1	19.8	22.8	22.5	21.8	22.5	22.50	**3.26**

Mean data of JLH 168

and Madhya Pradesh. So efforts were made at Cotton Improvement Project, MPKV, Rahuri during the year 2003-2008 and the strain RHC 0717 was developed by pedigree selection method.

The genotype was tested consecutively for six years under preliminary university trial, MLT and AICCIP trials. The university multilocation trials were conducted at Rahuri, Kopargaon and Padegaon during 2008-2009 to 2012-2013, whereas, the Co ordinated trials were conducted at five locations (Khandwa, Surat, Junagadh, Rahuri and Bhawanipatna) for three consecutive year *i.e.* 2010-2011 to 2012-2013. The fibre properties through HVI *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 wider spacing as well as higher doses of fertilizers. It was also tested for major pests and diseases at MPKV, Rahuri as well as in Co ordinated trials. The statistical analysis was carried out according to Panse and Sukhatme (1985).

Table 3. Full scale spinning report of *G. hirsutum* variety Phule Yamuna (RHC 0717) at CIRCOT, Mumbai.

Sl No	Entry	SL	UR	Mic	Str	E(%)	Count1	CSP1	Count2	CSP2
1	RHC 0717	26.3	50	4.2	21.6	>7.0	30	2247	40	1988

RESULTS AND DISCUSSION

For development of genotypes selection pressure was applied on segregating population of Krishiratna hybrid (K 03/01-26-46) during 2003-2004 to 2007-2008, superior plant were selected up to F6 generation and then tested under different trials. The details description of existing strain along with checks is presented in different tables.

RHC 0717 is a medium tall, semi spreading genotype with yellow colour petals and cream colour anthers, which is distinct from both the checks (in LRA 5166 & Phule 688, the petals are cream and anthers are yellow in colour). The ovate bolls are smaller in size with pointed tip distinguish the genotype (Table 1).

The performance of existing genotypes for different quantitative characters in different trial is presented in Table 2. During 2008-2009 to 2023-2014, the strain RHC 0717 recorded a mean seed cotton yield of 1910.89 kg/ha as compared to 1426.50 kg/ha in LRA 5166 and 1592.88 kg/ha in Phule 688, which is 33.96 per

Table 4. Screening of Phule Yamuna (RHC-0717) against major diseases in Coordinated Varietal Trials.

Year of testing	Trial location	Proposed variety RHC 0717	Zonal (Ck 1) check LRA 5166	Local check (Ck 2)
A. Bacterial blight				
2010-2011	Bhawanipatna	1	2	2
	Guntur	-	3	3
	Surat	0	4	3
2011-2012	Surat	4	3	3
	Junagadh	2	2	2
	Rahuri	-	-	-
2012-2013	Surat	1	3	4
	Junagadh	1	2	2
	Rahuri	-	-	-
B. Alternaria leaf spot				
2010-2011	Bhawanipatna	1	-	-
	Guntur	-	4	3
2011-2012	Junagadh	4	3	4
	Rahuri	2	1	1
	Surat	4	3	3
2012-2013	Surat	-	-	-
	Junagadh	2	3	3
	Rahuri	2	1	2
C. Grey mildew				
2010-2011	Bhawanipatna	2	2	2
	Guntur	-	0	3
2011-2012	Junagadh	0	0	0
2012-2013	Surat	-	-	-
	Junagadh	-	-	-
	Rahuri	0	0	0

Table 5. Screening of Phule Yamuna (RHC 0717) against sucking pest complex and bollworm.

Year of testing	Trial location	Proposed variety RHC 0717	Zonal (Ck 1) check LRA 5166	Local check (Ck 2)
A. Jassids				
2010-	Bhawanipatna	2.12 (II)	3.45 (II)	1.82 (II)
2011	Rahuri	4.6 (III)	4.1 (III)	4.7 (III)
	Surat	5.8 (II)	7.4(III)	5.3 (II)
2011-	Junagadh	9.0 (II)	16.0 (IV)	6.8 (II)
2012	Rahuri	8.56 (II)	5.68 (II)	4.46 (III)
	Surat	3.90 (II)	2.80(II)	2.50 (II)
2012-	Surat	II	I	I
2013	Rahuri	I	II	III
B. Whitefly				
2010-	Bhawanipatna	1.05	1.05	1.09
2011	Rahuri	5.9	4.6	3.6
	Surat	6.2	5.5	5.4
2011-	Junagadh	28.0	17.0	27.9
2012	Rahuri	9.17	15.28	13.61
	Surat	2.60	0.20	2.70
2012-	Surat	3.42	3.85	4.25
2013	Rahuri	4.47	3.50	4.33
C. Thrips				
2012-	Surat	6.65	6.45	4.41
2013	Rahuri	4.25	4.59	4.53
D. Aphids				
2012-2013	Junagadh	6.38	7.20	6.33
E. Open boll damage (Boll basis)				
2010-	Rahuri	18.8	19.8	20.5
2011	Surat	35.5	54.2	57.9
2011-	Junagadh	8.83	8.97	12.12
2012	Rahuri	20.95	18.35	24.65
	Surat	12.83	23.41	48.70
2012-2013	Junagadh	18.02	22.93	14.20
F. Open boll damage (Locule basis)				
2010-	Rahuri	12.2	19.8	13.1
2011	Surat	25.7	54.2	52.1
2011-	Junagadh	3.43	3.62	4.10
2012	Rahuri	10.37	13.16	12.01
	Surat	7.66	18.71	30.67
2012-2013	Junagadh	11.20	14.65	9.16
G. Leafhopper				
2012-	Surat	1.48	1.46	1.8
2013	Rahuri	4.56	2.17	5.28
	Junagadh	2.93	3.08	2.88
H. Mealybug				
2012-2013	Surat	1.52	1.64	1.52

cent and 19.96 per cent increase over check varieties respectively. Likewise lint yield of RHC 0717 was 677.44 kg/ha as compared to 497.33 kg/ha in LRA 5166 and 566.50 kg/ha in Phule 688. The bolls/plant of existing genotypes was 38 as compared to 29 and 36 in LRA 5166 and Phule 688 respectively. For all other characters *viz.*, ginning outturn, boll weight, 2.5 per cent span length, Micronaire and bundle strength the genotype RHC 0717 recorded more or less equal mean values. The fibre quality traits tested for RHC 0717 culture under full spinning test by ICC mode revealed that, the span length of 26.3 mm and strength 21.6 g/tex. which can spun in between 30-40 counts (Table 4). The culture RHC 0717 was evaluated under field conditions at different locations of Central zone during 2010-2011 to 2012-2013 for disease and pest reaction. The test variety showed disease free reaction to gray mildew, resistant to Bacterial Leaf Blight and moderately resistant to Alternaria Leaf Blight (Table 5). Likewise the, the genotype was also found tolerant to sucking peats and bollworm (Table 6).

In view of superior fibre properties and yield potential over the *G. hirsutum* check varieties LRA 5166 and Phule 688, the strain RHC 0717 was released under the name "Phule Yamuna" and recommended for commercial cultivation in cultivation in irrigated tract of central zone of India in the year 2014.

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REFERENCES

Anonymous 2015. AICRP on Cotton *"Annual Report"* 2014-2015.

Fryxell, P.A., Craven, L.A and Stewart, J.M.C.D. 1992. A revision of *Gossypium* sect. Grandi Calyx (*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, Fourth 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.

Evaluation of *Bt* cotton hybrids for yield and fibre quality traits

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ABSTRACT : A field experiment was conducted to evaluate fifty six intra-*hirsutum Bt* cotton hybrids including three *Bt* checks at Regional Agricultural Research Station, Lam farm, Guntur, Andhra Pradesh in *kharif* 2013-2014 following randomized block design with three replications. In the present investigation, analysis of data indicated significant differences between the *Bt* cotton hybrids for seed cotton yield which ranged between (2474 to 4116 kg/ha). Highest seed cotton yield (4116 kg /ha) was recorded with *Bt* hybrid KSCH 232 BGII followed by Ankur 2595 BG II (3981 kg /ha) and SP7517 BG II (3966 kg /ha). All these hybrids were significantly superior to *Bt* checks Bunny BG II (3234 kg /ha), Mallika BG II (3047 kg/ha) and Jaadoo BG II (2980 kg/ha). Number of bolls ranged from 29 to 58, boll weight ranged from medium boll (4.4 g) to big boll (6.5 g), 2.5 per cent span length from medium (27.2 mm) to long (33.6 mm) and bundle strength (20.8 g/tex) to strong (24.5 g/tex). Highest boll/plant was recorded by ACH 1 BGII followed by First class BG II. Higher boll weight was observed in Ankur 2595 BGII and ACHH 2 BGII hybrids. Whereas, Ankur 5464 BG II recorded highest 2.5 per cent span length and Ankur 2595 BGII and JKCH 8905 BG II shown maximum bundle strength. It is evident that some of the *Bt* cotton hybrids studied, have shown good performance in terms of both yield and fibre quality traits in the given environment.

Key words : *Bt* cotton, fibre quality traits, yield

Cotton is one of the important crops in India and it plays significant role in socio-economic status of Indian farmers. In India it occupies an area of about 12.655 million hectares and production of 40.0 million bales of cotton with an average productivity of 537 kg lint/ha (AICRP, Annual Report, 2014-2015). It plays a prominent role in farming and industrial economy of the country. With the introduction of *Bt* cotton hybrids, there has been a significant change in the cotton cultivation scenario of India. Now, around 90 per cent area under cotton is occupied by *Bt* cotton hybrids. However, the average production is very low compared to world’s average. This is mainly because 70 per cent of cotton area is under rainfed condition. There are many number of *Bt* cotton hybrids were released by private companies which are under cultivation in farmers fields. But still there is a need to evaluate high yielding *Bt* cotton hybrids along with good fibre properties for specific locations. Hence, the present study was undertaken to identify the high yielding *Bt* cotton hybrid for this location.

MATERIALS AND METHODS

A field experiment was conducted during *kharif*, 2013-2014 at Regional Agricultural Research Station, Lam farm, Guntur, Andhra Pradesh. The present study was carried out with 53 *Bt* cotton hybrids along with three checks (Bunny, Mallika and Jaadoo) in randomized block design with three replications. The inter and intra-row spacing adapted was 105 x 60cm. Each plot consisted of four rows of 6 m length and

Table 1. Mean Seed cotton yield and fibre quality traits of different *Bt* cotton hybrids

S.No	*Bt* cotton hybrid	Seed cotton yield (kg/ha)	Bolls/ plant	Boll weight (g)	2.5 per cent span length (mm)	Bundle strength (g/tex)
1	Western Nirogi 108	3201	43	5.2	27.9	20.9
2	NCH 2108	3340	44	5.4	29.5	22.4
3	AC H 4	2996	34	6.3	32.1	22.8
4	SCH 505	3228	42	5.5	32.3	23.6
5	KSCH 207	3467	40	6.2	28.3	22.6
6	ACH 2	2599	29	6.2	31.0	23.6
7	KCH 3011	3595	38	6.4	30.9	23.9
8	SWCH 4823	3003	33	6.5	29.6	23
9	PCHH 4 (Saraswathi)	3000	35	6.4	32.4	23.5
10	ACH 1	3463	58	4.4	27.2	20.6
11	NBC 101	3946	46	6.1	29.9	23.5
12	SCH 311	3165	38	5.8	30.9	22.8
13	Ankur 2595	3981	43	6.5	31.4	24.5
14	Western Niogi 51	2923	41	5.2	27.2	21.5
15	ACHH 2	3040	36	6.5	29.9	23.7
16	JKCH 8905	3247	34	6.5	31.2	24.5
17	KCH 3021	3737	49	5.6	33.3	24.4
18	KSCH 232	4116	51	5.3	28.3	22.4
19	DPC 5102 (Aravind)	3569	45	6.1	31.7	22.7
20	First class	2942	55	5.6	29.2	22.2
21	IAHH 4202	2963	46	4.6	31.2	22.9
22	DPC 9104 (Aravind)	3665	46	5.8	29.6	22.1
23	ACH 104 2	2877	36	6.0	31.8	22.3
24	KSCH 233	2956	41	5.6	32.0	22
25	81 SS 33	2725	36	5.7	29.4	22.4
26	PCHH 5073 (Meenakshi)	2910	34	6.4	28.3	22.2
27	60 SS 66	2853	40	5.6	32.7	22.4
28	Ankur 3818	3380	43	6.1	30.7	22.8
29	KCH 3041	3655	46	6.0	31.3	22.6
30	KSCH 209	3080	46	5.1	28.4	21.7
31	741 SS 66	3827	45	6.2	31.6	24.3
32	Ankur 5464	2802	36	6.1	33.6	23.3
33	SP 7585	3033	46	5.1	27.9	22.6
34	Ankur 2224	3501	51	5.2	32.2	22.1
35	KSCH 229	3742	47	5.8	31.0	21.7
36	SCH 234	3919	54	5.5	30.8	21.9
37	KCH 3031	2606	37	5.9	33.0	23.7
38	RCH 797	3913	47	6.2	31.4	23
39	IAHH 178	3553	51	5.2	30.9	21.6
40	KCH 3001	3463	42	6.4	32.2	22.9
41	Surpass Asha	3320	46	5.4	32.4	23.5
42	NCH 1311	3419	42	6.3	32.9	22.7
43	Ankur 4858	3188	47	5.2	27.4	22.1
44	DPC 7102 (Arind)	2474	38	5.2	30.2	22.2
45	63 88 33	3619	53	5.2	31.3	23.1
46	NCH 1049	3314	38	6.4	31.8	23.3
47	RCH 779	3400	43	6.1	31.7	23.1
48	NBC 102	3267	46	5.3	27.8	20.7
49	SP 7517	3966	49	5.8	32.0	22.6
50	DPC 9105 (Arind)	3503	53	4.9	29.4	22.8
51	KSCH 234	3115	38	6.3	29.5	22.2
52	SCH 777	3770	47	5.9	32.8	23.6
53	SCH 333	3545	45	5.6	32.7	24.3
54	Bunny	3234	42	5.7	32.9	24
55	Mallika	3047	40	5.6	31.0	23.3
56	Jaadoo	2980	40	5.4	32.2	23.2
	GM	3306	43	5.8	30.8	22.8
	CD (p=0.05)	731.0	7.2	0.27	1.15	1.3
	CV (%)	13.8	10.5	2.9	2.3	3.5

observations were recorded on ten randomly selected plants from each genotype/replication for characters *viz.,* bolls/plant, boll weight (g) and whereas, seed cotton yield (kg/ha), 2.5 per cent span length (mm) and bundle strength (g/tex) were recorded on plot basis. Recommended dose of fertilizers and need based plant protection measures were carried out for management of sucking pests to ensure a near perfect expression of the genotypes. *Kapas* was taken from the first picking and the lint was subjected to fibre quality testing at Central Institute for Research on Cotton Technology (CIRCOT) Regional Unit Lam, Guntur.

RESULTS AND DISCUSSION

In the present investigation, analysis of data indicated significant differences between the *Bt* cotton hybrids for seed cotton yield which ranged between (2474 to 4116 kg/ha). Highest seed cotton yield was recorded by KSCH 232 (4116 kg/ha). The hybrids *viz.,* KSCH 232 (4116 kg/ha), Ankur 2595 (3981 kg/ha) and SP7517 (3966 kg/ha) recorded significantly higher yield than the three check hybrids Bunny (3234 kg/ha), Mallika (3047 kg/ha) and Jaadoo (2980 kg/ha). Whereas, NBC 101 (3946 kg/ha), 741SS66 (3827 kg/ha) and RCH 797 (3913 kg/ha) recorded significantly higher yield than the two check hybrids Mallika (3047 kg/ha) and Jaadoo (2980 kg/ha). KCH 3021 (3737 kg/ha) and KSCH229 (3742 kg/ha) recorded significantly higher yield than check hybrid Jaadoo (2980 kg/ha). bolls/plant ranged between 29 (ACH 2) and 58 (ACH 1). Highest bolls/plant was recorded by ACH 1 (58) followed by First class (55), SCH 234 (54), 638833(53), DPC 9105 (53), KSCH 232 (51), Ankur 2224 (51) and IAHH 178 (51) against checks Bunny (42), Mallika (40) and Jadoo (40). Boll weight ranged from 4.4 g to 6.5 g. The entries *viz.,* Ankur 2595, ACHH 2, JKCH 8905 and SWCH 4823 recorded highest boll weight (6.5 g) followed by KCH 3011, PCHH 4, PCHH 5073, KCH 3001 and NCH 1049 recorded 6.4 g boll weight compared with the checks *viz.,* Bunny (5.7 g) , Mallika (5.6 g) and Jaadoo (5.4 g).

For 2.5 per cent span length the values ranged from 27.2 mm to 33.6 mm. The entries Ankur 5464 (33.6 mm) and KCH 3021 (33.3 mm) recorded highest 2.5 per cent span length over the checks Jadoo (32.2 mm) and Mallika (31.0 mm). Bundle strength ranged from 20.6 g/tex to 24.5 g/tex. The entries *viz.,* Ankur 2595 (24.5g/tex), JKCH 8905 (24.5 g/tex), KCH 3021 (24.4 g/tex), 741SS 66 (24.3 g/tex), SCH 333 (24.3) having superior strength over the three checks Bunny (24.0 g/tex), Mallika (23.3 g/tex) and Jaadoo (23.2 g/tex).

The desirable hybrids in respect of seed cotton yield are KSCH 232, Ankur 2595 and SP 7517 whereas, with respect to fibre properties Ankur 2595 and KCH 3021 were identified in the present investigation for this location. However it needs further confirmation on multi location basis. Similar research studies on *Bt* cotton hybrids were also reported by Deshmukh *et al.*, (2013), Bhongle *et al., (*2014) , Sangwan *et al.,* (2013), Patil *et al.,* (2013) and Patel *et al.*, (2013).

REFERENCES

AICRP Annual Report. 2014-2015. All India Coordinated Research Project on Cotton. Coimbatore, Tamilnadu, India.

Deshmukh, S.B., Rathod, T.H., Bhongle, S.A., Nemade, P.W. and Patil, B.R. 2013. Comparative study of BGI and BG II cotton hybrids under rainfed condition. National convention on *"Indian Cotton: Gearing up for Global leadership"*. January,6-8. : 42

Bhongle, S.A., Patil, B.R., Deshmukh, S.B. and Rathod, T.H. 2013. Evaluation of popular *Bt* cotton hybrids for fibre quality under rainfed conditions. National convention on *"Indian Cotton: Gearing up for Global leadership"*. January,6-8.: 47

Patel, D.H., Patel, V.I., Vadodaria, K.V. and Kumar,V. 2013. Evaluation of *Bt* cotton hybrids under rainfed condition. National Seminar on *"Technology for Development and Production of Rainfed Cotton"* October 24-25: 11

Patil,B.R, Bhongle,S.A, Deshmukh,S.B, Nemade, P.W and Ingole, O.V. 2013. Evaluation of *Bt* cotton bybrids under rainfed condition. National seminar on *"Technology for Development and Production of Rainfed Cotton'* October 24-25 : 9

Sangwan,R.S., Siwach,S.S., Sangwan, O., and Pundir, S.R. 2013. Evaluation of performance of *Bt* cotton hybrids under different moisture conditions. National convention on *"Indian Cotton: Gearing up for Global leadership"*. January,6-8. 53.

Stability for seed cotton yield and its components in cotton (*Gossypium hirsutum L.*)

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ABSTRACT : Eleven diverse *G.hirsutum* genotypes were evaluated during *kharif* 2010-2011,2011-2012 and 2012-2013 to study their stable performance over the periods for nine characters *viz.* Bolls/plant, Boll weight, ginning percentage, halo length, micronaire, fibre strength, seed index, lint index and seed cotton yield/plot of cotton *(G.hirsutum).* The performance of G x E interactions revealed variation was found significant for the characters, bolls/plant, halo length, seed index and seed cotton yield for the characters indicating the seasons wise quite diverse with regard to their effect on the performance of the genotypes for different traits studied. Among the genotypes NDLH 1928 performed stable over environments for the trait, seed cotton yield.

Cotton is the most important fibre and cash crop. It is fulfilling the domestic needs as well as earning foreign exchange for the country. The average production of cotton in India is lowest among cotton growing nations of the world. One of the major constraints in realizing higher productivity is that the crop is grown under diverse agro climatic condition and is highly sensitive to environmental fluctuation which causes instability in the production from year to year. So the present study was carried out to assess the stability of some promising cotton genotypes developed at Acharya N.G.Ranga Agricultural University, Regional Agricultural Research Station, Nandyal with checks.

MATERIALS AND METHODS

The present study was carried out with eleven genotypes of cotton (*Gossypium hirsutum. L*). These genotypes were grown in three seasons *i.e.,* 2010-2011, 2011-2012 and 2012-2013 in a randomized block design with three replications at R.A.R.S, Nandyal. Each entry consisted of 4 rows of 6 m length with inter and intra row spacing of 60 x 30 cm. The observations were recorded on five randomly selected competitive plants from each genotype in each replication for nine component characters *viz.,* bolls/plant, boll weight (g), ginning percentage (%), 2.5 per cent halo length(mm), fibre strength(g/tex), micronaire(10^{-6} g/inch), seed index, lint index and seed cotton yield per hectare. The yield, yield components and fibre quality characters were analyzed. The stability analysis was carried out as per Eberhart and Russell model (1966).

RESULTS AND DISCUSSION

The analysis of variance for stability with regard to seed cotton yield, yield components and fibre quality characters are presented in table 1. It shows that mean squares due to genotypes

Table 1. Analysis of variance (pooled) for yield and fibre component characters in cotton

Source of Variance	df	Seed cotton yield/ha	bolls/plant	Boll weight (g)	Mean squares			Fibre strength (g/tex)	Seed index	Lint index
					Ginning percentage (%)	2.5 per cent span length (mm)	Micronaire (10^{-6} g /inch)			
Varieties	10	169257.48**	38.19**	0.41	4.74	5.31**	0.22**	0.85*	2.58**	0.6310**
Env.+(var.* Env)	22	678721.46**	154.1**	0.27	4.46	1.29**	0.02	0.29	0.08*	0.03606
Env+(Lin)	1	14123383.84**	2566.98**	0.46	65.99**	20.02**	0.03	1.92*	1.11**	0.34501**
Var.*Env.(Lin)	10	43318.18	72.28**	0.24	0.72	0.58	0.01	0.19	0.05	0.01387
Pooled deviation	11	34118.76*	9.13**	0.28**	2.27	0.25	0.02	0.22	0.02	0.02815
Pooled error	60	11945.62	1.48	0.023	2.66	0.79	0.015	0.49	0.08	0.05740

** Significant at both 5 % and 1 % *Significant at 5%

Table 2. Estimates of stability parameters for yield and fibre traits of 11 varieties of G. *hirsutum*.

S. No	Varieties	Seed cotton yield /ha			bolls/plant			Boll weight (g)			Ginning percentage (%)			2.5 per cent span length (mm)		
		$\bar{\chi}$	βi	S^2Di	$\bar{\chi}$	βi	S^2Di	$\bar{\chi}$	βi	S^2Di	$\bar{\chi}$	βi	S^2Di	$\bar{\chi}$	βi	S^2Di
1	NDLH 1870	2319.0	0.922	15485.1	25.5556	1.178	-1.9872	3.2111	-0.965	-0.0264	36.1111	1.056	-0.2067	26.8889	1.793	-0.9642
2	NDLH 1906	2723.4	1.092	-2080.2	27.0000	1.563	29.9405	3.0444	-0.352	-0.0263	33.4445	0.889	-2.7068	28.0000	1.354	-0.7492
3	NDLH 1928	2761.0	1.033	28888.1	22.7778	1.077	3.5564	3.6556	-0.138	0.0291	32.7778	0.722	-2.4291	29.4444	1.310	-0.9043
4	NDLH 1939	2504.8	0.937	-11443.0	21.3333	0.724	-1.4444	4.1111	2.702	-0.0080	33.0000	0.833	-1.5401	30.0000	1.016	-0.8444
5	NDLH 1943	2542.1	1.035	11709.3	23.6667	1.201	-1.6695	3.6333	0.971	0.3103	32.7778	1.056	-1.5401	28.2222	-0.388	-0.9445
6	NDLH 1969	2366.9	0.709	-5808.4	22.0000	1.287	11.7580	4.0444	6.723	1.1919	33.8889	1.444	0.6267	31.6667	1.016	-0.8444
7	NDLH 1973	2021.3	1.116	69240.2	15.3333	-0.110	19.1801	4.0222	-0.919	0.0127	34.5556	0.444	0.6264	29.6667	1.016	-0.8444
8	NDLH 1975	2349.7	0.857	148304.1	17.5556	0.230	2.2078	4.1444	-1.875	0.1800	34.8889	0.611	-1.5402	30.6667	0.827	-0.6559
9	NDLH 1976	2602.7	0.839	-11968.0	26.0000	1.364	-1.6231	3.6667	1.920	0.3966	32.3333	1.333	-2.0400	30.2222	0.872	-0.9413
10	NDLH 1983	2071.6	1.412	-10602.2	20.3333	0.759	19.6324	3.4556	2.716	0.3534	34.1111	1.056	6.4599	29.8889	1.510	0.7370
11	NDLH 1755	2374.4	1.049	11541.8	24.0000	1.727	-1.3269	3.4556	0.216	0.3280	35.7778	1.556	-2.9288	29.3333	0.677	-0.9123
Mean		**2421.5**	-	-	**22.32**	-	-	**3.68**	-	-	**33.97**	-	-	**29.46**	-	-
SEm		130.6	-	-	2.14	-	-	0.37	-	-	1.07	-	-	0.35	-	-

$\bar{\chi}$= Mean values; βi = Regression coefficient; S^2Di=Deviation from regression coefficient

S. No	Varieties	Micronaire(10^{-6} g /inch)			Fibre strength (g/tex)			Seed index			Lint index		
		$\bar{\chi}$	βi	S^2Di	$\bar{\chi}$	βi	S^2Di	$\bar{\chi}$	βi	S^2Di	$\bar{\chi}$	βi	S^2Di
			âi	**S^2Di**		**âi**	**S^2Di**		**âi**	**S^2Di**		**âi**	**S^2Di**
1	NDLH - 1870	4.5778	2.360	-0.0174	22.0778	0.814	-0.3621	7.2889	0.825	-0.1007	3.8444	0.438	-0.0982
2	NDLH - 1906	5.3000	0.292	-0.0025	20.6556	-0.325	0.2331	7.7000	0.486	-0.1033	3.7333	0.121	-0.0634
3	NDLH - 1928	4.7889	2.401	-0.0090	22.2222	3.288	-0.4737	10.4333	0.856	-0.0957	5.0556	0.642	-0.0279
4	NDLH - 1939	4.5889	0.085	0.0028	21.7444	0.033	0.1181	9.2222	0.781	-0.0758	4.2556	0.689	-0.0693
5	NDLH - 1943	4.4778	4.593	0.0024	21.1111	0.717	-0.3449	8.3556	1.901	-0.0370	3.5111	1.256	-0.1038
6	NDLH - 1969	4.9556	0.251	0.0205	21.5000	1.856	0.0466	9.9000	2.375	-0.1022	4.5556	2.164	-0.0590
7	NDLH -1973	4.6556	1.202	0.0238	21.5333	1.270	-0.4200	8.6778	0.517	-0.0990	4.3444	0.766	-0.0861
8	NDLH - 1975	4.7222	-1.858	-0.0078	20.933	1.953	-0.4317	9.5778	1.506	-0.1032	4.2111	-0.432	-0.0736
9	NDLH - 1976	4.7111	-1.693	-0.0019	21.6667	0.684	-0.4598	9.2778	1.180	-0.0659	3.9111	1.043	-0.0818
10	NDLH - 1983	4.6667	2.608	0.0122	22.1111	0.814	-0.4865	9.1333	0.028	-0.617	4.3000	1.217	-0.1038
11	NDLH - 1755	4.2222	0.788	-0.0053	22.2000	-0.097	-0.3264	9.3222	0.543	-0.0884	4.7778	1.095	-0.0675
Mean		**4.69**	-	-	**21.61**	-	-	**8.99**	-	-	**4.23**	-	-
SEm		0.09	-	-	0.33	-	-	0.11	-	-	0.12	-	-

were found significant for most of the characters except for boll weight. The environment + (G x E) was significant for most of characters indicating distinct nature of environment and G x E interactions in phenotypic expressions. The environment (linear) was significant for all the characters except for boll weight indicating difference between environments and their influence on genotypes for expression of these traits. The G x E (linear) interaction showed significance for number of bolls/plant. This indicated significant difference among the genotypes for linear response to environments and behaviour of the genotypes which could be predicted over environments more precisely and G x E interactions was outcome of linear function of environmental components. Hence, performance of genotypes could be predicted based on stability parameters which would be feasible and reliable.

Among 11 varieties tested, NDLH 1928 registered highest seed cotton yield/ ha (2761 kg/ha) and produced a regression value of 1.033(~1) which significantly deviated from one. The S^2d was found nonsignificant. These values indicated that, NDLH 1928 is stable for all environments (Nidagundi *et al.,* 2010, Patil *et al.,* 2007 and Fatihi Kill and Eyup Hareem, 2006).

The varieties NDLH 1928 for number of bolls/plant, NDLH 1973 for boll weight, NDLH 1983 variety for ginning percentage, NDLH 1973 variety for micronaire (10^{-6} gm/inch) under regression showed nonsignificant deviation from zero. Hence, these varieties are considered as stable performers.

As the deviation from regression for remaining characters were non significant but had negative values for almost all varieties. But, on the basis of regression values the performance of varieties over environment can be ascertained. Average performance of varieties NDLH 1969 and NDLH 1973 for 2.5% span length (mm) and the variety NDLH 1755 for lint index had âi value near to one indicating that they are suitable for all environments.

It can be concluded from the present study that NDLH 1928 was stable in its performance for seed cotton yield.

REFERENCES

Eberhart, S.A and Russell, W.A. 1966. Stability parameters for comparing genotypes. *Crop Science*. **6** : 36 – 40.

Fatih Kill and Eyup Harem, 2006. Genotype x environment interaction and stability analysis of cotton yield in Aegeon region of Turkey. *Journal of environmental biology*. **27** : 427-30.

Patil, B.C., Kumar.V., Ratnakumari, S., Mishra, O.S., Patil, S.S., and Khadi, B.M., 2007. Stability of *G.hirsutum* genotypes for performance across Indian rainfed ecosystem.

Nidagundi, J. M., Patil, S.S., Salimath, P. M. and Hegde, M.G. 2010. Stability studies in cotton (*Gossypium hirsutum L.*): can stable performance of cotton genotypes in the national trials be used as reliability index in determining stable hybrids. Crop Improvement. **37** : 201.

Genetics of seed cotton yield and its attributing characters in cotton (*Gossypium hirsutum* L.)

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ABSTRACT : Genetic material comprised of sixty, three way crosses derived from fifteen diallel crosses produced by crossing six diverse parents *viz.*, 241-4-2, G Cot 100, RFS 3438,65- 2(s)-3,Hyps 152 and Suvin were studied to obtain information on genetics of seed cotton yield and its attributing characters. Gene actions were analyzed by adopting biometrical technique, triallel analysis to get information on epistatic gene action in addition to additive and dominance variances.. The data was analyzed to assess inheritance of gene action for seed cotton yield and its attributing characters *viz.*, monopodia/plant, sympodia/plant, bolls/plant, boll weight, seed index, lint index and ginning outturn. All the traits studied were governed by additive x dominance component of epistatic gene action except lint index which is governed by dominance x dominance gene action. Breeding methods like heterosis breeding would be followed for development of commercial hybrids to obtain higher yields as most of the traits were governed by epistatic gene action. In addition to heterosis breeding special mating designs like bi-parental mating and inter mating in early generations would be adopted to isolate superior segregants from future generations. The order of parents in which crosses must be effected should clearly revealed by the study to obtain superior transgressive segregants.

Key words : Cotton, gene action, seed cotton yield

Cotton is the prime fibre crop of India and ranks first in terms of cultivated area and second in terms of production next to China. The main objective of any crop improvement programme is aiming at increasing yield and production of crop. However yield is a complex character which is poly genetically controlled and influenced by number of yield attributing characters. Information on gene action or genes that govern a particular character in a crop plant is essential for planning and execution of breeding programme successfully. Though different biometrical techniques are used to estimate gene action, triallel analysis is a potential tool to study information on additive, dominance and epistatic gene actions and variances. Triallel analysis also gives the information on order of parents in three way cross combinations for obtaining superior transgressive segregates (Ponnuswamy *et al.*, 1974).

Three way cross was denoted by (A x B) C has been defind as cross between, line "C" and single cross (A x B). Lines "A" and "B" are called as grand parents and line "C" as immediate parent or full parental line (Rawling and Cockerham 1962). In the present study an attempt has been made to obtain information on gene actions in controlling yield and its attributes.

MATERIALS AND METHODS

Field experiments were conducted at Regional Agricultural Research Station, Lam

Guntur of Acharya N G Ranga Agricultural University. The material comprised of 60, three way crosses derived from fifteen diallel crosses produced by crossing six diverse parents *viz.*, 241-4-2(1), G Cot 100 (2), RFS 3438 (3), 65-2(s)-3 (4), Hyps 152 (5) and Suvin (6) in triallel mating design. During *kharif* 2009 six parents were mated in half diallel fashion and fifteen single cross hybrids were produced. During 2010-2011 these 15 single crosses were mated with six orizinal parents in triallel fashion and 60 three way crosses were obtained. All the three way crosses along with single crosses and parents were evaluated in randomized block design in three replications with 105 x 60 cm^2 spacing containing single row with ten hills. Five plants were randomly selected from each plot for data collection on yield and attributing characters *viz.,* monopodia/plant, sympodia/plant, bolls/plant, boll weight(g), seed cotton yield(kg/ha), seed index, lint index and ginning outturn and the mean data was subjected to triallel analysis (Singh and Chaudhary, 1985) to draw valid conclusions.

RESULTS AND DISCUSSION

The analysis of variance revealed that the general line effect of first kind (*hi*) was significant for all the characters except the monopodia/plant and bolls/plant (Table 1). The general line effect of second kind (*gi*) was significant for all the characters and two line specific effects of first kind (*dij*) was also significant except sympodia and bolls/plant. The two lines specific effects of second kind (*sij*) was significant for bolls/plant, seed cotton/plant, seed index, lint index and ginning outturn. The three line specific effect was significant for bolls /plant, seed index, lint index and ginning outturn. The three way cross analysis provides additional information regarding epistatic components of variances and effects and the order in which the parents are to be involved in crosses. The estimation of various effects are would provide information on *gca* and *sca* effects of a line to utilize as grand parent or/as parent.

Monopodia/plant : The general line effect of first kind was positive and significant for parent Suvin (*hi* = 0.267) and it would be used as grandparent in production of significant three way crosses. Though Suvin, a good combiner as grandparent, the other parents *viz.,* Hyps 152, G Cot 100 and 241-4-2 (positive *gi* values) were also considered as grandparents in production of best three way cross combinations.

Positive and significant two line specific effects of first kind (*dij*) were observed in three crosses *viz.,* 241-4-2 × 65-2(s)- 3 (0.307), G Cot 100 × RFS 3438 (0.202) and Hyps 152 × Suvin (0.288) ,which would produce three way crosses with improvement in monopodia/plant when these parents are utilized as grandparents. For two line specific effects of the second kind, one combination 65-2(s) - 3 × 241- 4- 2(*sji*=0.217) was significant with positive effect. Parent 65-2(s)-3 as a grandparent and line 241-4-2 can be utilized as parent to produce significant three way crosses (Table 2). The reciprocal differences in the crosses indicates the presence of order effects in the three way crosses. Similar reports were published earlier by Ramalingam (1996) in cotton.

Positive and significant three line specific effects were exhibited by triplet 5 × 6 × 1 (Hyps 152 × Suvin × 241 -4- 2) (*tijk*=0.273) for this trait. The two line specific effect of first kind (*dij*) was positively significant in cross Hyps 152 × Suvin, hence the performance of this triplet was due to interaction of parent 241-4-2 as immediate parent crossed to grandparents. This

Table 1. Analysis of variance for fibre characters in cotton (mean squares)

S.	Source	*df*				Mean squares				
			Monopodia	Sympodia	Bolls/ plant	Boll weight (g)	Seed cotton yield (Kg/ha)	Seed index (g)	Lint index (g)	GOT
1	Replications	2	0.25 NS	67.40*	1175.77*	1.14 NS	23773.4*	0.09 NS	1.01 NS	0.66 NS
2	Gene line effect of first kind *(hi)*	5	0.34 NS	4.129*	84.91 NS	3.27*	7868.10*	3.57*	8.73*	4.24*
3	Gene line effect of second kind *(gi)*	5	0.95**	6.59*	334.30*	6.27*	10318.3*	6.72*	1.33*	26.10*
4	Two line specific effect of first kind *(dij)*	9	0.54**	4.16 NS	222.51*	0.839 NS	5149.25*	6.52*	2.01*	5.81*
5	Two line specific effect of second kind *(sij)*	19	0.15 NS	4.29 NS	113.89*	0.42 NS	2651.59*	3.02*	8.31*	3.62*
6	Three line specific effect *(tijk)*	21	1.13 NS	2.56 NS	139.70*	0.57 NS	2053.6 NS	2.36*	9.17*	7.80*
7	Crosses	59	0.27*	3.89 NS	151.72*	1.24*	3758.8*	3.45*	1.07*	7.54*
8	Error	118	0.15	4.83	46.73	0.46	1559.54	0.11	4.39	1.48
	CD (p=0.05)		0.64	-	13.19	1.09	70.45	0.55	0.33	1.96
	CV (%)		19.8	14.6	16.5	16.8	21.5	3.1	3.9	3.6

clearly indicated the parent order effects in which crosses will be effected to produce significant three way crosses .

Predominance of additive × dominance component epistatic gene action was observed for this trait with higher magnitude of additive × dominance genotypic variance(Table 3).

Sympodia/plant : Crosses 241-4-2 × G Cot 100 (*dij*=0.128) and RFS 3438 × Suvin (*dij*=1.125) had shown significant positive two line specific effects of first kind for number of sympodia per plant. These crosses would be utilized as grandparents to produce significant three way crosses for sympodia/plant. The highest three line specific effects was recorded in the triplet 1 × 5 × 2 (*tijk*=1.614). Estimation of three line specific effects (*tijk*) were found positive and significant for triplet 1 × 5 × 2 (1.614). Though the two line specific effect of first kind and second kind were non significant in three way cross 1 × 5 × 2, the three line specific effect was positively significant, which was due to inter action of all the parents. The results of components of genetic variance indicated that additive × dominance component of epistatic gene action was the highest followed by additive component. The rest of the variances were negative. Ramalingam (1996) and Patil *et al.*, (2005) reported additive × dominance followed by dominance × dominance gene actions in governing the character which are in agreement with present findings. Whereas Laxman and Ganesh (2003) reported dominance × dominance type of epistatic gene action in governing the character.

Bolls/plant : The general line effect of first kind (*hi*) and second kind (*gi*) for the character number of bolls per plant were positive and significant for parent Suvin (*hi*=4.944 and *gi*=3.167). Parent Suvin may be utilized as grandparent as well as a parent to produce significant three way crosses. RFS 3438 exhibited positive general line effect of first kind (*hi*) and parent, 241-4-2 had shown positive general line effect of second kind (*gi*). The preference for parental consideration was parent

Table 2. Estimation of General, Specific Line effects for diallel and triallel crosses which shown significance for the fibre characters in cotton

S no	Character	General line effects				Two line effects			Three line effects	
		Line	*hi*	*gi*	Cross	*dij*	*sij*	*sji*	Cross	*tijk*
									5x6x1	0.273*
1	Monopodia	Suvin	0.267*		241-4-2 x 65-2(s)-3	0.307*				
					G Cot 100 x RFS 3438	0.202*				
					Hyps 152 x Suvin	0.288*				
					65-2(s)-3 x 241-4-2			0.217*		
2	Sympodia				241-4-2 x G Cot 100	0.128*			1x5x2	1.614*
					RFS 3438 x Suvin	1.215*				
3	Bolls/plant	Suvin	4.944*	3.16*	241-4-2 x G Cot 100	8.46*			1x5x3	4.596*
					RFS 3438 x Hyps 152	3.7*			2x3x4	5.4*
					65-2(s)-3 x Suvin	4.1*			2x5x6	7.133*
					65-2(s)-3 x Hyps 152	4.138*			2x6x1	7.811*
					RFS 3438 x Suvin		3.234*		3x4x6	9.589*
					241-4-2 x Suvin		2.677*			
					G Cot 100 x 241-4-2			4.844*	3x6x1	5.878*
					65-2(s)-3 x RFS 3438			3.61*	4x5x1	10.656*
					Hyps 152 x G Cot 100			5.387*		
									5x6x2	5.911*
4	Boll weight (g)	241-4-2	0.292*		241-4-2xG Cot 100	0.325*			1x3x4	0.524*
		65-2(s)-2	0.22*		RFS 3438 x 65-2(s)-3	0.537*			3x4x2	0.684*
		Hyps 152		0.362*					3x5x6	0.645*
									4x6x5	0.552
5	Seed cotton)	241-4-2	20.46*	14.82	241-4-2x G Cot 100	48.11*			1x3x5	34.50*
	yield (Kg/ha	Hyps 152		16.21*	65-2(s)-3 x Hyps 152	20.63*			4x5x1	26.59*
					RFS 3438 x Hyps 152	29.02*			5x6x4	27.73*
					65-2(s)-3 x RFS 3438			17.35*		
					Hyps 152 x G Cot 100			32.83*		

6	Seed index (g)	Hyps 152	0.206*		241-4-2x G Cot 100	1.103*	0.672*	1x3x5	1.273*
		Suvin	0.677*	0.655*	241-4-2x RFS 3438	0.302*	0.488*		
					241-4-2 x 65-2(s)-3	0.170*			
					G Cot 100 x Hyps 152	0.467*	0.165*		
					RFS 3438 x Suvin	0.280*	0.392*		
					65-2(s)-3 x Suvin	0.348*			
					Hyps 152 x Suvin	0.447*	1.311*		
					G Cot 100 x 65-2(s)-3		0.326*		
					65-2(s)-3 x Hyps 152		0.474*		
7	Lint index (g)	241-4-2	0.287*		241-4-2x G Cot 100	0.710*		1x2x3	0.264*
		G Cot 100	0.1402*	0.1138*	241-4-2x RFS 3438	0.115*		1x2x4	0.28*
		Suvin	0.0694*	0.2277*	241-4-2 x 65-2(s)-3	0.266*		1x3x5	0.78*
					G Cot 100 x Hyps 152	0.111*		1x5x2	0.424*
					RFS 3438 x 65-2(s)-3	0.145*		3x5x1	0.586*
					RFS 3438 x suvin	0.181*		3x6x2	0.546*
					Hyps 152 x Suvin	0.42*		4x5x3	0.602*
8	GOT	241-4-2	1.072*		241-4-2 x 65-2(s)-3	0.842*			
		G Cot 100	0.496*		G Cot 100 x 65-2(s)-3	0.821*			
		RFS 3438	0.404*		Hyps 152 x Suvin	1.038*			
		65-2(s)-3	0.600*		241-4-2x G Cot 100	1.029*			

Parents: 1.241-4-2; 2.G Cot 100; 3.RFS 3438; 4.65-2(s)-3; 5.Hyps 152; 6.Suvin

Suvin, as grand parent as well as parent whereas RFS 3438 as grand parent and 241-4-2 as a parent for crossing in production of significant crosses for the trait number of bolls per plant. Two line specific effects of first kind (*dij*) was positive and significant for crosses 241-4-2 × G Cot 100 (8.46), RFS 3438 × Hyps 152 (3.70), 65-2(s)-3 × Hyps 152 (4.31) and 65-2(s)-3 × Suvin (4.10) indicating that these combinations as grandparents would produce significant three way combinations. Line 65-2(s)-3 found to be a good grand parent than other genotypes as it exhibited significant crosses with two parents where as genotypes 241-4-2 and RFS 3438 with one parent each. The two line specific effect of second kind (*sij*) was positively significant in 241-4-2 × Suvin (2.677) and RFS 3438 × Suvin (3.234), hence parents 241-4-2 and RFS 3438 are proposed to be utilized as half parents (grand parents) to produce significant three way crosses with Suvin as a parent. Whereas the reciprocals were also significant in G Cot 100 × 241-4-2 (*sji*=4.844), 65-2(s)-3 × RFS 3438 (*sji*=3.61) and Hyps 152 × G Cot 100 (*sji*=5.387) indicating that lines G Cot 100, 65-2(s)-3 and Hyps 152 would also be utilized as half parent in addition to the above to produce significant three way crosses. In this case the reciprocals were considered as they are associated with order effects in three way cross hybrids. It was found to be interesting that many crosses had reciprocal differences for second kind effects indicating that the importance order of arrangement of parents in triplets.

The three line specific effects (*tijk*) were positive and significant in crosses *viz.*, 4 × 5 × 1 (10.656), 3 × 4 × 6 (9.589), 2 × 6 × 1 (7.811), 2 × 5 × 6 (7.133), 5 × 6 × 2 (5.9118), 3 × 6 × 1 (5.8788), 2 × 3 × 4 (5.4) and 1 × 5 × 3 (4.956). The triplet 4 x 5 x 1 (65-2(s)-3 × Hyps152 × 241-4-2) was the best in performance, due to the positive and significant two line specific effect of first kind (*dij*) in cross 65-2(s)-3 × Hyps 152 and the general line effect of 241-4-2. Parent 241-4-2 had positive *gca* effect for number of bolls per plant and which was proved as the best general combiner. Hence triplet 4 × 5 × 1 yielded best to produce a three way cross for bolls/plant. The alternative forms 1 × 4 × 5 and 1 × 5 × 4 had non significant *tijk* effects, clearly elucidated the order effect in which parents to be crossed.

Components of genetic variance for the trait indicated that the predominance of additive × dominance gene action followed by additive and dominance × dominance gene actions (Table 3). The epistatic component played major role than additive components in governing the character. Ramalingam (1996) reported similar results of additive × dominance gene action followed by dominance × dominance components of epistatic gene action. Patil *et al.,* (2005) also reported predominance of additive × dominance gene action which are in fully agreement with present results. Whereas Laxman and Ganesh (2003) reported predominance of dominance × dominance component of epistatic gene action in the inheritance of the character.

Boll weight (g) : The general line effects of first kind (*hi*) was positive and significant for parents 241-4-2 (0.292), 65-2(s)-3 (0.22) and second kind effect (*gi*) for Hyps 152 (0.362) (table. 2). The *gca* effects of diallel parents 241-4-2 and Hyps 152 were positively significant whereas in triallel, parents 241-4-2 and 65-2(s)-3 for general line effect of first kind and Hyps 152 for general line effect of second kind were found positively significant. This clearly indicated that parents 241-4-2, and 65-2(s)-3 were good general combiners to produce bigger bolls when used as grandparents, where as Hyps 152 as a parent (full parent) crossed to a single cross. The specific combining ability in diallel crosses was positively significant in crosses RFS 3438 × Suvin, 241-4-2 × RFS 3438 and RFS 3438 × Hyps 152.

The two line specific effects of first kind (*dij*) were positive and significant for crosses RFS3438 × 65-2(s)-3 (0.537) and 241-4-2 × G Cot 100 (0.325). These lines as grandparents will produce significant three way cross combinations. The two line specific effect of second kind (*sij*) was positive in seven crosses with reciprocal differences indicating the importance of parent order in three way crosses. The highest significant positive three line specific effects (*tijk*) were exhibited by 3 × 4 × 2 (0.684) followed by 3 × 5 × 6 (0.645), 4 × 6 × 5 (0.552) and 1 × 3 × 4 (0.524).

The triplet 3 × 4 × 2 (RFS 3438 × 65-2(s)-3 × G Cot 100) had shown highest positive significant three line specific effect for boll weight. The parent order 3 × 4 × 2 clearly elucidated the superior performance whereas its alternative forms, 2 × 3 × 4 and 2 × 4 × 3 had negative non significant *tijk* effects indicating the importance of order of parents to be used in three way crosses for obtaining highest gain in boll weight. The best triplet 3 × 4 × 2, parent 65-2(s)-3 was good general combiner whereas the other parents were poor general combiners. The two line specific effects of first kind were positively significant for RFS 3438 × 65-2(s)-3 as grandparents and the general line effect of second kind was positive for G Cot 100 which was the best choice as a parent to produce significant three way crosses. Thus the best performance can be attributed due to (i) *dij* effect (ii) *gi* effect and (iii) interaction of three parents used in particular order.

Additive × dominance gene action was predominant followed by additive and dominance × dominance components for inheritance of this trait (Table 3). It clearly revealed predominance of epistatic gene action playing major role in governing the character. Hence it is essential to go for two or three selections in segregating generations before starting selection for improvement of the character. Ramalingam (1996), Ganesh and Laxman (2003) and Patil *et al.,* (2005) reported predominance additive × dominance component followed by dominance × dominance of gene action for boll weight in cotton.

Seed cotton yield/plant (kg/ha) : The general line effects of first kind (*hi*=20.46) and second kind (*gi*=14.82) were positive and significant for parent 241-4-2 and parent Hyps 152 exhibited positive and significant general line effects of second kind (*gi*=16.213). These parents were good general combiners to produce best combination for seed cotton yield, while the parent 241-4-2 as grandparent as well as a

Table 3. Components of genetic variance for seed cotton yield and other characters

S. No.	Genetic variance	Mono-podia	Sym-podia	Bolls	Boll weight (g)	Seed cotton (Kg/ha)	Seed index (g)	Lint index (g)	GOT
$\sigma^2 a$	-0.0457	0.1716	40.8917	0.6624	1108.23	1108.23	-0.0075	-0.1680	2.201
$\sigma^2 d$	-0.2248	-6.8077	-276.0893	-0.0793	-5660.64	-5660.64	-6.2827	-0.7424	-9.010
$\sigma^2 aa$	0.1498	-0.1189	-48.3335	-0.6712	-785.53	-785.53	0.1767	0.3867	-2.541
$\sigma^2 ad$	0.4156	30.9391	1108.38	2.0758	25989.37	25989.37	19.7311	0.3055	30.426
$\sigma^2 dd$	-0.1039	-7.8949	30.20	0.3815	-3787.35	-3787.35	2.0724	2.3575	10.897
$\sigma^2 a/\sigma^2 d$	-0.2032	-0.0252	-0.148	-8.353	-0.185	-0.185	-0.0011	-0.226	-0.244
$\sigma^2 d/\sigma^2 a$	-4.9190	-39.6719	-6.751	-0.1197	-5.107	-5.107	-837.69	-4.419	-4.093

parent in three way crosses, and Hyps 152 as a parent (full parent) to cross to a single cross to produce significant three way crosses. When *gca* effects of diallel and triallel analyses were compared, the parents 241-4-2 and Hyps 152 were positive and significant for seed cotton yield per plant. The specific combining ability of cross combination 241-4-2 × Hyps 152 was positively significant with highest *per se* performance for seed cotton yield (326.66g). This combination exhibited the best specific combining ability to produce high yielding F_1 hybrid.

Two line specific effects were positive and significant for crosses, 241-4-2 × G Cot 100 (*dij*=48.11) and 65-2(s)-3 × Hyps 152 (20.63). These lines in the crosses as grandparents will produce superior three way cross combinations. Positive and significant two line specific effects of second kind were observed for crosses RFS 3438 × Hyps 152 (*sij* = 29.02), Hyps 152 × G Cot 100 (*sji*=32.833) and 65-2(s)-3 × RFS 3438(*sji*=17.35) indicating that parents RFS 3438, Hyps 152 and 65-2(s)-3 would be utilized as half parents in three way crosses to produce significant three way crosses. It was clear that genotypes RFS 3438 and Hyps 152 were utilized as grandparents in the three way crosses for obtaining high performance than other genotypes. The best performing triplet 241-4-2 ×RFS 3438 × Hyps 152 (1 × 3 × 5) had the highest *tijk* effect of (34.50), followed by 5 × 6 × 4 (*tijk*=27.73) and 4 × 5 × 1 (*tijk* = 26.59) in terms of three line specific effects. The parent order effect in 1 × 3 × 5 clearly elucidated, the order of parents in which crossing may have to be effected. The other forms of the same triplets 1 × 5 × 3 and 3 × 5 × 1 were non significant, which clearly shows the order of parents playing an important role to obtain significant three way crosses. The best performance of this triplet (1 × 3 × 5) may be due to the parents 241-4-2 and Hyps 152 as best general combiners for first kind and second kind effects and positively significant for two line specific effect of second kind for the cross RFS 3438 × Hyps 152 (sij=29.02) and interaction of all the three parents might have produced highest yielding hybrid.

Components of genetic variance for this character showed additive × dominance type of gene action as predominant followed by additive component (Table 3). It was clearly understood that predominance of epistatic gene action plays an important role in governing the character. Similar results of predominance of additive × dominance followed by dominance × dominance gene actions was earlier reported by Ramalingam (1996).

Seed index (g) : General line effects of first kind (*hi*) was positive and significant for parent Hyps 152 (0.206) where as parent Suvin had exhibited positive and significant general line effects of first and second kind (*hi*=0.677; *gi*=0.665) for seed index(table 2). These parents were good general combiners to produce best combination for seed index when parent Hyps 152 was used as grand parent and Suvin as grand parent, as well as full parent.

The two line specific effects of first kind (*dij*) were positively significant for crosses 241-4-2 × G cot 100 (1.303), Hyps 152 × Suvin (0.447), 65-2(s)-3 × Suvin (0.348), 241-4-2 × RFS 3438(0.302), RFS 3438 × Suvin (0.280) and 241-4-2 × 65-2(s)-3 (0.170). These parents as grandparents produced superior three way crosses for seed index. Two line specific effects of second kind (*sij*) was found positive and significant in Crosses *viz.*, Hyps 152 × Suvin (*sij*=1.311), 241-4-2 × RFS 3438 (*sij*=0.488), G Cot 100 × 65-2(s)-3(*sij*=0.326),G Cot 100 × Hyps 152(*sij*=0.165), RFS 3438 × 65-2(s)-3(*sij*=0.392) and 65-2(s)-3 × Hyps 152(*sij*=0.474). Parents 241-

4-2, G Cot 100, RFS 3438, 65-2(s)-3 and Hyps 152 were utilized as half parents in three way crosses to produce significant crosses for seed index. In these lines, genotypes G Cot 100 and RFS 3438 were considered as one of the grand parents as they produced significant crosses with three other genotypes each, for the trait seed index. The presence of reciprocal differences was the clear cut indication of order effect of parents in three way crosses.

Triplet 1 × 3 × 5 (241-4-2 × RFS 3438 × Hyps 152) had the highest *tijk* effect and the grandparents of this cross were positively significant for two line specific effects of second kind and immediate parent Hyps 152 showed positive and significant general line effects of first kind. The parent order effect clearly elucidated in triplet 1 × 3 × 5 which had the highest significant positive three line specific effect (*tijk*). The order of mating of parental sequences is important to obtain high performing triplets for seed index. This clearly indicates the order effects of parents in which mating has to be done.

The components of genetic variance for the trait indicated that additive × dominance component was predominance followed by dominance × dominance and additive × additive. It means that non fixable epistatic gene action played a major role in governing the character. Hence, it is necessary to go for recurrent selection cycles with step by step improvement for two to three generations for improving the trait. Ramalingam *et al.,* (1996) and patil *et al.,* (2005) reported that seed index was predominantly under the control of additive × dominance followed by dominance × dominance which are in full agreement with present finding. Whereas Laxman and Ganesh (2003) reported dominance × dominance being highest followed by additive × additive and additive × dominance for this trait.

Lint index (g) : Both first and second kind general line effects were positive and significant for two parents, *viz.,* G Cot 100 (*hi*=0.1402; *gi*=0.1138) and Suvin (*hi*=0.0694; *gi*=0.2277), these genotypes utilized as grand parents as well as full parents would produce significant three way crosses for lint index. Parent 241-4-2 was positively significant for general line effect of first kind (*hi*=0.287) and parent 65-2(s)-3 for general line effect of second kind (*gi*=0.0935) suggesting that the former can be utilized as grand parent and the later one as half parent respectively. Parents G Cot 100 and Suvin were considered as the best lines to involve in crosses as grand parents as well as parents in production of superior crosses for the trait lint index. When *gca* of diallel and triallel crosses were compared parents 65-2(s)-3, Hyps 152 and Suvin found positive significant for lint index. In triallel analysis Suvin shown positively significance for both general line effects whereas parent 65-2(s)-3 for general line effects of second kind. Lines *viz.*, G Cot 100, Suvin, 65-2(s)-3, 241-4-2 and Hyps 152 were the best general combiners for lint index.

Two line specific effects of first kind (*dij*) shown positive and significance in seven crosses *viz.*, 241-4-2 × G cot 100 (0.7016), Hyps 152 × Suvin (0.42), 241-4-2 × 65-2(s)-3 (0.2666), RFS 3438 × Suvin (0.1816), RFS 3438 × 65-2(s)-3 (0.145), 241-4-2 × RFS 3438 (0.115) and G Cot 100 × Hyps 152 (0.1116). Parents 241-4-2 and RFS 3438 were considered as one of the parent as grand parents to produce significant crosses for the trait lint index when compared with other genotypes. In between these two lines parent 241-4-2 is the best parent as it already proved as good general combiner for general line effects of first kind. These parents exhibited significant crosses with three other parents whereas remaining genotypes with two other parents.

Three line specific effect was found to be positive and significant for twenty three crosses. Among them triplet 1 × 3 × 5 (*tijk*=0.78), 4 × 5 × 3 (*tijk*=0.6022), 3 × 5 × 1 (*tijk*=0.5866) and 3 × 6 × 2 (*tijk* = 0.5466) were the best for lint index (Table 4.40). The highest three line specific effect was recorded in triplet 1 × 3 × 5 where as highest *per se* performance was shown by 1 × 2 × 4.

In the case of the triplet 1 x 3 x 5 (241-4-2 × RFS 3438 × Hyps 152), the grand parents 1 × 3 recorded positive significance for two line specific effects of second kind (*dij*=0.115) and the interaction of second parent Hyps 152 contributed to the production of high performing triplet. The other forms of the triplet 3 × 5 × 1 had shown positive significant *tijk* effect where as triplet 1 × 5 × 3 had negative *tijk* effect. The best performance of triplet 1 × 3 × 5 may be due to positive significant two line effects of first kind in grandparents and interaction of second parent Hyps 152 and pooling up of favourable alleles.

Components of genetic variance for this trait revealed that dominance × dominance component of gene action was predominant followed by additive × additive and additive × dominance gene actions, indicating the predominant role of epistatic gene action in governing the character. Similar results reported by earlier workers, Ramalingam (1996) and Laxman and Ganesh (2003) who opined that dominance × dominance components of genetic variance was governing the character.

Ginning outturn : The general line effect of first kind (*hi*) was positive and significant for 241-4-2 (1.072), G Cot 100 (0.496) and RFS 3438 (0.404), these parents would be utilized as grand parents to produce significant three way crosses. The general line effect of that second kind (*gi*) was positive and significant for parent 65-2(s)-3 (0.600) that would be utilized as a parent (full parent) to cross to a single cross in three way crosses.

Two line specific effects of first kind (*dij*) was positive and significant in crosses Hyps 152 × Suvin (1.038), 241-4-2 × 65-2(s)-3 (0.842) and G Cot 100 × 65-2(s)-3 (0.821) these crosses would produce significant three way crosses when used as grand parents. Parents 241-4-2 and G Cot 100 were equally good with the parent 65-2(s)-3, while selecting parents for the crossing programme. The two line specific effects of second kind (*sij*) was positive and significant in the cross 241-4-2 × G Cot 100 (1.029) indicating the usefulness of utilizing the parent 241-4-2 as half parent to produce significant three way crosses for ginning out turn. Parent 241-4-2 must be taken into consideration for the crossing programme in order to improve ginning out turn as it proved as a good general combiner and as a grand parent. In single crosses 241-4-2 × Hyps 152 and RFS 3438 × Suvin had shown positive significant sca effects for ginning out turn.

Three line specific effects (*tijk*) was found to be positive and significant in thirteen crosses. Among them the triplet, 1 × 6 × 3 (1.813) has shown the highest performance, in which the parents 241-4-2 and RFS 3438 were the best general combiners to produce significant three way crosses. It clearly elucidated the order effect of parents in which crossing to be effected to produce significant triplets. The alternative triplets, 1 × 3 × 6 and 3 × 6 × 1, in which the earlier one had negative Tijk effects and latter had positive effect. This clearly indicates the order effects of parents in production of significant triplets. In this triplet 1 × 6 × 3 the best performance was due to positive interaction of specific combing ability effects of grandparents with that of parent RFS 3438.

The fixable component of epistatic gene action was playing major role in governing the character. Hence pedigree method of breeding may be followed for improvement of the character. Ramalingam (1996) reported predominance of dominance × dominance component followed by additive gene action for this trait in cotton which are in partial agreement with present findings. Laxman and Ganesh (2003) indicated the predominance of non fixable epistatic interactions (additive × dominance followed by dominance × dominance) governing the character which were not in agreement with the present findings .

Based on the above studies all the characters were mostly governed by additive × dominance gene action (epistatic component). Hence trait improvement would be possible by adopting heterosis breeding for development of F1 hybrids based on specific combining ability of parents. Purelines were isolated by adopting special breeding methods like inter mating in early segregating generations for two to three generations with step by step improvement followed by pedigree method of breeding or special breeding methods like biparental selection scheme and recurrent selection schemes.

REFERNCES

Laxman, S and Ganesh, M. 2003. Combining ability for yield components and fibre characters in cotton (*Gossypium hirsutum* L.). *Jour. Res. Acharya N. G. Ranga Agri. Uni.* **31** : 19-23.

Patil, A.J. Meshram, L.D and Sakhare, S.B. 2005. Triallel analysis for seed cotton yield in hirsutum cotton. *Jour. Maharastra Agri. Uni.* **30** : 15-18.

Ponnuswamy, K.N., Das, M.N. and Handoo, M.I. 1974. Combining ability analysis for triallel cross in maize (*Zea mays* L.). *Theriti. Appl. Gene.* **45** :170-75.

Ramalingam, A. 1996. Genetics of seed cotton yield and its components in upland cotton (*Gossypium hirsutum* L.).Diallel and triallel analysis. *Ph.D. Thesis, TAU.*

Rawlings, J.O. and Cockerham, C.C. 1962. triallel analysis. *Crop Sci.* **2** : 228-31.

Singh, R.K and Chaudhary, B.D. 1985. *"Biometrical Methods in Quantitative Genetic Analysis"*. Kalyani Publishers, New Delhi pp. 215-218.

Level of heterosis for seed cotton yield and yield attributing traits in cultivated upland cotton (*Gossypium hirsutum* L.)

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Cotton is an important commercial crop which provides raw material in the form of lint to the textile industry. It is one of the few often cross pollinated crop which is accessible to development of homozygous genotypes as varieties and at the same time amenable for commercial exploitation of heterosis by exploitation of additive as well as non-additive genetic variance. The phenomenons of hybrid vigour in cotton are being exploited successfully since the release of commercial intra *hirsutum* and inter specific hybrids. India holds the distinction of being pioneer in the world in developing hybrids by conventional hand emasculation and pollination and commercial cultivation of hybrids. The development and release of world's first commercial intra *hirsutum* hybrid H4 and first inter specific hybrid Varalaxmi during the seventies, was an important milestone in the history of cotton improvement not only in India but also in the world. Heterosis is the superiority of the hybrid over the mid or better parent or over standard check and is the result of allelic or non-allelic interactions of genes under influence of particular environment. To develop potential hybrids in cotton it is necessary to exploit genetic diversity available in the form of visible differences in plant type traits and a cross between robust types and compact types can lead to improvement in higher productivity as a result of superimposition of the desirable features of these contrasting plant types in the F_1 hybrids (Ranganatha *et al.*, 2013). In the present study efforts was made to evaluate the selected diversified parental material for exploiting the hybrid vigour (standard heterosis) over the check hybrid (RCH 2 non Bt) for seed cotton yield, its contributing traits and fibre quality traits.

MATERIALS AND METHODS

The studies on standard heterosis for seed cotton yield and yield contributing characters was undertaken using 39 hybrids along with check hybrid namely RCH 2 non Bt at Cotton Research Station, Srivilliputtur during summer 2015. The hybrids were raised in three rows in two replications with a row length of 6 meters and the spacing adopted is 90 × 60cm. All the agronomic and plant protection measures were followed as per the recommended package of practices. Observations were recorded on five plants for the yield characters, *viz.*, seed cotton yield (kg/ha), bolls/plant, boll weight (g), monopodia/plant, sympodia/plant, plant height (cm), seed index, lint index and ginning percentage (%) and fibre quality traits *viz.*, 2.5% span length (mm), fibre strength (g/tex), micronaire value, uniformity ratio and elongation percentage (%). Statistical analysis of the data was conducted as per Panse and Sukhatme (1964).

Table 1. *Per se* performance of 40 intra *hirsutum* hybrids (H×H) for seed cotton yield, its ancillary characters and fibre quality traits

S. No	Hybrid	Plant height (cm)	Mono-podia/ plant	Sym-podia/ plant	Boll/ plant	Boll weight (g)	*Kapas* yield (kg/ha)	Seed index	Lint index	Gin-ning (%)	Mic-ronaire value	Staple length (mm)	Uni for-mity ratio	Fibre strength (g/tex)	Elon-gation (%)
1.	C 11-9 × 98955	74.1	1.6	13.7	18.1	2.9	714.3	7.4	3.5	31.3	2.3	25.5	46.8	23.1	5.9
2.	African I-2 × TCH 1705-250	94.8*	0.3	17.5	38.3*	3.4	1975.3*	7.2	4.0	35.1	3.3	27.0	50.6	24.5	6.7
3.	C 10-3 × TCH 1705-250	74.6	1.3	13.7	24.7	2.7	1010.8	5.9*	3.7	40.5*	2.5	24.3	49.9	23.7	7.0
4.	484 × TCH 1705-250	93.3	0.5	16.7	34.7*	3.5*	1807.8	7.2	3.7	33.5	4.0	25.8	52.5	25.8	6.9
5.	VS 9-S-11-1 × TCH 1705-250	76.3	1.4	16.0	30.1	2.8	1252.2	5.7*	2.5	29.9	2.5	26.1	45.0	23.3	5.1
6.	481 × 329	88.9	1.8	18.7*	37.9*	3.6*	2037.1*	8.2	4.0	31.6	2.3	25.7	44.9	20.8	5.9
7.	VS 9-S-11-1 × Surabhi	95.4*	1.6	14.9	26.9	3.2	1265.5	8.1	3.9	30.8	2.3	29.6	41.4	25.6	5.4
8.	C 10-3 × 329	81.4	1.6	19.1*	38.9*	3.4	1984.2*	8.4	3.7	30.6	2.8	28.7	44.5	23.8	4.8
9.	C 11-9 × KC 3	85.8	1.9	19.7*	38.6*	3.3	1878.3	6.9	2.9	27.3	2.7	25.0	45.8	20.5	5.7
10.	484 × COD-5-1-2	90.9	0.6	14.7	32.6	3.7*	1759.3	8.8	4.1	31.9	2.2	25.4	44.9	23.9	6.5
11.	484 × KC 3	98.4*	0.6	23.8*	45.2*	3.2	2138.5*	6.7	3.5	34.4	3.7	26.6	50.2	21.6	6.8
12.	VS 9-S-11-1 × 98955	81.2	1.5	13.2	20.6	2.8	846.6	7.4	3.4	30.9	2.1	26.4	43.8	21.8	5.3
13.	C 12-2 × Surabhi	85.5	1.2	19.8*	40.3*	3.3	1975.3*	9.1	3.3	25.7	2.6	28.4	43.4	22.5	4.9
14.	C 12-2 × TCH 1705-250	94.1*	0.6	16.1	29.4	3.3	1428.6	7.5	3.5	32.1	2.7	26.9	53.0	24.6	6.3
15.	TCH 1705-169 × Surabhi	88.1	1.5	14.7	32.4	3.7*	1772.5	6.5	3.0	30.8	2.9	28.3	47.0	21.6	5.4
16.	484 × Surabhi	92.9	1.4	20.8*	45.7*	3.2	2169.3*	7.7	4.3*	35.8*	3.3	28.3	50.6	22.8	5.5
17.	C 10-3 × COD-5-1-2	80.4	1.1	14.3	21.2	3.0	970.1	7.6	3.8	36.6*	2.2	28.1	45.0	20.9	5.6
18.	VS 9-S-11-1 × TCH 1705-250	96.6*	1.1	16.1	38.0*	3.4	1926.8	7.0	3.2	31.6	2.7	25.5	50.4	24.4	5.5
19.	TCH 1705-169 × 98955	88.2	1.6	13.7	18.3	2.6	654.8	7.4	3.2	30.0	2.1	23.8	45.9	17.9	6.1
20.	C 12-2 × KC 3	79.1	0.7	19.2*	34.4*	2.6	1345.9	4.4*	2.8	38.3*	3.2	28.1	49.5	20.2	4.5
21.	487 × TCH 1705-250	95.7*	1.2	20.7*	44.3*	3.5*	2248.7*	6.2*	3.5	35.1	3.1	24.4	54.1	20.5	6.2
22.	TCH 1705-152 × 329	97.6*	1.2	17.8	36.0*	3.0	1635.8	7.1	3.5	32.0	2.4	26.1	50.7	24.0	5.8
23.	African I-2 × COD-5-1-2	106.2*	1.0	18.8*	41.3*	3.7	2275.1*	8.3	4.0	32.0	2.7	28.8	49.4	24.5	5.6
24.	TCH 1705-169 × COD-5-1-2	95.5*	1.0	13.7	17.2	3.4	820.1	7.9	3.9	33.4	2.8	26.9	50.6	21.5	5.8
25.	TCH 1705-152 × COD-5-1-2	85.7	0.8	14.6	21.1	2.9	908.3	6.6	3.4	33.8	2.5	25.4	49.0	20.3	5.8
26.	C 10-3 × 98955	65.7	0.8	12.6	14.5	2.8	606.1	8.6	4.0	29.8	2.8	27.5	48.7	24.2	5.1
27.	487 × TCH 1608	84.8	1.2	13.6	20.0	2.7	773.8	6.0*	2.8	31.4	2.6	26.1	48.1	19.6	5.4
28.	TCH 1705-169 × KC 3	80.0	1.1	12.1	23.0	2.4	820.1	6.1*	2.8	31.6	2.5	25.4	47.4	21.1	5.5
29.	African I-2 × 329	105.2*	1.4	18.3*	38.9*	4.7*	2751.3*	9.0	4.5*	33.7	3.8	31.5	51.3	23.8	5.1
30.	481 × TCH 1705-250	91.8	0.5	15.1	34.6*	3.1	1587.3	7.3	4.1	35.8*	3.2	25.4	54.2	22.3	6.4
31.	484 × TCH 1608	91.4	0.4	13.9	29.7	3.0	1296.3	7.4	3.5	30.3	2.8	26.8	48.7	20.2	5.8
32.	C 10-3 × TCH 1608	87.1	0.5	13.7	24.9	3.3	1200.4	6.6	2.9	30.5	2.2	27.0	45.0	18.6	4.9
33.	C 12-2 × 98955	88.4	0.6	15.5	15.2	2.9	608.5	6.9	3.0	30.5	2.3	28.3	42.5	19.2	5.4
34.	C 11-9 × TCH 1608	87.4	1.4	15.2	29.9	2.5	1111.1	6.4	3.1	30.4	2.6	27.0	46.7	22.3	5.8
35.	C/11-9 × TCH 1608	86.0	0.9	15.3	18.8	3.2	899.5	5.6*	2.6	30.4	2.1	26.4	45.6	22.1	5.7
36.	TCH 1705-152 × Surabhi	88.0	1.2	13.1	27.8	2.7	1101.9	6.6	3.6	34.9	2.6	27.6	44.9	22.3	5.3
37.	C 10-3 × Surabhi	77.9	1.5	14.8	30.0	3.7*	1693.1	8.5	3.9	31.0	3.3	28.5	47.2	21.4	4.7
38.	C 11-9 × 329	83.3	1.4	18.9*	35.2*	3.1	1613.8	9.1	4.4*	32.3	3.3	30.0	51.6	24.2	4.8
39.	484 × 329	85.4	0.5	13.1	28.0	3.8*	1591.7	6.6	3.5	34.3	2.3	28.9	42.1	18.5	5.9
40.	RCH 2 Non Bt	86.6	2.1	18.3*	36.0*	3.6*	1892.9	7.2	4.9*	40.4*	3.3	27.5	46.0	22.3	5.3
	Mean	**87.7**	**1.1**	**16.1**	**30.3**	**3.2**	**1458.7**	**7.2**	**3.6**	**32.5**	2.7	27.0	47.7	22.2	5.7
	SED	2.9	0.4	1.1	1.2	0.2	242.9	0.5	0.3	1.4					
	CD (p=0.05)	5.9	0.8	2.2	2.4	0.3	488.2	1.0	0.6	2.8					
	CV	3.4	4.1	6.9	3.9	5.3	16.7	7.1	9.1	4.4					

Table 2. Estimates of standard heterosis for 40 intra *hirsutum* hybrids (H×H) for seed cotton yield and its ancillary characters

S.	Hybrid	Plant height (cm)	Mono-podia/ plant	Sym-podia/ plant	Boll/ plant	Boll weight (g)	*Kapas* yield (kg/ha)	Seed index	Lint index	Gin-ning (%)
1.	C 11-9 × 98955	-14.43 **	-23.81 ns	-25.14 **	-49.72 **	-20.83 **	-62.26 **	2.08 ns	-29.59 **	-22.52 **
2.	African I-2 × TCH 1705-250	9.47 **	-85.71 **	-4.37 ns	6.39 ns	-6.94 ns	4.36 ns	0.00 ns	-19.39 **	-13.12 **
3.	C 10-3 × TCH 1705-250	-13.86 **	-38.10 *	-25.14 **	-31.39 **	-25.00 **	-46.60 **	-18.06 *	-24.49 **	0.12 ns
4.	484 × TCH 1705-250	7.74 *	-76.19 **	-8.74 ns	-3.61 ns	-4.17 ns	-4.50 ns	-0.69 ns	-25.51 **	-17.08 **
5.	VS 9-S-11-1 × TCH 1705-250	-11.89 **	-33.33 ns	-12.57 *	-16.39 **	-22.22 **	-33.85 *	-21.53 **	-50.00 **	-26.11 **
6.	481 × 329	2.66 ns	-14.29 ns	2.19 ns	5.28 ns	0.00 ns	7.62 ns	13.19 ns	-19.39 **	-21.78 **
7.	VS 9-S-11-1 × Surabhi	10.16 **	-23.81 ns	-18.58 **	-25.28 **	-11.11 *	-33.15 *	12.50 ns	-21.43 **	-23.76 **
8.	C 10-3 × 329	-6.00 ns	-23.81 ns	4.37 ns	8.06 *	-6.94 ns	4.82 ns	16.67 *	-25.51 **	-24.38 **
9.	C 11-9 × KC 3	-0.92 ns	-9.52 ns	7.65 ns	7.22 *	-8.33 ns	-0.77 ns	-4.86 ns	-41.84 **	-32.43 **
10.	484 × COD-5-1-2	4.97 ns	-71.43 **	-19.67 **	-9.44 **	1.39 ns	-7.06 ns	22.22 **	-16.33 *	-21.16 **
11.	484 × KC 3	13.63 **	-71.43 **	30.05 **	25.56 **	-12.50 *	12.98 ns	-6.94 ns	-28.57 **	-14.98 **
12.	VS 9-S-11-1 × 98955	-6.24 ns	-28.57 ns	-27.87 **	-42.78 **	-22.22 **	-55.27 **	2.08 ns	-31.63 **	-23.64 **
13.	C 12-2 × Surabhi	-1.27 ns	-42.86 *	8.20 ns	11.94 **	-9.72 *	4.36 ns	25.69 **	-33.67 **	-36.39 **
14.	C 12-2 × TCH 1705-250	8.66 *	-71.43 **	-12.02 ns	-18.33 **	-9.72 *	-24.53 ns	4.17 ns	-28.57 **	-20.54 **
15.	TCH 1705-169 × Surabhi	1.73 ns	-28.57 ns	-19.67 **	-10.00 **	1.39 ns	-6.36 ns	-9.72 ns	-39.80 **	-23.89 **
16.	484 × Surabhi	7.27 *	-33.33 ns	13.66 *	26.94 **	-11.11 *	14.60 ns	6.94 ns	-12.24 ns	-11.39 **
17.	C 10-3 × COD-5-1-2	-7.16 *	-47.62 *	-21.86 **	-41.11 **	-16.67 **	-48.75 **	4.86 ns	-23.47 **	-9.53 **
18.	VS 9-S-11-1 × TCH 1705-250	11.55 **	-47.62 *	-12.02 ns	5.56 ns	-5.56 ns	1.79 ns	-2.78 ns	-34.69 **	-21.91 **
19.	TCH 1705-169 × 98955	1.85 ns	-23.81 ns	-25.14 **	-49.17 **	-27.78 **	-65.41 **	2.08 ns	-35.71 **	-25.74 **
20.	C 12-2 × KC 3	-8.66 *	-66.67 **	4.92 ns	-4.44 ns	-27.78 **	-28.90 *	-38.89 **	-43.88 **	-5.32 ns
21.	487 × TCH 1705-250	10.51 **	-42.86 *	13.11 *	23.06 **	-4.17 ns	18.80 ns	-13.89 ns	-29.59 **	-13.12 **
22.	TCH 1705-152 × 329	12.70 **	-42.86 *	-2.73 ns	0.00 ns	-16.67 **	-13.58 ns	-1.39 ns	-28.57 **	-20.92 **
23.	African I-2 × COD-5-1-2	22.63 **	-52.38 **	2.73 ns	14.72 **	1.39 ns	20.19 ns	14.58 *	-19.39 **	-20.92 **
24.	TCH 1705-169 × COD-5-1-2	10.28 **	-52.38 **	-25.14 **	-52.22 **	-6.94 ns	-56.67 **	9.03 ns	-20.41 **	-17.33 **
25.	TCH 1705-152 × COD-5-1-2	-1.04 ns	-61.90 **	-20.22 **	-41.39 **	-20.83 **	-52.01 **	-9.03 ns	-31.63 **	-16.46 **
26.	C 10-3 × 98955	-24.13 **	-61.90 **	-31.15 **	-59.72 **	-22.22 **	-67.98 **	19.44 **	-19.39 **	-26.24 **
27.	487 × TCH 1608	-2.08 ns	-42.86 *	-25.68 **	-44.44 **	-25.00 **	-59.12 **	-16.67 *	-43.88 **	-22.40 **
28.	TCH 1705-169 × KC 3	-7.62 *	-47.62 *	-33.88 **	-36.11 **	-33.33 **	-56.67 **	-15.28 *	-42.86 **	-21.78 **
29.	African I-2 × 329	21.48 **	-33.33 ns	-0.00 ns	8.06 *	30.56 **	45.35 **	24.31 **	-8.16 ns	-16.58 **
30.	481 × TCH 1705-250	6.00 ns	-76.19 **	-17.49 **	-3.89 ns	-15.28 **	-16.14 ns	0.69 ns	-17.35 **	-11.39 **
31.	484 × TCH 1608	5.54 ns	-80.95 **	-24.04 **	-17.50 **	-18.06 **	-31.52 *	2.08 ns	-29.59 **	-25.12 **
32.	C 10-3 × TCH 1608	0.58 ns	-76.19 **	-25.14 **	-30.83 **	-8.33 ns	-36.58 **	-8.33 ns	-40.82 **	-24.63 **
33.	C 12-2 × 98955	2.08 ns	-71.43 **	-15.30 *	-57.78 **	-19.44 **	-67.86 **	-4.86 ns	-38.78 **	-24.50 **
34.	C 11-9 × TCH 1608	0.92 ns	-33.33 ns	-16.94 **	-16.94 **	-30.56 **	-41.30 **	-11.11 ns	-36.73 **	-24.75 **
35.	C/11-9 × TCH 1608	-0.69 ns	-57.14 **	-16.39 **	-47.78 **	-12.50 *	-52.48 **	-22.22 **	-46.94 **	-24.88 **
36.	TCH 1705-152 × Surabhi	1.62 ns	-42.86 *	-28.42 **	-22.78 **	-25.00 **	-41.79 **	-9.03 ns	-27.55 **	-13.61 **
37.	C 10-3 × Surabhi	-10.05 **	-28.57 ns	-19.13 **	-16.67 **	2.78 ns	-10.55 ns	18.06 *	-21.43 **	-23.27 **
38.	C 11-9 × 329	-3.81 ns	-33.33 ns	3.28 ns	-2.22 ns	-13.89 **	-14.74 ns	26.39 **	-10.20 ns	-20.17 **
39.	484 × 329	-1.39 ns	-76.19 **	-28.42 **	-22.22 **	4.17 ns	-15.91 ns	-8.33 ns	-29.59 **	-15.10 **
40.	RCH 2 Non Bt	0.00 ns	0.00 ns	0.00 ns	0.00 ns	0.00 ns	0.00 ns	0.00 ns	0.00 ns	0.00 ns
	SE	2.10	0.26	0.78	0.85	0.12	171.7	0.30	0.22	1.02

RESULTS AND DISCUSSION

The *per se* performance and heterosis over the check hybrid (RCH 2 non *Bt*) for the character under study is presented in Table 1 and 2. The range of mean value among the intra *hirsutum* crosses for seed cotton yield varied from 606.1 to 2751.3 kg/ha. The highest and the lowest seed cotton yield was recorded in the cross combinations of African I-2 × 329 and C 10-3 × 98955 respectively. The hybrid combination African I-2 × COD 5-1-2 ranked second in seed cotton yield with 2275.1 kg/ha, followed by 487 × TCH 1705-250 (2248.7 kg/ha). The crosses namely African I-2 x 329 and C 11-9 × 329 exhibited the highest value of 31.5mm and 30.0mm respectively for 2.5 per cent span length. Maximum number of bolls was recorded in 484 × Surabhi (45.7) followed by 484 × KC 3 (45.2), 487 × TCH 1705-250 (44.3) and African I-2 × COD 5-1-2 (41.3). The crosses African I-2 × 329 exhibited highest boll weight of 4.7g followed by 484 × 329 (3.8g) and African I-2 × COD 5-1-2, 484 × COD 5-1-2, TCH 1705-129 × Surabhi and C 10-3 × Surabhi (3.7g). The hybrid African I-2 × 329 also recorded highest value for plant height (105.2cm), Lint index (4.5). The cross combination of African I-2 × COD 5-1-2 also observed highest *per se* performance for plant height (106.2cm) and fibre strength (24.5g/tex). The hybrid 487 × TCH 1705-250 recorded significant *per se* performance for number of sympodia (20.7) and seed index (6.2). The cross combination C 11-9 × 329 also exhibited significant mean value for number of sympodia (18.9), number of bolls (35.2), lint index (4.4) and fibre strength (24.2g/tex).

The maximum heterosis for seed cotton yield was observed in cross African I-2 × 329 (45.35%) and this hybrid also recorded highest for boll weight (30.56%) and significant value for plant height (21.48%). The hybrid 484 × Surabhi having the highest heterosis value for boll number (26.94%) followed by 484 × KC 3 (25.56%) and 487 × TCH 1705-250 (23.06%). The trait number of symbodia per plant exhibited highest heterosis for 484 × KC 3 (30.05%). The result indicated that there is ample scope for developing productive intra *hirsutum* hybrid with desirable cross combinations for seed cotton yield and its components characters. Tuteja *et al*., (2006) and Verma *et al*., (2006) and Gaurav Khosla *et al*., (2007) reported similar findings in intra *hirsutum* hybrids.

Based on the above *per se* performance and standard heterosis, the hybrid African I-2 × 329 was identified for yield and fibre quality traits, African I-2 × COD 5-1-2 and 487 × TCH 1705-250 were identified for yield and yield attributing traits and the hybrid C-11-9 × 329 for fibre quality traits. High heterotic crosses which have shown more than 25 per cent heterosis for seed cotton yield and its component traits could be exploited for increasing yield in intra *hirsutum* cotton hybrids. The present study indicated that, there is tremendous scope for heterosis breeding for commercial exploitation and also manifestation of considerable amount of heterosis for improving productive intra *hirsutum* long staple cotton hybrids with desirable fibre qualities.

REFERENCES

Gaurav Khosla, B.S. Gill, and R. S. Sohu. 2007. Heterosis and combining ability analysis for plant and seed characters in upland cotton (*Gossypium hirsutum* L). *J. Cotton Res. Dev.* **21 :** 12-15.

Panse, V.G. and P.V. Sukhatme. 1964. Statistical methods for agricultural workers. ICAR, New Delhi. pp 1-361.

Ranganatha, H.M., S. P. Shreekanth, S.M. Manjula and B.C. Patil. 2013. Studies on heterosis in cotton (*Gossypium hirsutum* L.) for seed cotton yield and its components. *Asian Jour. Bio Sci.* **8 :** 82-85.

Tuteja, O.P., Sunil Kumar, Singh, Mahendar and Luthra Puneet. 2006. Heterosis for seed cotton yield and fibre quality characters in cotton (*Gossypium hirsutum* L). *J. Cotton Res. Dev.* **20:** 48-50.

Verma, S.K., O.P. Tuteja, Sunil Kumar, Ram Prakash, Ram Niwas and D. Monga. 2006. Heterosis for seed cotton yield and its qualitative characters of *Gossypium hirsutum* L. in cotton. *J. Cotton Res. Dev.* **20 :** 14-17.

Genetic improvement for fibre quality traits in *arboreum* cotton

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ABSTRACT : Cotton is an inevitable source of natural fibre in the textile industry throughout the world. *G.arboreum* cultivars have inherent abillty of resistance against insect pests and diseases and withstand moisture stress. At the same time they have short and coarse fibre which is not suited for high speed spinning in modern textile industry. At Cotton Research Station Mahboob Baugh Farm,VNMKV Parbhani efforts have been made to develop high yielding *arboreum* strains having high fibre quality.

In the present investigation, fifteen newly developed strains of *arboreum* cotton were evaluated for yield and fibre quality traits along with checks *viz.,* PA 402, PA 08, and NH 615 under rainfed condition at Cotton Research Station Mahboob Baugh Farm,VNMKV Parbhani during *kharif* 2012-2013. The crop suffered due to moisture stress during vegetative and terminal growth stages. The strain PA 739 recorded highest seed cotton yield (1465 kg / ha) followed by PA 778 (1400 kg / ha) and PA 796 (1386 kg /ha). A range of 34.03 (PA 791) to 36.83 per cent (PA781) was observed for ginning outturn amongst the strains under testing.The strain PA 781 recored highest ginning outturn (36.83 %) followed by PA 778 (36.31 %). In quality paramenters, most of the newly developed strains are superior than the check varieties. In respect of fibre length measured as 2.5 per cent span length, all the strains except PA 739 were superior to the check varieties.The strain PA 789 had maximum fibre length (32.9 mm) followed by PA 794 (32.7 mm) and PA 795 (32.1 mm).With respect to fibre strength, all the strains were superior to check varieties. The strain PA 789 recorded highest fibre strength (24.5 g /tex) follwed by PA 788 (23.9 g /tex) and PA 794 (23.08 g /tex).Uniformity ratio ranged from 47 to 52. Micronaire vanue ranged from 4.1 to 5.5. Majority of the new genotypes showed distinct superiority for short fibre content over check varieties. Considering averall fibre quality parameters,genotypes PA 789 and PA 794 were found superior fibre quality traits.

Key word : *G.arboreum,* genetic improvement, fibre quality,

India practically grows all the four cultivated species of which diploid *G. arboreum*, *G.herbaceum* and tetraploid *G.hirsutum* are windely grown in most of the cotton growing states. Amongst the two cultivated diploid species *G. arboreum*, commonly known as *desi* cotton was predominantly under cutivation prior to the introduction of tetraploid *G.hirsutum* in states of Maharashtra ,Karnataka, Madhya Pradesh and Andhra Pradesh.The cultivation of varieties and hybrids of American cotton spread mainly because of their superior fibre qualities than desi cotton. *Desi* cotton though have high or comparable prductivity, wider adaptability and inherent ability to resist major pest and diseases, possessed inferior fibre qualities than american cotton .The american cotton being highly susceptible to major sucking pests and bollworms,the plant protection measures to control than have gone beyond the reach of marginal cultivators. Therefore, at Cotton Research Station, MB Farm, VNMKV, Parbhani efforts have been made to develop high yielding *arboreum* strains having high quality lint. In the present investigation new strains have been evaluated for yield and quality traits in comparison to cultivated varieties.

MATERIALS AND METHODS

In the present investgation fifteen newly developed strains of *arboreum* cotton were evaluated for yield and quality traits along with three check varieties *viz.,* PA 402, PA 08 and NH 615. Trial was conducted in randomized block design with three replications. Each strain was planted in 4 row plot of 5.4 meter length with a spacing of 45 x 22.5 cm. Sowing was done by dibbling method using 2 seeds/hill. Optimum plant stand was maintained by thinning of extra plants. Normal recommended agronomical package of practices were followed to raise the crop.Observations were recorded on seed cotton yield (on plot basis)and yield contributing traits (on five competitive plants taken randomly).Lint samples were sent to CIRCOT, Nagpur for evaluation of quality traits.Mean values were subjected to standard statistical analysis.

RESULTS AND DISCUSSION

Significant level of variability was observed for most of the traits studied in present material. To give more emphasis on quality

Table 1. Seed cotton yield ,accessory traits and fibre quality traits of *arboreum* cotton strains.

Sr. No.	Genotype	Seed cotton yield (kg/ha)	Lint yield (kg/ha)	Ginning Out-turn (%)	Boll wt (g)	2.5 per cent SL length	UR (%)	Fineness Microna 10-6 g /	Bundle	E1 strength Tenacity (g / tex) at 3.2 mm gauge	SFI (%)
1	PA 739	1465	522	36.09	2.78	27.3	51	5.4	22.9	5.2	10.2
2	PA 753	1162	402	34.96	2.64	29.9	51	5.0	21.1	4.8	6.9
3	PA777	1055	368	34.88	2.54	29.6	47	4.9	20.8	5.5	6.8
4	PA 778	1400	506	36.31	2.76	30.5	48	5.2	21.1	4.8	7.3
5	PA 781	1232	450	36.83	2.70	31.4	48	4.8	22.2	5.0	5.6
6	PA 788	1352	478	35.47	2.84	30.1	52	4.9	23.9	4.9	6.4
7	PA 789	898	298	33.45	2.60	32.9	50	4.3	24.5	5.3	5.0
8	PA 790	1120	380	34.07	2.64	29.5	49	4.8	21.6	5.4	6.9
9	PA 791	999	336	34.03	2.56	31.7	48	4.7	22.8	4.8	5.7
10	PA 792	1173	401	34.35	2.68	30.4	48	5.5	20.2	5.4	7.2
11	PA 793	1167	408	35.13	2.76	30.9	46	5.5	23.4	6.4	6.0
12	PA 794	1055	360	34.15	2.70	32.7	49	4.1	23.8	5.5	5.7
13	PA 795	1145	384	33.83	2.58	32.1	49	4.7	20.4	5.3	6.1
14	PA 796	1386	498	36.10	2.80	30.4	51	4.7	22.4	5.4	9.2
15	PA 797	1083	372	34.49	2.66	31.4	50	4.5	22.0	4.9	5.3
Checks49											
16	PA 402 (c)	1197	420	35.35	2.74	28.5	49	5.2	21.0	5.1	9.1
17	PA 08 (c)	1306	472	36.41	2.70	27.6	49	5.0	20.7	5.6	9.1
18	NH 615 (c)	1123	442	39.69	2.92	29.3	50	4.3	20.9	5.6	7.2
	SE±	24.69									
	CD (p=0.05)	73.58									
	CV(%)	4.94									

aspects, results on seed cotton yield, boll weight, ginning percent, lint yield in addition to quality parameters have been discussed.

Evaluation of high quality G. *arborum* genotypes for yield and yield contributing characters : Statistical analysis of variance for seed cotton yield revealed the significant differences among the genotypes. Highest seed cotton yield was recorded by PA 739 (1465 kg/ ha) followed by PA 778 (1400 kg / ha) and PA 796 (1386 kg/ ha) which were at par among themselves but significantly superior over all the genotypes and check.The maximum lint yield was recorded by PA 739 (522 kg /ha) followed by PA 778 (506 kg / ha) and PA 796 (498 kg/ ha). The highest boll weight was recorded by PA 788 (2.84 g) followed by PA 796 (2.8 g) and PA 739 (2.78g). A range of 34.03 (PA 791) to 36.83 per cent (PA781) was observed for ginning outturn amongst the strains under testing.The strain PA 781 recored highest ginning outturn (36.83 %) followed by PA 778 (36.31 %) and PA 796 (36.10 %).

Evaluation of high quality *G. arborum* genotypes for fiber quality: In quality paramenters, most of the newly developed strains are superior than the check varieties. In respect of fibre length measured as 2.5 % span length, all the strains except PA 739 were superior to the check varieties.The strain PA 789 had maximum fibre length (32.9 mm) followed by PA 794 (32.7 mm) and PA 795 (32.1 mm).With respect to fibre strength, all the strains were superior to check varieties. The strain PA 789 recorded highest fibre strength (24.5 g / tex) follwed by PA 788 (23.9 g /tex) and PA 794 (23.08 g /tex). Uniformity ratio ranged from 47 to 52.In case of uniformity ratio, genotypes PA 789, PA 797, and PA 796 were found excellent. Micronaire value ranged from 4.1 to 5.5.The genotypes PA 794 and PA 789 were having fine fibre. The elongation percentage ranged from 4.8 to 6.4. Majority of the new genotypes showed distinct superiority for short fibre content over check varieties. On overall basis the best entries in respect of fibre quality were observed to be PA 789 and PA 794.Our results are in confirmity with the findings of Jain (1996), Patil *et al.,* (1988), Kumar *et al.,* (2003) and Yadava *et al.,* (2000) were having similar findings for quality traits.

REFERENCES

Deshpande L.A. Deosankar D.B. and Deshmukh D.C. 1991. Combining ability analysis for economic traits in interspecific cross of *desi* cotton *ISCI Journal,* **16** :19-26

Jain, S. 1996. Heterosis for fibre characters in intra and inter specific hybrids of cotton. *J. Cotton Res.Dev.***10** :147-49.

Kulkarni V.N. , Khadi B. M.,Deshpande L.A,Sreenivasan S and Bisankopp M. S. 2003 Hirsutisation of diploid cultivated cotton. Proceedings of *"World Cotton Research Congress-3"*, Cape Town,South Africa , pp 85-94

Kumar, Manoj, Chhabra, B.S. and Kumar, Ramesh 2003. Heterosis for seed cotton yield and fibre quality characters in intra *G. hirsutum* hybrids. *J. Cotton Res. Dev.* **17 :**27-29.

Patil, F.B., Thombre, M.V. Shinde, Y.M. and Darade, R.S. 1988. Heterosis in fibre propreties of cotton under multiple environments. *J.Maharashtra Agric. Univ.* **13 :** 277-80.

Pole, S.P., Sudewad, S.M Kamble, S.K. and Borgaonkar, S.B.2008. Heterosis for seed cotton yield and yield components in upland cotton (*Gossypium hirsutum* L.). *J Cotton Res. Dev* **22 :** 139-42.

Shastry, P.P. and Tomar D.S. 2004. Screening of *hirsutum* genotypes against major cotton diseases under natural field conditions.Proceeding of International Symposium on *"Strategies for Sustainable Cotton Production –A Global Vision 3"* USA, Dharwad November ,23-25 Crop Protection . PP 375-76

Yadaava O.P, Lather B.P.S. and Dhayia B.N. 2000 Studies on variability, correlation and path analysis in desi cotton (*Gossypium arboreum* L.) *J.Cotton Res. Dev.* **14** : 143-46.

Multivariate analysis of genetic diversity in upland cotton (*Gossypium hirsutum* L.)

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ABSTRACT : Genetic divergence was carried out with sixty genotypes of upland cotton based on 15 characters using Mahalanobis’ D^2 statistic and principal component analysis. On the basis of D^2 statistic 60 genotypes were grouped into 11 clusters indicating that the genetic diversity and geographical diversity were not related and PCA identified seven principal components which explained 78.696 variability in upland cotton. The PCA enabled loading of similar type of variables on a common principal component. Divergence studies indicated that geographical diversity is always not necessarily associated with the genetic diversity. Multivariate analysis revealed maximum divergence among HYPS 152, GISV 267, MCU 5, L 389 and TCH 1741 signifying their role in exploitation of heterosis.

Key words: genetic divergence, D^2 analysis and Principal Component Analysis

Cotton is the king of apparel fibres, since times immemorial popularly called as “White Gold” has played a pivotal role in the history and civilization of mankind. It alone accounts for 70 per cent of total fibre consumption in textile sector with approximately 38 per cent of the country’s export.The diversity of parents is of prime importance, since the crosses made between the genetically divergent parents are likely to throw desirable recombinants in the progenies. The present study was carried out with two methods of clustering based on D^2 analysis and principal component analysis. Mahalanobis’ D^2 statistic is an effective tool in quantifying the degree of genetic divergence at genotypic level and provides quantitative measure of association between geographic distribution and genetic diversity based on generalized distance and principal component analysis was carried out to transform the inter dependent traits into a set of independent traits as well as to reduce the dimensionality of the data structure (Banfield, 1978). The present investigation is an attempt to study genetic divergence in 60 genotypes of upland cotton using multivariate analysis.

MATERIALS AND METHODS

The present study was carried out with 60 genotypes of cotton (*Gossypium hirsutum* L.) obtained from different research centres across the country in randomized block design with three replications at Regional Agricultural Research Station, Lam Farm, Guntur, Andhra Pradesh during *kharif* 2014-2015. The inter- and intra-row spacing adapted was 105 x 60cm. Each plot consisted of one row of 6m length and observations were recorded on five randomly selected plants from each genotype per replication for characters *viz.,* plant height (cm), Days to 50 per cent flowering, number of monopodia/plant, sympodia/plant, bolls/plant, boll weight (g), seed index (g), lint index (g), micronaire (10^{-6}g/in), bundle strength (g/tex), lint yield/plant (g) and seed cotton yield/plant(g). Ginning outturn (%), 2.5 per cent span length (mm) and uniformity ratio were recorded on plot basis. The fibre quality characters were analyzed at CIRCOT regional unit Lam, Guntur. The data were statistically analyzed to study diversity by Mahalanobis' D^2 statistic and principal component analysis (PCA) as described by Jackson (1991).

RESULTS AND DISCUSSION

On the basis of D^2 values the sixty genotypes were grouped into 11 clusters (Fig. 1), out of which cluster I was the biggest cluster with 34 genotypes followed by clusters II and III which consisted of nine genotypes each while, the remaining clusters *i.e.,* cluster III consisted of single genotype as shown in Table 1.

The percent contribution towards genetic divergence was maximum by 2.5 per cent span length (18.14) followed by seed index (17.57), days to 50 per cent flowering (13.62), micronaire (10.56), monopodia/plant (10.45), bundle strength (8.02), bolls/plant (6.1), seed cotton yield/plant (5.48), plant height (4.41), boll weight (1.86), lint index (1.41), lint yield/plant (1.19), uniformity ratio (0.68), ginning outturn (0.34) and sympodia /plant (0.17) as shown in Table 2.

The maximum intra cluster distance was observed for cluster III (35.23) followed by cluster II (31.03) and cluster I (24.95), while, it was zero for clusters IV, V, VI, VII, VIII, IX, X and XI as shown in Table 3. The high intra cluster distance in cluster III indicates the presence of wide genetic diversity among the genotypes present within this cluster.

The inter cluster distance was maximum between cluster IX and X (185.35), followed by cluster X and XI (177.20), cluster VII and XI (122.06), cluster VIII and X (115.83), cluster V

Table 1. Clustering pattern of 60 cotton (*Gossypium hirsutum* L.) genotypes by Tocher's method.

Cluster No.	No. of genotypes	Name of the genotype
I	34	SCS 1002, CNH 120 M/B, BS-3, GJHV 511, CCH 11-2, ARBH 701, RAH 1066, PRAMUK, GJHV 375, GJHV 02145, L 808, CCH 1831, RB 57, AKALA 15-77 D, CNH 19, CCH 11-1, P 5629, H 1300, SCS 1211, ARBA 271, KH 1101, TSH 04/115, CNH 44, HS 293, L 1058, RHC 0811, CNH 1116, NDLH 1938, NH 644, 241-2-4, L 804, DS 56, GJHV 516, BJA 592
II	9	SCS 1001, HS 292, KH 1301, SCS 1210, ARBH 1301, CPD 1301, L 1801, SCS 1214, HAG 1055
III	9	RSA 2455, H 7, TSH 0499, H 1442, TCH 1741, MCU 5, LH 2256, CPD 1302, L 1011
IV	1	CNH 50
V	1	IH 615
VI	1	L 604
VII	1	TCH 1705
VIII	1	GISV 267
IX	1	HYPS 152
X	1	IH 65
XI	1	L 389

Table 2. Contribution of different characters towards genetic divergence in 60 cotton genotypes.

Character	Contribution towards divergence (%)	Times ranked first
Plant height (cm)	4.41	78
Days to 50 per cent flowering	13.62	241
Monopodia/plant	10.45	185
Sympodia/plant	0.17	3
Bolls/plant	6.1	108
Boll weight (g)	1.86	33
Ginning out-turn (%)	0.34	6
Seed index (g)	17.57	311
Lint index (g)	1.41	25
2.5 per cent span length (mm)	18.14	321
Micronaire (10^{-6}g/in)	10.56	187
Bundle strength (g/tex)	8.02	142
Uniformity ratio	0.68	12
Seed cotton yield/plant (g)	5.48	97
Lint yield/plant (g)	1.19	21

Table 3. Average intra and inter cluster D^2 values among 11 clusters in 60 cotton genotypes

Cluster No	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
I	**24.95 (4.99)**	36.11	44.31	35.50	39.20	32.89	54.01	60.22	55.00	71.39	67.87
II		**31.03 (5.57)**	59.14	47.71	41.25	56.21	47.40	46.12	66.54	67.14	96.02
III			**35.23 (5.94)**	72.00	61.17	51.30	101.74	55.47	69.07	96.15	69.18
IV				**0.00 (0.00)**	14.84	32.80	32.58	100.36	99.37	39.77	95.15
V					**0.00 (0.00)**	53.87	41.62	83.04	110.20	25.77	104.69
VI						**0.00 (0.00)**	64.72	91.44	63.98	99.52	73.68
VII							**0.00 (0.00)**	91.50	90.11	70.71	122.06
VIII								**0.00(0.00)**	59.03	115.83	87.48
IX									**0.00 (0.00)**	185.35	27.69
X										**0.00 (0.00)**	177.20
XI											**0.00 (0.00)**

Note: Bold and diagonal values indicate intra-cluster D^2 distance; figures in parentheses are D values

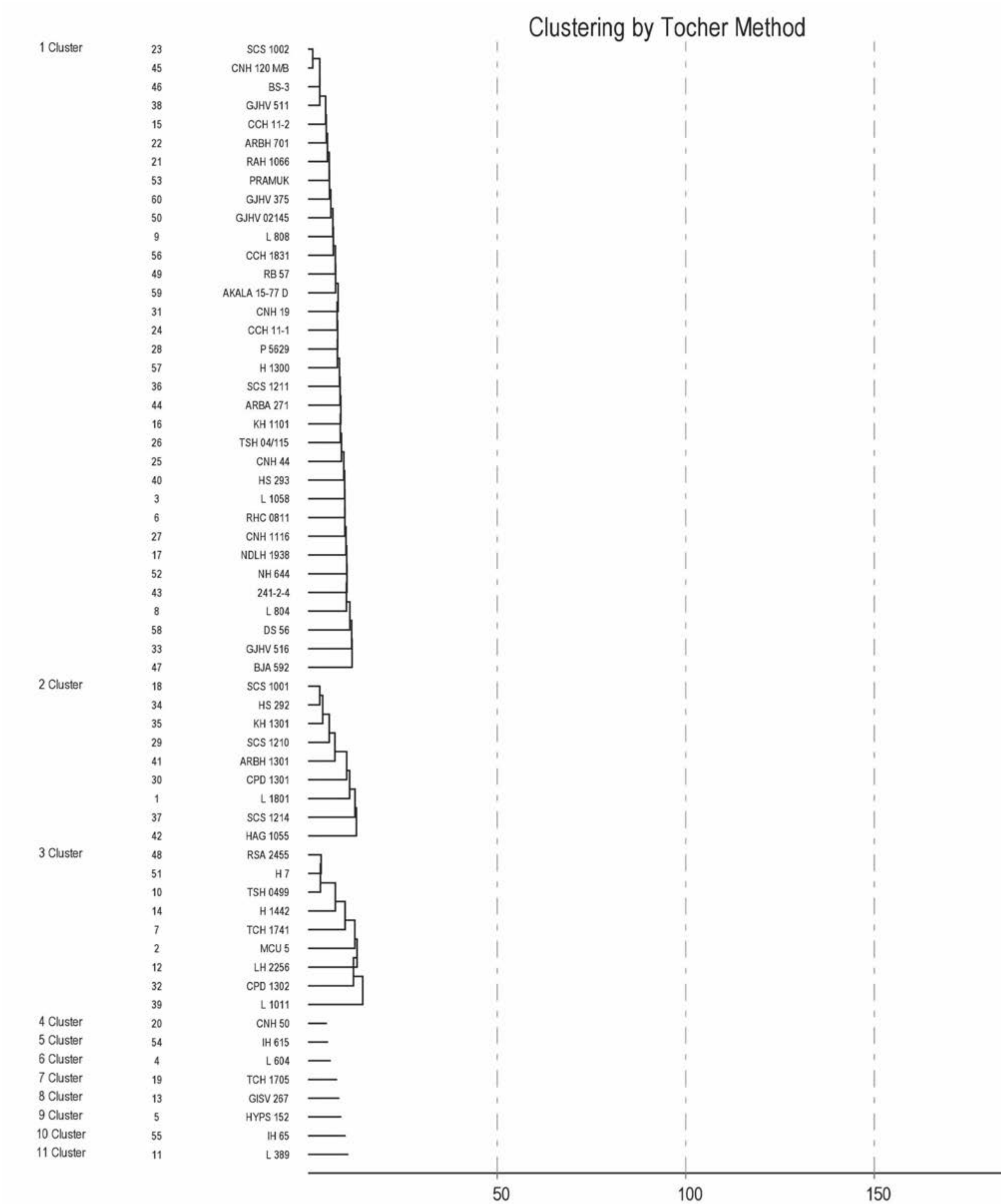

Fig. 1. Dendrogram showing relationship among 60 cotton (*Gossypium hirsutum* L.) genotypes in eight clusters based on Mahalanobis' D^2 values.

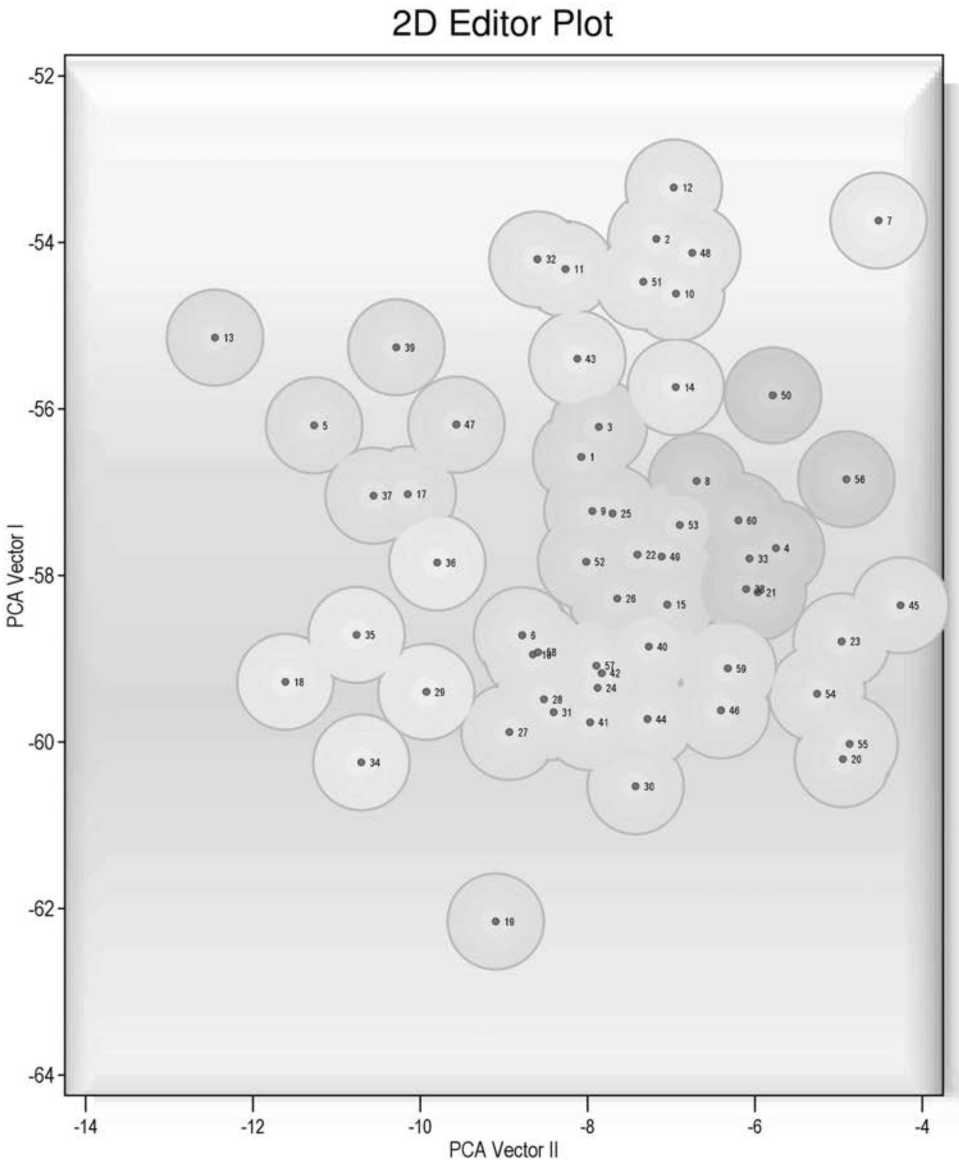

Fig. 2. Two dimensional graph showing relative position of 60 cotton(*Gossypium hirsutum* L.) genotypes based on PCA scores**.**

and IX (110.20), cluster V and XI (104.69), cluster III and VII (101.74) and cluster IV and VIII (100.36). This suggested that there is wide genetic diversity between these clusters. Based on these studies crosses can be made between genotypes of these clusters to obtain desirable transgressive segregants.

By Mahalanobis' D^2 statistic, it could be inferred that based on intra-and inter-cluster distance among the groups, it is suggested to make crosses between the genotypes of cluster IX (HYPS 152) and cluster X (IH 65), between genotypes of cluster X (IH 65) and cluster XI (L 389), between the genotypes of cluster VII (TCH

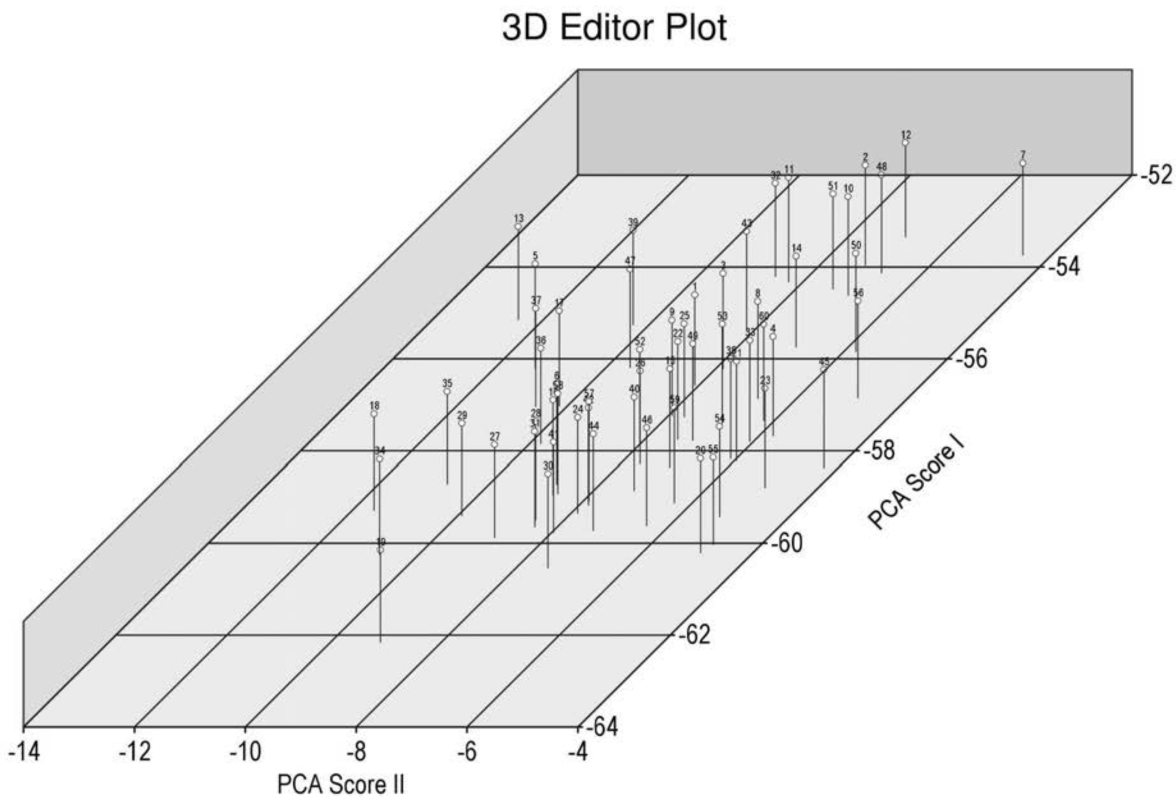

Fig. 3. Three dimensional graph showing relative position of 60 cotton (*Gossypium hirsutum* L.) genotypes based on PCA scores.

1705) and cluster XI (L 389), between the genotypes of cluster VIII (GISV 267) and cluster X (IH 65) after confirming their general combining ability.

Principal component analysis identified seven principal components (PCs), which contributed 78.696 per cent of cumulative variance. The first principal component contributed maximum towards variability (19.33) followed by PC_2 (16.04), PC_3 (11.476), PC_4 (10.616), PC_5 (8.959), PC_6 (7.095) and PC_7 (5.177) as shown in Table 4. The significant factors loaded in PC1 towards maximum genetic divergence were plant height, ginning outturn, lint yield/plant, bolls/plant, 2.5 per cent span length, seed index, lint index, monopodia/plant, days to 50 per cent flowering, seed cotton yield/plant, sympodia/plant and boll weight. 2D and 3D graphs (Fig. 2, 3) showed wide divergence between GISV 267, MCU 5, HYPS 152, TCH 1741, CNH 120 M/B, LH 2256 and IH 65 signifying their usefulness in cotton breeding to develop high heterotic hybrids.

General notation exists that the larger is the divergence between the genotypes, the higher will be the heterosis. Therefore, it would be desirable to attempt crosses between the genotypes belonging to distant clusters for getting highly heterotic crosses which are likely to yield a wide range of segregants on which selection can be practiced.

Table 4. Eigen values, proportion of the total variance represented by first seven principal components, cumulative per cent variance and component loading of different characters in cotton (*Gossypium hirsutum* L.).

	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6	PC_7
Eigene Value (Root)	2.90	2.41	1.72	1.59	1.34	1.06	0.78
per cent Var. Exp.	19.33	16.04	11.48	10.62	8.96	7.10	5.18
Cum. Var. Exp.	19.33	35.37	46.85	57.46	66.42	73.52	78.70
Plant height (cm)	0.38	0.11	0.17	0.18	0.31	0.24	0.37
Days to 50 per cent flowering	0.10	-0.33	0.26	-0.43	-0.07	0.18	0.19
Monopodia/ plant	0.22	0.28	-0.34	-0.31	-0.20	0.22	0.11
Sympodia/ plant	0.05	-0.04	0.12	-0.52	0.31	0.05	-0.43
Bolls/ plant	0.27	0.34	0.05	0.07	0.53	-0.02	0.10
Boll weight (g)	0.03	-0.15	-0.15	0.50	-0.10	0.41	-0.02
Ginning outturn (%)	0.31	-0.35	-0.18	0.03	0.05	0.27	-0.12
Seed index (g)	0.26	-0.34	-0.37	0.05	0.19	-0.03	-0.24
Lint index (g)	0.26	-0.22	-0.14	0.11	0.24	-0.63	-0.10
2.5 per cent Span length (mm)	0.27	-0.16	0.35	0.27	-0.35	-0.13	-0.22
Micronaire (10g/inch)	-0.47	-0.12	-0.29	0.02	0.11	0.07	-0.17
Bundle Strength (g/tex)	-0.14	-0.34	-0.35	-0.09	0.18	0.04	0.46
Uniformity ratio	-0.29	-0.23	0.23	0.08	0.15	-0.26	0.39
Seed cotton yield/ plant(g)	0.09	-0.40	0.32	-0.12	-0.03	0.15	0.06
Lint yield/ plant (g)	0.30	0.03	-0.28	-0.19	-0.43	-0.33	0.29

The genotypes HYPS 152, GISV 267, MCU 5, L 389 and TCH 1741 showed maximum inter-cluster distance in Mahalanobi's D^2 analysis, principal component analysis and also have better per se performance in sympodia per plant, number of bolls per plant, boll weight, seed index, lint index and quality characters. So they can be exploited for the development of heterotic hybrids in future breeding programmes.

Selection of parents for hybrid breeding programme is of prime importance in the utilization of heterosis. For obtaining hybrids with high level of heterosis a question generally arises regarding the ideal distance (degree of divergence) at phenotypic level. Arunachalam and Bhandopadhyay (1984) have proved experimentally more number of heterotic combinations with higher level of heterosis was from the parents grouped into moderate divergent groups. Hence, selection of varieties should be more dependent on genetic diversity than the geographical diversity. Similar findings were also reported by Muraleedhar *et al.,* (2005) and Karunakar Raju *et al.,* (2005).

Two methods of grouping revealed the single concept of non correspondence of genetic divergence and geographical diversity. In a broad sense all the three methods of classifying genotypes into different groups is equally useful but hierarchical cluster analysis gave an additional advantage of identifying sub-cluster of the major groups at different levels so that small group can be critically analysed.

LITERATURE CITED

Arunachalam, V. and Bhandopadhyay, V.A. 1984. Limits to genetic divergence for occurrence of heterosis- experimental evidence from the crop plants. *Ind. Jour. of Gene. Plant Breed.* **44** : 548-54.

Banfield, C.F. 1978. Principal component analysis for genstat. *Jour. Stat. Comp. Simul.* **6** : 211-22.

Jackson, J.E. 1991. *A User's Guide to Principal Components.* John Wiley and Sons Inc., New York.

Karunakar Raju, G.B., Chenga Reddy, V. and Panduranga Rao, C. 2005. Multivariate analysis of genetic diversity in upland cotton (*Gossypium hirsutum* L.). *Andhra Agricul. Jour.* **52** : 66-74.

Muraleedhar, S.A., Murthy, J.S.V.S., Rama Kumar, P.V. and Srinivasa Rao, V. 2005. Mahalanobis' D^2 and principal component analysis of genetic diversity in tetraploid cotton (*Gossypium hirsutum* L.). *Andhra Agricul. Jour.* **52** : 99-104.

Effect of DR gin settings and moisture content on gin productivity, energy consumption and fibre attributes

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ABSTRACT : In India, almost entire cotton is ginned using Double Roller (DR) ginning machines. DR gin settings and moisture content in cotton during ginning plays a vital role in deciding the fibre quality, processing and maintenance costs of machinery.

The present research aims to assess the effect of moisture content and machine settings on fibre quality attributes, lint productivity, energy consumption and other electrical parameters for a DR gin of 1370 mm (54") roller length. In this work, the moisture content was varied from 4-20per cent while the gap between moving and fixed knife (*i.e.* clearance) was kept as 1.0 mm, 1.2 mm and 1.4 for each moisture content. The results were compared based on lint productivity, energy consumption and fibre attributes.

DR gin gave maximum lint productivity of 84 kg/h at 8per cent moisture content for 1.2 mm clearance. The lint productivity reduced with both increase and decrease in moisture content. The reduction in lint productivity was within 5-10per cent range for 6-10per cent moisture level, however, it reduces exponentially in case the moisture content increases beyond 10per cent level. It was observed that the lint productivity of the DR gin reduced by over 75per cent for 20per cent moisture content. Though, there was no significant variation in micronaire values and strength parameters with increase in moisture content over 8per cent level, it leads to significant reduction in colour grade and increase in seed cuts and seed coat neps formation. However, ginning of cotton at higher moisture content yield higher fibre length possibly due to increase in fibre strength at elevated moisture content. Moreover, the fibre properties of the lint produced at 1.0 mm and 1.4 mm clearances were not statistically different than that of 1.2 mm clearance.

The energy consumption per unit lint production was found to be lowest near 8per cent moisture level, however, it increased to maximum value at 20per cent moisture content. It may be concluded that the optimum settings for DR gin are as 8per cent moisture content, 1.2 mm clearance, $1/3^{rd}$ of the staple length for cut off and 85 mm as fixed knife position.

Key words : Eenergy consumption, ginning, lint productivity, moisture content, power

Cotton is very important commercial crop of India and preliminary material being used in Textile Industries all over the world. Cotton is the only fibre which is used more than any other fibre in the world. It plays very important role in Industrial and Agricultural economy of the country and contributes around 4per cent of GDP. As India's economy considerably depends on cotton cultivation, it is the chief source of income in India. It has been found that around 6 million farmers and approximately 40-50 million population are involve in cotton businessand its processing (ICAC 2010). India tops the world in cotton acreage and is the second only to china in cotton production with 37.7 million bales (170 kg each) production in 2014-2015 (Cotton Incorporated, 2015).There are many cotton growing countries are therenamely

China, India, USA, Pakistan, Uzbekistan, Brazil, Greece, Australia Turkey, and many other countries.According to International Textile Manufactures Federation (ITMF) grade, Indian cotton is considered extremely contaminated cotton group followed by Togo, Turkey, Mali and Uzbekistan for past several years whereas cotton produced in USA, Israel, Brazil and Cameroon are categorized as very clean cotton (ITMF 2013).With the modernization of Indian ginneries, the level of contamination in the Indian cotton started to decline, specially since 2003 as reported in the latest ITMF survey (ITMF 2013). From 2003 onwards a significant growth in cotton export and reduction in cotton import were found since when there was improvement in the quality of the cotton bales.

In India mostlyDouble Roller (DR) gin are used to gin cotton while developed countries they are using mainly saw gin. In India more than 1 lakh DR gins are being used in around 4000 ginneries across 9 states in India. It is well known that DR gin preserves inherent fibre qualities and yield about 0.5 mm higher staple length, and comparatively a very smaller amount of nep formation than saw gin.The cotton is need to give some pre- cleaning treatment before ginning because it contains trash content in a large amount. Ginning is a mechanical process in which cotton is separated into its constituents specifically lint (cotton fibre) and seed. The quality of cotton before and after ginning must be almost similar. If any damage is observed while ginning,cannot be repaired afterward.This may produce defect in yarn and fabrics quality while spinning and weaving processes. Apart from this one of the most important factor which significantly affects the fiber quality is the moisture content. Many researches was conducted to optimize moisture content required for optimal ginning. Literature shows that the moisture content at the time of ginning should be in the range of 7per cent to 8per cent .Leonard *et al.,* (1970) applied several moisture treatment varies from 2.4 to 8.8per cent and found that there was a significant improvement in the fibre length with increasingmoisture content.Anthony and Griffin (2001) reported that as moisture content of cotton is increased individual fibre strength is also increased while the fibre seed attachment force remains constantupto 13per cent moisture content. Single fibre breaking force increases with increasing moisture content in the range of 3 to 15 per cent , while fibre-seed attachment forces remain constant from 3per cent to about 11 per cent and then decreases upto 15per cent Moore and Griffin (1964). Past many researches suggested that 6.5 to 8.25 per cent moisture content is suitable for ginning.

As the primary aim of ginning is of course to get higher productivity but also to obtain optimum fibrequality to fulfill the need of textile industries .There are instances of ginning cotton at hight moisture content than recommended values. However the high moisture content damages the seed and fibre quality and leads to damage of critical components of Double Roller (DR) gins such as beater shaft, gears, bearings, roller etc. that increases cost of ginning and energy consumptions. Apart from moisture content, setting of DR ginis also one of the most important parameters to obtain good productivity and required fibre quality. It is suggested that at the time of ginning in DR gin, the clearance between fixed and moving knife should be 1.2 to 1.5mm and cut off should be one third of the staple length (± depending on the moisture content). Seven per cent moisture content in seed cotton is considered best for these settings to obtained maximum productivity and optimum fibre quality. But the seed cotton comes to ginners differs in moisture content. In India there is no drying practices are used to bring its moisture content to optimal level. There was not much work done in this respect. Therefore there is a need to optimize settings of DR gin at different moisture content and to analyses its effect on fibre quality, energy consumption and other electrical parameters.

This research work deals with the optimization of double roller (DR) gin settings for ginning of cotton with different moisture content and the effect of these settings and moisture content on fibre quality, energy consumptions and other electrical parameters. The present research work was carried out on DR gin having roller length 54". The moisture content was varied from 4- 12per cent while the clearance between moving and fixed knife was kept as 1 mm, 1.2 mm and 1.4 mm for each moisture content. The cutoff for each setting was kept 1/3rd of the cotton staple length and cotton of 30 mm staple length was used for all experiments. The results were compared based on lint productivity, energy consumption and fibre attributes.

MATERIALS AND METHODS

The research work to identify the effect of moisture content and machine settings on different parameter such as fibre quality, lint productivity, energy consumption and other electrical parameters was carried out at Ginning Training Centre of ICAR-CIRCOT, Nagpur on DR gin roller length 54". Cotton cultivar Mallika was used for experiments. Clamp on power analyzer was used to measure the electrical parameters. The Data measured on power meter were transferred to a desktop computer on real time basis. A Moisture Meter and an Oven Dryerwere utilized to measure the moisture content of different samples. The moisture content in cotton was varied from 4-20per cent and three clearances *i.e.* 1.0, 1.2 and 1.4 mm between the fixed and moving knives were attempted. The lint productivity of the DR gin was determined at different machine settings and moisture content. Various electrical parameters were also measured to study the load, power consumption and current of the electric motor at each setting and moisture content.

RESULTS AND DISCUSSION

The effect of clearance on productivity of DR gin : The lint productivity of the DR gin with respect to the moisture content for clearances of 1.0, 1.2 and 1.4 mm between the fixed and moving knives is shown in Fig. 1. It can be seen from this figure that the productivity of the DR gin for all clearances increases with the moisture content and reaches to the maximum and therefrom starts decreasing as depicted in Figure (1). There are two prominent reasons for lower yield of the DR gins at low moisture content. The first and foremost important reason for lower productivity at lower moisture content is that weight of cotton is less with lower moisture content as compared to the weight of cotton at higher moisture content that causes the jumping of cotton over the moving knives, which results in moving of cotton away from the ginning portions (*i.e.* at the Centre of rollers where fixed and moving knife overlap over each other). Hence, there is less availability of cotton for ginning at lower moisture content leading to reduction of gin productivity. The second reason for the less productivity at lower moisture content is that cotton gets charged with the lower moisture content, the charged dry cotton fibres do not easily adhere with the ginning rollers causing lower ginning productivity.

It can be further seen from Fig. 1 that the DR gin productivity for all clearances starts decreasing after reaching to a maximum level at around 8per cent moisture content. The DR gin lint productivity even reduces to over 60per cent at 20per cent moisture content from the highest productivity. It is primarily due to reason that the compressibility of cottonseeds reduces with the increasing moisture content in cotton that causes the reduction of compression loads of cottonseeds at higher moisture content.

Moreover, the strength of the cotton fibres is increased with increase in moisture content. The cottonseeds instead of getting removed from cotton, it tries to follow the path of ginned lint (because it has become softened) where it gets crushed between the fixed knives and rollers. The crushed lint obstructs the ginning operation forcing fitters to increase the pressure between the fixed knives and rollers that lead to reduction of the gin productivity. The increased strength of fibres causes delayed breaking of fibres near seed root while ginning that results, the pulling force applied by rollers upon fibres becomes sufficient enough to draw cottonseeds along with the ginned lint.

It can be seen from Fig. 1 that the DR gin yields the highest productivity 1.2 mm clearance as compared to other two clearances (*i.e.* 1.0 and 1.2 mm). The maximum lint productivity of the DR gin is obtained as 84 kg/h of operation at 8per cent moisture content for 1.2 mm clearance. However, the productivity of the DR gin reduces with increase as well decrease in the clearances from 1.2 mm. The increase/decrease in clearance of the DR gin causes decrease/increase of pressure applied over cotton while ginning. The decreased pressure over cotton reduces the separation rate of fibres present over cottonseeds while the increased pressure reduces the amount of cotton entering the ginning portions. These two phenomena result in reduction of the gin productivity with increasing or decreasing of clearance from 1.0 mm. It can be seen from Table 1.4 that the DR gin productivity is highest at 8per cent moisture content and 1.2 mm clearance between the fixed and moving knives; it is reduced by 11.90per cent and 15per cent in case the clearances are changed to 1.0 and 1.4 mm, respectively. Hence, it can be concluded that 1.2 mm clearance between the fixed and moving knives is the optimum setting for ginning of cotton having moisture content ranging from 4-15per cent .

It can be seen from Fig. 1 that productivity of the DR gin becomes maximum at 1.0 mm clearance in case moisture content reaches 15per cent level. It happens because higher moisture content lead to rupture of cottonseeds during ginning as explained above. Hence, ginners reduce the gap between the fixed and moving knives in order to reduce the intake quantity of cotton and increase the pressure so that the chances of rupturing cottonseeds are reduced. Though, the reduced clearance to 1.0 mm results in ginning of cotton at higher moisture content,

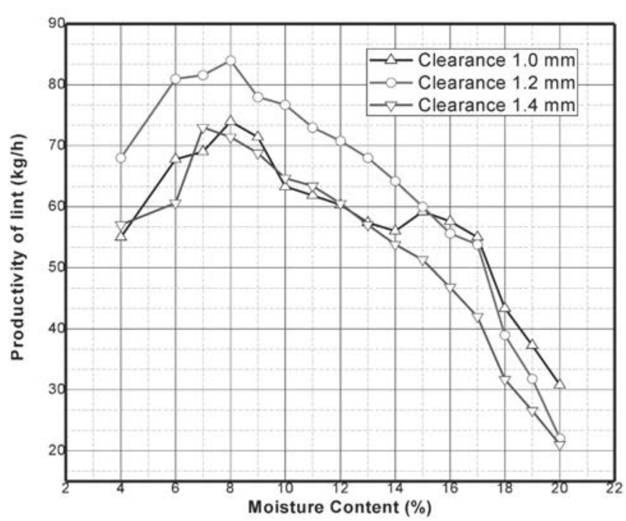

Fig. 1. DR gin productivity at different clearances and moisture content

Table 1.1. Results obtained from Machine Setting – I(*i.e.* Distance between fixed and moving knife – 1.0 mm)

M.C (%)	Productivity (kg/hr)	Energy (kWh)	kWh/ kg lint	Current (A)	Voltage (kV)	PF
4	55.0	4.36	0.079	7.88	3.98	0.803
6	67.8	4.45	0.065	8.08	3.90	0.815
7	69.0	4.53	0.062	8.12	3.93	0.821
8	74.0	4.63	0.062	8.16	3.95	0.830
9	71.4	4.65	0.065	8.31	3.83	0.845
10	63.3	4.73	0.074	8.43	3.83	0.847
11	61.9	4.84	0.078	8.49	3.87	0.851
12	60.3	4.98	0.082	8.4	4.01	0.853
13	57.4	5.05	0.088	8.56	3.97	0.859
14	56.0	5.13	0.091	9.18	3.74	0.862
15	59.2	4.98	0.084	7.99	4.15	0.867
16	57.6	4.764	0.083	7.99	3.85	0.870
17	55.0	4.616	0.084	7.93	3.94	0.830
18	43.4	4.458	0.165	7.86	4.14	0.797
19	37.3	4.537	0.121	7.83	4.09	0.796
20	30.8	4.482	0.164	7.85	4.05	0.792

Table 1.2 Results obtained from Machine Setting – II (*i.e.* Distance between fixed and moving knife – 1.2 mm)

M.C (%)	Productivity (kg/hr)	Energy (kWh)	kWh/ kg lint	Current (A)	Voltage (kV)	PF
4	68.0	4.266	0.063	8.14	3.75	0.806
6	81.0	4.326	0.053	7.88	3.88	0.812
7	81.6	4.578	0.056	8.23	3.95	0.816
8	84.0	5.196	0.062	9.06	3.97	0.827
9	78.0	5.142	0.066	9.14	3.88	0.835
10	76.7	4.700	0.061	8.26	3.92	0.838
11	73.0	4.780	0.065	8.5	3.84	0.845
12	70.8	4.970	0.070	8.65	3.81	0.848
13	68.0	5.020	0.074	8.52	3.89	0.851
14	64.2	5.050	0.078	8.64	3.84	0.854
15	60.0	4.970	0.083	8.53	3.83	0.854
16	55.6	4.680	0.084	8.73	3.53	0.852
17	53.8	4.422	0.074	8.48	3.52	0.853
18	39.0	4.395	0.091	8.01	3.68	0.861
19	31.8	4.086	0.128	7.51	3.99	0.790
20	22.0	3.780	0.173	7.10	3.98	0.775

the productivity of the DR gin and quality of the lint are compromised. Hence, it is not advisable to gin cotton having over 12per cent moisture content. There are steep and significant reductions in the gin productivity and the quality of lint in case ginning of cotton containing over 12per cent moisture content.

1.2 The effect of clearance on energy consumption of DR gin : The energy consumption of the DR gin with respect to the moisture content for clearances of 1.0, 1.2 and 1.4 mm between the fixed and moving knives is shown in Fig. 3. It can be seen from this figure that the energy consumption of the DR gin for all clearances increases with the moisture content and reaches to maximum and therefrom starts decreasing as depicted in Fig. 3. The energy consumed by the DR gin is utilized for pulling of cotton fibers. With the increase in moisture content of cotton, gin productivity increases as discussed in the preceding section resulting in pulling of more fibers leading to increase in energy consumption at higher moisture content. It can be concluded that the energy consumption in DR gin is directly proportional to lint productivity.

Lint production rate for all clearances starts decreasing after reaching to a maximum level at around 8per cent moisture content; therefrom it starts decreasing, which led to decrease in energy consumption as shown in Fig. 3. However, the energy consumption starts decreasing after 10per cent moisture content as shown in Fig. 3, it occurs mainly due to significant increase in strength of wet cotton fibers over 10per cent moisture content resulting in increased requirement of energy for removal of fibers from cotton. It can be seen from the figure after 14 per cent moisture content productivity of DR gin again starts gradually decreasing with increase in moisture content. It is mainly happened due to considerable decrease in the productivity of DR

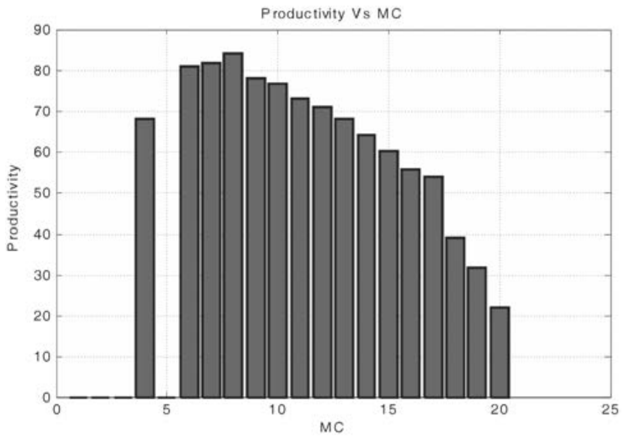

Fig. 2. Bar Diagram Showing Optimum Productivity point

beyond 14per cent moisturecontent that reduces the load on the motor leasing to reduction in energy consumption.

It can be seen from Figure (3) that energy consumption of the DR gin becomes maximum at 1.0 mm clearance in case moisture content reaches 15per cent level. Ginners reduce the gap between the fixed and moving knives at higher moisture content in order to avoid crushing of cottonseeds while ginning cotton at higher moisture content. The reduced gap increases the pressure at ginning area, which lead to increase in load on motor resulting in higher energy consumption. Table 1.5 shows that the energy consumption for 1.0 mm clearance is over 15per cent at higher moisture content as compared to energy consumption at 1.2 mm clearance.

1.3 The effect of clearance on energy consumption/lint of DR gin : The energy consumption per unit lint production increases gradually with the moisture content and reaches to a maximum value at 9 per cent moisture content *i.e.* maximum productivity point therefrom at slightly reduces because reduction in DR gin productivity. However, it further increases with

Table 1.3. Results obtained from Machine Setting – III (*i.e.* distance between fixed and moving knife – 1.4 mm)

M.C (%)	Productivity (kg/hr)	Energy (kWh)	kWh/ kg lint	Current (A)	Voltage (kV)	PF
4	57.0	4.000	0.066	6.30	3.25	0.876
6	60.6	4.064	0.067	6.69	3.54	0.964
7	73.0	4.505	0.074	6.50	4.16	0.962
8	71.4	4.655	0.065	7.33	3.69	0.967
9	68.8	4.592	0.067	7.43	3.58	0.970
10	64.7	4.629	0.072	7.58	3.53	0.972
11	63.4	4.642	0.073	7.45	3.59	0.975
12	60.5	4.844	0.080	6.78	4.10	0.979
13	57.0	4.950	0.090	7.02	4.14	0.983
14	53.8	5.040	0.093	7.64	4.28	0.889
15	51.3	4.572	0.089	6.89	4.37	0.853
16	46.8	4.267	0.091	7.50	3.87	0.826
17	42.0	4.038	0.096	7.35	3.75	0.823
18	31.7	3.982	0.126	7.08	4.12	0.767
19	26.6	3.894	0.146	7.30	3.70	0.810
20	21.0	3.804	0.098	7.12	4.07	0.759

increase in moisture content mainly because in increase in strength of fibre with increased moisture content requiring higher energy for pulling of fibres from cotton.

1.4 The effect of clearance on current (on DR gin) : It can be seen from Fig. 4 that the current of the motor increases with the moisture content till it reaches a maximum level at 9per cent moisture content (point of maximum productivity). Therefrom, again starts decreasing with increase in moisture content primarily because reduction in ginning rate reduces the load on motor resulting in lesser current drawn from the supply. It can be further observed that the current drawn by motor at 1.4 mm clearance is considerably lower than that of clearances of 1.0 and 1.2 mm. It is mainly due to reason that at 1.4 mm clearance, the pressure in the ginning reason reduced to significant level leading to reduction on motor load

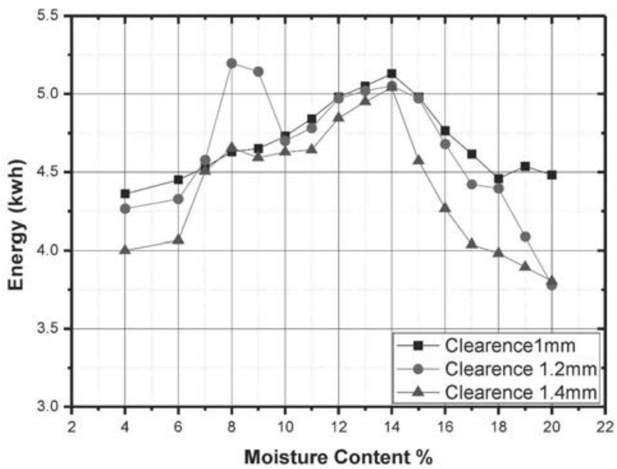

Fig. 3. DR gin energy consumption at different clearances and M.C.

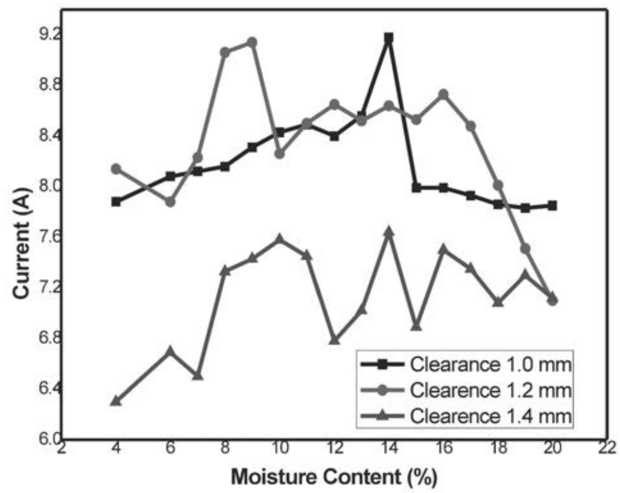

Fig. 4. DR gin current variation at different clearances and moisture content

Table 1.4 Effect of clearance and moisture content on DR gin productivity

Moisture Clearance Content (%)	Lint Productivity (kg/h) with different clearances			Per cent Increased/ w.r.t. 1.2 mm decreased	
	1.0 mm	1.2 mm	1.4 mm	1.0 mm	1.4 mm
4	55.00	68.00	57.00	-19.11	-16.17
6	67.80	81.00	60.60	-16.29	-25.18
7	69.00	81.60	73.00	-15.44	-10.53
8	74.00	84.00	71.40	-11.90	-15.00
9	71.40	78.00	68.80	-08.46	-11.79
10	63.30	76.70	64.70	-17.47	-15.64
11	61.86	73.00	63.40	-15.26	-13.15
12	60.30	70.80	60.50	-14.83	-14.54
13	57.40	68.00	57.00	-15.58	-16.17
14	56.00	64.20	53.80	-12.77	-16.19
15	59.20	60.00	51.30	-01.33	-14.50
16	57.60	55.60	46.80	03.59	-15.82
17	55.00	53.80	42.00	02.23	-21.93
18	43.40	39.00	31.70	11.28	-18.71
19	37.30	31.80	26.60	17.29	-16.35
20	30.80	22.00	21.00	40.00	-4.54

Table 1.5. Effect of clearance and moisture content on DR gin energy consumption

Moisture Clearance Content (%)	Energy consumption (kwh) with different clearances			Per cent Increased/ w.r.t. 1.2 mm Decreased	
	1.0 mm	1.2 mm	1.4 mm	1.0 mm	1.4 mm
4	4.360	4.266	4	2.20	-6.23
6	4.450	4.326	4.064	2.86	-6.05
7	4.530	4.578	4.505	-1.04	-1.59
8	4.630	5.196	4.655	-10.89	-10.41
9	4.650	5.142	4.592	-9.56	-10.69
10	4.730	4.700	4.629	0.63	-1.51
11	4.840	4.780	4.642	1.25	-2.88
12	4.980	4.970	4.844	0.20	-2.53
13	5.050	5.020	4.950	0.59	-1.39
14	5.130	5.050	5.040	1.58	-0.19
15	4.980	4.970	4.572	0.20	-8.00
16	4.764	4.680	4.267	1.79	-8.82
17	4.616	4.422	4.038	4.38	-8.68
18	4.458	4.395	3.982	1.43	-9.39
19	4.537	4.086	3.894	11.03	-4.69
20	4.482	3.780	3.804	18.57	0.63

resulting in reduced amperage drawn from the supply.

1.5. Effect of moisture content and gin settings on fibre parameters : Table 1.6 shows fibre attributes data of lint ginned for different moisture content at 1.2 mm clearance. The fibre properties were analysed using HVI 900 at 27^0C temperature and 65per cent RH, standard operating conditions recommended for testing

Table 1.6 Fibre Parameters for different moisture content at 1.2 mm clearance

M.C. (%)	2.5 per cent S.L. (mm)	UR (%)	MIC (µg/ inch)	Ten (g/Tex)	EL (%)	SFI (%)	Colour Grades		
							Rd (%)	b+(%)	CG
4	29.7	47.0	4.0	22.8	4.6	7.6	87.2	7.1	11-1
6	30.0	48.0	4.1	23.8	4.6	6.4	86.1	7.2	11-1
7	30.4	48.5	4.3	23.6	4.7	6.3	85.6	7.3	11-1
8	30.7	47.6	4.3	23.4	4.8	6.5	85.9	7.4	11-1
9	30.5	49.2	4.2	23.7	4.7	6.4	86.0	7.3	11-1
10	30.3	49.6	4.2	25.7	4.9	5.2	84.5	7.3	11-1
11	30.2	48.4	4.2	23.9	4.6	6.3	85.8	7.3	11-1
12	31.7	49.0	4.2	25.8	4.8	5.3	78.1	8.4	31-1
13	31.2	49.1	4.3	25.6	4.9	5.4	74.3	8.5	31-4
14	31.3	48.9	4.2	25.3	4.9	5.2	72.6	8.7	42-1
15	31.1	49.2	4.2	25.9	5.4	4.7	69.2	8.1	42-2
16	31.3	49.3	4.3	25.8	5.3	5.1	69.4	8.1	42-2
17	31.3	48.9	4.3	25.7	5.2	4.8	73.4	8.6	41-3
18	31.2	49.0	4.3	23.5	5.3	4.6	68.8	8.2	42-2
19	31.21	48.3	4.2	23.7	4.8	5.0	85.9	7.6	41-4
20	31.43	47.6	4.2	23.6	5.6	5.2	67.8	8.2	42-2

of cotton samples. It can be inferred from this table that 2.5per cent span length of cotton is around 30.5 mm in the range of 7-11per cent moisture content, there is significant deterioration in the fibre length (*i.e.* >0.5mm) at 4per cent moisture content. It is mainly due to reason that cotton becomes brittle at low moisture content that lead to breakage of fibres while ginning. This fact can be ascertained with SFI data, which is increased at 4per cent moisture content.

It can be seen from Table 1.6 that 2.5per cent staple length of cotton increases noticeably at moisture content 12per cent and above. It is possibly due to reason that the strength of cotton fibres is increased at higher moisture content resulting in less breakage of fibres at higher moisture content that is evident from SFI data showed in the table. However, at higher moisture content the colour grades of cotton are reduced from 11-1 to lower values (*i.e.* 31-1, 31-2, 42-2, etc.). It is mainly due to reason that ginning of cotton at higher moisture content causes mixing of crushed cottonseeds with the ginned lint that reduces the reflective index (*i.e.* whiteness) of cotton.

It may be stated herewith that the fibre properties of lint produced at 1.0 mm and 1.4 mm clearances were not statistically different from the fibre properties of lint produced at 1.2 mm clearance. Hence, the fibre data for 1.0 mm and 1.4 mm clearances are not presented in this work.

CONCLUSION

In the present work, we have considered three machine settings for optimization of a DR gin with roller length 54". Lint output and electrical parameters of the machine at different moisture content for three clearances *i.e.* 1.0 mm, 1.2 mm and 1.4 mm are evaluated in this work. The main objective of this work was to optimize the productivity of DR gins by considering all the three settings to suggest the best settings of the DR gin.

Here, we get three optimum points for individual setting where all the related parameter getting optimum value. If we compare the observation tables for all the three settings, we can clearly see that the maximum productivity obtained is 84 kg/h at 8per cent moisture content for setting II *i.e.* where distance between fixed & moving knife is 1.2 mm. Hence it can be concluded that the setting II is best among the three settings tried in this work.

The salient findings of this work are as follows:

There were steep and significant reductions in the gin productivity and the quality of lint in case ginning of cotton containing over 12per cent moisture content. The energy consumption for 1.0 mm clearance was over 15per cent at higher moisture content as compared to energy consumption at 1.2 mm clearance.The current drawn by motor at 1.4 mm clearance was considerably lower than that of clearances of 1.0 and 1.2 mm.

REFERENCES

Anthony, W. S. and A. C. Griffin 2001. Fiber breakage at gins: moisture and heat. *Cotton Gin Oil Mill Press* **102 :** 6-9.

ICAC 2010. 69th Plenary Meeting of the International Cotton Advisory Committee at LUBBOCK, Texas, USA from 20 to 25 Sep. 2010.

ITMF 2013. Cotton Contamination Surveys**,** International Textile Manufacturers Federation FederationInternationale Des Industries Textiles Internationale Vereinigung Der Textilindustrie 2003 • 2005 • 2007 • 2009 • 2011 • 2013 ITMF

Leonard, C. G., J. E. Ross and R. A. Mullikin 1970. Moisture conditioning of seed cotton in ginning as related to fiber quality and spinning performance. USDA-ARS, Marketing Research Report 859. U.S. Gov. Print. Office, Washington DC.

Moore, V. P. and C. Griffin, Jr 1964. The relationship of moisture to cotton quality preservation at gins. USDA-ARS, ARS 42-105. U.S. Gov. Print. Office, Washington DC.

Cotton Incorporated 2015. Monthly Economic Letter, Cotton Market Fundamental and Price Outlook, Cotton Incorporated, Oct. 2015.

Genetic variability studies in *Gossypium spp* for the development of superior fibre quality lines

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ABSTRACT : The present investigation on cotton (*Gossypium* spp) were undertaken to study the variability, heritability and genetic advance in the interspecific crosses of cotton to develop superior long staple and high fibre strength lines with *G. hirsutum* background by introgression of *G. barbadense* line. One backcross generation BC I (CG64 × (CG64 × CG45SB)) and two modified backcross generations namely, MBC I (CG67 × (CG64 × (CG64 × CG45SB)) and MBC II (CG92 × (CG64 × (CG64 × CG45SB)) were developed for line development programme. High heritability and high genetic advance were observed for span length and fibre strength in most of the generations of all the three crosses. This indicates the preponderance of additive gene action in the inheritance of this traits and offers the scope for improvement through simple selection procedures. In the present study, long staple (28.5-31.3 mm) with high fibre strength (28.9-33.1 g/tex) line with *hirsutum* background were obtained in the back cross I populations. Similarly in modified back cross I, long and extra-long staple (32.1-34.5mm) lines with high fibre strength (28.9-31.3g/tex) and in modified backcross II, long and extra-long staple (30.9-33.5mm) lines with high fibre strength (29.7-33.2g/tex) with recurrent plant background were obtained. The fibre quality parameters were assessed by SITRA fibre testing lab in ICC mode and confirms the findings of the present study.

Cotton 'King of Fibre' is the most important natural textile fibre and the sixth largest vegetable oil source in the world, and it is the cornerstone of textile industries worldwide (Ulloa *et al.,* 2006). In the agro based industry economy of the country cotton, the 'White Gold' enjoys a pre eminent status among all the commercial crops by providing livelihood to nearly sixty million people and is an important agricultural commodity providing remunerative income to millions of farmers both in developed and developing countries.

A long term challenge faced by cotton breeders is the simultaneous improvement of yield and fibre quality to meet the demands of the cotton cultivators as well as the modernized textile industry. Although fibre production has greatly increased, rapid development in the modern textile industry requires cotton fibre of higher quality. Because of competition in the global economy, yarn and textile manufacturers have adopted more efficient production machinery capable of generating more products per unit of time. Thus, the widespread use of high speed spinning technology has increased the demand for raw cotton fibre with higher strength. Hence, cotton fibre quality must be improved to remain competitive with synthetic fibres and to meet the needs of new spinning and weaving methods. Besides fibre strength, fibre length and fibre fineness are the primary qualities that influence textile processing (Kohel, 1999).

The tetraploid species *viz.*, *G. hirsutum* L. and *G. barbadense* L. accounted for 90 per cent and 8 per cent of the world cotton production

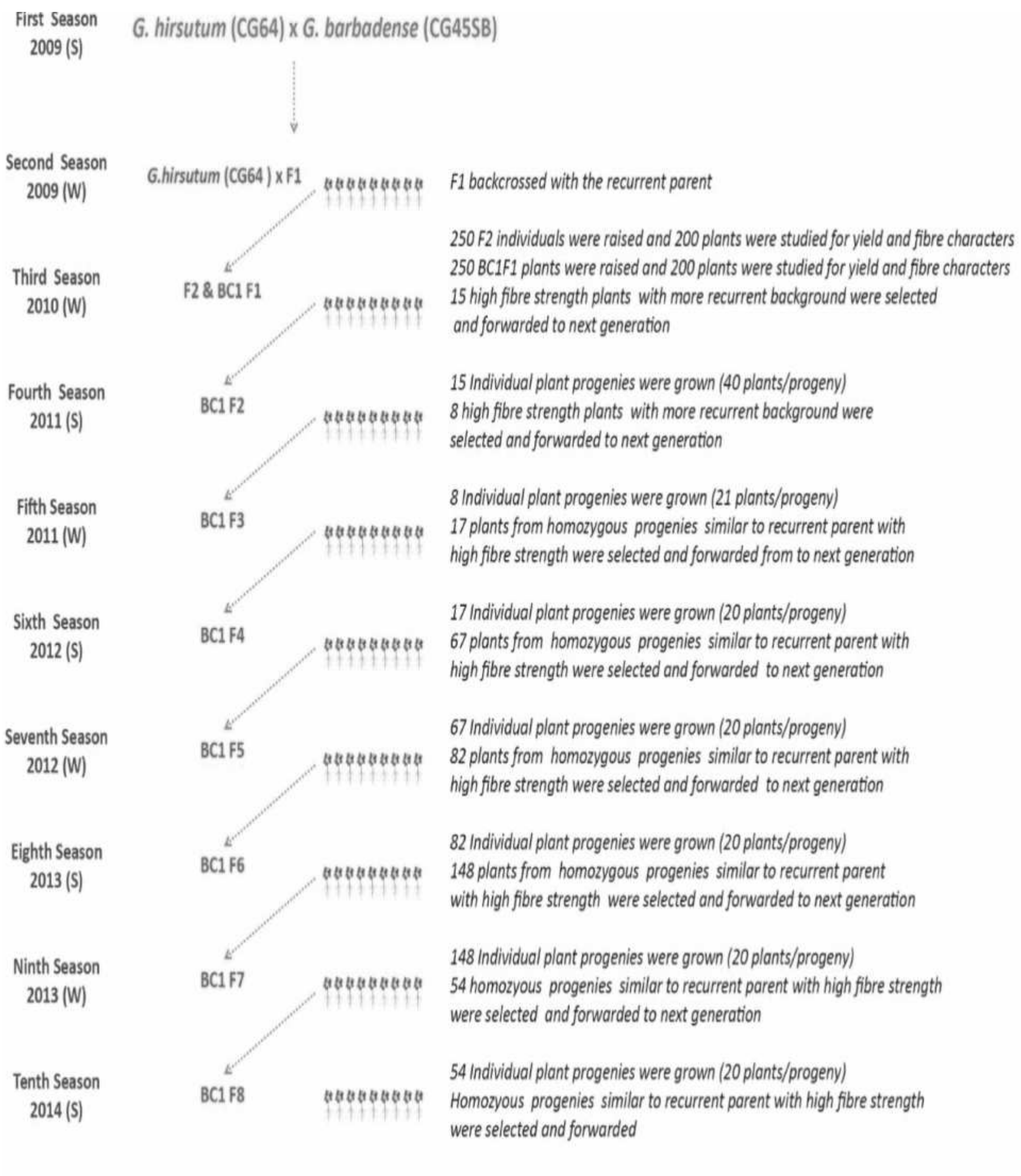
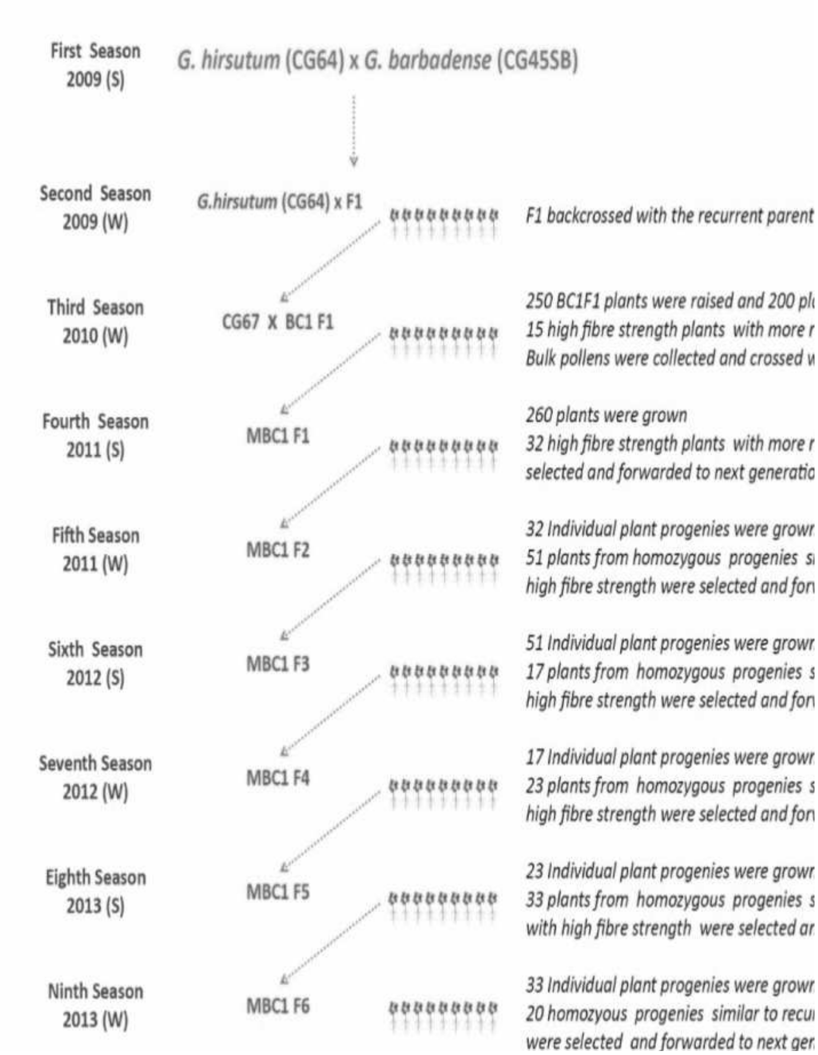


Figure 1. The breeding scheme for Backcross I programme

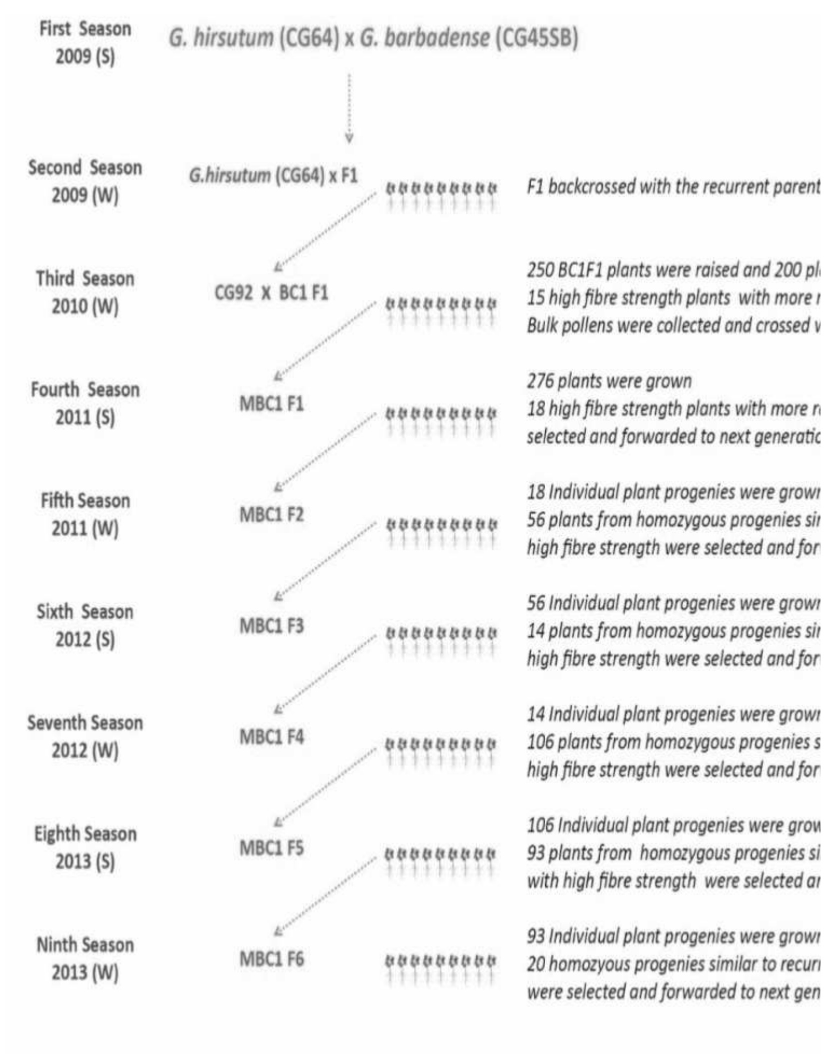
respectively (Zhang *et al.,* 2008). Soregaon *et al.* (2007) stated that interspecific hybrids in cotton have better performance compared to non-hybrid for fibre yield, ginning efficiency, fibre length, fibre fineness and fibre uniformity. The yield of interspecific hybrids is comparable with *G. hirsutum* L., whereas the fibre properties (length, fineness and strength) to *G. barbadense* L. (Davis, 1978).

Creating genetic variability is pre-requisite for plant breeders to exercise selection, as a part of continuous variation is due to heredity. The phenotypic and genotypic coefficients of variation were estimated using genotypic and phenotypic variances respectively. The coefficient of variation indicates only the extent of variability existing for various traits, but does not give any information about the



heritable portion of it. Therefore, heritability accompanied by estimates of genetic advance and genetic advance as per cent mean were also estimated.

Heritability in itself provides no indication about the genetic progress that would result from selection. However, at a fixed selection pressure, the amount of advance varies with magnitude of heritability. Genetic advance in a population cannot be predicted from heritability alone, the genetic gain for specific selection pressure has to be worked out. Many investigations had been made on heritability for seed cotton yield and other traits. Basbag and Gencer (2004) indicated that seed cotton weight per boll and 100 seed weight had high heritability; bolls per plant had low heritability, while other characters had moderate heritability. The characters with high heritability suggested some possibilities in obtaining required genotypes by selection in early segregating generations (F2, F3); while



selection for improvement was delayed due to low heritability for some characteristics. Basal and Turgut (2005) mentioned that moderate heritability estimates were observed for earliness ratio (0.53), fiber strength (0.50) seed cotton weight/boll (0.42) and lint per cent (0.40), however, bolls/plant and seed cotton weight/ plant showed low heritability estimates, 0.33 and 0.22, respectively.

MATERIALS AND METHODS

The present scientific studies on cotton (*Gossypium* spp) were conducted in the Rasi Research farm, Attur, Tamil Nadu. These studies were taken up to develop high fibre quality lines using cultivated tetraploid genotypes of upland cotton (*G. hirsutum*) namely CG 64, CG67 and CG 92 and Sea Island cotton (*G. barbadense*) namely CG45SB were crossed during 2009 summer. Three cross combinations were obtained namely, one backcross generation BC I (CG64 × (CG64 × CG45SB)) and two modified backcross generations MBC I (CG67 × (CG64 × (CG64 × CG45SB)) and MBC II (CG92 × (CG64 × (CG64 × CG45SB)). The schematic picture of breeding scheme, number of plants raised and number of plants selected in each generation of backcross I and modified backcross I and II are shown in Figs. 1 to 3 respectively. The backcross populations were evaluated for productivity and fibrequality parameters realizing the emphasis laid on developing ELS (Extra Long Staple and high fibre strength lines.

Each replication consists one row of P_1, P_2 and F_1. B_1 and F_2 were raised each in 20 rows and 5 rows of two different recurrent parents. The spacing adapted was 120 × 60 cm. Recommended agronomic practices and need based plant protection measures were followed under irrigated condition to obtain good crop stand. The experiments were raised in the winter (August – February) and summer (January to July) seasons. Selected plants in each single plant progeny were observed and their biometrical and fibre quality traits were recorded. The fibre quality traits were estimated by High Volume Instrument USTER® HVI Spectrum in ICC mode.

The mean and variances were analysed based on the formula given by Singh and Chaudhary (1977). The genotypic and phenotypic coefficient of variation was computed according to Burton and Devane (1953). The extent of genetic advance to be expected from selecting five per cent of the superior progeny was calculated using the following formula (Robinson *et al.*, 1955). Heritability measures the relative amount of the heritable portion of variability and provides useful information for effective selection. The ration of the total genetic variation to the total phenotypic or observed variation is termed as co-efficient of heritability in broad sense whereas the ratio of the additive genetic variation to the total observed variation is called the co-efficient of heritability in the narrow sense.

RESULTS AND DISCUSSIONS

The mean, variance and coefficient of variance based on the data of individual plant observation for 11 characters were presented in the Table 1, 2 and 3 for back cross population I, modified backcross populations I and modified backcross populations II respectively.

Among the parents, mean performance of the parent P_2 was higher than P_1 in all yield contributing characters *viz.,* number of bolls per plant, boll weight, seed cotton yield, ginning per cent and lint index, whereas for fibre quality characters namely, 2.5 per cent span length and

Table 1. Estimates of variability, heritability and genetic advance as per cent of mean in backcross population - I

Season	Particulars		Bolls / plant	Boll weight (g)	Seed cotton yield/ plant (g)	Gin-ning (%)	Lint index	Seed index	2.5 per cent span length (mm)	Uni-formity ratio	Fibre strength (g/tex)	Micro-naire	Elong-ation
2010 (W)	CG 45SB (P_1)	Mean	45.3	2.9	120.4	26.5	5.3	12.4	38.9	45.1	33.4	2.9	5.4
		Range	35.0 -56.0	2.4-3.2	102.3 -134.6	24.6-27.5	4.9-5.5	11.2-12.9	37.6-39.8	44.2-46.1	32.2-34.6	2.4-3.1	5.1-5.7
	CG 64(P_2)	Mean	76.8	4.4	182.7	35.5	5.4	10.5	30.6	46.1	23.1	4.3	6.3
		Range	54.0-89.0	4.1- 4.9	167.4 - 197.7	34.6-36.4	5.2-5.8	9.8-12.5	28.9-31.7	45.3-46.8	22.1-24.5	4.1-4.5	5.4-6.7
	F_2	Mean	74.7	3.9	193.9	30.7	4.7	11.3	32.2	47.3	24.9	4.1	5.7
		Range	34.0-121.0	2.5-5.1	95.1-332.0	24.7-36.5	4.0-5.8	8.7-13.4	28.1-38.3	46.5-47.7	20.1-29.8	2.7-4.7	4.7-6.9
		PCV	21	13.5	66.3	7.8	7	8.2	10.3	0.8	12.2	12.6	19.8
		GCV	16.3	11.6	65.9	7.6	6.1	6.6	10.2	0.5	11.6	10.1	19.6
		h2	60.5	73.5	98.5	94.7	76.4	65.7	97.5	40.1	90.5	64.5	97.9
		GA (%)	6.6	28.3	9.6	9.9	19.3	11.5	11.4	1.1	13	23.4	36.5
	BC_1F_1	Mean	58	3.8	203	31.8	5	10.7	35.1	46.5	27.2	3.5	5.6
		Range	41.0-125.0	2.3-4.5	114.0-326.9	27.8-34.5	4.3-5.7	8.0-12.9	30.1-38.7	42.7-46.9	21.6-32.7	2.5-4.7	4.6-6.7
		PCV	41.7	16.3	43.9	8.4	16.4	18.1	4.6	4.9	8.1	16.1	25.7
		GCV	41.5	15.6	43.4	8	15.9	17.5	4.5	4.7	8	15.8	25.6
		h2	99	92.3	97.8	91.3	94	93.3	96.8	95.5	98.7	97.1	99
		GA (%)	17.3	39.5	10.8	9.7	35.2	25.1	7.2	6.2	19.3	43	43.6
2011 (S)	CG 45SB (P_1)	Mean	54	2.9	121.3	25.5	5.2	11.7	39.8	45.6	33.2	2.8	4.7
		Range	41.0-73.0	2.5-3.2	103.4-143.6	24.5-27.6	4.8-5.9	11.4-12.8	38.6-41.2	44.7-46.1	32.6-34.6	2.5-3.2	4.3-5.1
	CG 64 (P)	Mean	78.5	4.18	229.18	35.85	5.4	9.88	30.5	46.25	24.5	4.3	5.3
		Range	56.0-86.0	3.7-4.5	211.1- 245.8	33.4-36.5	4.9-5.9	8.7-10.5	29.1-31.2	45.6-46.8	23.1-25.2	3.9-4.6	4.5-5.6
	BC_1F_2	Mean	61.5	3.58	228.44	31.59	4.68	9.99	33.7	45.37	28	3.6	5.2
		Range	36.0- 78.0	2.7-4.2	145.6-258.9	28.9-32.4	4.2-5.9	8.5-10.8	28.9-35.4	44.8-45.9	26.5-31.0	2.7-4.7	4.7-6.1
		PCV	44.3	37.8	61.2	13	19	15.9	5.6	4.5	8.5	15.7	36.1
		GCV	41.9	37.7	59.5	12.8	14.7	15.4	5.1	4.3	8.2	15.3	36
2011 (S)	BC_1F_2	h^2	89.4	99.5	94.4	76.7	59.5	94.1	82.6	93.9	94.8	94.8	99.2
		GA	17.1	66.6	13.4	12.8	24.7	24.4	6.9	6.1	11.6	40.7	54.1
2011 (W)	CG45SB (P_1)	Mean	42	2.9	87.2	26.5	4.5	12.1	39.8	46.3	32.5	2.9	4.5
		Range	35.0-56.0	2.7-3.3	56.7-102.3	24.7-27.1	4.3-4.7	11.1-13.4	38.6-40.3	45.8-46.9	30.9-33.4	2.5-3.2	4.1-4.8
	CG64(P_2)	Mean	76.3	4.1	180.1	35.6	5.2	9.2	30.7	46.3	24.3	4.3	4.9
		Range	56.0-87.0	3.8-4.6	162.7-210.3	33.4-36.5	4.7-5.9	8.7-10.3	28.7-31.4	46.2-47.5	23.4-25.6	3.9-4.5	4.7-5.5
	BC_1F_3	Mean	42	3.91	126.7	31.54	4.54	9.4	30.3	46.31	30.2	4	4.3
		Range	36.0-77.0	2.8-4.3	98.0-213.1	27.6- 33.7	4.0-5.2	8.6-10.7	28.7-33.2	45.0-46.8	27.8-33.4	2.7-4.6	4.1-4.6
		PCV	39.2	19.7	46.7	15.6	15.3	15.4	6	2.1	9.9	21.9	15.3
		GCV	38.3	18.8	44.6	15	15.2	11.2	5.8	1.8	9.7	21.8	14.7
		h2	95.5	91.1	81.5	77.7	80.3	52.6	93	74	95.9	98.7	92.1
		GA (%)	29	48.9	23.8	16.8	28.6	14.2	8.5	3.3	11.3	47.4	36
2012 (S)	CG45SB(P_1)	Mean	51	2.9	112.3	26.5	4.2	12.1	39.7	44.7	32.6	3	4.5
		Range	42.0-74.0	2.5-3.2	93.4-123.4	25.5-27.6	4.1-4.3	11.6-13.4	38.3-40.1	44.0-45.1	30.9-34.1	2.6-4.5	4.2-4..7
	CG64(P_2)	Mean	74.8	4.1	215.8	35.9	5.2	9.9	31	46.3	24.5	4.2	5.3
		Range	63.0-81.0	3.5-4.7	176.5-276.3	33.6-36.5	4.6-5.7	8.9-12.3	28.9-33.2	45.4-46.9	23.4-25.6	3.9-4.5	5.4-5.7

Table 1 contd...

Table 1 contd...

	BC_1F_4	Mean	79.3	3.12	173.92	34.37	4.45	9.53	29.8	46.82	28.9	4.4	5.1
		Range	45.0-91.0	2.6-3.7	154.3-167.6	30.3-36.5	4.1-5.4	9.3-11.7	28.4-31.4	45.3-46.9	27.9-32.5	4.1-4.7	4.5-6.1
		PCV	30.6	19.97	38.64	7.88	14.2	16.45	6.1	2.08	6.5	20.3	15.9
		GCV	30.5	19.2	35.4	7.55	14.1	15.16	5.9	1.78	6.3	19	12.4
		h2	76.8	92.48	91.5	91.8	67.8	84.95	94	73.56	93.9	87.9	61.1
		GA (%)	22	48.2	22.04	9.05	23.14	24.3	8.9	3.19	14.2	38.8	22.3
2012 (W)	CG45SB(P_1)	Mean	37	2.6	156.7	26.7	4.3	11.6	39.2	45.6	33.5	2.7	4.7
		Range	34.0-43.0	2.4-2.9	123.4-176.8	24.3-27.8	4.1-4.5	11.2-12.5	38.7-40.1	45.2-46.2	32.4-35.4	2.4-2.9	4.4-5.1
	CG64(P_2)	Mean	92.8	4.1	265.66	34.91	4.76	10.94	29.6	45	24.4	4.3	5.2
		Range	89.0-103.0	3.4-4.6	234.5-278.9	33.6-36.5	4.4-4.9	9.4-11.5	28.4-30.9	44.6-45.8	22.1-25.4	4.2-4.7	4.8-5.4
	BC_1F_5	Mean	75.7	4.05	225.67	34.17	4.22	10.11	28.7	46.5	29.4	4.3	5
		Range	45.0-89.0	3.5-4.5	176.8-319.0	33.4-36.5	4.0-4.7	8.9-11.7	27.6-30.9	46.0-46.9	28.7-33.4	4.1-4.9	4.1-5.7
		PCV	24.3	15.34	22.85	7.03	16.09	14.55	5.6	2.34	7.2	13.1	10.6
		GCV	23.2	13.07	22.3	6.43	15.59	14.54	5.5	2.11	6.6	12.9	10.2
		h2	86.3	72.56	75.26	83.77	93.92	99.78	98.4	87.9	83.5	97.8	86.5
		GA (%)	26.7	33.53	33.22	7.83	37.79	27.53	8.9	4.62	26.9	35.1	12.5
2013 (S)	CG45SB(P_1)	Mean	45	2.8	167.8	26.5	4.7	11.3	40.2	45.6	32.4	2.8	4.5
		Range	32.0-57.0	2.5-3.5	145.6-178.9	24.5-27.8	4.1-5.2	10.2-12.3	38.7-41.2	44.2-45.8	30.9-33.7	2.6-3.1	4.4-5.1
	CG64(P_2)	Mean	80	3.78	177.75	35.74	5.22	10.28	29.8	45.9	23.2	4.6	4.6
		Range	46.0-93.0	3.5-4.4	156.7-186.7	34.1-36.5	4.3-5.6	9.6-11.2	28.4-31.5	45.3-46.1	22.1-24.5	4.1-4.7	4.1-5.2
	BC_1F_6	Mean	69.9	3.12	182.89	32.57	4.55	9.41	29.1	45.84	30.1	4.9	5
		Range	49.0-82.8	2.7-3.5	167.6-203.4	29.1-33.4	4.1-4.9	8.7-11.2	28.7-31.3	44.9-46.2	29.1-33.1	4.3-5.2	4.1-5.4
		PCV	21	13.48	36.34	7.84	7.03	8.19	10.3	7.9	6.7	12.6	19.8
		GCV	20.3	11.56	35.85	7.63	7.14	6.64	10.2	5	6.6	10.1	19.6
		h2	78.9	73.51	78.51	94.73	76.41	65.73	97.5	50.06	87.4	64.5	97.9
		GA (%)	36.6	28.27	29.64	9.87	29.3	11.53	11.4	4.07	23.4	23.4	36.5
2013 (W)	CG45SB (P_1)	Mean	47	2.7	153	26.7	4.6	11.5	38.7	45.7	33.1	2.9	5.4
		Range	36.0-67.0	2.5-3.6	123.4-189.7	25.6-27.6	4.1-5.2	11.2-12.3	37.4-39.6	45.3-46.2	32.1-34.2	2.7-3.1	5.3-5.8
	CG64(P_2)	Mean	74.3	3.76	195.27	35.67	5.37	10.86	30.2	46.57	23.2	4.3	5.9
		Range	54.0-82.0	3.4-4.5	145.6-207.8	34.2-36.1	4.9-5.6	10.5-11.4	29.9-31.4	45.6-47.9	22.1-24.3	3.9-4.7	5.4-6.1
2013 (W)	BC_1F_7	Mean	88.3	3.44	213.68	33.32	5	10.01	28.9	45.51	30	4.9	5
		Range	73.0-92.0	3.0-4.1	166.0-254.6	31.2-34.5	4.5-5.6	9.4-11.3	27.9-31.5	44.7-46.1	29.1-34.4	4.4-5.1	4.6-5.7
		PCV	20.7	11.55	25.27	15.64	19.69	9.83	14.1	11.67	6.4	20.6	10.6
		GCV	20.6	10.14	24.92	15.26	17.73	9.33	14	11.23	6.3	18.4	10.5
		h2	87.6	77.1	87.24	77.09	63.55	90.06	83.5	54.62	76.5	63	79.7
		GA (%)	19.8	29.1	26.89	7.38	18.22	18.38	7.3	2.11	21.3	19	23.4
2014 (S)	CG45SB(P_1)	Mean	47	2.7	176.7	26.6	4.6	11.6	40.3	45.6	33.4	2.8	4.5
		Range	35.0-67.0	2.4-3.1	134.5-199.7	25.4-27.7	4.3-5.1	11.1- 12.0	39.8-41.5	44.7-45.8	31.2-35.5	2.5-3.1	4.3-4.7
	CG64(P_2)	Mean	65	4.2	190.8	35.03	5.35	10.15	29.8	46.9	23.7	4.8	6.3
		Range	43.0-78.0	3.6-4.7	167.0-203.7	34.5-36.7	4.3-5.6	9.9-10.7	28.7-31.6	46.2-47.5	22.3-24.3	4.5-4.9	5.6-6.4
	BC_1F_8	Mean	66.9	3.22	183.6	32.47	5.09	10.55	29.4	46.38	30.4	4.9	5.1
		Range	56.0-87.0	2.9-3.5	144.5-223.4	30.8-33.6	4.4-5.4	9.9-10.9	28.5-31.3	45.8-46.5	28.9-33.1	4.7-5.1	4.5-5.9
		PCV	18.9	12.1	15.4	17.9	17.3	19.8	9.1	14.3	6.1	17.1	8.2
		GCV	18.4	11.7	15.1	17.8	17.1	19.6	9	14.3	6	16	8.2
		h2	78.5	68.8	65.3	99	87.6	76.9	98.4	99.3	79.4	92.1	67.8
		GA (%)	23.4	24.4	28.9	9.5	32.5	23.4	8.2	4.1	29	24.9	24.9

Table 2.Estimates of variability, heritability and genetic advance as per cent of mean in modified backcross population-I

Season	Particulars		Bolls / Plant	Boll weight (g)	Seed cotton yield/ plant (g)	Gin-ning (%)	Lint index	Seed index	2.5 per cent span length (mm)	Uni-formity ratio	Fibre strength (g/tex)	Micro-naire	Elong-ation
2011 (S)	CG45SB (P_1)	Mean	56	3.1	121.5	26.5	4.5	12.3	39.5	43.5	33.4	2.9	4.5
		Range	47.0 - 62.0	2.9-3.1	110.5-133.2	24.2-27.3	4.1- 4.6	12.0-12.5	39.0-40.1	43.2-43.7	32.5-34.1	2.6-3.1	4.2-4.7
	CG67 (P2)	Mean	76	4.3	228.1	31	4.6	10.3	36.1	43.7	25.3	3.4	4.8
		Range	71.0 -83.0	4.1-4.9	212.4 -234.3	30.12-32.10	4.4 -5.1	9.8-10.9	35.6-36.7	43.2-43.8	24.9-25.6	3.1-3.9	4.4-5.1
	MBC1F1	Mean	88.5	4.4	333.7	31.1	4.9	10.7	36.3	43.7	24.4	3.2	4.7
		Range	64.0 -115.0	3.5-5.6	178.3 - 412.3	29.3 -34.5	3.9 -5.7	9.7-13.1	34.1-38.3	43.1-43.8	24.3-31.5	3.1-4.2	4.6-5.9
		PCV	28.9	14.5	33.7	23.4	24.9	25.3	4.6	26.2	35.8	14.3	13
		GCV	28.8	13.7	33.4	21.8	24	23.4	4.2	26.3	35.6	13.4	11.6
		h2	85.7	76.5	98.8	78.7	65.7	67.9	78.2	63.1	78.3	93.4	91.1
		GA (%)	19.2	19.9	25.6	6.2	29.2	12.9	10.1	3.5	25.3	24	19.6
2011 (W)	CG45SB (P1)	Mean	64	2.6	180.2	25.7	4.6	12.4	40.1	44	34.2	2.7	4.9
		Range	45.0 - 67.0	2.8-3.4	125.0 -198.0	27.5	4.2-5.3	11.9-13.1	38.9-40.2	44-44.8	33.5-35.7	2.5-3.1	4.2-5.6
	CG67 (P2)	Mean	83	4.1	236.2	32.2	5.1	10.8	36	44.3	25.4	3.1	5.7
		Range	56.0 -106.0	3.9-5.1	198.0 -332.2	31.6 -33.4	5.1-5.6	10.1-11.3	35.1-36.5	44.1-44.7	24.6-26.1	3.1-3.6	4.7-6.1
	MBC1F2	Mean	92.4	3.7	244	32.6	4.9	10	33.4	44.8	26.9	3.4	4.9
		Range	43.0-142.0	2.6-4.7	78.0 - 345.5	26.7-32.4	4.1-5.4	8.9-12.3	31.4-38.1	44.1-45.2	24.1- 29.6	2.8-4.1	4.1-5.5
		PCV	35.6	24.6	45.3	34.3	57.5	35.5	24.4	32.1	23	19.2	12.3
		GCV	34.1	24.3	43.4	32.1	55.4	32.5	23.8	31.6	22.7	19.1	10.1
		h2	96.2	98.6	97.6	67.9	88	76.6	90	78.4	91.5	99.6	65.3
		GA (%)	21.1	21.3	34.6	4.8	23.8	13.6	10.1	13.7	26	14.4	18.2
2012 (S)	CG45SB (P1)	Mean	57	3.2	150	26.9	4.5	12.8	39.1	44.1	32.4	3.1	4.4
		Range	39.0-65.0	2.5-3.5	93-201	24.9 -27.8	3.9-5.0	11.2-13.4	38.7-40.8	44.2-45.4	31.2-34.2	2.6-3.7	4.2-4.8
	CG67 (P2)	Mean	97.8	4.3	255.7	32.8	4.6	9.2	34.2	43.3	25	3.2	4.7
		Range	87.0 -106.0	4.1-4.8	200.1-306.2	31.3 -34.5	4.1-5.1	8.3-10.7	34.1-35.2	43.1-44.0	24.3-26.1	2.9-3.9	4.3-5.7
	MBC1F3	Mean	101.9	3.6	258.1	31.6	4.2	9.1	34.6	44	27.9	3.6	4.4
		Range	87.0 -130.0	3.0-4.7	120.0 - 285.5	29.7 -33.2	3.9-5.9	8.5-10.3	32.4-35.1	43.1-44.2	26.1- 30.1	2.9-3.9	4.2-4.9
		PCV	15.9	58.8	32.3	17.7	32.8	36.2	17.4	15.1	18.4	45.9	50.8
		GCV	15	58.5	30.9	17.6	31.1	34.4	17.3	15	18.2	45.8	49.1
		h2	89.6	99.4	91.5	79	98.7	87.6	56.3	82.3	85.3	99.8	76.6
		GA (%)	22.8	27.3	26.7	5	29.1	21.8	11.9	9.4	36.3	17.8	21.3

Table 2 contd...

Table 2 contd...

2012 (W)	CG45SB	Mean	59	2.9	142.3	26.8	4.6	11.9	40.2	44.6	32.8	3.1	4.7
	(P1)	Range	45.0 - 68.0	2.5-3.2	98-167	25.2-27.1	4.4-5.1	10.8-12.3	39.5-41.2	44.3-45.2	31.3-33.7	2.9-3.2	4.5-5.1
	CG67	Mean	88.8	4.5	281.7	31.7	4.8	10.5	35.4	44.8	25.8	3.8	5.7
	(P2)	Range	76-97	4.1-4.9	267.2 - 298.0	30.4 -32.5	4.1-4.9	10.2-10.7	34.5-35.6	44.1-45.8	24.3-25.8	3.9-4.2	5.3-5.9
	MBC1F4	Mean	97	4	272.3	30.2	4.6	11.4	33.5	43.3	28.7	3.5	5.1
		Range	86.0 -114.2	3.5-4.2	201.0 - 295.5	28.7-32.2	4.3-5.1	10.9-11.9	32.1-34.6	43.0-43.7	27.6- 29.1	2.9-3.9	4.2-4.9
		PCV	12.4	19.2	27.2	8.9	18.7	23.3	11.2	8.9	14.4	16.8	17.5
		GCV	12	18.7	27	8.8	18.1	21.5	10.1	8.5	14.3	10.9	16.9
		h2	93.6	97.6	90.7	67.9	96.6	96.1	54.9	75.6	97.4	64.8	96.4
		GA (%)	20.7	20.6	22.3	4.7	20.5	9.6	4.4	5.4	33.8	25.5	19
2013 (S)	CG45SB	Mean	67	3.2	171.3	27.1	5	12.3	38.9	44.1	32.9	3.1	4.7
	(P1)		56.0-78.0	2.9-3.7	134.4 -198.3	25.7-28.3	4.6-5.4	11.5-12.7	37.6-39.7	43.5-44.7	31.5-33.5	2.6-3.6	4.3-5.1
	CG67	Mean	89	4.4	372.8	31.3	5.2	11.3	34.9	43.4	25.8	3.5	4.8
	(P2)		75-97	4.0-4.7	342.7-397.5	30.9 -32.2	4.7-5.5	10.9-11.9	33.4-35.1	43.2-43.7	25.2-26.2	3.1-3.7	4.3-5.1
	MBC1F5	Mean	92.1	4.1	362.9	31.3	4.7	10.4	32.6	45.4	29.3	3.6	4.5
		Range	72.0-109.0	3.9-4.7	332.6-398.7	29.6 -31.9	4.3-5.4	9.8-11.5	31.5-35.6	44.3-45.7	28.7-30.5	3.4-4.1	4.6-5.1
		PCV	10.5	18.3	24.2	9.7	13.7	13.9	5.5	7.6	14.8	15.2	13
		GCV	10.7	18	23.9	9.4	12.7	12.1	5	6.3	14.3	12.2	10.5
		h2	97.6	98.4	87.7	79	92.8	86.7	89.6	82.8	88.5	80.5	65.3
		GA(%)	23.9	18.3	30.1	5.5	19.9	14.6	5.1	5.4	25.1	26.4	19.8
2013 (W)	CG45SB	Mean	45	2.9	94.3	24.8	4.3	11.9	38.7	44	31.9	2.9	4.9
	(P1)	Range	37.0 - 49.0	2.5-3.1	57.3 -112.3	24.1-25.4	4.1-4.6	11.4-12.5	37.8-39.8	43.8-44.2	30.1-33.6	2.6-3.7	4.5-5.3
	CG67	Mean	51.3	4.3	134.3	32.1	4.9	11	35.2	44.5	26	3.6	5
	(P2)	Range	45.0 - 67.0	3.9-4.8	121.3-156.3	31.1 -33.2	4.1-5.3	10.8-11.3	34.5-36.1	43.8-45.1	25.3-26.8	3.4-4.1	4.6-5.7
	MBC1F6	Mean	54.6	4.1	154.9	31	5	11.2	33.4	44.9	29.3	4.2	4.5
		Range	43.0 -71.0	4.2-4.7	127.3-178.9	28.9 -32.3	4.5-5.7	10.8-11.7	32.1-34.5	44.1-45.3	28.9-31.3	3.9-4.5	4.6-5.1
		PCV	7.4	14.8	12.7	8.1	12	11.1	5.7	6.7	15.4	13.2	12.8
		GCV	7.1	12.9	11.4	7.9	10.3	10.4	5.6	5.5	15.1	12.2	10.3
		h2	96.3	87.6	88	79	85.8	94	98.5	85.6	93.1	92.7	69.2
		GA (%)	25.6	23.9	26.6	4.6	20.6	11.2	3.5	7.6	35	20.7	16

Table 3. Estimates of variability, heritability and genetic advance as per cent of mean in modified backcross population-II

Season	Particulars		Bolls / plant	Boll weight (g)	Seed cotton yield/ plant (g)	Gin-ning (%)	Lint index	Seed index	2.5 per cent span length (mm)	Uni-formity ratio	Fibre strength (g/tex)	Micro-naire	Elong-ation
2011 (S)	CG45SB (P1)	Mean	78	3.2	174.3	26.4	5.1	12.4	40.3	44	34.6	3.1	4.2
		Range	45 .0 - 87.0	2.9-3.1	154.3 -89.7	24.3-27.6	4.7-5.9	11.9-13.2	39.8-41.2	43.5-44.7	32.6-35.3	2.9-3.2	4.0-4.3
	CG92 (P2)	Mean	89	4.37	271.69	34.72	5.73	10.3	34.5	44.67	26.07	3.27	4.33
		Range	76.0 - 97.0	3.9-5.7	213.1-301.3	33.1-34.76	5.1-6.1	8.7-11.5	33.5-34.7	44.2-44.89	24.7-27.1	3.1-3.4	4.5-4.9
	MBC1F1	Mean	75.53	4.79	253.32	32.5	5.37	11.22	34.93	44.85	24.07	3.43	4.33
		Range	43.0-121.0	3.4-6.1	178.1-345.2	27.3-35.1	4.4-5.6	9.8-13.4	31.4-37.8	43.4-44.5	24.7-31.2	2.9-3.7	4.2-5.1
		PCV	34.55	17.06	28.88	6.31	13.94	13.81	15.17	1.77	34.5	13.71	16.13
		GCV	34.22	16.5	28.87	6.3	10.49	13.72	15.02	1.22	36.5	12.96	9.05
		h2	68	86.7	78.9	67.8	75.25	99.37	87.05	68.68	78.59	94.58	56.13
		GA (%)	19.5	18.97	32.45	12.1	20.27	7.59	13.78	2.4	16.78	22.19	20.31
2011 (W)	CG45SB (P1)	Mean	69.45	2.9	167.2	25.7	4.5	11.9	38.9	45	32.4	2.9	4.33
		Range	54.0-76.0	2.3-3.9	154.0-186.7	24.3-26.8	4.1-5.2	11.0-12.3	37.8-39.6	44.5-46.1	31.3-34.2	2.5-3.5	4.1-4.6
	CG92(P2)	Mean	84.67	4.77	282.66	34.89	6.23	11.73	34.73	45.33	24.93	3.37	4.63
		Range	67.0-92.0	4.1-5.3	234.0-345.6	33.31-35.61	5.4-7.1	10.9-12.4	32.8-35.4	44.6-46.7	24.3-25.7	3.1-3.7	4.4- 5.1
	MBC1F2	Mean	73.04	3.8	258.1	33.3	5.1	10.1	33.36	45.07	27.13	3.19	4.5
		Range	32.0-136.0	2.5-4.6	115.4.1-413.2	26.41-34.56	4.7-6.3	8.7-12.1	29.1-35.6	44.5-45.9	24.3-32.3	2.7-3.8	4.3-4.9
		PCV	19.35	23.16	30.99	9.15	20.58	17.69	13.82	2.19	23.4	21.68	16.3
		GCV	19.07	21.72	29.53	8.91	18.48	16.65	13.62	1.78	22.7	19.69	14.52
		h2	98.52	93.77	86.78	57.38	89.79	94.14	94.83	81.19	79.6	80.84	76.81
		GA (%)	23.41	34.56	24.56	13.67	23.45	8.7	9.24	1.27	20.45	21.01	11.2
2012 (S)	CG45SB (P1)	Mean	54	2.8	135.8	25.6	4.5	12.1	40.4	43.45	31.9	3.1	4.5
		Range	45.0-67.0	2.4-3.1	124.5-145.6	24.34-26.32	4.3-4.8	11.2-12.7	38.9-41.5	43.0-43.9	30.1-32.7	2.9-3.4	4.3-5.2
	CG92 (P2)	Mean	94.67	3.77	249.5	32.89	5.17	9.67	33.1	44.1	25	3.5	4.67
		Range	83.0-108.0	3.5-4.4	223.4-262.1	31.32-34.21	4.1-6.3	8.7-10.2	32.7-34.5	42.5-47.6	24.6-26.4	3.1-3.7	4.3-5.1
	MBC1F3	Mean	97.98	4.2	261.95	33.07	4.76	9.75	32.63	43.43	27.14	3.59	4.57
		Range	67.0-123.0	3.7-4.8	178.0-314.5	31.57-34.34	4.3-5.4	9.1 -12.1	29.6-34.7	43.2-43.6	26.8-34.2	2.9-3.7	4.2-5.2
		PCV	20	17.43	27.79	5.67	11.88	12.96	10.45	1.42	13.56	15.95	13.79
		GCV	19.83	16.96	27.6	5.23	11.82	11.01	10.32	0.57	12.5	15.7	12.53
		h2	78.98	97.3	77.45	71.37	67.89	84.98	83.22	40.1	73.1	98.46	80.1
		GA (%)	34.21	20.64	19.17	7.8	20.34	14.66	12.47	1.41	19.67	17.89	23.73
2012 (W)	CG45SB (P1)	Mean	62	3.2	156.7	25.4	4.5	11.7	39.8	44.5	32.3	3.1	4.7
		Range	55.0-71.0	2.7-3.8	134.5-176.4	24.45-27.65	4.2-4.7	11.1-12.2	38.6-41.2	43.6-45.7	31.4-34.6	2.9-3.3	4.3-4.9
	CG92 (P2)	Mean	87.67	4.9	300.79	34.57	6	11.43	34.67	44.7	26.33	3.3	5.1
		Range	76.0-93.0	3.9-5.4	267.8-385.6	32.56-35.2	5.3-6.5	11.4-12.1	34.2-35.6	43.4-45.6	25.3-27.1	2.9-3.5	4.7-5.6

Table 3 contd...

Table 3 contd...

	MBC1F4	Mean	93.83	4.6	258.64	32.25	5.05	10.74	32.12	44.05	27.6	3.72	4.9
		Range	76.0-115.0	3.8-5.4	214.5-277.8	30.2-34.56	4.6-6.7	9.7-11.3	29.8-34.2	43.2-45.3	26.4-31.2	3.2-3.9	4.6-5.4
		PCV	16.24	13.84	25.16	8.61	12.7	13.45	5.16	2.26	19.41	15.04	9.66
		GCV	15.3	13.29	23.63	8.39	12.19	13.31	4.58	1.84	18.22	13.25	8.29
		h2	94.16	96.91	93.94	78.6	96.76	98.96	88.76	81.38	73	88.09	85.8
		GA (%)	26.17	21.13	24.56	4.96	17.66	8.66	4.98	2.89	21.34	25.12	17.05
2013 (S)	CG45SB (P1)	Mean	75	2.9	167.8	26.3	4.5	12.6	40.3	45.3	34.5	2.9	4.5
			64.0-86.0	2.7-3.5	134.5-178.9	24.56-27.89	4.1-4.6	11.2-13.2	38.7-42.3	44.2-45.7	32.78-35.67	2.6-3.2	4.2-4.8
	CG92 (P2)	Mean	76.75	4.28	229.6	35.14	6.28	11.68	34.2	45.5	26.1	3.4	4.75
			68.0-83.0	4.1-5.3	214.5-254.6	32.34-36.71	5.4-7.1	11.2-12.7	33.2-36.5	44.3-46.1	25.4-27.8	3.0-3.7	4.2-5.4
	MBC1F5	Mean	73.65	4.6	219.69	33.68	5.57	10.93	30.92	44.51	29.15	4.07	4.49
		Range	67.0-82.0	3.9-5.2	197.1-236.7	32.1-34.56	4.7-6.8	9.2-12.3	28.7-33.5	43.4-46.1	28.7-32.4	3.6-4.4	4.3-5.4
		PCV	15.42	12.34	15.64	7.05	15.6	13.55	6.27	2.51	15.77	19.51	11.59
		GCV	15.12	11.97	14.98	6.98	14.94	12.71	6.11	2.18	15.63	18.78	5.46
		h2	67.89	89.76	67.89	89.02	95.77	93.83	97.57	86.94	87.73	96.23	47.08
		GA(%)	19.85	23.45	21.34	3.48	21.23	12.66	4.23	2.93	24.12	22.63	14.02
2013 (W)	CG45SB (P1)	Mean	58	3.2	172.2	25.4	5.3	12.1	38.7	44.4	33.2	2.9	4.7
		Range	49.0-64.0	2.8-3.4	145.3-189.9	23.45-26.56	4.7-5.8	11.7-12.6	37.8-39.9	43.7-44.9	32.7-35.7	2.5-3.1	4.2-5.5
	CG92 (P2)	Mean	76.75	4.23	226.87	35.14	6.28	11.78	34.23	44.5	25.9	3.4	4.85
		Range	69.0-89.0	3.8-5.4	212.0-256.3	34.5-35.78	5.5-7.3	10.9-12.4	33.7-35.6	43.7-45.1	24.9-27.6	2.9-3.8	4.3-5.3
	MBC1F6	Mean	71.52	4.67	252.27	33.12	5.8	11.7	31.13	44.06	31.34	4.1	4.5
		Range	43.0-83.0	4.1-5.2	214.6-275.7	31.23-34.56	5.1-6.9	10.7-12.9	30.9-33.5	44.2-45.3	29.7-33.2	3.5-4.7	4.3-5.2
		PCV	10.34	9.78	12.34	6.47	12.7	12.72	8.34	6.65	11.21	10.19	14.37
		GCV	9.76	8.56	12.17	6.39	11.95	12.2	8.22	6.53	11..17	9.19	12.11
		h2	79.84	67.89	89.76	98.8	94.06	95.95	98.49	98.21	89.44	90.16	70.38
		GA (%)	23.41	19.63	34.56	3.53	16.71	10.94	4.37	3.34	23.4	17.62	20.93

fibre strength, the parent P_1 recorded higher mean values.

All the derived back cross progenies showed long staple length (28.5 to 31.3), while the modified back cross progenies expressed long and extra-long 2.5 per cent staple length. All the progenies recorded high fibre strength than the parent P_2 (more than 28 g/tex).Micronaire mean values showed, the back cross progenies was coarse when compared with P_2 and modified back cross progenies was having ideal micronaire (3.5 to 4.7) value. The derived population was on par P_2 for the traits uniformity ratio and elongation per cent.

Variability : In early generation of backcross population I, high PCV, GCV were recorded in boll number, seed cotton yield and elongation ratio. While the early generations of modified back cross I and II populations, the traits namely, bolls/plant, seed cotton yield, lint index, seed index, fibre strength and uniformity ratio showed high PCV, GCV indicating greater variability and scope for improvement of the character. Similar findings were reported byRanganatha *et al.,* (2013), Rao and Gopinath (2013), Dhivya *et al.,* (2014) and Khan *et al.,* (2015).

Moderate and low PCV, GCV were recorded in ginning per cent, boll weight, lint index, seed index, 2.5 per cent span length and micronaire in early generations of back cross population I. In case of modified back cross populations low PCV, GCV were recorded for boll weight, 2.5 per cent span length, micronaire and elongation per cent. Similar results were earlier reported by Rao and Gopinath (2013), Kusugal *et al.,* (2014), Pujer *et al.,* (2014) and Khan *et al.,* (2015).

Most of the traits exhibiting high or moderate phenotypic and genotypic coefficient of variation in early generations whereas in later generations it goes down to moderate or low. In all the generations the phenotypic variation was higher than genotypic variation and showed the presence of environmental influence over the traits. It clearly indicates that the majority of characters showed narrow range of variation in later generation because of single plant selection.

Heritability and GA as per cent of mean: High heritability and high genetic advance were observed in all the traits in the advanced generations of all the three crosses. This indicates the preponderance of additive gene action in the inheritance of these traits and offers the scope for improvement through simple selection procedures. Similar results were earlier reported by Rao and Gopinath (2013), Dhivya *et al.*, (2014), Pujer *et al.*, (2014) and Khan *et al.*, (2015).

High heritability coupled with moderate or low genetic advance were observed in ginning per cent, 2.5 per cent span length and uniformity ratio indicating the role of additive and non-additive gene action in the inheritance of this trait. This can be improved through cyclic hybridization, diallel selective mating and biparental mating. The results are in agreement with the research findings of Pujer *et al.*, (2014) and Khan *et al.*, (2015).

In the present study, long staple (28.5-31.3 mm) with high fibre strength (28.9-33.1 g/tex) line with *hirsutum* background were obtained in the back cross I populations. Similarly in modified back cross I, long and extra-long staple (32.1-34.5) lines with high fibre strength (28.9-31.3) and in modified backcross II, long and extra-long staple (30.9-33.5) lines with high fibre strength (29.7-33.2) with recurrent plant background were obtained. The fibre quality parameters were assessed by SITRA and CIRCOT fibre testing labs in ICC mode and confirms the findings of the present study.

REFERENCE

Basbag S., and Gencer O., 2004. Investigations on the heritability of seed cotton yield, yield components and technological characters in cotton (*G. hirsutum* L.), *Pak. J. Biol. Sci.,* **7 :** 1390

Burton G.W., and Devane E.M., 1953. Estimating heritability in fall fescue (*Festecd cirunclindcede*) from replicated clonal material, *Agron. J.,* **45 :** 478-81

Dhivya, R., P. Amala Balu, R. Pushpa and D. Kavithamani 2014. Variability, heritability and genetic advance in upland cotton (*Gossypium hirsutum* L.). *African J. Plant Sci.* **8 :** 1-5.

Khan, F. U. Z., S. U. Rehman, M. A. Abid, W. Malik, C. M. Hanif, M. Bilal, G. Qanmber, A. Latif, J. Ashraf and U. Farhan . 2015. Exploitation of Germplasm for Plant Yield Improvement in Cotton (*Gossypium hirsutum* L.) *J Green Physiol Genet Genom* **1** : 1-10.

Kohel, R.J. 1999. Cotton germplasm resources and the potential for improved fibre production and quality.In: Cotton fibres. A.S. Basra (eds.), The Haworth press, New York. Pp167–182.

Kusugal, A., S. S. Patil, K. J. Pranesh, S. Rajeev and H. K. Reddy. 2014. Improving genetic base of Gossypium barbadense for developing potential inter specific hybrids. *Electronic J. Plant Breeding,* **5 :** 594-601

Pujer, S., S.S. Siwach, JagadeeshDeshmukh, R.S. Sangwan and O. Sangwan. 2014. Genetic variability, correlation and path analysis in upland cotton (*Gossypium hirsutum* L.). *Electronic J. Plant Breeding,* **5 :** 284-89

Ranganatha, H.M., Shreekanth, S.P., Manjula, S.M and Kumar, B.N.A. 2013. Genetic variability studies in segregating generation of upland cotton (*Gossypium hirsutum* L.). Molecular *Plant Breeding.* **4 :** 84-88.

Robinson H.E., Comstock R.E. and Harvay P.H., 1951, Genotypic and phenotypic correlations in corn and their implications in selection, *Agron. J.,* **43 :** 282-87

Rao, P.J.M and Gopinath, M. 2013. Variability and association studies for yield and yield components in upland cotton (Gossypium hirsutum L.) under chalkasoils.*Electronic J. Plant Breeding.* **4 :** 1093-96.

Singh R.K., and Chaudhary B.D., 1977, *Biometrical Methods in QuantitativeGenetic Analysis,* Kalyani Publishers New Delhi

Soregaon, C.D., R.P. Veereshgowda, I.S. Katageri and B.M. Khadi. 2007. Introgression of fibre traits of *Gossypium barbadense* L. into *Gossypium hirsutum* L. *Indian J. Genet.* **67 :** 56–61.

Ulloa, M., Hutmacher, R.B., Davis, R.M., Wright, S.D., Percy, R and Marsh, B. 2006. Breeding for Fusarium wilt race 4 resistances in cotton under field and greenhouse conditions. *Jour. Cotton Sci.* **10 :** 114-27.

Zhang, H.B., Y. Li, B. Wang and P.W. Chee. 2008. Recent Advances in Cotton Genomics. Intl. *J. Plant Genomics,* 1–20.

Genetic analysis in cotton (*Gossypium hirsutum* L.) for mechanical harvesting characters

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ABSTRACT : The present investigation on cotton (*Gossypium hirsutum* L.) was undertaken to study the genetics of plant ideotype characters and to develop superior cotton hybrids suitable for mechanical harvesting. Twenty one crosses obtained by crossing 7 × 3 genotypes in line × tester fashion and their parents were evaluated for 11 biometric traits. Based on mechanical harvesting viewpoint, the desirable features such as earliness, short and compact plant type, absence of monopodial branch, short sympodial branch, synchronous boll bursting, bigger and high weighing bolls, high single plant yield and high ginning per cent with desired fibre quality characters were considered as suitable for developing ideotypes. The lines namely L316, L186, L317, L64 and the testers namely T308, T293 showed significant *per se* performanceand *gca* effects. The hybrids *viz.*, L316 × T308, L64 × T293 and L95 × T240 recorded significant overall performance, considering the suitability for mechanical harvesting, *per se* performance and*sca* effects. These selected hybrids further need to be evaluated for their efficacy to defoliant and plant growth regulator applications.

Cotton is one of the important commercial crops and it serves as a main source of raw material to the textile industry in India. It has the distinction of having the largest area under cotton cultivation in the world with 12.2 million hectares and constituting about 25 per cent of the world area under cotton cultivation. In India almost the entire cotton is harvested through hand-picking by human labor spending about 0.9 man-hr/kg of cotton and costing almost 10 times more of irrigation and two times the weeding costs (Muthumilselvan *et al.*, 2007). India is lagging behind many other large producers of cotton in mechanization of harvesting. In USA, machines are used to harvest the entire cotton crop, whereas in some regions of China, it is predicted that by 2020, about 60 per cent of cotton will be mechanically picked (Business line, 2012). It is expected that the country will soon have to mechanize its cotton harvesting operations as it is facing labor shortages and rising farm wages.

There are various types and designs of cotton harvesting machines available in the world. In advanced countries like USA, Australia, Brazil and Russia, cotton picking is carried out mechanically by cotton pickers (most commonly used machines) and cotton strippers. These harvesters are designed to suit for the particular plant types and planting system, established in those countries. For Indian researchers, manufacturers and farmers it is a very difficult task to design and select a cotton harvester due to non-uniformity in plant stature, staggered blooming characteristics (Prasad *et al.,* 2004) and different planting systems followed in different regions of the country.

With regard to the plant stature, cotton genotypes that are presently cultivated in India have an inherent defect in the form of large bushy plant type and asynchronous boll maturity, which makes it impossible to use mechanical harvesters in cotton. In order to successfully employ cotton harvesters, high yielding varieties or hybrids with short stature, zero monopodial, less sympodial, early maturing, synchronous boll opening need to be developed and tested under high density planting system. Literature search indicates that, the research on breeding for crop ideotypes suitable for mechanical harvesting are very limited in cotton. This warrants immediate attention of researchers for the development of suitable genotypes for mechanical harvesting through ideotype breeding.

Cotton improvement programmes primarily lay emphasis on development of hybrids, which have contributed in improving the productivity of cotton (Christopher *et al.,* 2003). In heterosis breeding programme, the selection of parents or inbreds based on their morphological diversity with good combining ability is very important in producing superior hybrids. The analysis of general combining ability and specific combining ability helps in identifying potential parents or inbreds for the production of superior hybrids. The Line × Tester analysis (Kempthorne, 1957) is one of the simplest and efficient methods of evaluating large number of inbreds/parents for their combining ability. Based on the information from Line × Tester analysis development of commercially viable hybrids is possible.

MATERIALS AND METHODS

The experimental material used in the present study comprised of 10 parents (7 lines and 3 testers) and 21 (7×3) crosses along with a check. The hybrids were derived by following the line × tester mating design. The experiment was conducted at Research Farm of Rasi Seeds, which is situated at Attur, Tamil Nadu. 21 crosses with check were raised with three replications in a randomized block design (RBD) and each cross was raised in three rows of 6 m length with the spacing of 90 × 15 cm. The parents (7 lines and 3 testers) were also raised separately in the same way of the adjacent block. Recommended agronomic practices and need based plant protection measures were followed under irrigated condition to obtain good crop stand. Data were recorded for 11 biometric traits namely days to fifty per cent flowering, days to first boll bursting, plant height, plant width, height of lower most boll, sympodial branches/plant, bolls/ plant, boll weight, seed cotton yield/plant, ginning per cent and lint index.

The mean data collected from F_1s, parents and checks were subjected to statistical analysis to estimate the combining ability of parents and hybrids and heterosis of hybrids using the TNAUSTAT statistical analysis software, (Tamil Nadu Agricultural University, Coimbatore).The mean data of 21 hybrids and their parents for each quantitative character were tabulated and subjected to appropriate analysis of variance separately (Panse and Sukhatme, 1964)

RESULTS AND DISCUSSION

The range of ideotype values suitable for mechanical harvesting for the plant architecture and yield traits at the spacing suitable for high density planting are define based on the literatures search and results of the present study. Analysis of variance for plant architecture traits are presented in Table 1. Analysis of variance showed significant differences among the parental genotypes for all the 11traits studied. The crosses showed significant differences for all the 11traits. The interaction between the parents and the crosses also recorded significant differences for all characters except days to fifty per cent flowering and ginning per cent.Giri *et al.*, (2006) and Subba Reddy and Nadarajan (2006) reported significant differences

Table 1. Analysis of variance for plant architecture and yield traits

Source	DF	DFF	DBB	PH	PW	HLB	NSY	NB	BW	SCY	GP	LI
Replication	2	9.88	74.11	38.71	0.46	0.40	2.40	0.82	0.02	3.51	4.19	0.03
Genotypes	30	6.30**	15.87**	505.22**	346.51**	50.34**	5.02**	40.30**	1.06**	559.61**	23.04**	1.37**
Parents	9	3.20**	12.00*	833.11**	330.37**	46.21**	7.54**	15.39**	0.91**	771.4**	32.01**	1.92**
Lines	6	2.10	14.65*	1125.83**	339.52**	55.97**	10.49**	21.94**	0.49**	486.3**	37.65**	1.44**
Testers	2	4.00*	0.44	340.11**	46.33**	39.00**	0.78	3.44**	0.88**	383.8**	2.66	1.17**
Lines *V/s.* Testers	1	8.23**	19.21	62.86**	843.56**	2.06	3.36**	0.03	3.50**	3257.7**	56.89**	6.29**
Cross *V/s.* Parents	1	2.57	25.81*	2328.11**	1053.99**	4.55*	12.19**	502.27**	12.37**	2395.88**	0.10	6.97**
Error	60	1.14	4.94	6.92	3.70	0.90	0.32	0.38	0.02	4.97	3.05	0.06

Table 2. Analysis of variance for combining ability for plant architecture and yield traits

Source	DF	DFF	DBB	PH	PW	HLB	NSY	NB	BW	SCY	GP	LI
Replication	2	6.49	55.44	20.06	0.02	0.49	2.02	0.62	0.04	3.86	1.64	0.05
Lines	6	6.81**	9.42	591.48**	438.88**	53.98**	2.70**	35.76**	0.97**	550.01**	30.32**	0.96**
Testers	2	23.16**	13.44	44.49**	102.78**	39.73**	5.44**	20.33**	0.37**	664.48**	0.40	2.52**
L × T	12	5.86**	21.57**	141.05**	294.09**	57.19**	3.61**	26.07**	0.40**	235.00**	18.35**	0.49**
Error	40	1.11	4.24	7.18	4.07	0.76	0.35	0.45	0.02	5.86	3.15	0.07

**– Significant at 1% level, *– Significant at 5% level

among the cotton genotypes for all the yield and yield related traits.

The analyses of variance for combining ability for the plant architecture traits are presented in Table. 2. The ANOVA sowed that mean squares due to lines were highly significant for all the traits except for the days to first boll bursting. The testers showed highly significant differences for all the traits except days to first boll bursting and ginning per cent. The interaction between L × T had significant deviation for all the 11traits of the present study. Similar findings were reported by Punitha *et al.*, (2008). The relative estimates of variances due to additive and dominance components are presented in Table 3. The dominance variance was higher than the additive variance for all the 11 biometric traits. The ratio between additive and dominance variance was less than one for all the characters studied.

The mean performance of parents are presented in Table 4 and the mean performance of hybrids are presented in Table 5. Based on the mean performance the lines namely L316 and L64 and the testers namely T308 and T293were good for majority of the characters and can be considered as donor for developing mechanical picking suitable hybrids. The lines namely L64 and L317 can be considered good for plant architecture traits namely plant height, plant width, and boll height as they possess short and compact plant stature.The general combining ability (*gca*) effects of parents are presented in Table 6 and specific combining ability (*sca*) effects of hybrids are furnished in Table 7. The estimates of *gca* effects of parents revealed that the line L64 exhibited significant *gca* effect for the traits like, plant height, plant width, bolls/plant, boll weight and seed cotton yield/plant. Significant *gca* effect for days to fifty per cent flowering, lower boll height, sympodial branches, bolls/plant, boll weight and seed cotton yield/plant was noticed in the parental line L186.Among the testers, T308 recorded significant positive effect for the characters namely days to first boll bursting, plant height,

Table 3. Genetic components for plant architecture and yield traits

Source	DFF	DBB	PH	PW	HLB	NSY	NB	BW	SCY	GP	LI
ó^{2} A	0.05	0.12	3.27	0.63	0.07	0.00	0.06	0.00	3.58	0.05	0.01
ó^{2} D	1.58	5.78	44.62	96.68	18.81	1.09	8.54	0.13	76.38	5.07	0.14
ó^{2} A / ó^{2} D	0.03	0.02	0.07	0.01	0.00	0.00	0.01	0.03	0.05	0.01	0.06

Table 4. Mean performance of parents for plant architecture and yield traits

Parents	DFF	DBB	PH	PW	HLB	NSY	NB	BW	SCY	GP	LI
Lines											
L64	49.00	104.00	84.00*	56.00	25.00	16.00*	12.00	5.18	54.37	33.85	4.85
L78	51.00	105.00	98.00	63.00	28.00*	15.00*	9.00	4.93	39.79	37.49	5.54
L95	49.00	105.00	88.00*	57.00	20.00	14.00*	11.00	4.45	49.60	34.91	5.20
L129	50.00	102.00	86.00*	49.00	27.00*	12.00	14.00*	5.67*	58.67	37.91	6.08
L186	49.00	102.00	135.00	73.00	31.00*	14.00*	13.00*	5.04	73.41*	30.85	4.31
L316	49.00	99.00*	81.00*	55.00	19.00	12.00	16.00*	4.66	76.13*	40.75*	6.23
L317	49.00	100.00	80.00*	39.00*	22.00	11.00	9.00	4.66	57.41	40.08	5.84
Mean	**49.00**	**102.00**	**93.00**	**56.00**	**25.00**	**13.00**	**12.00**	**4.94**	**58.44**	**36.55**	**5.44**
Testers											
T240	51.00	105.00	104.00	43.00*	28.00*	12.00	13.00*	5.67*	86.03*	38.59	5.72
T293	51.00	104.00	101.00	49.00	26.00	13.00	11.00	6.24*	89.27*	40.84*	6.74*
T308	49.00	104.00	84.00*	41.00*	21.00	13.00	12.00	5.16	68.26	39.60	6.85*
Mean	**50.00**	**104.00**	**96.00**	**44.00**	**25.00**	**13.00**	**12.00**	**5.69**	**81.20**	**38.68**	**6.44**
Mean of parents	**50.00**	**103.00**	**95.00**	**50.00**	**25.00**	**13.00**	**12.00**	**5.32**	**69.82**	**37.61**	**5.94**
S.E (d)	0.62	1.28	1.52	1.11	0.55	0.33	0.36	0.08	1.29	1.01	0.14
CD (p=0.05)	1.72	3.60	4.25	3.11	1.53	0.91	1.00	0.23	3.60	2.82	0.40

* Significant at 5% level

sympodial branches, bolls/plant and seed cotton yield/plant. Similarly, the tester T293 recorded high *gca* effect for days to first boll bursting, plant width, boll weight and seed cotton yield. On overall consideration based on the *gca* effect and high mean values, the lines namely L316, L186, L317 and L64 while the testers namely T308 and T293 were considered as good general combiners and could be desirable parental source for developing suitable hybrids for mechanical harvesting

Plant stature is an important attribute for mechanical harvesting followed by yield and fibre quality traits. The characters taken for the present investigationwere considered as important to determine the suitability of the hybrids for mechanical harvesting (Veerangouda *et al.,* 2012). The hybrids synthesized in the present study were compared against the ideotype range for plant architecture traits and the promising hybrids are selected.The hybrids L317 × T240 falls within the ideotype range for eight characters followed by L316 × T308, L64 × T293 and L64 × T308 for seven characters. The four hybrids L64 × T240, L95 × T240, L95 × T293 and L186 × T240 had six characters in the mechanical picking ideotype range. The hybrid L129 × T293 had only three characters in the ideotype range which indicates unsuitability of this hybrid for mechanical harvesting.

The hybrid L64 × T293 had significant *per se* performance for the traits *viz.,* plant height, plant width, bolls/plant, boll weight, seed cotton yield/plant and lint index. The cross L316 × T308 exhibited significant *per se* performance for traits

Table 5. Mean performance of hybrids for plant architecture and yield traits

Gross	DFF	DBB	PH	PW	HLB	NSY	NB	BW	SCY	GP	LI
L64 × T240	49.00	100.00*	106.00	48.00*	19.00	13.00	14.00	6.23*	74.09	34.69	6.05
L64 × T293	49.00	105.00	98.00*	43.00*	23.00	14.00	22.00*	6.68*	90.67*	37.06	7.08*
L64 × T308	51.00	105.00	95.00*	49.00*	23.00	14.00	17.00	6.11	82.31*	38.62	6.08
L78 × T240	50.00	106.00	117.00	76.00	22.00	15.00*	15.00	5.95	69.14	36.67	6.29
L78 × T293	54.00	106.00	108.00	62.00	27.00*	13.00	13.00	6.13	70.74	38.24	7.25*
L78 × T308	49.00	105.00	98.00*	39.00*	22.00	14.00	14.00	5.35	61.93	34.75	6.14
L95 × T240	50.00	109.00	91.00*	56.00*	28.00*	12.00	14.00	5.72	64.59	38.70	6.24
L95 × T293	51.00	107.00	94.00*	48.00*	24.00	13.00	14.00	5.78	76.00	40.41*	7.25*
L95 × T308	49.00	100.00*	106.00	73.00	19.00	14.00	19.00*	6.24*	88.44*	40.45*	6.61
L129 × T240	50.00	102.00	108.00	64.00	27.00*	13.00	14.00	6.17	67.38	40.06	5.93
L129 × T293	52.00	106.00	121.00	68.00	22.00	15.00*	17.00	6.06	80.45*	38.43	6.66
L129 × T308	53.00	103.00	111.00	72.00	29.00*	14.00	17.00	6.35*	78.24	34.29	6.10
L186 × T240	48.00*	99.00*	113.00	68.00	28.00*	15.00*	23.00*	6.22*	95.08*	35.63	6.05
L186 × T293	50.00	104.00	121.00	61.00	23.00	15.00*	17.00	5.83	91.40*	36.18	6.08
L186 × T308	49.00	105.00	120.00	66.00	34.00*	15.00*	19.00*	6.46*	83.37*	31.62	5.62
L316 × T240	49.00	107.00	100.00*	66.00	27.00*	12.00	17.00	5.03	60.48	39.02	6.13
L316 × T293	50.00	102.00	107.00	64.00	21.00	15.00*	17.00	5.27	65.91	37.70	6.34
L316 × T308	50.00	102.00	94.00*	61.00	16.00	14.00	21.00*	5.76	84.09*	41.75*	7.26*
L317 × T240	48.00*	102.00	100.00*	51.00*	28.00*	14.00	19.00*	5.23	58.60	36.85	5.26
L317 × T293	52.00	104.00	97.00*	52.00*	23.00	12.00	12.00	6.35*	67.96	35.49	6.13
L317 × T308	49.00	104.00	100.00*	66.00	19.00	15.00*	19.00*	5.95	87.69*	41.39*	6.23
Grand mean	**50.00**	**104.00**	**105.00**	**60.00**	**24.00**	**14.00**	**17.00**	**5.95**	**76.12**	**37.52**	**6.32**
S.E (d)	0.62	1.28	1.52	1.11	0.55	0.33	0.36	0.08	1.29	1.01	0.14
CD (P=0.05)	1.72	3.60	4.25	3.11	1.53	0.91	1.00	0.23	3.60	2.82	0.40

* Significant at 5% level

Table 6. General combining ability effects of parents for plant architecture and yield traits

Parents	DFF	DBB	PH	PW	HLB	NSY	NB	BW	SCY	GP	LI
Lines											
L64	-0.44 ns	-0.57 ns	-5.49 **	-12.86 **	-2.24 **	-0.29 ns	0.98 **	0.39 **	6.23 **	-0.73 ns	0.08 ns
L78	0.78 *	1.43 *	2.84 **	-0.75 ns	-0.35 ns	0.27 ns	-3.13 **	-0.14 **	-8.85 **	-0.97 ns	0.24 **
L95	-0.11 ns	1.32 ns	-8.16 **	-0.75 ns	-0.46 ns	-0.84 **	-1.35 **	-0.03 ns	0.22 ns	2.33 **	0.38 **
L129	1.56 **	-0.13 ns	8.06 **	8.37 **	1.87 **	0.16 ns	-0.79 **	0.24 **	-0.77 ns	0.07 ns	-0.09 ns
L186	-1.00 **	-1.35 ns	13.06 **	5.14 **	4.43 **	0.94 **	2.87 **	0.23 **	13.83 **	-3.05 **	-0.41 **
L316	-0.33 ns	-0.13 ns	-4.60 **	4.25 **	-2.68 **	-0.17 ns	1.54 **	-0.59 **	-5.96 **	1.97 **	0.25 **
L317	-0.44 ns	-0.57 ns	-5.71 **	-3.41 **	-0.57 ns	-0.06 ns	-0.13 ns	-0.10 *	-4.70 **	0.39 ns	-0.45 **
SE	0.35	0.69	0.89	0.67	0.29	0.20	0.22	0.05	0.81	0.59	0.09
Testers											
T240	-0.89 **	-0.17 ns	0.11 ns	1.51 **	1.59 **	-0.56 **	-0.29 ns	-0.15 **	-6.21 **	-0.15 ns	-0.33 **
T293	1.16 **	0.87 ns	1.40 *	-2.54 **	-0.84 **	0.11 ns	-0.81 **	0.07 *	1.47 **	0.12 ns	0.36 **
T308	-0.27 ns	-0.70 ns	-1.51 *	1.03 *	-0.75 **	0.44 **	1.10 **	0.08 **	4.75 **	0.03 ns	-0.03 ns
SE	0.23	0.45	0.58	0.44	0.19	0.13	0.15	0.03	0.53	0.39	0.06

**– Significant at 1% level, *– Significant at 5% level, ns – Non Significant like plant height, bolls/plant, seed cotton yield, ginning per cent and lint index. Hence, the aforesaid hybrids are suitable for mechanical harvesting as they performed well for maximum number of plant architecture and yield traits. Based on *sca* effects, the hybrid L316 × T308 had significant *sca* effects for plant height, plant width, bolls/plant, boll weight, seed cotton yield/ plant, ginning percent and lint index. The hybrid L64 × T293 recorded significant *sca* effects for days to fifty per cent flowering, plant height, bolls, boll weight, seed cotton yield and lint index, while L78 × T240 exhibited significantly positive effects for four traits namely sympodial branches, bolls/plant, boll weight and seed cotton yield/ plant.

Hence, the hybrids *viz.*, L316 × T308, L64 × T293and L95 × T240 were considered as good specific combiners and could be used for heterosis breeding programme to develop hybrids for mechanical harvesting. Since cotton is an often cross pollinating crop, varietal crosses can be easy by hand emasculation. Hence, these hybrids could be utilized in heterosis breeding programme. The hybrid L64 × T308 could be recommended for recombination breeding as its parents showed significant *gca* effects and the hybrid recorded, non significant *sca* effects traits namely plant height, bolls/plant, boll weight and seed cotton yield

Table 7. Specific combining ability effects of hybrids for plant architecture and yield traits

Cross	DFF	DBB	PH	PW	HLB	NSY	NB	BW	SCY	GP	LI
L64 × T240	0.11 ns	-2.05 ns	6.11 **	-0.62 ns	-4.14 **	-0.33 ns	-3.27 **	0.04 ns	-2.05 ns	-1.95 ns	-0.02 ns
L64 × T293	-1.94 **	0.24 ns	-3.17 *	-0.90 ns	1.95 **	0.33 ns	5.25 **	0.27 **	6.85 **	0.15 ns	0.32 *
L64 × T308	1.83 **	1.81 ns	-2.94 ns	1.52 ns	2.19 **	0.00 ns	-1.98 **	-0.32 **	-4.80 **	1.80 ns	-0.29 ns
L78 × T240	0.22 ns	0.62 ns	9.44 **	15.60 **	-3.03 **	1.44 **	1.17 **	0.29 **	8.08 **	0.27 ns	0.06 ns
L78 × T293	1.84 **	-0.43 ns	-1.17 ns	5.65 **	4.06 **	-0.89 *	0.03 ns	0.25 **	2.00 ns	1.56 ns	0.33 *
L78 × T308	-2.06 **	-0.19 ns	-8.27 **	-21.25 **	-1.03 *	-0.56 ns	-1.21 **	-0.55 **	-10.09 **	-1.83 ns	-0.39 *
L95 × T240	1.11 ns	3.73 **	-6.22 **	-4.73 **	3.08 **	-0.78 *	-1.60 **	-0.04 ns	-5.54 **	-1.01 ns	-0.13 ns
L95 × T293	0.06 ns	0.68 ns	-4.51 **	-8.02 **	0.84 ns	0.22 ns	-0.75 ns	-0.20 *	-1.81 ns	0.44 ns	0.19 ns
L95 × T308	-1.17 ns	-4.41 **	10.73 **	12.75 **	-3.92 **	0.56 ns	2.35 **	0.24 **	7.35 **	0.57 ns	-0.06 ns
L129 × T240	-0.56 ns	-1.49 ns	-5.44 **	-5.51 **	-0.92 ns	-0.78 *	-1.49 **	0.13 ns	-1.77 ns	2.62 *	0.03 ns
L129 × T293	-0.60 ns	1.46 ns	6.27 **	2.87 *	-3.16 **	0.89 *	1.70 **	-0.20 *	3.63 *	0.72 ns	0.07 ns
L129 × T308	1.16 ns	0.03 ns	-0.83 ns	2.63 *	4.08 **	-0.11 ns	-0.21 ns	0.07 ns	-1.86 ns	-3.33 **	-0.10 ns
L186 × T240	0.00 ns	-3.27 **	-4.78 **	1.38 ns	-1.81 **	0.44 ns	3.51 **	0.20 *	11.35 **	1.30 ns	0.46 **
L186 × T293	-0.05 ns	0.68 ns	1.27 ns	-1.24 ns	-4.71 **	0.11 ns	-1.97 **	-0.41 **	-0.02 ns	1.58 ns	-0.20 ns
L186 × T308	0.05 ns	2.59 *	3.51 *	-0.14 ns	6.52 **	-0.56 ns	-1.54 **	0.20 *	-11.33 **	-2.89 **	-0.26 ns
L316 × T240	0.00 ns	3.51 **	-0.11 ns	0.94 ns	3.63 **	-1.11 **	-1.16 **	-0.17 *	-3.47 *	-0.32 ns	-0.12 ns
L316 × T293	-0.71 ns	-2.54 *	4.94 **	2.98 *	0.73 ns	1.22 **	-0.63 ns	-0.15 ns	-5.72 **	-1.91 ns	-0.60 **
L316 × T308	0.71 ns	-0.97 ns	-4.83 **	-3.92 **	-4.37 **	-0.11 ns	1.79 **	0.32 **	9.19 **	2.23 *	0.72 **
L317 × T240	-0.89 ns	-1.05 ns	1.00 ns	-7.06 **	3.19 **	1.11 **	2.84 **	-0.46 **	-6.60 **	-0.91 ns	-0.28 ns
L317 × T293	1.40 *	-0.10 ns	-3.62 *	-1.35 ns	0.29 ns	-1.89 **	-3.63 **	0.44 **	-4.92 **	-2.54 *	-0.11 ns
L317 × T308	-0.51 ns	1.14 ns	2.62 ns	8.41 **	-3.48 **	0.78 *	0.79 *	0.02 ns	11.53 **	3.45 **	0.39 *
SE	0.61	1.19	1.55	1.64	0.50	0.34	0.39	0.08	1.40	1.03	0.15

**– Significant at 1% level, *– Significant at 5% level, ns – Non Significant DFF– Days to fifty per cent floweringDBB– Days to first boll burstingPH– Plant heightPW– Plant width HLB– Height of lower most boll NSY– Number of sympodial branches per plantNB– Number of bolls per plantBW– Boll weightSCY– Seed cotton yield per plant GP– Ginning per centLI– Lint index

REFERENCES

Business Line, India Faces Uphill Task in Mechanizing Cotton Farming, Dec. 13, 2012.

Christopher. L., Cheatham, J. N., Jenkins, Jack, C., Mc Carty, J. Clarence, E. Waston and J. Wu. 2003. Genetic variance and combining ability of crosses of American cultivars, Australian cultivars and wild cottons. *J. Cotton Sci.,* **7 :** 16-2

Giri, R.K., K.S. Nirania, Y. Dutt, R.S. Sangwan and P.P. Jain 2006. Heterosis for seed cotton yield and its contributing traits in upland cotton (*Gossypium hirsutum* L.). *J. Cotton Res. Dev.,* **20 :** 39–47

Kempthorne, O. 1957. *An Introduction to Genetic Sstatistics.* John Wiley and Sons, Inc. New York.

Muthumilselvan, M., Rangaswamy, K., Ananthakrishnan, D. and Manian, R. 2007. Mechanical Picking of Cotton. *Agricultural Review,* **28 :** 118-26.

Panse, V.G. and P.V. Sukhatme. 1964. *Statistical Methods for Agricultural Workers,* 2ndEdn., ICAR, New Delhi. p361.

Prasad, J., TarunKapur, Sandhar, N. S., Majumdar, G., Patil, P. G., Shukla, S. K., Jaiswal, B. N. and Patil, A. B., 2004. Test code and procedure for spindle type cotton picker. NATP, CIAE, Bhopal

Punitha, D., T.S. Raveendran and P. Vindhiyavarman. 2008. Combining ability studies in hybrid cotton(*Gossypium hirsutum* L.). *Intl. J. Plant Sci.,* **3 :** 40–45.

Subba Reddy, B. and N. Nadarajan. 2006. Combining ability analysis for yield and other economic traits in white × colour linted crosses of *Gossypium hirsutum* cotton. *J. Cotton Res. Dev.,* **20 :** 25–31.

Veerangouda, M., Asokan, D., and Guruswamy, T. 2012. Comparative evaluation of biometric parameters of cotton at kapas picking stage. *Karnataka J. Agric. Sci.,* **25 :** 363-66

CROP PRODUCTION, MECHANIZATION AND ECONOMIC DEVELOPMENT

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Performance of American cotton genotypes in relation to different spacing and fertilizer levels in south western regions of Punjab

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ABSTRACT : Cotton is an important commercial fibre crop of south western region of Punjab. The regional specific optimization of crop geometry and fertilizer doses for a particular genotype is necessary for maximum yield potential in cotton. A field experiment was conducted at PAU, Regional Research Station, Bathinda during *kharif* 2014 to study the effect of crop spacing and fertilizer doses on performance of cotton genotypes. The experiment consisted of three genotypes (LH 2256, F 2276 and LH 2108), three spacings (67.5 × 45cm, 67.5 × 60 cm and 67.5 × 75) and three fertilizer levels (75, 100 and 125 per cent RDF) were evaluated in split plot design with three replications. The genotypes LH 2256 and F 2276 were *at par* to each other and gave significantly higher seed cotton yield over check LH 2108. Significant higher bolls/plant and boll weight in genotypes (LH 2256 and F 2276) over check (LH 2108) led to produce significantly more seed cotton yield. Among the plant spacing treatments, seed cotton yield was significantly higher under 67.5 × 45 cm and 67.5 × 60 cm than 67.5 × 75 cm. Recommended dose of fertilizers (RDF) produce significantly higher bolls/plant and boll weight than at 75 per cent of RDF led to significantly higher seed cotton yield under RDF than 75 per cent of RDF. Seed cotton yield under RDF was *at par* with yield under 125 per cent of RDF. Thus, thegenotypes LH 2256 and F 2276 can be grown under 67.5 × 60 cm and recommended dose of fertilizers for getting higher seed cotton yield.

Cotton, also called as “White Gold”, is premier cash crop of most the countries with an enormous potential in sustaining employment generation (both in rural and urban sector). Cotton is one of the most important fibre crops of India and plays a dominant role in Indian farming and industrial economy. There is great scope to exploit yield potential of the cotton crop. The *Bt* cotton technology has been widely accepted by the Indian farmers due to its inbuilt technology of bollworm management. The higher prices of *Bt* cotton seed and the additional amount incurred on control of sucking pests, has increased the production cost. Thus, to overcome this situation, development of location specific package of practices to augment productivity of varieties is of prime importance. Efficient use of improved genotypes, precise nutrient management and adoption of optimum plant density are some of the agronomic measures, that needs to be tested for realizing the cost effective production in an area.

It is well established fact that adequate quantities of nutrients are needed for achieving high yields. The nutrient management in cotton is complex phenomenon due to simultaneous production of vegetative and reproductive structures during the active growth phase. Cotton plant being heavy feeder needs good supply of nutrients especially in deficient soils.

Hence, adequate supply of fertilizers is essential to sustain a high yield which was reflected in many research investigation carried out by previous scientists (Raut *et al.*, 2005 and Katore *et al.*, 2008). In cotton growing areas, imbalanced fertilization of cotton crop also affects the vegetative and reproductive growth, thereby causing low productivity. Balanced fertilization is one of the major key factors for enhancing the cotton yields.

Plant population is one of the most important factors for efficient utilization of available sources. There must be optimization of plant population for increase in production. The determination of optimum plant spacing with fertilizer dose is necessary for maximum utilization of various resources like light, soil moisture and CO_2 to augment crop yield. Keeping these points in view, the present studies were under taken to investigate the response of different cotton genotypes to different fertilizer levels at different crop spacing.

MATERIALS AND METHODS

The field experiment was conducted at PAU, Regional Research Station, Bathinda during *kharif* 2014. Soil of the experimental field was loamy sand with pH 8.5, low in OC (0.30%), low in available nitrogen, medium in available phosphorus and higher potassium. The experiment was conducted in split plot design having a total of 27 treatment combinations with 3 replications. Main plots consisted of three genotypes (LH 2256, F 2276 and LH 2108), sub plots consisted of three spacing (67.5 × 45cm, 67.5 × 60 cm and 67.5 × 75) and sub-sub plots consisted of three fertilizer levels (75 % RDF, 100 % RDF and 125 % RDF). Phosphorus was applied as basal dose through DAP. Nitrogen was applied through urea as per treatment in two equal splits *i.e.* first half at the time of thinning and second half at flowering stage of crop. The cultural practices and plant protection measures were given as per the recommendations of Punjab Agricultural University, Ludhiana.

RESULTS AND DISCUSSION

The results presented in Table 1 shows that sympods/plant were significantly higher in LH2256 as compared to LH 2108 and F 2276 which were *at par* to each other whereas number of monopods/plant were non-significant among the genotypes. LH 2256 and F 2276 produce significant higher bolls/plant and boll weight over check (LH 2108) led to produce significantly more seed cotton yield. The genotypes LH 2256 and F 2276 were *at par* to each other and gave significantly higher seed cotton yield by margin of 18.1 and 14.6 per cent over check LH 2108. The probable reason for this might be the higher values in respect of yield attributes that has contributed in achieving the maximum seed cotton yield by the respective genotype. These results are in closer conformity with the findings of Sisodia and Khamparia (2007).

Among the plant spacing treatments, monopods/plant were found to be maximum at a spacing of 67.5 × 75 *at par* with spacing of 67.5 × 60 but significantly higher that at 67.5 × 45 whereas the sympods/plant were increase significantly with each increase in spacing. Also, the bolls/plant was found to be significantly different for all the three spacing with a greater number of bolls in a wider spacing. The boll

Table 1. Seed cotton yield and yield parameters as influenced by genotypes, spacing and fertilizer doses in American cotton

Treatment	Plant height (cm)	Monopods/ plant	Sympods/ plant	Bolls/ plant	Boll weight (g)	Seed cotton yield (q/ha)
Varieties						
LH 2256	138.3	3.28	31.3	45.5	3.61	23.98
F 2276	140.7	3.16	29.6	45.0	3.39	23.27
LH 2108	136.2	3.26	29.1	40.5	3.02	20.30
CD (p=0.05)	NS	NS	1.0	2.9	0.26	1.94
CV	11.3	14.7	4.4	8.7	10.21	11.4
Spacing (cm)						
67.5 × 45	141.3	3.01	26.7	37.8	3.20	23.96
67.5 × 60	135.7	3.26	30.2	45.1	3.33	23.40
67.5 × 75	138.2	3.44	33.0	48.0	3.49	20.20
CD (p=0.05)	NS	0.23	1.6	2.7	NS	0.98
CV	7.1	11.9	9.2	10.3	13.54	7.36
Fertilizer levels						
RDF	138.0	3.28	30.0	44.8	3.58	23.05
75% RDF	135.7	3.19	29.8	41.8	3.17	21.37
125% RDF	141.5	3.23	30.2	44.4	3.27	23.14
CD (p=0.05)	4.1	NS	NS	2.2	0.24	1.06
CV	5.4	14.5	11.8	9.2	13.23	8.53

weight was found to be the highest in wider spacing of 67.5 × 75 but there was no significant difference between the boll weight in three different spacing. The seed cotton yield was found to be the highest in narrow spaced plants (67.5 × 45) and it was *at par* with the yield at the spacing of 67.5 × 60 but significantly higher than that of wider spacing of 67.5 × 75. The yield and other yield attributing parameters of cotton vary with the plant densities (Kaur *et al.*, 2010).

The plant height (cm) was found to be more at a fertilizer level of 125 per cent RDF which was *at par* with the plant height at RDF. Recommended dose of fertilizers (RDF) produce significantly higher bolls/plant and boll weight than at 75 per cent of RDF led to significantly higher seed cotton yield under RDF than 75 per cent of RDF. Increased level of fertilizer increased the boll numbers and boll weight, which ultimately helped in increasing the seed cotton yield. Similar results were reported by Sunitha *et al.*, (2010). As boll weight was significant higher in RDF than 125 per cent RDF and number of bolls were *at par* among the RDF and 125% RDF led to statistically similar seed cotton yield under RDF and under 125 per cent RDF. Seed cotton yield under RDF and 125 per cent RDF was significantly higher by the margin of 7.9 and 8.3 per cent over the yield under 75 per cent RDF. The genotypes LH 2256 and F 2276 can be grown under 67.5 × 45 cm and 67.5 × 60 cm and recommended dose of fertilizers and 125 per cent of recommended dose of fertilizers for getting higher seed cotton yield.

REFERENCES

Katore, J. R., Wankhade S. T., Ingole P. G., Kubde K. J. and Tiwari, V. A. 2008. Quality and yield of *hirsutum* cotton hybrid as influenced by spacing and fertilizer level. *Crop. Prot. Prod.,* **4** : 39-42.

Kaur Parminder, Kaur Maninder, Gill M.S. and Buttar G. S. 2010. Response of *Bt* cotton hybrid RCH 134 to varied spacing and fertility levels under Punjab conditions. *J. Cotton Res. Dev.,* **24**: 189-92.

Raut, R.S., Thokale, J. G. and Mehetre, S. S. 2005. Effect of fertilizer and spacing on inter specific hybrid Phule 388 under summer irrigated condition. *J. Cotton. Res. Dev.,* **19** : 200-201.

Sisodia, R. I. and Khamparia, S. K. 2007. American cotton varieties as influenced by plant densities and fertility levels under rainfed conditions. *J. Cotton Res. Dev.* **21:** 35-40.

Sunitha, V., Chandrasekher, K. and Veeraraghavaiah, R. 2010. Performance of Btcotton hybrids at different nitrogen levels. *J. Cotton Res. Dev.* **24 :** 52-55.

Productivity and profitability of BG II cotton hybrids as influenced by different planting geometry and nitrogen levels under rainfed condition in vertisols of Andhra Pradesh

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ABSTRACT : A field experiment was conducted during *kharif,* 2011 at Regional Agricultural Research Station, Nandyal, Andhra Pradesh, India for optimization of nutrient requirement and plant geometry for ruling BG II cotton hybrids of this region under rainfed condition in vertisols. Higher monopodia/plant(1.34), kapas yield (2026 kg/ha), oil percentage (18.32), net returns (‘47,592 /ha) and benefit cost ratio (BCR) of 2.27 were observed under closer spacing (90 x 45 cm). The number of bolls/plant (27.74), *kapas* yield (1983 kg/ha), net returns (‘48,286/ha) and BCR of 2.38 was observed with Bunny BG II hybrid and was *on par* with Mallika BG II (25.34, 1969 kg/ha, ‘47,656 /ha and 2.36, respectively). Higher boll weight (4.82 g) was observed in Mallika BG II. *Kapas* yield (1863 kg/ha), net returns (‘42,446 /ha) and BCR of 2.18 was significantly higher with the application of 180 N kg/ha.

Key words : BG II cotton hybrid, nitrogen level, plant geometry, rainfed, vertisols

Cotton is said to be “King of Fibres”. In fact it is true because cotton has a great importance in global economy. Cotton is grown in about 80 countries but only five countries viz., China, India, USA, Pakistan and Brazil accounted for about 81 per cent of the global area and provided 75 per cent of the world’s cotton in 2009-2010. During 2007-2008, these countries together produced 30.2 million tonnes (m t) of lint. In 2013-2014, the global area and production of cotton were 33.1 million ha and 117 million bales respectively with a productivity of 766 kg lint /ha whereas cotton in India was cultivated in 126.5 lakh ha with production of 400 lakh bales with a productivity of 537 kg lint / ha.Transgenic cotton was introduced for commercial cultivation in 1996 in the USA, Australia, China, Mexico and Argentina (James, 2006). The global adoption of transgenic cotton has risen dramatically from 0.8 (1996) to 15.5 m ha in (2008). In India cotton is produced in 117.27 lakh ha with production of 390 lakh bales and productivity of 565.36 kg/ha during 2013-2014. In India around 85 per cent of the cotton area is under *Bt* hybrids. Agronomic performance of *Bt* cultivars may vary substantially from their non *Bt* counterparts (Jenkins *et al.,* 1997). Today, biotech cotton confers improved pest (bollworm) management and retention of early formed fruiting parts leading to higher and earlier boll load. The plants are also early in maturity. In India, *Bt* hybrids had short stature along with inbuilt resistance to bollworm leads to retention of early formed fruiting parts and promotes earliness by 20-30 days (Mayee *et al.,* 2004). The plant had shallower roots and produced less dry matter and also retain more bolls particularly the early formed ones at lower nodes. Higher sink in *Bt* cotton leads to lower source to sink ratio, faster senescence and crop maturity compared to the non *Bt* version (Hebbar *et al.,* 2007). Early fruit load, coupled with faster fruit load could constrain nutrient supply leading to smaller plants and may lower the yield potential (ICAC, 2010). To overcome these potential problems changes in agronomic practices are needed for achieving maximum benefits from the technology. Spacing is an important factor which influenced the yield as well as plant stand. There is a positive relationship between optimum plant population and yield (Rao, 1985). The productivity of cotton can be obtained with suitable agronomic practices like maintenance of optimum plant density and use of optimum dose of fertilizer. Hence, keeping this in view, the present study was carried out to find out the suitable plant geometry and nitrogen level in popularly grown BG II cotton hybrids.

A field study was carried out during *kharif* 2011 at the research farm of Regional Agriculture Research Station, Nandyal, Kurnool District, Andhra Pradesh. The soil was deep black with pH 8.51, low in available nitrogen (138 kg/ha), high in available phosphorous (43 kg/ha) and potassium (408 kg/ha). A total of 589.9 mm rainfall was received in 35 rainy days during the crop period. The experiment was laid out in split split plot design with plant geometry as main plots, BG II hybrids as sub plots and nitrogen levels as sub sub plots and replicated thrice. The main plot treatments consist of two plant geometries *viz.,* 120 x 60 (normal spacing of locality) and 90 x 45 cm (higher density). The sub plot treatments consist of three BG II hybrids *viz.,* Bunny, Rasi and Mallika. Three nitrogen levels 120, 150 and 180 kg/ha were allocated in sub sub plots. Sowing was done on 07.08.2011 by dibbling method. Entire phosphorous (60 kg/ha) as single super phosphate and potassium (60 kg/ha) as murate of potash were applied as basal. Nitrogen as urea was applied in four splits at basal, 30, 60 and 90 days after sowing. All other recommended package of practices was followed during the crop season. Plant protection measures were taken up as per requirement especially for sucking pests during the crop growth. Data pertaining to yield attributing characters like plant height, monopodia, sympodia, bolls/plant and boll weight were recorded from randomly selected five plants in each treatment and seed cotton yield was recorded from the net plot. Fiber characters like strength, fineness, uniformity and elongation of each treatment were measured using spinlab high volume instrument (HVI-900). The data was statistically analyzed by standard procedure of Panse and Sukhatme (1967).

Effect of plant geometry: There was no significant effect of plant geometry on sympodia and bolls/plant, ginning percentage, lint index and seed index (Table 1). Higher plant height (79.16 cm), monopodia/plant (1.34), *kapas* yield (2026 kg/ha), oil percentage (18.32) were observed under 90 x 45 cm. Similar differences in plant height due to plant geometries were reported by Bhalerao *et al.,* (2008). A closer geometry (90 x 45 cm) recorded 33.64 per cent higher seed cotton yield (2026 kg/ha) as compared to wider geometry of 120 x 60 cm (1516 kg/ha). Higher seed cotton yield under closer geometry was observed due to significantly higher plant population (Table 1). Similar effect of higher plant density has also been reported by Giri and Gore (2006) and Buttar *et al.,* (2010). Plant geometry did not significantly influence quality characters *viz.,* staple length, uniformity ratio, micronaire, strength. Net returns (‘47,592 /ha) and BCR of 2.27 were observed under closer spacing (90 x 45 cm) (Table 2).

Effect of BG II hybrids: Higher plant

Table 1: Yield parameters and yield of cotton hybrids as influenced by plant geometry and nitrogen levels

Treatment	Plant stand/ha	Plant height (cm)	Mono-podia/ plant	Symp-odia/ plant	Bolls/ plant	Boll weight (g)	*Kapas* yield (kg/ha)	Gin-ning (%)	Lint index	Seed index	Oil (%)
Plant geometry (cm)											
120 × 60	13181	74.94	1.23	14.48	26.81	3.82	1516	32.63	5.14	10.70	17.98
90 × 45	23700	79.16	1.34	14.08	24.50	4.32	2026	33.33	5.55	11.25	18.32
S.Em±	270	0.30	0.015	0.51	1.68	0.08	16	0.20	0.13	0.25	-
C.D. (p=0.05)	1643	1.87	0.095	NS	NS	0.50	97	NS	NS	NS	-
BG II hybrids											
Bunny	18346	80.18	0.96	15.07	27.74	4.14	1983	32.89	5.16	11.16	19.28
Rasi	18388	72.17	2.01	12.9	23.88	3.25	1361	33.00	4.50	9.33	16.66
Mallika	18587	78.81	0.90	14.87	25.34	4.82	1969	33.06	6.38	12.44	18.51
S.Em±	239	1.99	0.08	0.72	0.82	0.14	121	0.29	0.18	0.27	-
C.D. (p=0.05)	NS	6.94	0.26	NS	2.69	0.46	393	NS	0.60	0.90	-
Nitrogen levels (kg/ha)											
120	18300	75.37	1.23	14.24	24.90	4.06	1701	32.94	5.72	11.83	18.20
150	18465	77.15	1.34	14.33	25.11	4.08	1750	33.50	4.94	10.11	18.20
180	18556	78.63	1.30	14.27	26.96	4.06	1863	32.50	5.38	11.00	18.03
S.Em±	219	1.01	0.79	0.41	0.69	0.08	55	0.21	0.24	0.41	-
C.D. (p=0.05)	NS	2.96	NS	NS	2.02	NS	161	0.61	0.72	1.21	-
CV (%)	5.04	5.59	25.91	12.2	13.14	9.09	13.21	2.72	19.61	16.13	-

height (80.18cm) was observed in Bunny and is on par with Mallika (78.81cm). Significantly higher monopodia/plant was observed in Rasi (2.01).The sympodia/plant was not significantly influenced by BG II hybrids. The bolls/plant were significantly more with Bunny (27.74) hybrid and was on par with Mallika (25.34). Higher boll weight(4.82) was observed in Mallika. Kapas yield was significantly more with the Bunny (1983 Kg /ha) and is *on par* with Mallika (1969 Kg /ha) which was 45.7 per cent higher than mallika (1361 Kg /ha), primarily owing to significantly improved number of sympodia, bolls/plant and boll weight. Sisodia and Khamparia (2007) also recorded significantly higher cotton yield due to more number of sympodia and bolls/plant. The ginning percentage was not significantly influenced by BG II hybrids. Higher lint index (6.38) and seed index (12.44) was observed in Mallika. Higher oil per cent (19.28) was observed in Bunny. Among the hybrids, Bunny recorded higher staple length (31.58) and higher micronaire (3.71). Mallika recorded higher strength (24.63) and uniformity ratio (51.54). Optimum source indices at the desired growth and reproductive phases resulted in better sink development, which ultimately reflect in higher production efficiency of improved genotypes. Net returns (‘48,286 /ha) and BCR of 2.38 was observed with Bunny BG II hybrid.

Effect of nitrogen levels: Taller plants (78.63 cm) were observed with the application of 180 kg N /ha. The monopodia/plant, sympodia/plant and boll weight were not significantly influenced by different fertilizer levels. Kapas yield (1863 Kg /ha) was significantly more with the application of 180 kg N /ha and is *on par*

Table 2. Quality parameters and economics as influenced by plant geometry and nitrogen levels

Treatment	Staple length (mm)	Strength (g/tex)	Uniform ratio (%)	Micro-naire value	Gross returns (/ha)	Cost of cultivation (/ha)	Net returns (/ha)	BC ratio
Plant geometry (cm)								
120 × 60	29.99	23.03	50.99	3.56	63672	35000	28672	1.82
90 × 45	30.07	22.42	50.75	3.55	85092	37500	47592	2.27
S.Em±	0.09	0.28	0.60	0.08	-	-	-	-
C.D. (p=0.05)	NS	NS	NS	NS	-	-	-	-
BG-II hybrids								
Bunny	31.58	22.77	49.87	3.71	83286	35000	48286	2.38
Rasi	27.81	20.77	51.19	3.41	57162	35000	22162	1.63
Mallika	30.71	24.63	51.54	3.54	82656	35000	47656	2.36
S.Em±	0.26	0.17	0.24	0.08	-	-	-	-
C.D. (p=0.05)	0.87	0.56	0.80	0.27	-	-	-	-
Nitrogen levels (kg/ha)								
120	29.85	22.95	50.83	3.57	71442	35000	36442	2.04
150	29.76	22.62	51.01	3.59	73500	35400	38100	2.07
180	30.48	22.60	50.77	3.50	78246	35800	42446	2.18
S.Em±	0.11	0.17	0.36	0.06	-	-	-	-
C.D. (P=0.05)	0.33	NS	NS	NS	-	-	-	-
CV (%)	3.78	3.29	3.00	7.54	-	-	-	-

Cotton - ‘ 5000/q; Urea - ‘ 5.5/kg

with 150 kg N /ha (1750 Kg /ha). The increase in yield may be attributed to favourable effect of nitrogen application on yield attributing characters i.e. plant height(78.63 cm) and bolls/ plant(26.96). Similar positive response was observed by Palomo *et al.,* (2003), Prasad and Siddique (2004), Meena *et al.,* (2007) and Singh and Gill (2007). It may be due to increased availability of nutrients which helped the plant to attain its maximum yield potential. The above findings are in accordance with the results reported earlier by Khamparia *et al.* (2009).The ginning percentage (33.5) was observed higher under 150 kg N /ha. Higher seed index (5.72) and lint index (11.83) was observed with the application of 120 kg N /ha. Application of 180 kg N /ha reported higher staple length (30.48). The other quality characters like micronaire, strength and elongation ratio were unaffected by fertilizer levels. Net returns ('42,446 /ha) and BCR of 2.18 was significantly higher with the application of 180 N kg/ha. Similar finding was reported by Basavanneppa (2005).

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REFERENCES

Basavanneppa, M. A. 2005. Productivity and profitability of cotton influenced by fertilizer management under Tungabhadra Project area of Karnataka. *J. Cotton Res. Dev.,* **19**:66-68.

Bhalerao, P. D., Gawande, P. P. Ghatol P. U. and Patil B. R. 2008. Performance of *Bt* cotton hybrids for various spacing under rainfed condition. *Agric. Sci. Digest,* **28** : 54-56.

Buttar, G. S., Sekhon, K. S. and Singh Sudeep, 2010. Effect of different spacing and nitrogen levels on growth and yield attributes of American cotton (*Gossypium hirsutum* L.) *Bt* hybrids under irrigated conditions. *J. Cotton Res. Dev.,* **24**:73-75.

Giri, A. N. and Gore, S. B. 2006. Effect of plant densities and NPK levels on yield of newly released desi varieties of cotton (*Gossypium arboretum* L.). *J. Cotton Res. Dev.,* **20**:77-79.

Hebbar, K.B., Rao, M. R. K and Khadi, B.M. 2007. Synchronized boll development of *Bt* cotton hybrids and their physiological consequences. *Curr. Sci.,* **93:** 693-95**.**

ICAC, 2010. Biotech cotton also requires agronomic changes. *ICAC Recorder,* **37:** 16.

James, C. 2006. Global Status of Commercialized Biotech/GM Crops: 2006. *ISAAA Briefs No. 35,* International Service for the Acquisition of Agri-biotech Applications, Ithaca, NY.

Jenkins, J.N., McCarty, Jr. J.C., Buehler, R.E., Kiser, J., Williams, C. and Wofford, T. 1997. Resistance of cotton with î-endotoxin genes from *Bacillus thuringiensis* var. *kurstaki* on selected lepidopteran insects. *Agron. J.,* **89:** 768-80.

Khamparia S. K., Upadhaya, A. Shah M.S. and Sisodia R.I. 2009. Evaluation of agronomic requirements of *Bt* cotton hybrid under different spacing and fertility levels in rainfed conditions. National symposium on *"Bt Cotton: Opportunities and Prospects"* Crop Production, 17-19 November, 2009, CICR, Nagpur, pp. 85.

Mayee, C.D., Phundan Singh, Punit Mohan and Agarwal, D.K. 2004. Evaluation of *Bt* transgenic intra hirsutum hybrids for yield and fibre properties. *Ind. J. Agri. Sci.,* **74 :** 746-47.

Meena,R.L., Babu, V.R. and Nath, A.2007. Effect of fertilizer management on cotton under saline soils of Gujarat. *Bharatiya Krishi Anusandhan Patrika,* **22**:206-10.

Palomo, G., Gaytan, M. A., Espinoza, B. A., Martinez, A. H. J. and Jasso, C. D. 2003. Nitrogen doses and irrigation number on cotton yield and seed quality. *Revista Fitotecnia Mexicana,* **26**:95-99.

Panse, V.G. and Sukhatme, P.V. 1967. *Statistical Methods of Agricultural Workers.* 2 nd edition ICAR, New Delhi.

Prasad, M. and Siddique, M. R. B. 2004. Effect of nitrogen and mepiquat chloride on yield and quality of upland cotton (*Gossypium hirsutum* L.). *Indian J. Agri. Sci.,* **74**:560-62.

Rao, M.H. 1985. Effect of planting time and plant population on two promising genotypes to American upland cotton. *Indian J. Agron.,* **27** : 307-09.

Singh Kulvir and Gill, J.S.2007. Effect of different spacing and nitrogen levels on growth and yield attributes of desi cotton (*Gossypium arboretum* L.) hybrids. *J. Cotton Res. Dev.,* **21**:77-79.

Sisodia, R. I. and Khamparia, S. K. 2007. American cotton varieties as influenced by plant densities and fertility levels under rainfed conditions. *J. Cotton Res. Dev.,* **21**:35-40.

Agronomic evaluation of popular *Bt* cotton hybrids in Marathwada region under rainfed condition

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ABSTRACT : A field experiment was conducted during year 2013-14 with an objective to find out suitable spacing and fertilizer levels for popular *Bt* cotton hybrids under rainfed condition. The experiment was conducted at Cotton Research Station Nanded (M.S.) and was laid out in split split plot design with three replications. Two spacings (120 x 45 and 90 x 45 cm) in sub plot and three fertilizer levels (100%, 125% and 150%) were evaluated in sub sub plot for three popular *Bt* cotton hybrids (BG II) among farmers in main plot. The rainfall to the tune of 1,337 mm (52 per cent more than average) was received which was distributed in 56 rainy days during the season. The results indicated that hybrid Ajeet 155 *Bt* recorded highest seed cotton yield (3302 kg / ha), and boll weight (4.30 g) and was *at par* with Dr. Brent (MRC 7347). Comparatively dwarf plants with less number of branches in hybrid Mallika *Bt* resulted to lower seed cotton yield.

Reduction in number of bolls and boll weight was noticed in closer plant spacing (90 x 45 cm) however was compensated for seed cotton yield (3239 kg / ha) by 6.82 per cent because of higher plant population. This resulted to increased monetary values in closer spacing (90 x 45 cm) in terms of GMR (Rs 1,61,380/h) and NMR (Rs 1,03,080/ha) significantly. The interaction of hybrid x spacing revealed that Mallika hybrid performed better under (90 X 45 cm) spcing where as hybrids Ajeet 155 *Bt* and Dr Brent *Bt* were similer under both spacings. The *Bt* cotton hybrids responded to increase in growth, yield and attributing characters due to increase of fertilizer levels. However, the 150 per cent RDF level recorded highest seed cotton yield (3332 kg/ha), GMR (Rs 1,65,190/ha) and NMR (Rs1,02,880/ha) and was found *at par* with 125 per cent RDF.

Key words : *Bt* cotton hybrid, economics, fertilizer, spacing, yield

Cotton crop plays dominant role in industrial and agricultural economy. It is grown under rainfed condition on more than 65 per cent area in India. Cotton cultivation in Maharashtra state is gone up after introduction of transgenic cotton, presently grown on about 41.92 lakh ha (2014-2015). *Bt* cotton use spread rapidly, resulting reduced bollworm infestation and insecticidal use which greatly increased productivity. Cotton is the most important commercial crop of Marathwada region for the last 50 years in the state which covers 41 per cent state area of the crop. Cotton yields in rainfed ecosystem are low owing to erratic rainfall, uneven distribution and moisture stress at reproductive stages leading to inconsistent yields.

Maximum yield of *Bt* cotton can be realized by adopting new and high yielding *Bt* cotton hybrids with suitable agronomic practices *viz.*, optimum plant density and fertilizer management. More than 100 *Bt* cotton hybrids are available in regional market which are having greater variation in growth habit, duration and adoptability to agronomic practices. Preliminary studies on *Bt* cotton have shown that they mature earlier than non *Bt* cotton. This early senescence and increased productivity may require higher nutrient requirement to support boll number and higher yields. Establishment of acceptable population of cotton seedling is paramount to obtain high yield. Optimum plant population varies by location, environment, cultivar and growers performance. High and suitable productivity of cotton can be achieved with suitable plant population associated with balanced nutrition and consequently its availability in soil.

Different *Bt* cotton hybrids differ in their productivity under various plant geometries and should be fertilized more with closer spacing for higher yields. But research studies on this aspect are less. Keeping in view of the above facts, the present investigation was planned to find out optimum plant geometry and economical fertilizer requirement for popular *Bt* cotton hybrids under rainfed condition.

MATERIALS AND METHODS

A field experiment was conducted at Cotton Research Station, Nanded to identify optimum plant spacing and fertilizer requirement for three popular *Bt* cotton hybrids among farmers under rainfed condition in Mararthwada region for the year 2013-2014. The soil of experimental site was clay loam having pH 7.75. The soil was low in organic carbon (0.75%) and available nitrogen (105.0 kg/ha); medium in phosphorus (10.35% kg / ha) and high in potassium (530.80 kg / ha) content. The experiment was laid out in split split plot design with three replications. Sowing was done on June 18th, 2013. Three *Bt* cotton hybrids (BG II) on farmers field *viz.* Mallika (NCS 207), Ajeet 155 and Dr. Brent (MRC 7347) in main plot; were studied in normal spacing *i.e.* 120 x 45 cm and closer spacing with higher population *i.e.* 90 x 45 cm in sub plot. Three fertilizer levels RDF (120:60:60 NPK kg / ha), 125 per cent RDF and 150 per cent RDF were tested for response on growth, yield and economics of the *Bt* cotton hybrids. Cumulative rainfall 1337 mm (52% excess over average) was received during June - December 2013 well distributed in 56 rainy days.

RESULTS AND DISCUSSION

Effect of *Bt* cotton hybrids : The *Bt* cotton hybrid Ajeet 155 recorded highest seed cotton yield (3302 kg/ha) reflecting an increase of 12 per cent over Mallika *Bt*, but was *on par* with *Bt* hybrid Dr. Brent (3199 kg/ha). Pendharkar *et al.,* (2010) also reported higher yield from Ajeet 155 *Bt*. This is mainly due to significant increase in yield contributing characters noticed in Ajeet 155 *Bt*. Significantly higher boll weight (4.29 g) and yield/plant (166.27 g) were registered with Ajeet 155 *Bt* when compared with Mallika *Bt*. Higher number of bolls/plant (45.69) were recorded from *Bt* hybrid Dr. Brent which contributed to increased yield of that hybrid over Mallika. Higher number of yield contributing characters in Ajeet 155 may be attributed due to taller plant height (180.51 cm) associated with greater number of sympodial branches (20.27) over Mallika *Bt* (Table 1).

Increase in seed cotton yield of Ajeet 155 *Bt* resulted to significantly higher gross as well as net monetary returns and B:C ratio (Rs 1,64,550/ha, Rs 1,06,790/ha and 2.55, respectively) over Mallika *Bt*.

Effect of spacing : Significantly higher seed cotton yield (3239 kg/ha) was registered with closer spacing (90 x 45 cm) and it was 6.40 per cent greater over normal spacing (120 x 45

Table 1. Plant growth and yield contributing characters as influenced by *Bt* cotton hybrids, plant geometry and nutrient levels

Treatment	Plant height (cm)	Mono-podia/ plant	Sym-podia/ plant	Boll weight (g)	Yield/ plant (g)	No. of Bolls/ plant
Main plot : *Bt* cotton hybrids						
H_1: Mallika	153.84	0.93	17.97	4.15	142.33	35.87
H_2: Ajeet 155	180.51	1.08	20.27	4.29	166.27	43.07
H_3: MRC 7347	174.32	1.12	19.81	3.59	153.65	45.69
SE+	4.46	0.04	0.056	0.03	4.06	0.69
CD (p=0.05)	17.50	0.15	2.19	0.11	15.90	2.72
Sub-plot: Plant geometry						
G1 : Normal spacing (120 x 45 cm)	166.24	1.08	19.47	4.15	168.65	44.64
G2 : Closer spacing (90 x 45 cm)	172.87	1.01	19.23	3.87	139.52	38.44
SE+	4.53	0.02	0.04	0.06	1.90	0.31
CD (p=0.05)	N.S.	N.S.	N.S.	0.20	6.56	1.06
Sub sub plot : Nutrient levels						
F_1: RD - NPK (100:50:50)	161.88	0.98	17.92	3.82	144.90	38.37
F_2: 125 (% RD) – NPK	171.11	1.03	19.30	4.04	153.32	41.81
F_3: 150 (% RD) – NPK	175.62	1.12	20.82	4.17	164.02	44.44
SE+	3.02	0.03	0.61	0.06	3.74	1.12
CD (p=0.05)	8.80	0.10	1.78	0.17	10.89	3.26
Interaction H x G						
SE+	7.85	0.04	0.61	0.10	3.29	0.53
CD (p=0.05)	N.S.	N.S.	N.S.	0.34	11.36	1.84
Interaction H x F						
SE+	5.23	0.06	1.06	0.10	6.47	1.94
CD (p=0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Interaction G x F						
SE+	4.27	0.05	0.86	0.08	5.28	1.58
CD (p=0.05)	N.S.	N.S.	N.S.	N.S.	15.40	4.60
Interaction H x G x F						
SE+	7.40	0.08	1.50	0.14	9.15	2.74
CD (p=0.05)	N.S.	N.S.	N.S.	N.S.	26.67	N.S.
C.V. (%)	7.55	13.79	13.43	6.21	10.29	11.41
Grand mean	**169.56**	**1.04**	**19.35**	**4.01**	**154.08**	**41.54**

cm). The increased yield in closer plant spacing was evident due to higher plant population (24,691 plants/ha) over normal (18,518 plants/ ha), although there was significant reduction in bolls/plant and boll weight in closer spacing. Greater number of bolls (44.64)/plant and boll weight (4.15 g) in normal spacing could be attributed to more available space, better aeration, adequate interception of light as well as lesser competition of nutrients to plants in normal spacing with lower plant density. Similar results were reported by Raghu Rami Reddy and Gopinath (2008), Sree Rekha and Pradeep (2012). The plant growth characters were not found to differed due to spacing. Similar results were reported by Malavath *et al.,* (2014).

The closer spacing (90 x 45 cm) with higher plant population was significantly remunerative in respect of GMR (Rs 1,61,380/ ha) and NMR (Rs 1,03,080/ha) over normal

Table 2. Seed cotton yield and economics as influenced by *Bt* cotton hybrids, plant geometry and nutrient levels

Treatment	Seed cotton yield (kg/ha)	GMR (Rs/ha)	NMR (Rs/ha)	B:C ratio
Main plot : *Bt* cotton hybrids				
H_1: Mallika	2904	144710	89333	2.60
H_2: Ajeet 155	3302	164550	106790	2.85
H_3: MRC 7347	3199	159400	102260	2.79
SE+	66.54	3316	2154	0.04
CD (p=0.05)	260.80	12997	8444	0.15
Sub plot: Plant geometry				
G1 : Normal spacing (120 x 45 cm)	3032	151060	95843	2.73
G2 : Closer spacing (90 x 45 cm)	3239	161380	103080	2.76
SE+	59.53	2967	2067	0.04
CD (p=0.05)	205.69	10250	7143	N. S.
Sub-sub plot : Nutrient levels				
F_1: RD - NPK (100:50:50)	2932	147230	93017	2.71
F_2: 125 % RD – NPK	3141	156240	99482	2.75
F_3: 150 % RD – NPK	3332	165190	105880	2.78
SE+	73.67	3671	2458	0.04
CD (p=0.05)	214.71	10698	7163	N. S.
Interaction H x G				
SE+	103.11	5138	3581	0.06
CD (p=0.05)	N.S.	N. S.	12372	N. S.
Interaction H x F				
SE+	127.60	6358	4257	0.08
CD (p=0.05)	N.S.	N. S.	N. S.	N. S.
Interaction G x F				
SE+	104.19	5191	3476	0.06
CD (p=0.05)	N.S.	N. S.	N. S.	N. S.
Interaction H x G x F				
SE+	180.46	8992	6020	0.11
CD (p=0.05)	N.S.	N. S.	N. S.	N. S.
C.V. (%)	9.97	9.97	10.48	6.76
Grand mean	**3135**	**156220**	**99460**	**2.75**

spacing (120 x 45 cm). Although, significant variation in B:C ratio was not observed in respect to spacing.

Effect of nutrient levels : In comparison with recommended NPK level, effects of higher doses (125% and 150% NPK) were studied in *Bt* cotton hybrids. Application of 150 per cent NPK level produced taller plants (175.62 cm). It was significantly superior over 100 per cent NPK level for plant height (161.88 cm). The number of monopodial and sympodial branches/plant were found to highest in 150 per cent NPK level. The higher nutrient availability through graded levels of fertilizers might have increased number of levels and production of photosynthates which reflected in more number branches/plant. These observations are in conformity with Jadhav *et al.,* (2015). Application of nutrient level 150 per cent NPK recorded highest number of bolls/plant (44.44), boll weight (4.17 g), both resulting to increased yield per plant (164.02 g). Greater supplement of nutrients to the crop resulted in synthesis of higher photosynthates

Table 3. Interaction of *Bt* cotton hybrids x plant geometry for NMR (Rs/ha)

Bt cotton hybrids /	Plant geometry	
	G_1 : 120 x 45 cm	G_2 : 90 x 45 cm
H$_1$- Mallika	81,952	96,715
H$_2$- Ajeet 155	1,05,560	1,08,020
H$_3$- MRC 7347	1,00,010	1,04,500
SE+	3,581	
CD (p=0.05)	12,372	

which in turn helped to produce seed cotton yield/ plant. The result of seed cotton yield presented in Table 2 indicated that 150 per cent NPK level yielded significantly higher seed cotton yield (3332 kg/ha) over 100% NPK (2932 kg/ha). But it was statistically on par with 125 per cent NPK. Similar trend of seed cotton yield was also observed for gross and net monetary returns. The highest GMR (Rs 1,65,190/ha) was realized with 150 per cent NPK level, it was marginally higher (Rs 6,398/ha) over 125 per cent NPK. However, the nutrient levels were found statistically equal for B:C ratio.

Table 4. Picking wise share of seed cotton and GOT (%) as influenced by *Bt* cotton hybrids, plant geometry and nutrient levels

Treatment	Picking wise share of seed cotton yield			GOT (%)
	First picking	Second picking	Third picking	
Main plot : *Bt* cotton hybrids				
H$_1$: Mallika	57.11 (35.01)	26.44 (15.36)	17.00 (9.81)	37.16
H$_2$: Ajeet 155	43.57 (25.95)	25.95 (15.10)	30.70 (17.97)	36.16
H$_3$: MRC 7347	60.92 (37.73)	21.93 (12.67)	17.14 (9.90)	35.11
SE+	1.42	0.81	1.15	0.25
CD (p=0.05)	5.56	N.S.	4.50	0.97
Sub-plot: Plant geometry				
G1: Normal spacing (120 x 45 cm)	53.27 (32.53)	25.77 (14.99)	21.14 (12.30)	36.24
G2: Closer spacing (90 x 45 cm)	54.46 (33.26)	23.77 (13.76)	22.10 ()12.82	36.05
SE+	0.94	0.71	0.80	0.36
CD (p=0.05)	N.S.	N.S.	N.S.	N.S.
Sub-sub plot : Nutrient levels				
F$_1$: RD - NPK (100:50:50)	54.29 (33.08)	24.22 (14.05)	20.99 (12.21)	35.74
F$_2$: 125 (% RD) – NPK	53.78 (32.84)	25.72 (14.95)	21.45 (12.45)	36.10
F$_3$: 150 (% RD) – NPK	53.53 (32.76)	24.39 (14.12)	22.41 (13.03)	36.59
SE+	1.19	0.54	1.05	0.44
CD (p=0.05)	N.S.	N.S.	N.S.	N.S.
Grand mean	**53.87 (32.89)**	**24.97 (14.38)**	**21.62 (12.56)**	**36.14**

*-Figures in parenthesis are Arcsin transformed values.

Interaction of *Bt* cotton hybrids x spacing : The *Bt* cotton hybrid x spacing interaction was significant for net monetary returns (Table 3). The *Bt* hybrids Ajeet 155 and Dr. Brent were found to equally profitable in both the plant spacings. The hybrid Ajeet 155 *Bt* under closer spacing was the most remunerative interaction (Rs 1,08,020/ha). The interaction effects indicate that *Bt* cotton hybrid Mallika was significantly remunerative under closer spacing (90 x 45 cm) over normal spacing as compared to other hybrids for net monetary returns. This might be due to comparatively less competition resulting higher yield of Mallika *Bt* under closer spacing as compared to other hybrids.

Picking wise share of cotton : *Bt* cotton hybrids had distinct variation in picking wise share of seed cotton (Table 4). The hybrids Dr. Brent and Mallika had significantly higher share over Ajeet 155 at first picking showing their earliness. However, at third picking, Ajeet 155 *Bt*, had significantly more seed cotton yield share over rest of the two hybrids. This might be due to more boll retention at later stage in Ajeet 155 with availability of moisture received from late rains in the month of October and November. The plant geometry and nutrient levels had no significant impact on picking wise share of seed cotton.

Ginning outturn : The Mallika *Bt* hybrid recorded highest ginning outturn (37.06%) where as Dr. Brent had significantly lowest Ginning outturn (35.11%). Plant geometry and nutrient levels didn't affected GOT statistically (Table 4).

REFERENCES

Jadhav, S. G., Chavan, D. A., Gokhale, D. N. and Nayak, S. K. 2015. Influence of plant geometry, growth regulator and nutrient management on performance of *Bt* cotton under irrigated condition. *Int. J. Trop. Agric.* **33** : 1755-58.

Malavath, R., Naik, R., Pradeep, T. and Chuhan, S. 2014. Performance of *Bt* cotton hybrids to plant population and soil types under rainfed condition. *Agrotechnol.* **3** : 120. Doi:10.4172/2168-9881.1000120

Pendharkar, A. B., Solunke, S. S., Sawargaonkar, G. L. and Kote, G. M. 2010. Response of *Bt* cotton hybrids to different plant spacings under rainfed condition,. *Adv. Res. J. Crop Improv.*, **1** : 180-82.

Raghu Rami Reddy, P. and Gopinath, M. 2008. Influence of fertilizers and plant geometry on performance of *Bt* cotton hybrid. *J. Cotton Res.Dev.* **22** : 78-80.

Sree Rekha, M. and Predeep, T. 2012. Performance of *Bt* cotton hybrid (RCH 2) at different plant densities and scheduling of nitrogen under rainfed conditions. *Crop Res.* **44** : 182-85.

Physiological assessment for drought tolerance in cotton *hirsutum* genotypes under rainfed conditions in vertisols

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ABSTRACT : A field experiment was conducted at Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh, during 2013-2014 *kharif* season in black cotton soils under rainfed conditions. in strip plot design with two irrigation levels as main treatments *viz*; rainfed and need based irrigation and twenty five cotton entries as sub treatments in two replications to screen the entries for drought tolerance in black cotton soils. The crop suffered due to low moisture stress during boll formation and boll development stages. Under rainfed conditions, the entries viz; BGII 802, CNH 14, L 765, L788, BHC 2413, CA 105, L761, L770, RHC 0717 and LRA 5166 recorded higher RWC, the entries viz; H 1454/12, SCS 793, BGII S 802, HAG 805, CSH 1111, L 765, IH 70, RHC 0717,H1465/12 and ARBH 2004 recorded higher specific leaf weight and the entries viz; L 761, GBHv 177, L 770, L 762, ARBH 2004, H1454/12 and IH 70 recorded higher SCMR values. The per cent reduction in seed cotton yield under rainfed conditions ranged from 11.49 to 49.36. The entries Viz; *viz;* IH 70, H 1462/12, ARBH 2004, L 762, CA 105, BHC 2413, BS 79 and GBhv 177 recoded higher seed cotton yield under rainfed conditions and the higher seed cotton yield in these entries was associated with the drought tolerance parameters to drought with more than two contributing characters of drought.

Key words : Cotton, Drought, RWC, SLW, SCMR and Seed Cotton Yield

Cotton plays an important role in Indian agriculture, industrial development, employment generation and in improving national economy. Out of about 50 species of cotton in the world, only four have been domestically cultivated for cotton fibre. *Gossypium hirsutum* and *Gossypium barbadense* are the most commonly cultivated species of cotton in the world. *Gossypium hirsutum* is the most important agricultural cotton, accounting for more than 90 per cent of world fibre production. In India, the cultivated sp. *Gossypium hirsutum* is grown in an area of 126.55 lakh ha with a productivity of 537 kg/ha. In Andhra Pradesh, cotton is one of the most important commercial crops. Cotton is grown mainly under rainfed conditions in Andhra Pradesh. The unpredictable nature of rainfall and frequent dry spells cause wide fluctuations in yield from year to year. It is grown in all the three-agro climatic zones of Andhra Pradesh under different agro climatic conditions. Climate change affects the rainfed areas of Andhra Pradesh badly. Deficient rains causes reduction in seed cotton yield. High temperatures also hasten the development especially during the boll filling period, thus resulting in smaller bolls, lower yields and poor lint quality (Hodges et al. 1993). Due to these reasons, the ability of plants to tolerate drought conditions is crucial for agricultural production worldwide. A drought tolerant variety improves the cotton yield and thus a boon to farming community. Keeping all these points in view, the present study is taken up to identify the entries for drought tolerance.

MATERIALS AND METHODS

A field experiment was conducted at Regional Agricultural Research Station, Lam, Guntur, Andhra Pradesh, during kharif 2013-2014 season in black cotton soils under rainfed conditions. The experiment was laid out in a strip plot design with two irrigation levels as main treatments *viz*; rainfed and need based irrigation and twenty cotton entries as sub treatments in two replications to screen the entries for drought tolerance. The total rainfall during the period under study was 1045 mm in 56 rainy days. The crop suffered due to low moisture stress during boll formation and boll development stages. Five plants at random were selected in each plot and the number of sympodia per plant, number of bolls per plant, boll weight and seed cotton yield per plant were recorded. Third and forth fully opened leaves were collected for estimating Relative water content (RWC), chlorophyll stability index (CSI), Specific leaf area SLA) and specific leaf weight (SLW). Leaf chlophyll content was estimated according to Hiscox and Israelstam (1979). The mean data of five plants were subjected to statistical analysis by adopting the standard procedures described by Panse and Suhkatme (1985).

RESULTS AND DISCUSSION

Physiological and bio-chemical parameters: The data on physiological parameters were presented in Table No. 1 Variability was noticed in drought tolerance parameters *viz;* Relative Water Content (RWC), Specific Leaf Weight (SLW), Chlorophyll Stability Index (CSI) and SPAD Chlorophyll Meter Reading (SCMR).

The Relative Water Content (RWC) is the measure of the amount of the water present in the leaf tissue and the treatment having higher RWC under stress conditions would be preferable to maintain water balance. In the present study, under rainfed condition, the entries viz; BGII 802, CNH 14, L 765, L788, BHC 2413, CA 105, L761, L770, RHC 0717 and LRA 5166 recorded higher RWC. The percent reduction in RWC under rainfed conditions ranged from 0.66 (CNH 14) to 22.67 (H 1462/12). Higher percent reduction in RWC under rainfed condition was recorded in BGII S H 1462/12, CSH 1111, GJHv 500 and LRA 5166 and lower per cent reduction was noticed in CNH 14(0.66), L 761(0.85), IH 70 (1.16), GSHv 162 (1.97), BGIIS 802 (2.58) and H 1454/12(2.76). Malik *et al.,* (2006) reported that higher RWC is positively correlated with boll weight and seed cotton yield in cotton. The entries Viz; CNH 14 (75.6%), BGII 802 (75.4%) and IH 70 (68%) not only recorded higher RWC under rainfed conditions, but also had shown less percent reduction compared to need based irrigated conditions indicating their drought tolerant ability under moisture stress conditions.

Higher specific leaf weight was recorded in the entries viz; H 1454/12, SCS 793, BGII S 802, HAG 805, CSH 1111, L 765, IH 70, RHC 0717, H1465/12 and ARBH 2004 under rainfed conditions. The percent reduction in specific leaf weight under rainfed conditions compared to need based irrigated conditions ranged from -13.04 to 4.92 indicating the increase in leaf thickness in some of the entries. The percent increase in SLW was higher in entries *viz* CA 105(13.04), L770 (12.77), L762 (9.43), L 761(9.26), H1454/12(9.52) and BHC 2413(5.88) indicates the ability for adaptation under moisture stress conditions.

The significant positive correlation between SCMR and chlorophyll density across genotypes under a range of drought stress conditions was reported in the study conducted by Arunyanark *et al.,* (2015) and they also demonstrated that the SCMR could be a rapid tool to assess the genotypic variation for leaf chlorophyll density in order to identify the drought tolerant genotypes.In the present study, higher SCMR values were recorded in the entries viz; L 761, GBHv 177, L 770, L 762, ARBH 2004, H1454/12 and IH 70 under rainfed conditions. The percent reduction in SCMR under rainfed conditions compared to need based irrigated conditions ranged from 1.75 (RHC 0717) to 15.23 (L 763). Less reduction under rainfed conditions was noticed in the entries *Viz* RHC 0717 (1.75%), ARBH 2004(2.52%), L 761(3.38%), IH 70 (3.33%) and BS 79 (4%). The entries *viz*; L761 (48.8), ARBH 2004 (42.6) and IH 70 (40.7) had not only recoded higher SCMR values, but also had shown less reduction under rainfed conditions compared to need based irrigated conditions indicating their inbuilt tolerance to moisture stress.

Yield and yield attributing characters: The data pertaining to the seed cotton yield and yield attributing characters are presented in Table 2. Significant variation was noticed among

Table 1. Screening of cotton entries for Physiological parameters related to drought tolerance at Regl.Agril.Res. Station, Lam, Guntur during 2012-2013

Name of the entry	RWC (%)			SLW (mg/cm$^{2)}$			SCMR		
	I_1	I_0	Per cent reduction	I_1	I_0	Per cent increase and decrease	I_1	I_0	Per cent reduction
1 GBhv 177	72.3	68.4.	5.39	6.1	5.9	-3.28	42.5	39.3	7.53
2 BGII S 802	77.4	75.4	2.58	6.7	6.8	1.49	34.9	31.9	8.60
3 LRA 5166	79.1	69.8	11.76	5.8	5.9	1.72	38.4	35.1	8.59
4 RHC 0717	75.9	69.8	8.04	6.7	6.4	-4.48	34.2	33.6	1.75
5 H1462/12	71.9	55.6	22.67	6.7	6.5	-2.99	43.2	39.6	8.33
6 SCS 793	70.2	64.6	7.98	6.8	6.9	1.47	43.5	41.3	5.06
7 ARBH 2004	73.4	69.4	5.45	5.8	6.0	3.45	43.7	42.6	2.52
8 L 770	72.9	69.0	5.35	4.7	5.3	12.77	50.4	45.8	9.13
9 L 762	69.9	65.6	6.15	5.3	5.8	9.43	46.7	43.9	6.00
10 L 761	70.2	69.6	0.85	5.4	5.9	9.26	50.3	48.6	3.38
11 GJhv 500	73.3	64.9	11.46	5.7	5.3	-7.02	39.4	35.6	9.64
12 CA 105	72.5	69.3	4.41	4.6	5.2	13.04	45.6	40.7	10.75
13 NDLH 1938	74.8	68.6	8.29	6.2	6.4	3.23	46.4	41.7	10.13
14 GSHv 162	65.9	64.6	1.97	6.1	6.4	4.92	54.1	46.1	14.79
15 BS 79	70.2	64.6	7.98	4.6	4.8	4.35	42.5	40.8	4.00
16 H 1454/12	68.9	67.0	2.76	6.3	6.9	9.52	46.4	41.7	10.13
17 L 765	75.9	70.6	6.98	6.4	6.6	3.12	39.2	35.6	9.18
18 L 788	74.8	69.7	6.82	5.3	5.5	3.77	41.8	38.7	7.42
19 BHC 2413	72.5	69.7	3.86	5.1	5.4	5.88	35.9	32.7	8.91
20 IH 70	68.8	68.0	1.16	6.8	6.7	-1.47	42.1	40.7	3.33
21 L 763	67.6	64.2	5.03	6.1	5.8	-4.92	39.4	33.4	15.23
22 HAG 805	68.4	65.1	4.82	6.8	6.7	-1.47	37.5	36.2	3.47
23 CSH 1111	75.8	58.8	22.43	6.5	6.5	0.00	38.6	34.3	11.14
24 PH 1075	69.5	66.1	4.89	5.8	5.9	1.72	41.4	37.8	8.70
25 CNH 14	76.1	75.6	0.66	5.3	5.5	3.77	41.6	38.6	7.21

Table 2. Screening cotton genotypes for seed cotton yield and yield parameters under rainfed conditions at Regl. Agrl. Res. Station, Lam, Guntur -34 during 2013-2014

Treatment	Boll/ plant	Boll weight (g)	Sympodia	Seed cotton yield (g/plant)	Seed cotton yield (kg/ha)
Vertical factor: Irrigation treatments					
I_1	27.81	3.851	21.47	103.56	1522
I_0	25.21	3.804	19.65	101.90	1449
Mean	**26.51**	**3.827**	**20.56**	**102.73**	**1485**
SEm	0.173	0.0304	0.28	0.36	15.79
C D (p=0.05)	0.500	0.10	0.84	1.06	46.54
Horizontal factor: Cotton entries					
GBhv 177	26.03	3.212	19.30	84.15	1304
BGII S 802	23.20	3.475	16.97	80.65	1165
LRA 5166	23.12	3.225	18.30	75.00	1332
RHC 0717	27.02	3.375	20.97	91.25	1406
H1462/12	31.12	3.950	22.63	123.75	1782
SCS 793	27.52	4.850	17.23	134.10	1208
ARBH 2004	27.70	4.775	21.45	133.83	1858
L 770	23.77	3.725	17.63	89.28	1104
L 762	32.95	3.225	22.13	107.02	1920
L 761	21.77	3.000	19.98	65.75	973
GJhv 500	24.53	3.325	18.05	81.90	1149
CA 105	27.20	4.150	20.63	113.78	1759
NDLH 1938	24.10	3.975	20.73	96.45	1131
GSHv 162	26.80	4.075	22.23	109.83	1434
BS -79	27.37	4.275	22.88	118.25	1787
H 1454/12	23.20	4.125	21.30	98.23	1469
L 765	21.35	4.000	23.55	85.93	1216
L 788	26.40	3.950	21.30	104.63	1596
BHC 2413	25.62	3.925	22.80	100.97	1523
IH 70	35.10	4.250	23.15	151.43	2122
L 763	26.95	3.175	21.38	86.90	1716
HAG 805	25.52	3.625	20.38	94.15	1375
CSH 1111	25.45	4.625	17.73	119.05	1426
PH 1075	26.60	3.375	20.30	91.25	1538
CNH 14	32.45	4.025	20.95	130.73	1744
Mean	**26.51**	**3.827**	**20.56**	**102.73**	**1486**
SEm +	2.49	0.069	0.286	9.57	174
C D @ 0.05	7.34	0.200	0.840	28.23	514.3
Interaction : Vertical x horizontal					
SEm +	1.169	0.089	1.562	5.79	96.44
C D (p=0.05)	NS	NS	NS	NS	NS
CV (%)	16.24	13.27	10.74	7.97	9.18

the different entries in recording number of sympodia per plant, number of bolls per plant, boll weight and seed cotton yield per plant. Significantly higher seed cotton yield was recorded in IH 70 followed by L762 and ARBH 2004 and the higher yield in these entries were associated with higher sympodial number, boll number and boll weight. The entries Viz; ARBH

2004,L-762,CA 105,BS 79, H 1454/12, L-788, IH 70, L 763 and CNH 14 recorded higher seed cotton yield under need based irrigated conditions, whereas the entries *viz;* IH 70, H 1462/12, ARBH 2004, L 762, CA 105, BHC 2413, BS 79 and GBHv 177 recoded higher seed cotton yield under rainfed conditions. The per cent reduction in seed cotton yield under rainfed conditions ranged from 11.49 to 49.36. The lowest seed cotton yield reduction was recorded in the entry GSHv 177 and the highest seed cotton yield reduction was noticed in CNH 14.

From the experimental results, it is inferred that the entries viz; IH 70, H 1462/12, ARBH 2004, L 762, CA 105, BHC 2413, BS 79 and GBHv 177have shown good performance under rain fed conditions with their inbuilt tolerance to drought having more than two contributing characters of drought tolerance in addition to yield attributing characters.

REFERENCES

Arunyanark, A. , S. Jogov, N. Vorosoot, C. Akkaseang, T. Kesmala and A. Patanthai 2015. Stability of Rrelationship beteen chlorophyll density and soil plant analysis developed chlorophyll meter reading in peanut across different drough stress conditions. Science Alert (An open access publisher)

Hiscox, J.D and Israelstam, G.F.1979.A method for the extraction of chlorophyll from leaf tissue without maceration. *Canadian Journal of Botany*.**57:** 1332-34.

Hodges HF, Whisler FD, Bridges SM, Reddy KR, Mc Kinion J M 1998. Simulation in crop management: GOSSYM/ COMAX. In: Peart RM, Curry AB (eds) Agricultural system modeling and simulation. Dekker, New York, pp 235– 81

Malik, T.A. Sana-Ullah Malik, S 2006..Genetic linkage studies of drought tolerant and agronomic traits in cotton. *Pakistan Journal Botany* : 1613-19

Panse V G and Sukhatme 1985. Statistical methods for Agricultural Workers, ICAR, New Delhi. p. 232

Poly mulch as moisture conservation technique in ET based drip irrigated *Bt* cotton in vertisols of Andhra Pradesh

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ABSTRACT : The field experiment conducted at Regional Agricultural Research Station, Lam, Guntur during *kharif 2013*-2014 and 2014-2015 to study the response of *Bt* cotton to drip irrigation based on evapotranspiration and moisture conservation with poly ethylene mulching in randomized block design with eight treatments and three replications indicated that there was significant difference in growth, yield contributing characters and seed cotton yield with different treatments tested. The conducive growth environment and microclimate under polyethylene mulching with or without drip on growth components finally reflected in better assimilate partitioning to reproductive structures as evidenced from the production of 5 – 46.8 per cent enhancement in producing number of bolls per plant compared to rainfed thus contributing significantly to higher seed cotton yield under poly mulched ET drip irrigation ranging from 7.5 – 47 per cent compared to rainfed. Among the treatments 0.6 Epan + polymulching recorded significantly higher seed cotton yield with maximum water and nitrogen use efficiency.

Key words : Drip irrigation, poly mulch, water use efficiency

Cotton is one of the most important commercial crop in Andhra Pradesh. The cotton crop is very sensitive to moisture stress. Excess moisture in the initial growth stages and uncontrolled water stress at later stages may adversely affect the cotton yield. Cotton is mostly grown under rainfed situation and if water is available farmers irrigate the fields in flood method which leads to severe flower and boll drop. Being a wide spaced row crop, drip irrigation offers much scope in terms of enhancing cotton productivity for yield and water. Enhancement in cotton yield to the tune of 39 per cent due to scientific scheduling of irrigation through drip over conventional irrigation has been reported (Lomte and Kagde, 2009). The practice of mulching with polyethylene is well proved for complete control of evaporation and saving the precious water in agriculture besides other advantages like weed control and enhanced seed cotton yield to the tune of 1.9 fold in cotton (Nalayani *et al.*, 2009). Drip irrigation has been shown to increase crop water productivity of cotton by increasing yields and decreasing the amount of water used (Cetin and Bilgen, 2002). But, the information on scheduling of irrigation based on evapotranspiration and moisture conservation with poly ethylene mulching in *Bt.* cotton in vertisols is very much lacking and hence this study was under taken.

MATERIALS AND METHODS

The field experiment was conducted at Regional Agricultural Research Station, Lam, Guntur during *kharif* 2013-2014 and 2014-2015 to study the response of *Bt* cotton to drip irrigation based on evapotranspiration and moisture conservation with poly ethylene mulching in randomized block design with eight 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^{-1}), medium in available phosphorus (28 kg ha^{-1}) and high in available potassium (856 kg ha^{-1}). The treatments were T_1 Control, T_2 polymulching, T_3 drip irrigation at 0.4 E pan , T_4 drip irrigation at 0.4 E pan + poly mulch, T_5 drip irrigation at 0.6 E pan, T_6 drip irrigation at 0.6 E pan+ poly mulch, T_7 drip irrigation at 0.8 E pan and T_8 drip irrigation at 0.8 E pan + poly mulch. The material used for polymulching was of 30 micron thickness with silver colour top layer to reflect more solar radiation on the crops and black bottom layer to enhance the soil temperature. The polyethylene mulch sheet was spread over the drip lateral pipes carefully and the edges were sealed with soil without much air trapped inside. The sowing lines were marked on the polyethylene sheets using sowing rope with markings at required spacing (60cm plant to plant). The holes were made using a two inch GI pipe against the already spread and edges sealed poly mulch at 60 cm spacing followed by sowing of cotton seeds carefully in the sowing holes. The spacing followed was 100 cm X 60 cm. Irrigations were given as per the treatments. The volume of water to be given through drip was calculated using following the formula $V=E_p$ x K_p (0.7) x K_c x A Where, V + Volume of water to be given (liters) / dripper, E_p = Pan evaporation (mm), K_p = Pan co efficient (0.7), K_c = Crop co efficient which vary for different growth stages of crop as per FAO Irrigation water Management Training Manual No.3 (Brouwer and Heibloem, 1986). For cotton, the crop co-efficient (K_c) was 0.45 for initial stage (0-25 DAS), 0.75 for development stage (26-70 DAS), 1.15 for boll development stage (71-120 DAS) and 0.75 for maturity stage (121-harvest). The evaporation reading recorded from the class A open pan evaporimeter was considered as 100 percent Etc and after adjusting to pan factor (for Guntur, it is 0.7), crop coefficient, the volume of water to be given for 0.4 Epan, 0.6 Epan and 0.8 Epan had been calculated using the above formula and irrigation was given as per the treatments on alternate days.

During the season, the cotton crop received 549.6 and 541.4 mm rainfall in the first and second year of experimentation respectively. Growth and yield parameters like number of monopodia, number of sympodia, number of bolls per plant, boll weight, seed cotton yield, seed index, lint index, GOT (%) and fibre quality, water use efficiency and nitrogen use efficiency was calculated accordingly. The results of both the years of experimentation has shown the same trend and hence the data of two years were pooled and analysed using standard analysis of variance.

RESULTS AND DISCUSSION

The poly ethylene mulching promoted the growth of cotton Jadoo BG II hybrid as could be seen from plant height enhancement 17 to 39 cm, and increment in number of sympodia per plant to tune of 4.24 to 7.23 under drip system, polymulch + drip system than rainfed (control). This might be due to favourable micro climate under polyethylene mulching and drip with higher available soil moisture lesser weeds competition and other favourable growth environment (Chen and Yin, 1989, Nalayini *et al.*, 2009). The conducive growth environment and micro climate under polyethylene mulching with or without drip on growth components were finally reflected in better assimilate partitioning to reproductive structures as recorded from production of 10.1 to 38.2 per cent enhancement in bolls per plant than rainfed (control). Growth stimulating condition under polyethylene mulching and polymulch + drip system has resulted in significant enhancement in assimilates partitioning towards economic produce. Thus, contributing significantly to higher seed cotton yield ranging from 10.96 to 40.35 per cent higher yield than rainfed. Elias and Goldhamer (1991) have reported 39 per cent enhanced yield in California due to polymulching in cotton crop. The drip irrigation also enhanced the seed cotton yield ranging from 17.99- 29.84 per cent higher yield than rainfed (control). The polyethylene mulch + drip system at 0.6 Epan has recorded significantly higher seed cotton yield (Table 1). Lowest seed cotton yield was recorded in rainfed (control). Poly mulching recorded significantly superior seed cotton yield over control and was on par with 0.8 Epan +P. There was no significant variation in seed index, lint index and ginning out turn among the treatments. The water use efficiency is an important factor for gaining maximum returns from limited water resources. Polymulching recorded a complete control of loss of water due to evoparationand thereby recorded higher water use efficiency than rainfed (control). Among the treatments, 0.6 Epan + polymulching recorded the highest water use efficiency of 6.9 kg seed cotton/ha/mm of water than rainfed with 6.02 kg seed cotton/ha/ mm of water.

Table 1. Growth, yield attributes, seed cotton yield and water use efficiency of cotton as influenced by drip polymulching and drip with polymulchin

Treatments	Plant height (cm)	Mono-podia/ plant	Sym-podia/ plant	Bolls/ plant	Boll wt. (g)	Seed index (g)	Lint index (g)	GOT (%)	Seed cotton yield (kg/ha)	Cons-umptive use (mm)	WUE (kg/ ha/ mm)	NUE (kg/ ha/ mm)
Control	136	1.93	18.615	60.72	4.04	9.72	4.87	33.32	3284	545.5	6.02	27.37
Polymulching (P)	158	2.2	22.865	66.83	4	9.945	5.275	34.61	3681	545.5	6.75	30.67
0.4 Epan	160	2.07	24.185	72.1	3.925	9.095	4.865	33.15	3875	632.3	6.20	32.29
0.4 Epan +P	153	1.73	23.25	74.765	4.01	9.75	4.9	33.42	4116	632.3	6.58	34.30
0.6 Epan	175	2.4	25.85	78.265	4.205	10.095	5.01	33.16	4264	675.7	6.39	35.70
0.6 Epan +P	160	2.53	25.185	83.9	4.11	9.22	4.615	33.28	4609	675.7	6.90	38.41
0.8 Epan	169	2.47	25.75	71.565	4.01	9.84	4.87	33.15	3979	719.1	5.64	33.15
0.8 Epan +P	160	2.73	23.85	66.885	3.94	9.86	4.935	33.28	3644	719.1	5.16	30.36
SEm +	7.05	0.265	1.085	1.555	0.09	12.25	0.235	0.605	104.03	-	-	-
CD (p=0.05)	21.49	NS	3.27	4.785	NS	NS	NS	NS	315	-	-	-

REFERENCES

Lomte, D. M and Kadge, N.V. 2009. Responce of hybrid cotton (*Gossypium hirsutum* L.) to different levels of drip irrigation on Vertisol. *J.Cotton Res.Dev.***23**: 100-03.

Nalayani, P., Anandham R., Sankaranarayanan K. And Rajendran T.P. 2009. Polyethylene mulching for enhancing crop productivity and water use efficiency in cotton (*Gossypium hirsutum* L.) and maize (*Zea mays)* cropping system. *Ind. Jour.Agro.* **54**:409-14.

Cetin, O and Bilgen, L. 2002. Effects of irrigation methods on scheduling and yield of Cotton. Agric. *Water Manag.***54**: 1-15.

Brouwer, C. And Heibloem, M. 1986. Irrigation water needs. Irrigation water management. Training Manual No.3, FAO, Rome, Italy

Chen, Q.E. and Yin, J.S. 1989. Effects of plastic mulch on soil properties and cotton growth in saline-alkali soils. *Jour. Soil Sci.* (China) **20**: 1-3.

Elias, F and Goldhamer, D.A. 1991. Plastic mulch increases Cotton Yield, reduces need for preseason irrigation. *California Agriculture* **45**: 25-28.

Effect of macro nutrients and liquid fertilizers on the growth and yield of *Bt* cotton (*Gossypium hirsutum* L.) under irrigation

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ABSTRACT ***:*** The field experiment was conducted at Research farm, College of Agriculture, Raichur on medium black soil during *kharif*, 2011 to study the effect of macro nutrients and liquid fertilizers on the growth and yield of *Bt* cotton (*Gossypium hirsutum* L.) under irrigation. The experiment was laid out in split plot design with three replications. Application of three levels of macro nutrients (75, 100 and 125% RDF) was tried in main plots. Foliar spray of liquid fertilizers was allotted to the sub plots *viz.,* S_1: Control, S_2: Foliar application of nutroplus (2 ml/l of H_2O (N/ 11.96%, K/7.25%, Mg/ 2.90%, Ca/14.5% and B/0.15%), S_3: Foliar application of Bio 20 @ 3 ml/ l of H_2O (N/20%, P/20%, K/20%, Mg/1.5%, Fe/0.146%, Zn/0.0.73%, Cu/ 0.073%, Mn/0.073%, Bo/0.029%, Mo/0.0012% and Co/0.0012%), S_4 : Foliar application of 1 per cent $MgSO_{-4}$ (Mangala $MgSO_4$) + 0.5 per cent $ZnSO_4$ (Mahazinc) and S_5: Foliar application of 2 per cent KNO_3. The results revealed that application of 125 per cent RDF recorded the highest seed cotton yield (q /ha), total number of bolls harvested/plant, seed cotton yield/plant, leaf area (dm^2 /plant), leaf area index, dry matter production and its distribution, gross returns, net returns and B:C ratio.(19.25q /ha, 26.19, 106.92 g /plant, 103.26 dm^2 /plant, 1.91, 336.83 g /plant, Rs.79,718/-, Rs.56,740/- and 3.51, respectively). Among the liquid fertilizers, foliar spray of liquid fertilizer, Bio 20 @ 3 ml/1 recorded significantly higher seed cotton yield (18.10 q /ha), bolls harvested/plant (24.88), seed cotton yield/plant (100.66 g), leaf area (73.20 dm^2 /plant), leaf area index (1.35), dry matter production and its distribution (308.90 g/plant), gross returns (Rs 75,022 /ha), net returns (Rs 51,964 /ha).

Key words : Bio 20, liquid fertilizers, RDF

Cotton (*Gossypium hirsutum* L.) is one of the most important fibre crops of India playing key role in Indian economy by contributing nearly 33 per cent of total foreign exchange earnings of India. In India cotton has an area of 10.19 m ha with a production of 35.6 m bales and productivity of 496 kg lint /ha during 2011-2012 as against an area of 5.88 m ha with a production of 3.04 m bales and productivity of 88 kg /ha in 1950-1951 as per Cotton Advisory Board during 2011-12. In Karnataka, cotton occupies an area of 5.40 lakh ha with a production of 14.0 lakh bales and with productivity of 434 kg lint/ha (CAB 2011). The Northern dry zone of the state (Zone 2 and 3) cover partly the Tungabhadra and Upper Krishna Command areas (TBP and UKP). In these regions, *Bt* cotton is intensively cultivated on black soil under irrigation. The area under this crop in these command areas has been increasing distinctly over the past half decade and occupying more than 1.5 lakh ha during 2009-2010. The average seed cotton yield is around 20 q /ha which is far less than actual potential yield. To meet these demands, the cotton production and productivity has to be increased considerably. The factors responsible for low productivity in Tungabhadra Project (TBP) area of Karnataka are mainly due to imbalanced use of fertilizers, deficiency of micronutrients and physiological disorders (shedding of floral parts like squares, flowers and bolls) and due to pests (cotton bollworms). In this direction, a detailed research on combined effect of macro nutrients and liquid fertilizers was undertaken to maximize the seed cotton yield.

MATERIALS AND METHODS

The field experiment was conducted during *kharif*, 2011 at Agricultural College Farm, Raichur situated in North Eastern Dry Zone (Zone-2) of Karnataka at 16° 12' N latitude and 77° 20' E longitude with an altitude of 389 meters above the mean sea level. The experiment was laid out in split plot design with RDF (75, 100 and 125 %) in main plots and liquid fertilizers {control, foliar application of nutroplus @ 2 ml/lit, foliar application of Bio 20 @ 3 ml/lit, foliar application of $MgSO_4$ (1%) + $ZnSO_4$ (0.5%) and Foliar application of KNO_3 (2%) in sub plots with three replications. In main plot treatments *i.e.,* half of the nitrogen dose, entire dose of phosphorus and potassium in the form of urea, diammonium phosphate (DAP) and muriate of potash (MOP) were applied as basal dose and remaining half of the nitrogen in the form of urea was top dressed in three equal splits at 50, 80 and 110 days after sowing in the ring formed 5 cm away from the plant. The sub plot treatments *i.e.,* foliar spray of liquid fertilizers were imposed at flowering (90 DAS), boll formation stage (110 DAS) and boll bursting (125 DAS) of the cotton crop. The experimental field was clayey (56.05 % clay) in texture with the available nitrogen (218.00 kg /ha), phosphorus (32.00kg /ha), potassium (180.67 kg /ha) and organic carbon content (0.60 %), respectively. Sowing was done by hand dibbling as per the treatments on 08-07-2011.

RESULTS AND DISCUSSION

Effect of fertilizer levels : Application of 125 per cent RDF produced significantly higher seed cotton yield (19.25 q /ha), seed cotton yield (106.92 g /plant), mean boll weight (4.13g), number of bolls/plant (26.19), leaf area per plant (103.26 dm/plant), leaf area index (1.91), gross returns (Rs 79,718 /ha), net returns (Rs 56,740 ha), benefit cost ratio (3.51), NPK uptake (107.81, 30.08 and 109.25 kg /ha). (Table 1 and 2) over 100 per cent RDF (17.04 q /ha, 94.86 g / plant,24.42 , 100.63 dm/plant , 1.86, Rs 70,505 / ha, Rs 48,723 /ha 3.24,103.00, 26.80 and 104.53 kg NPK /ha, respectively). Seed cotton yield is governed by several factors, which have a direct or indirect impact. The factors which have a direct influence on seed cotton yield are yield components *viz.,* bolls harvested/plant, good opened bolls/plant, mean boll weight, lint index, ginning percentage and growth parameters like dry matter production and its amassing into various plant parts (leaf, stem and reproductive parts) and leaf area have a direct influence on the seed cotton yield and inturn have their dependence on growth fluctuation Solunke *et al.,* (2009), Hallikeri and Halemani (2002). The climatic factors may have circumlocutory influence on the seed cotton yield. In the present investigation, all these growth and yield attributing characters increased significantly due to application of RDF and might have contributed for increased yield, which were noticed with the application of 125 per cent RDF (Table 1 and 2). These results are in orthodoxy with those of, Anup Das *et al.,* (2006), Basavanneppa *et al.,* (2009), Solanke *et al.,* (2000), Katkar *et al.* (2002) and Moola Ram and Giri (2006) due to application of higher level of RDF.

Table 1. Leaf area (dm/plant), LAI , boll weight (g), bolls/plant, seed cotton yield (g/plant) and seed cotton yield (q/ha) of *Bt* cotton as influenced by macro nutrients and liquid fertilizers

Treatments	Leaf area (dm/plant)	LAI	Boll weight (g)	Number of bolls/plant	Seed cotton yield (g/plant)	Seed cotton yield (q/ha)
Main plots						
F_1 RDF (75%)	98.51	1.84	3.74	20.68	76.90	13.82
F_2 RDF (100%)	100.63	1.86	3.89	24.42	94.86	17.04
F_3 RDF (125%)	103.26	1.91	4.13	26.19	106.92	19.25
Mean	**100.80**	**1.87**	**3.92**	**23.75**	**92.89**	**16.70**
S.Em±	0.22	0.009	0.01	0.08	1.32	0.15
C.D. (p=0.05)	0.63	0.027	0.03	0.24	3.73	0.42
Sub plots						
S_1 Control	96.90	1.79	3.75	22.85	85.64	15.20
S_2 Foliar spray nutroplus (2%)	100.66	1.87	3.85	23.40	90.40	16.34
S_3 F.S. Bio 20 (3%)	102.93	1.91	4.06	24.88	100.66	18.10
S_4 F.S. $MgSO_4$ (1%)+$ZnSO_4$ (0.05%)	101.56	1.89	3.95	23.50	92.45	16.64
S_5 F.S. KNO_3 (2%)	102.18	1.88	3.97	24.12	95.32	17.21
Mean	**100.80**	**1.87**	**3.92**	**23.75**	**90.89**	**16.70**
S.Em±	0.29	0.006	0.01	0.11	1.71	0.19
C.D. (p=0.05)	0.81	0.018	0.04	0.31	4.82	0.55
S at the same F level						
S.Em±	0.56	0.01	0.03	0.27	4.18	0.47
C.D. (p=0.05)	1.65	NS	NS	NS	NS	NS
F at the same or different S levels						
S.Em±	1.11	0.01	0.02	0.24	3.41	0.35
C.D. (p=0.05)	3.35	NS	NS	NS	NS	NS

DAS – Days after sowingNS – Non significant

Effect of liquid fertilizers : Foliar spray of Bio 20 @ 3 ml/lit produced significantly higher seed cotton yield per ha (18.10 q /ha) followed by 2 per cent KNO_3 (17.21 q /ha) and 1 per cent $MgSO_4$ + 0.5 per cent $ZnSO_4$ (16.64 q /ha), foliar application of nutroplus 2 ml/l (16.34q /ha) and 1 per cent $MgSO_4$ + 0.5 per cent $ZnSO_4$ (16.64 q / ha) recorded *on par* results. Foliar spray of Bio 20 @ 3 ml/lit produced higher seed cotton yield (100.66 g /plant) over control (85.64 g /plant). These were *on par* with the results obtained by the spray of 2 per cent KNO_3, 1 per cent $MgSO_4$ + 0.5 per cent $ZnSO_4$ and nutroplus 2 ml/lit (95.32, 92.45 and 90.40 g /plant, respectively.). Higher boll weight (4.06g) was recorded by the application of Bio 20 @ 3 ml/l, which differed significantly with foliar spray of 2 per cent KNO_3 (3.97g) and 1 per cent$MgSO_4$+0.5 per cent $ZnSO_4$ (3.95g), foliar spray of nutroplus 2 ml/l (3.85g) and control (3.75g). Foliar application of Bio 20 @ 3 ml/lit produced significantly higher number of bolls per plant at harvest (24.88) when compared to other foliar sprays. Foliar application of Bio 20 @ 3 ml/ lit (102.93 dm2 /plant) recorded highest leaf area/plant. Significantly higher nitrogen uptake (110.80 kg/ha) was recorded with Bio 20 @ 3 ml/ l over control (93.36 kg/ha) which inturn was on par with 2 per cent KNO3 (106.14 kg/ha). Higher phosphorus uptake (30.16 kg/ha) was recorded with the foliar spray of Bio 20 @ 3 ml/ lit over control (22.67 kg/ha). Foliar spray of nutroplus 2 ml/l of H2O, 1 per cent MgSO4 + 0.5 per cent ZnSO4 and 2 per cent KNO3 recorded *on par* results (26.64, 26.87 and 27.45 kg/ha,

Table 2. Gross returns (Rs/ha), net returns (Rs./ha), BC ratio, nitrogen (kg/ha), phosphorus (kg/ha) and potassium (kg/ha) uptake of *Bt* cotton as influenced by macro nutrients and liquid fertilizers

Treatments	Gross returns (Rs/ha)	Net returns (Rs/ha)	BC ratio	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potassium (kg/ha)
Main plots						
F_1 RDF (75%)	57,231	36,572	2.77	98.38	23.39	100.67
F_2 RDF (100%)	70,505	48,723	3.24	103.00	26.80	104.53
F_3 RDF (125%)	79,718	56,740	3.51	107.81	30.08	109.25
Mean	**69,151**	**47,345**	**3.17**	**103.06**	**26.75**	**104.81**
S.Em±	212.98	266.42	0.01	1.45	0.67	0.90
C.D. (p=0.05)	601.50	752.43	0.03	4.09	1.90	2.53
Sub plots						
S_1 Control	63,762	44,072	3.29	93.36	22.67	91.42
S_2 Foliar spray nutroplus (2%)	67,304	44,186	2.90	102.00	26.64	104.30
S_3 F.S. Bio 20 (3%)	75,022	51,964	3.25	110.80	30.16	112.25
S_4 F.S. $MgSO_4$ (1%)+$ZnSO_4$ (0.05%)	68,608	47,924	3.31	103.00	26.87	107.50
S_5 F.S. KNO_3 (2%)	71,064	48,578	3.16	106.14	27.45	108.63
Mean	**69,151**	**47,345**	**3.17**	**103.06**	**26.75**	**104.81**
S.Em±	274.96	343.95	0.01	1.87	0.87	1.16
C.D. (p=0.05)	776.53	971.38	0.03	5.28	2.46	3.27
S at the same F level						
S.Em±	673.50	842.50	0.03	4.58	2.13	2.84
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS
F at the same or different S levels						
S.Em±	399.86	635.03	0.01	2.71	1.53	2.33
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS

DAS – Days after sowingNS – Non significant

respectively). Significantly higher potassium uptake (112.25 kg/ha) was recorded with the foliar spray of Bio 20 @ 3 ml/l and lower uptake (91.42 kg/ha) without foliar spray of liquid fertilizers. The treatments 1 per cent MgSO4 + 0.5 per cent ZnSO4 and 2 per cent KNO3 recorded *on par* results (107.50 and 108.63 kg/ha, respectively). Significantly higher gross returns (Rs. 75,022 /ha) were obtained with the application of 3 ml/l Bio 20 when compared to other foliar sprays. While lower gross return (Rs. 63,762 /ha) was recorded in control. Foliar spray with Bio 20 @ 3 ml/l recorded higher net returns (Rs. 51,964 /ha) as compared to 2 per cent KNO_3 (Rs. 48,578 /ha), 1 per cent $MgSO_4$ + 0.5 per cent $ZnSO_4$ (47,924 /ha) and 2 ml/lit nutroplus (Rs. 44,186 /ha). With regard to Bc ratio, foliar spray of 1 per cent $MgSO_4$ + 0.5 per cent $ZnSO_4$ (3.31) and control (3.29) recorded *on par* results and differed significantly than Bio 20 @ 3 ml/l, 2 per cent KNO_3 and nutroplus 2 ml/lit (3.25, 3.16 and 2.90, respectively).). Liquid fertilizer Bio 20 contains both macro and micro nutrients *viz.,* N, P, K, Mg, Zn, Fe, Co, Cu, Bo, Mo, Mn, which helped in chlorophyll formation, photosynthesis and uptake of other nutrient and enabled the plant to absorb the required nutrients from the solution through leaf surface and met the demand of crops for nutrients at the later stage. All these growth and yield attributing characters increased significantly due to application Bio 20 and which might have contributed for increased yield.(Table 1 and 2).

REFERENCES

Anup Das, Prasad, M., Gautam, R.C. and Shivay, Y.S., 2006. Productivity of cotton (*Gossypium hirsutum* L.) as influenced by organic and inorganic sources of nitrogen. *Indian J. Agric. Sci.,* **76** : 354-57.

Basavanneppa, M. A., Aladakatti, Y. R., Biradar, D. P. and Nidagundi, J. M., 2009. Response of Bt cotton to foliar nutrition under irrigated condition. National Symposium on *"Bt-Cotton: Opportunities and Prospects"* Nov.17-19, 2009. p.73. *Cotton Advisory Board* (CAB), 2011.

Hallikeri, S.S. and Halemani, H.L., 2002. Effect of spacing and fertilization on *hirsutum* cotton variety sahana under irrigated conditions. *J. Cotton Res. Dev.*, **16**: 181-85.

Katkar, R.N., Turkhede, A.B., Solanke, V.M., Wankhade, S.T. and Sakhare, B.A., 2002. Effect of integrated nutrient management of organic manures and fertilizers on soil properties and yield of cotton. *J. Cotton Res. Dev.*, **16**: 89-92.

Moola Ram and Giri, A. N., 2006. Response of newly released cotton (*Gossypium hirsutum* L.) varieties to plant densities and fertilizer levels. *J. Cotton Res. Dev.*, **20**(1): 85-86.

Solanke, V.M., Wankhede, S.T., Turkhede, A.B., Katkar, R.N. and Malvi, S.D., 2000. Agronomic requirement of new *hirsutum* hybrids in relation to their plant densities and fertilizer levels. *PKV Res. J.,* **24**(1): 1-4.

Solunke, P.S., Thokale, J.G. and Borve, U.S., 2009. Influence of foliar feeding of different micronutrients on yield and economics of hybrid cotton. National Symp. *"Bt. Cotton – Opportunities and Prospects",* Nagpur, p. 70.

Efficacy of glyphosate and other herbicides in management of weeds in rainfed cotton (*Gosspium hirsutum* L.) under high density planting system

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Cotton crop is prone to severe weed competition during its slow initial growth stage. It is infested with grasses, sedges and broad leaf weeds under upland ecosystem during the rainy season. The yield reduction due to weed infestation could be to the tune of 60 per cent (Sadangi and Barik, 2007). The crop weed competition for moisture and nutrients aggravates under high density planting system (HDPS) under the rainfed cotton growing tracts of India. Manual weeding and intercultivation are difficult due to closure crop canopy, low soil moisture and at times incessant rainfall during vegetative stages under HDPS. It is common recommendation to apply pendimethalin as pre-emergence spray supplemented with two to three intercultivations (Prabhu *et al.,* 2010). Several workers evaluated the use of post emergence herbicides like pyrythiobac sodium (Rao, 2011), glyphosate (Prabhu *et al.*, 2011 and Rao, 2011), and quizalofop-p-ethyl (Prabhu *et al.*, 2011 and Rao, 2011) either alone or in combination. The primary mode of action of pendimethalin is to prevent plant cell division and elongation in susceptible species. Pyrithiobac sodium inhibits acetolactase synthase, a key enzyme in biosynthesis of branched chain amino acids. Quizalofop-p-ethyl inhibits acetyl CoA carboxylase, a key enzyme in biosynthesis of fatty acids. Glyphosate kills plants by inhibiting enol pyruvyl shikimate phosphate synthase a key enzyme necessary for the biosynthesis of aromatic amino acids like phenylalanine, tyrosine and tryptophane, auxins, phytoalexins, folic acids, lignin and many other secondary products. Thus an attempt has been made in this study for sequential application of pendimethalin and quizalofop-p-ethyl, tank mixing of pyrithiobac sodium and quizalofop-p-ethyl and post-emergence application of glyphosate at different doses having different modes of action along with one hoeing in order to achieve the most effective and economic method of weed management in cotton grown under HDPS.

MATERIALS AND METHODS

A field experiment was carried out at the research farm of the All India Coordinated Cotton Improvement Project located in the Regional Research and Technology Transfer Station, Bhawanipatna, Odisha University of Agriculture and Technology during *kharif,* 2014 to evaluate different weed management methods in cotton grown under HDPS. The trial was laid out in a randomized block design with three replications using 11 treatments as mentioned in Table 1. The soil of the experimental site was clay loam in texture, low in available N, medium in available P and K with pH of 7.3. The cotton cultivar Suraj was sown with a spacing of 60 x

10 cm. The crop was raised with all recommended package of practices other than the weed control measures which were under testing. Pendimethalin was applied as pre emergence (PRE) spray @ 1.0 kg ha^{-1} at one day after sowing (DAS). Post emergence (POE) application of pyrithiobac sodium @ 62.5 g/ha and quizalofop-p-ethyl @ 50 g/ha was made at 20 DAS and glyphosate @ 0.5 kg/ha, 0.75 kg/ha and 1.0 kg/ha was done at 40 DAS. All the herbicides were followed by one hoeing at 40 DAS except glyphosate and the weedy check. One hoeing was done at 20 DAS in the glyphosate treated plots. In the weed free treatment, three hoeing and weeding were carried out at 20, 40 and 60 DAS. The herbicides were sprayed with knapsack sprayer fitted with flat fan nozzle using the spray volume of 500 l/ha. Weed density and dry weight were recorded at 30, 60 and 90 DAS.

RESULTS AND DISCUSSION

Data presented in Table-1 showed that among all the weed management treatments weed free check recorded significantly the highest seed cotton yield (SCY), bolls/plant, bolls/m and boll weight. This was followed by one hoeing at 20 DAS + Glyphosate @ 1.0 kg/ha, one hoeing at 20 DAS + Glyphosate @ 0.75 kg/ha and one hoeing at 20 DAS + Glyphosate @ 0.50 kg/ha which were *at par*.

The weeds/m was significantly the lowest in weed free check at 30 DAS (44), 60 DAS (20) and 90 DAS (12.7). Among the herbicides, the lowest weeds/m^2 was observed with one hoeing at 20 DAS + Glyphosate @ 1.0 kg/ha at 30 DAS (131), 60 DAS (73) and 90 DAS (51) followed by T_8 and T_7. The weed density was the highest in weedy check plot. Weed population showed a decreasing trend from 30 DAS to 90 DAS in all the treatments.

The weed dry weight/m^{-2} was significantly the lowest in weed free check at 30 DAS (29.9 g), 60 DAS (14.4 g) and 90 DAS (9.5 g). Among the herbicides, the lowest weed dry weight/m^{-2} was observed with T_9 at 30 DAS (88.9 g), 60 DAS (52.3 g) and 90 DAS (38.8 g) followed by T_8 and T_7. The weed dry weight was the highest in weedy check plot. Weed dry weight showed a decreasing trend from 30 DAS to 90 DAS in all the treatments.

The weed control efficiency was significantly the highest in weed free check at 30 DAS (87.2 %), 60 DAS (93.1 %) and 90 DAS (95.2 %). Among the herbicides, the highest weed control efficiency was observed with T_9 at 30 DAS (62.2 %), 60 DAS (74.7 %) and 90 DAS (80.6 %) followed by T_8 and T_7.

CONCLUSION

Therefore, it may be concluded that the integrated method of one hoeing at 20 DAS + post-emergence application of Glyphosate @ 1.0 kg ha^{-1} as directed spray at 40 DAS was the most effective and economic method of weed control in rainfed cotton grown under high density planting system.

REFERENCES

Patel, J.G., Raj, V.C., Usadadiya, V.P., Parmar, R.R., Sutaria, C.M., Leva, R.L. and Kumar, V. 2011. Comparative efficiency and economic viability of herbicides for controlling weeds in *Bt* cotton (*Gossypium hirsutum L.*). Book of papers of *"World Cotton Research Conference-5,"* 7-11 November, 2011, Mumbai, India, pp: 396-98.

Prabhu, G., Halepyati, A.S. and Pujari, B.T. 2010. Weed management studies in *Bt* cotton (*Gossypium hirsutum*) under irrigated

Table 1. Characters influenced by different treatments

Treatments	SCY (kg/ha)	Bolls/ plant	Bolls/ m^2	Boll weight (g)	Weed density (No,/m^2)			Weed dry weight (g/ m^2)			Weed control efficiency (%)		
					30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T1- Pendimethalin @ 1.0 kg a.i/ha as Pre- emergence + one hoeing at 40 DAS	1436	3.0	62	2.4	272	214	192.7	184.7	153.8	144.5	21.3	25.5	27.5
T2- Quizalofopethyl @ 50 g a.i/ha 20 DAS + one hoeing at 40 DAS	1147	2.6	54	2.3	284	226	205.3	193.3	163.0	154.0	17.6	21.2	22.8
T3- Pyrithiobac Sodium @ 62.5g a.i/ha 20 DAS +one hoeing at 40 DAS	1476	3.4	71	2.4	247	189	168.3	168.2	136.3	126.3	28.5	34.2	36.9
T4- Pendimethalin 1.0kg a.i/ha + Quizalofopethyl 50g a.i/ha at 20 DAS + one hoeing at 40 DAS	1584	4.5	93	2.3	227	169	147.7	154.1	121.4	110.8	34.4	41.4	44.6
T5- Pendimethalin 1.0kg a.i/ha + Pyrithiobac Sodium @ 62.5g a.i/ha 20 DAS + one hoeing at 40 DAS	1632	4.6	97	2.6	211	153	132.3	143.7	110.4	99.3	38.7	46.5	50.1
T6- Pyrithiobac Sodium @ 62.5g a.i/ha + Quizalofopethyl 50g a.i/ha at 20 DAS + one hoeing at 40 DAS	1544	4.3	89	2.3	258	200	178.7	175.2	143.8	134.0	25.5	30.6	33.0
T7-One hoeing at 20 DAS + Glyphosate @ 0.5kg a.i/ha as directed spray at 40 DAS	2605	5.1	107	2.8	202	144	122.7	137.1	103.4	92.0	41.5	49.8	53.7
T8- One hoeing at 20 DAS + Glyphosate @ 0.75kg a.i/ha as directed spray at 40 DAS	2632	5.4	113	2.9	179	121	100.3	121.9	87.4	75.3	48.1	57.8	62.4
T9- One hoeing at 20 DAS + Glyphosate @ 1.0 kg a.i/ha as directed spray at 40 DAS	2677	5.8	132	2.9	131	73	51.7	88.9	52.3	38.8	62.2	74.7	80.6
T10- Weed free check (manual weeding at 20, 40 and 60 DAS)	3013	6.6	167	3.1	44	20	12.7	29.9	14.4	9.5	87.2	93.1	95.2
T11-Weedy check	884	1.9	40	1.9	346	288	266.7	235.1	207.1	200.0	0	0	0
SEm +	164.4	0.22	4.67	0.13	6.74	6.49	6.51	4.58	4.68	4.87	1.81	2.21	2.34
CD (p=0.05)	465.21	0.67	14.02	0.38	20.21	19.49	19.50	13.74	14.04	14.62	5.44	6.58	6.97

conditions. Proceeding of XIX National Symposium on *"Resource Management Approach towards Livelihood Security"*, 2- 4 December, 2010, UAS, Bangalore, pp: 263.

Prabhu, G., Halepyati, A.S. and Pujari, B.T. and Desai, B.K. 2011. Integrated weed management in *Bt* cotton (*Gossypium hirsutum L.*) under irrigated conditions. *Karnataka J. Agric. Sci.* **24** : 529-30.

Rao, A.S. 2011. Evaluation of pyrithiobac alone and in combination with grassy herbicides on weed control in cotton. Book of papers of *"World Cotton Research Conference-5"*, 7-11 November, 2011, Mumbai, India, pp: 406-09.

Sadangi, P.K. and Barik, K.C. 2007. Effect of weed management practices on nutrient depletion by weeds, yield and economics in winter irrigated cotton (*Gossypium hirsutum*). *Indian J. Agron.* **52** : 172-75.

Empowerment of women to mitigate drugery in cotton picking

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Abstract Agriculture is the primary source of employment for most developing countries including India. Women in Haryana are involved in most of the agricultural operations viz. transplanting, weeding, harvesting, post-harvest activities picking and plucking. Hisar is a pre-dominantly cotton growing district. Cotton is known as ‘White Gold’ grown in 85000 ha. Cotton picking is the tedious job exclusively handled by women folk. The study was conducted in the month of October- November at cotton farms of nine villages viz., Kirtan, Ladwa, Kishangarh, Bhagana, Talwandi Rana, Tokas, Neolikalan, Umra and Sadalpur of Hisar districts compromising of 200 respondents. Schedule was developed to collect data on socio economic profile of the respondents. However, cot bag was further tested on all the 200 women for 1 hour of cotton picking activity with both existing and improved method. During experiment time and activity profile, work output and acceptability of the cot bag was assessed. They reported very severe pain in palm, wrist, fingers, neck and shoulders. To mitigate these problems cotton picking bag developed by CCSHAU, Hisar was recommended. The results revealed that by using conventional bag the rural women could pick upto 40 kg of cotton in 7hr and earned Rs 200/day but by using cotton picking bag they could pick 50 kg of cotton in 7 hr, thus, earning Rs 250/person/day. Adequate rest pauses coupled with training on use of proper body postures along with light exercises for back and shoulders need to be given during the work to delay the onset of fatigue and its recuperation.

Key words : Cot bag, cotton picking, msusculo-skeletal problems

Women are involved in most of the agricultural operations *viz.,* transplanting, weeding, harvesting, post harvest activities like-picking and plucking, while in other agricultural related activities, they share the work with men folk. Hisar is a pre dominantly cotton growing district. Cotton is known as ‘White Gold’ and plays an important role in the agriculture and industrial activities of the nation .Our economy is consistently influenced by cotton through its production and processing sectors, and by generating direct and indirect employment to more than 8 million people. In Haryana, the cotton area includes five major districts namely Sirsa, Fatehabad, Hisar, Jind and Bhiwani and constitute 90 per cent of the crop in the state. Cotton picking is the tedious job exclusively handled by women folk. In Haryana, average 6-7 hours are spent daily in cotton picking. These jobs involve considerable amount of drudgery. Drudgery is conceived as physical and mental strain, fatigue, monotony and hardship experienced by human beings. Traditionally, she uses a cloth sheet/ head cloth for collecting picked cotton by tying it in the form of bag on their shoulders and back. Cotton picking with existing method leads to drudgery of the woman and retards her working efficiency. During the activity, cotton gets collected at the bottom of bag forming a ball like structure which droops down at her back. This touches her lower thighs and popliteal area and causes hindrance while walking during the activity. To mitigate these problems, cotton picking bag developed by CCS

HAU, Hisar was recommended. It is made of cotton clothes and designed as per anthropometric measurements of women. Shaped pockets provided in front and below waist line make it user friendly. It reduces drudgery of women while picking cotton. Cushioned belts avoid strain on shoulder, hand and neck. The present study was planned with following specific objectives:-

OBJECTIVES

- Assessment of socio economic and work profile of women involved in picking cotton.
- Studying musculo skeletal discomforts perceived by women while performing activity.
- Ascertaining acceptability of cot bag for selected parameters.

MATERIALS AND METHODS

The study was conducted in the month of October- November at cotton farms of nine villages *viz.,* Kirtan, Ladwa, Kishangarh, Bhagana, Talwandi Rana, Tokas, Neolikalan, Umra and Sadalpur of Hisar districts compromising of 200 respondents. Schedule was developed to collect data on socio economic profile of the respondents. However, cot bag was further tested on all the 200 women for 1 hr of cotton picking activity with both existing and improved method. During experiment time and activity profile, work output and acceptability of the cot bag was assessed. Musculo-skeletal problems as perceived by women while picking cotton through traditional method and with the help of cot bag was measured through Human Body map (Corlette and Bishop, 1976). Five point scale ranging from very severe pain (5) to very mild pain (1) was used to quantify the stress on muscles used in work. Participatory Rural Appraisal (PRA) was conducted in these villages.

RESULTS AND DISCUSSIONS

Results pertaining to the study are presented under relevant headings as socio-economic profile of respondents, economic profile, acceptability parameters for cot bag, perception of women on health, work and drudgery reduction ability of cot bag etc.

Table 1. Socio personal profile of respondents n=200

Socio personal variables	Frequency	Percentage
Age		
Upto 20 years	25	12.50
20-40 years	160	80.00
Above 40 years	15	7.50
Education		
Illiterate	63	31.50
Upto primary	88	44.00
Upto high school	47	23.50
Graduate	2	01.00
Family Education Status		
Low	123	61.50
Medium	75	37.50
High	2	01.00
Marital Status		
Unmarried	37	18.50
Married	163	81.50
Family Type		
Nuclear	62	31.00
Joint	138	69.00
Family Size		
Up to 4 members	58	29.00
5-7 members	127	63.50
Above 7 members	15	7.50

Perusal of data in Table 1 reveals that overwhelming majority of respondent's falls in the age group of 20-40 years of age (80.00%) followed by those who were up to 20 years of age (12.50) and above 40 years of age (7.50). Majority was educated up to primary level (44.00%), however 31.50 were illiterate. Remaining were educated up to high school level (23.50) while small percentage (1.00) have got formal education up to graduate level. Majority of respondents were having a low family education status (61.50%) followed by those who were having medium level (37.50), while just one percent have high level of education. Mostly were married (81.50%), having a joint family system (69.00%) and a family size between 5-7 members (63.50 %).

Regarding Economic profile of the respondents, data in Table 2 indicates that agriculture was the main occupation for more than half of the respondents (60.00%) followed by one-third respondents (31.50%) who were engaged as labourers primarily in agriculture sector. Only few (1.00) were in govt. service. Monthly family income was above Rs 6,000/ for about 40 per cent of the respondents followed by 31.50 who had income below Rs 3,000 and 29 per cent were having monthly income between Rs 3,000-6,000.

Perusal of data in Table 3 indicates that output of cotton picking was found to be more with the help of cot bag than the existing traditional jholis that women were using for picking. The increase in the amount of the cotton picked was due to proper collection of cotton in the improved cot bag. Unlike the traditional jholi, cot bag is very well adjustable on the shoulder and head of the workers and does not interfere with the hand and body movements of the workers. Hence, it can be concluded that cot bag showed better work output than existing tradition al jholi.

Musculo skeletal discomfort : Fig. 1 shows the musculo skeletal discomfort of cotton pickers. As hands are mainly involved continuously in cotton picking so very severe pain was reported in fingers and palms (m.s. = 4.8 and 4.5, respectively) . Moreover, they get abrasions while plucking cotton pods from hard and pointed cotton shells. This was followed by severe discomfort in mid back (m.s. = 4.4) , wrists (m.s. = 4.1) and lower back (m.s.= 4.0) .

Fig 1. Magnitude of musculo-skelatal discomfort

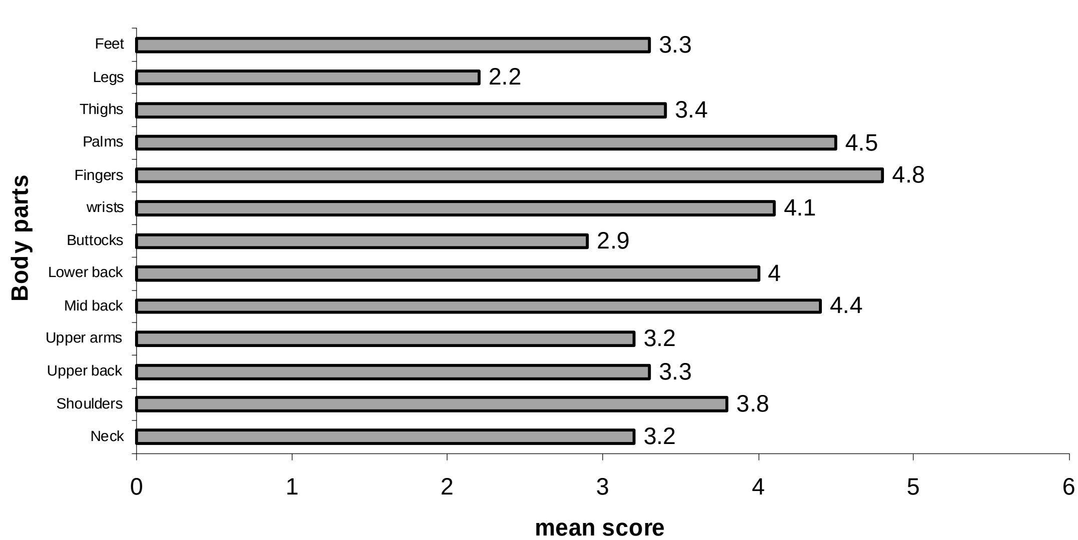

Table 2. Economic profile of respondents n=200

Economic variables	Frequency	Percentage
Occupations		
Agriculture	120	60.00
Private Sector	5	02.50
Govt. Service	2	01.00
Business	10	05.00
Labourer	63	31.50
Monthly Income		
Below Rs 3,000/month	63	31.50
Rs 3,000-6,000/month	58	29.00
Above Rs 6,000/month	79	39.50

Severe to moderate discomfort was reported in shoulders (m.s. = 3.8), thighs (m.s.= 3.4) and upper back and feet (m.s. = 3.3 each). During the activity, cotton gets collected at the bottom of bag forming a ball like structure which droops down at her back. This touches her lower thighs and popliteal area and causes hindrance while walking during the activity.This may be due to reason that that they used to stoop and change their posture 48 times for picking cotton pods from lower plants. Secondly, they used to bend to pick the cotton pods fallen on the ground while putting them in the pockets of bag at their back. For this they used to twist their hands and wrist putting stress on their shoulders too. Moreover, this stooping and bending was done while carrying weight of cotton pods in the bag hanged on their shoulders which they occasionally shifted at their head to relieve their shoulders for time being.

Table 3. Increase in cotton picking/day by cotton picking bag n=200

Cotton picking per day	Traditional Method		Cotton picking bag	
	Frequency	Percentage	Frequency	Percentage
Upto 20 Kg.	18	09.00	5	02.50
20-40 Kg.	170	85.00	87	43.50
40 Kg. & above	12	6.00	108	54.00

Data in Table 4 reveals that majority of women were highly relieved (60%) and relieved (37.50%) by using cot bag. Two third (71.50%) indicated that there work output was highly improved. It was considered highly acceptable and acceptable (64 and 36% respectively) by respondents. On field acceptability of cot bag, it was perceived to be highly acceptable by majority of women (59%). Data further indicate that overwhelming majority perceived reduction in pain in shoulder (92%), followed by neck and head (68%) and legs & thighs (50%). Regarding improvement in work efficiency, 98 percent reported picking more by using cot bag in comparison to traditional jholi. About fifty percent (48%) feel less fatigue on using cot bag, reducing back pain (53%) and less pain in hands (27%). Cot bag helped in reducing the drudgery of a women to a considerable extent as cot bag is evenly distributed over shoulder to hip region which helps the workers to maintain straight back without undue pressure on shoulders and lower back. Further workers were able to pick approximately 10 kg cotton more with cotton picking bag in 7 hours and thus earning Rs 250/day in comparison to traditional method of cotton picking where they were plucking approximately 40 kg cotton in 7 hr earning Rs 200/day. Therefore, it is important to introduce training programmes in villages to promote usage of cot bag not only to reduce drudgery of women but to enhance earning capacity and ultimately raising standard of living of farm families.

Table 4. Acceptability parameters for Cot Bag n=200

Parameters	Frequency	Percentage	
Biomechanical Stress			
	No relief	-	-
	Moderate relief	5	02.50
	Relieved	75	37.50
	Highly relieved	120	60.00
Work Output			
	No improvement	-	-
	Moderate relief	10	05.00
	Improved	47	23.50
	Highly improved	143	71.50
Tool Factor			
	Not acceptable	-	-
	Needs modification	-	-
	Acceptable	72	36.00
	Highly acceptable	128	64.00
Field Acceptability			
	Not acceptable	-	-
	Needs persuasion	-	-
	Acceptable	82	41.00
	Highly acceptable	118	59.00
Health Related Parameters			
	Reduce pain in shoulder	184	92.00
	Reduce pain in neck & hand	136	68.00
	Reduce pain in legs & thighs	100	50.00
Work Efficiency Related			
	Increase work efficiency	50	25.00
	Pick more cotton as compared to conventional bag	196	98.00
Drudgery Reduction Related			
	Less fatigue as compared to conventional bag	96	48.00
	Reducing backache	106	53.00
	Less pain in hands	54	27.00

CONCLUSIONS

Summarizing, cotton picking is primarily women’s responsibility in most part of India especially in Haryana. On an average women spends 6-7 hr in picking cotton collecting 25-30 kg of cotton/day during harvesting season. Cotton picking with existing method of using traditional jholi results in various musculo skeletal problems for the women. Output of cotton picking was found to be more with the help of cot bag. Majority found it to be highly acceptable. Overwhelming majority (92%) perceived that using cot bag reduced pain in their shoulders, backache (53%) and pain in hands (27%) and overall helped in reducing the drudgery of a women to a considerable extent as cot bag is evenly distributed over shoulder to hip region which helps the workers to maintain straight back without undue pressure on shoulders and lower back. Further workers were able to pick approximately 10 kg cotton more with cotton picking bag in 7 hr and thus earning Rs 250/day in comparison to traditional method of cotton picking where they were picking approximately 40 kg cotton in 7 hr and earning Rs 200/day. Therefore, it is important to introduce training programmes in villages to promote usage of cot bag not only to reduce drudgery of women, but enhance earning capacity and ultimately raising standard of living of families.

REFERENCES

Corlette, E.N. and Bishop, R.P. 1988. 'A technique for assessing postural discomfort, Ergonomics **19 :** 175-80.

Durnin J., Rahaman M. 1967. The assessment of amount of fat in the human body from measurements of skinfold thickness. *British Jour. Nutrition*, **21 :** 681-88

Garrow J S. 1981. Treat obsesity seriously. A clinical Manual. Edibug Churchill, Livingstone

Oberoi K., Singh S. 2007. Methodologies for assessment of ergonomic cost of work in book on Ergonomic Interventions for Health and Productivity by Suman Singh, Himanshu Publications, New Delhi, 40-66

Varghese, M.A., Saha, P.N. and Atreya, N. 1994. A rapid appraisal of occupational workload from a modified scale of perceived exertion, *Ergonomics* **37 :** 485-91.

Staple length composition of production and export of cotton in India

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ABSTRACT : India’s raw cotton production and export witnessed a substantial increase over the years still not self sufficient in its total domestic requirement of different staple length group cotton for its flourishing textile industry. Hence, the study attempts to quantify the **c**omposition of Indian raw cotton production and exports by staple length. The time series data on area, production and export of raw cotton from India for the period 1996-1997 to 2013-2014 was elicited from the websites of Ministry of Commerce and Industry, Government of India (www.commerce.nic.in) and Cotton Corporation of India Ltd., During the last 18 years the production of long staple cotton has increased (12.32 per cent/annum) while the production of short staple cotton has decreased (6.78%/annum) and that of Extra Long Staple (ELS) cotton remained constant around 5 lakh bales annually. This has witnessed a paradigm shift in export of staple length composition of raw cotton from India. The percentage share of short staple cotton in total raw cotton exports has declined from 92.25 to a mere 1.21 per cent for the period from 2002-2002 to 2013-2014. While the percentage share of long staple cotton in total raw cotton export has increased from 6.79 to 95.50 per cent during the same period. But there was no much change in the export share of ELS cotton. However during the same period, the export share of ELS cotton was increased from nil to a mere 1.87 per cent except a share of more than 10 per cent during 2005-2006 to 2008-2009. At present more than 90 per cent of cotton area covered under *Bt* hybrids in India, inadvertently it has led to a surplus production of long staple cotton *i.e.,* 87 per cent against the requirement of 32-35 per cent. In case of short staple and ELS cotton the production is less than the requirement. Hence, India imports ELS and short staple cotton from other countries. During 2013-2014, India imported 10.47 lakh bales of short staple and ELS cotton and exported 105 lakh bales of long staple cotton which constituted 95.80 per cent of total raw cotton exports. Therefore to encourage the production of short staple and ELS cotton in India research efforts should be made to develop *Bt* hybrids (as in long staple cotton) in these fibre length classes.

Key words : *Bt* hybrids, ELS, export share, production, raw cotton, staple length, TPM

Cotton is an important fibre crop of India which plays a vital role in the country’s economy by meeting the domestic textile industry requirements and export demand. Its contribution is significant in terms of enhanced farm income, employment and export earnings. As per the estimate of FAO, India is one among the major players in raw cotton exports and its share of world exports of cotton expected to increase 20 per cent by 2023. Cotton exports among agricultural commodities play a vital role in India’s total exports valued at Rs. 21676.33 crores during 2013-2014 which was declined to Rs.11314.82 crores during 2014-2015. Cotton is one among the top five agricultural commodities exported from India and accounts for 59 per cent of the raw material consumption in textile industry (WWF report, 2012).

India is unique among the major cotton producing countries because a broad range of agro climatic and soil conditions permits cultivation of all varieties and different staple length of cotton. India has been the traditional producer and exporter of short staple cotton (Bengal *desi*) it was reported that till the end of the 1960's, longer staple cotton was imported while the surplus short staple cotton was exported (World Bank, 1999). During 1980's India was a leading exporter of extra long staple (ELS) cotton (DCH 32) and has been emerged as a regular exporter of long staple (LS) cotton after the introduction of *Bt* cotton in 2002-2003. As the staple composition of cotton production in India has changed significantly the relative share of different staple group of cotton in total raw cotton export was also changed. India's cotton production witnessed a substantial increase over the years. But the production of ELS and short staple cotton is shrinking and we are importing the same from other countries. Hence, the study attempts to quantify the composition of Indian raw cotton production and exports by different class of staple length.

MATERIALS AND METHODS

The study is based on the secondary data on production and export (value and quantity terms) of raw cotton (HS Code: 520100; COTTON, NOT CARDED OR COMBED) from India for the period 1996-1997 to 2013-2014, was elicited from the websites of Ministry of Commerce and industry (www.commerce.nic.in), Food and Agriculture Organization (www.faostat.fao.org) and Cotton Corporation of India Ltd., (www.cot**corp**.gov.in). Export of five different staple length class raw cotton from India *viz.,* Short staple (below 20.50mm), Medium (20.50 to 24.50mm), Medium long (24.50 to 28.00mm), Long staple (28.5 to 34.50mm) and Extra Long staple (34.50 and above) cotton were considered for the analysis.

Growth rates in production and export of raw cotton by staple length : The following functional farm was used to estimate the growth in production and export of raw cotton by staple length in quantity terms

$$Y_t = Y_o (1 + r)^t \qquad (1)$$

Transforming this to logarithmic farm

$$\ln Y_t = \ln Y_o + t \ln (1 + r) \qquad (2)$$

Where ;

Y_t = Quantity of cotton export/production

r = Compound Annual Growth Rate (CAGR)

ln = Natural Logarithm

If $\ln Y_o = \hat{a}_1$ and $\ln (1 + r) = \hat{a}_2$, then the equation (2) becomes

$$\ln Y_t = \hat{a}_1 + \hat{a}_2 t \qquad (3)$$

β_1 and β_2 are estimated by Ordinary Least Square (OLS) technique and CAGR is estimated by, r = (antilog β_2 -1) * 100

Shifts among the staple length groups : The shifts and retention percentage in export among the different staple length groups of cotton in India over a period of time were analysed by employing the first order Markov chain model. Markov chain analysis is an extension of probability theory developed by A.A.Markov in 1907 (Sujatha *et al.,* 2007). This econometric analysis helps us to know the shift of export share among the different staple length classes of cotton from one period to another over a period of time. The estimation of transitional probability matrix (P) is central to this analysis. The transition probability matrix (TPM) is a rectangular array would summarize the transition probabilities for a given Markov process.

$$P = \begin{matrix} P00 & P01 & P02 & \ldots & \ldots \\ P10 & P11 & P12 & \ldots & \ldots \\ P20 & P21 & P23 & \ldots & \ldots \end{matrix}$$

The Matrix P is called probability matrix. The probabilities P_{ij} must satisfy

$0 \leq P_{ij} \leq 1$ and $\Sigma P_{ij} = 1$ for I = 1, 2.........N

The elements P_{ij} of the matrix P indicates the probability that export will switch from staple length class i to staple length class j with the passage of time. In other words the matrix explains the switching behavior of cotton export in India among the different staple length group over a period of time indicating the direction of change in export share of these groups. The row elements in the transitional probability matrix imply the probability of retention (Diagonal element of the row) of export share by the corresponding group and extent of loss in export share (other than diagonal element of the row) on account of competing groups. The column elements indicate the probability of retention in export share and gain by the respective group from the other staple length group. An examination of the diagonal elements indicates the retention of export share in its favour. The proportionate changes in export share of different classes of cotton from year to year are as a result of the factors like weather, technology, price and institutional changes. Therefore it can be assumed that the combined influence of these individual forces indicates a stochastic process. In the present context, the export of different staple length class of cotton is considered to be a random variable which depends only on the past exports, which can be denoted algebraically as r

$$E_{jt} = \sum_{i=1}^{r} E_{jt-1} * P_{ij} + e_{jt} \text{ .... (4)}$$

Where,

E_{jt} = Export of the j^{th} staple group during the year t.

E_{jt-1} = Export of the j^{th} staple group during the period t-1.

P_{ij} = probability that the exports will shift from i^{th} staple group to j^{th} staple group.

e_{jt} = error term which is statistically independent of E_{jt-1}.

t = number of years considered for the analysis

r = number of staple length groups included in the model

The transition probabilities of the Markov chain model were estimated by Minimum Absolute Deviations (MAD) estimation procedure, which minimizes the sum of absolute deviations. The conventional linear programming technique was used, as this satisfies the properties of transitional probabilities of non negativity restrictions and row sum constraints in estimation. The linear programming formulation was stated as

Min O P* + I_e

Subject to, X P* + V = Y

G P * = 1

P * ³ O

Where,

P* is a vector in which probability P_{ij} are arranged; O is a null vector; I is an appropriately dimensioned vector of areas; e is the vector of absolute error (| U |); Y is the vector of export of each staple length group; X is a block diagonal matrix of lagged values of Y; V is the vector of errors; and G is a grouping matrix to add the row elements of P arranged in P* to unity. These P* vectors were arranged to obtain the transitional probability matrix which indicates the overall structure of the transitions that had taken place in the system.

RESULTS AND DISCUSSION

CAGR of production and export of raw cotton in India by staple length : Compound annual growth rates (CAGR) for production and export of different staple length group were analysed for a period of eighteen years *i.e.,* from 1996-1997 to 2013-2014. The production of short staple (-6.78%) and medium staple (-5.13%) cotton exhibited a negative growth whereas medium long (4.54%), long staple (12.32%) and ELS (0.11%) exhibited a positive growth. In over all the production of raw cotton was increased at 7.98 per cent/annum (Table. 1). There was a significant increase in production of long staple cotton mainly attributed to introduction of Bt-cotton. Growth in export quantity of different staple length group of cotton revealed that medium (-3.15%) and ELS cotton (-0.03 %) exhibited a negative export growth whereas short staple (1.05%), medium long (54.85%) and long staple cotton (105.64%) exhibited a positive export growth. In overall the export of raw cotton was increasing at 34.85 per cent/annum in quantity terms. The increase in export of medium long and long staple cotton was on account of improvement in yields during the current decade. It was reported that over the past 35 years, the average growth of cotton production in India has been 4.6 per cent. However, since 2000, cotton production in India has been growing rapidly 11.6 per cent annually. The surge in cotton production in India is mainly due to the introduction of *Bt (Bascillus thuringiensis)* cotton in 2002 (Caesar B.Cororaton,2008).

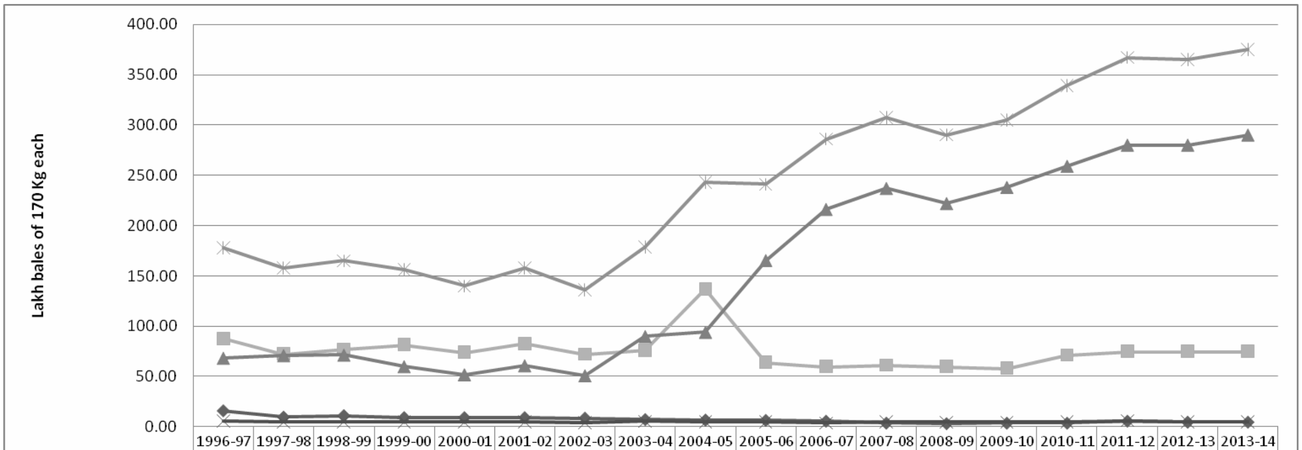
Table 1. CAGR of production and export of raw cotton in India by staple length group (1996-1997 to 2013-2014)

Particulars	CAGR (%)	
	Production	Export
Short staple (below 20.5 mm)	-6.78**	1.05^{NS}
Medium (20.5 to 24.5 mm)	-5.13*	-3.15*
Medium long staple (24.5 to 28 mm)	4.54^{NS}	54.85**
Long staple (28.5 to 34.5 mm)	12.32**	105.64**
Extra Long Staple (34.5 and above)	0.11^{NS}	-0.03^{NS}
Overall	**7.98****	**34.85****

* Significant at 5% ** Significant at 1 %
NS-Non Significant
Note: Short staple also includes Bengal *deshi* cotton.

Staple length composition of Indian raw cotton in production and export : During the last 18 years output of long staple cotton grew rapidly increasing by 12.32 per cent annually. In contrast the production of short staple cotton dropped drastically decreased by 6.78 per cent annually. Whereas the production of ELS cotton remained constant around 5 lakh bales annually (Fig.1). As a result of this in 2001-2002, export share of the short staple cotton in total raw cotton exports was more than 92 per cent and that of medium staple cotton was about 7 per cent whereas there was no export of medium long and long staple cotton (Fig.2). The export of long staple cotton started slowly picking up only after 2002. The export share of long staple cotton which was just about 5 per cent in 2002-2003 increased to more than 95 per cent in 2013-2014 and at the same time the export share of short staple cotton decreased to a mere 1 per cent in 2013-2014 which was more than 92 per cent during 2001-2002. While export of ELS cotton was picked up from 2003-2004 and increased to 17.45 per cent in 2007-2008 thereafter started decreasing and its share touched a lowest 0.42 per cent during 2012-2013. This is attributed to the fact that *Bt* cotton varieties are medium long and long staple varieties.

The wider adoption of *Bt* hybrids poses



	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Short Staple	16.25	10.00	11.50	9.50	9.50	9.50	9.00	7.60	7.11	6.80	6.00	4.00	3.50	4.00	4.00	6.00	5.00	5.00
Medium Long	87.54	72.50	77.00	81.50	74.00	82.50	72.00	75.90	136.80	64.00	60.00	61.00	60.00	58.00	71.00	75.00	75.00	75.00
Long Staple	68.45	71.00	71.50	60.00	52.00	61.00	51.00	89.95	94.07	165.40	216.15	237.00	222.00	238.00	259.00	280.00	280.00	290.00
Extra Long Staple	5.66	4.50	5.00	5.00	4.50	5.00	4.00	5.50	5.02	4.80	3.85	5.00	4.50	4.50	5.00	6.00	5.00	5.00
Total	177.90	158.00	165.00	156.00	140.00	158.00	136.00	178.95	243.00	241.00	286.00	307.00	290.00	304.50	339.00	367.00	365.00	375.00

Fig 1. Cotton production in India by staple length during 1996-1997 to 2013-2014

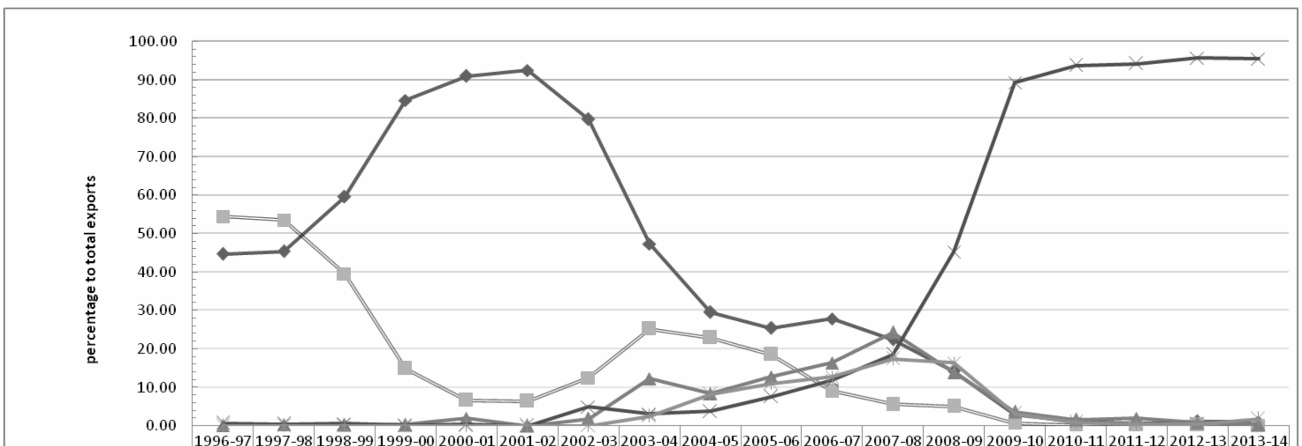
production and utilization problems as Bt cotton was developed in hybrids with trait for medium and long staples. Thus, with more than 90 per cent of cotton area in India coming under *Bt* hybrids, inadvertently it has led to a surplus production of medium long and long staple cotton more than what India can consume (87 % against 32-35%). Simultaneously, there is a reduction in the production of short staple cotton, a trait of desi against the requirement of 10-15 per cent (Ramasundaram *et al.,* 2011). The current production of ELS cotton in the country is only around 5 lakh bales against the requirement of 7 lakh bales. This indicates that India is not self sufficient in its total domestic requirement of different staple length group cotton for its flourishing textile industry. In case of short staple and extra long staple (ELS) cotton Indian production is less than the requirement hence it imports ELS and short staple cotton from other countries. India's production of ELS cotton is far below the local requirements of the textile mills (Cotton Exports Guide, 2007). India during 2013-2014 imported 10.47 lakh bales of short staple and ELS cotton to meet requirements of its domestic textile industry (Commodity profile - cotton, 2015). It was reported that the fibre quality and yield of ELS varieties have deteriorated in recent years causing marketing problems and lower returns

Table 2. Transitional probability matrix of Indian raw cotton exports: Period I (1996-1997 to 2002-2003)

Staple length group	Short staple	Medium	Medium Long	Long Staple	ELS	Others
Short staple	**0.9738**	0.0173	0.0050	0.0039	0.0000	0.0000
Medium	0.2726	**0.7240**	0.0000	0.0034	0.0000	0.0000
Medium long	0.8624	0.0000	**0.0000**	0.0000	0.0000	0.1376
Long staple	1.0000	0.0000	0.0000	**0.0000**	0.0000	0.0000
ELS	1.0000	0.0000	0.0000	0.0000	**0.0000**	0.0000
Others	0.0000	0.0000	0.0000	1.0000	0.0000	**0.0000**

to growers therefore farmers are increasingly shifting to long staple varieties which have higher yields and fewer quality problems (Dhruv Sood, 2014). Where as in case of medium and long staple cotton Indian production exceeds the requirement and thus have exportable surplus in these groups. The country had exported 105 lakh bales of long staple cotton in 2013-2014 which constituted 95.47 per cent of total raw cotton exports from India.

Shifts in production and export among different staple length group or raw cotton : The transitional probability matrix was obtained to find out the retention of export share of different staple length group cotton in two periods *i.e.,* period I (1996-1997 to 2002-2003) and period II (2003-2004 to 2013-2014). Rows of the TPM indicate the export share of corresponding group lost to the other group. On the other hand columns indicate export share gained by the respective group and diagonal elements of the TPM reflects retention of export share by each group. During the period I, short staple cotton retained 97.38 per cent of export share in total raw cotton export from India and medium staple cotton retained 72.40 per cent (Table. 2). While medium long, long staple and ELS cotton have exhibited zero retention of export share in total raw cotton export. Short staple cotton which retained more than 97 per cent of its share in total raw cotton exports from India during first period did not retained much of its share in the second period. Short staple retained 54 per cent and medium short staple retained a mere 5 per cent of export share compared to first period. On the other hand medium long and long staple group which exhibited zero retention during first period retained more than 99.28 per cent and 37.99 per cent of export share respectively in total raw cotton exports during the period II (Table 3). Hence the TPM revealed that during the period I short staple and medium staple cotton dominated the total raw cotton export of India. While, during the period II medium long and long staple cotton dominated the total raw



	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Short Staple	44.69	45.43	59.62	84.67	91.00	92.48	79.77	47.32	29.60	25.49	27.87	22.44	14.25	2.85	1.05	0.61	1.11	1.05
Medium Short	54.40	53.57	39.57	14.87	6.68	6.41	12.48	25.26	22.93	18.53	9.01	5.58	5.02	0.67	0.22	0.38	0.19	0.16
Medium Long	0.14	0.35	0.21	0.30	1.93	0.00	1.81	12.31	8.36	12.76	16.45	24.36	13.85	3.71	1.58	2.00	0.82	0.33
Long Staple	0.67	0.45	0.60	0.15	0.38	0.00	4.98	3.10	3.73	7.61	11.86	18.56	45.27	89.29	93.76	94.19	95.69	95.47
Extra Long Staple	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.49	8.25	10.96	12.76	17.45	16.36	3.19	0.94	0.46	0.42	1.87

Fig. 2. Staple wise raw cotton exports (% to total raw cotton exports) from India (1996-1997 to 2013-2014)

Table 3. Transitional probability matrix of Indian raw cotton exports: Period II (2003-2004 to 2013-2014)

Staple length group	Short staple	Medium	Medium long	Long staple	ELS	Others
Short staple	**0.5425**	0.3822	0.0000	0.0000	0.0000	0.0754
Medium	0.0358	**0.0537**	0.0000	0.0000	0.0000	0.9105
Medium long	0.0000	0.0000	**0.3799**	0.0587	0.5614	0.0000
Long staple	0.0000	0.0000	0.0000	**0.9928**	0.0000	0.0072
ELS	0.0000	0.0000	0.0000	1.0000	**0.0000**	0.0000
Others	0.3176	0.0000	0.3955	0.0000	0.2311	**0.0558**

cotton exports. Based on the above findings, it was concluded that India's cotton production witnessed substantial increase over the years. But the production of ELS and Short staple cotton is shrinking and we are importing the same from African countries, Egypt, Isrel and USA. Hence efforts should be made to encourage production of short staple and ELS verities of cotton to meet the domestic textile industry requirement by improving productivity and quality of fibre in line with the Bt hybrids.

REFERENCES

Anonymous, 1999. Indian cotton and textile industries: Reforming to compete, document of the World Bank, Allied publishers, 121.

Anonymous, 2012. WWF-India Report: Cotton market and sustainability in India.

Anonymous, 2007. Cotton Exporters Guide, International Trade Centre, Geneva, 268.

Anonymous, 2015. Commodity Profile for Cotton-January 2015.

Caesar B.Cororaton and Jatinder S.Bedi, 2008. IFRI Discussion Paper 00801, Cotton Textile Apparel sectors of India situations and challenges faced, International Food Policy Research Institute.

Dhruv Sood, 2014. GAIN Report No.IN4111, Arrivals slow and with lower prices …..MSP operations underway, Cotton and products update, India-2014, 3.

P. Ramasundaram, Suresh A Kurup and Ramesh Chand, 2011. *Manoeuvring Technology for surplus extraction: the case of BT cotton in India*, Policy Brief No. 37, National Centre for Agricultural Economics and Policy Research (NCAP), New Delhi.

Sujatha R.V., K.Suhasini and Y.Eswara Prasad , 2007. *43rd Annual Conference of the Indian Econometric Society,* Department of Humanities and Social Science, IIT Bombay.

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Global competitiveness of cotton in Tamil Nadu

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ABSTRACT : This paper combines policy analysis matrix techniques to model the analysis of profitability from cotton cultivation. Policy analysis matrices are computed for a sample of cotton growers located in the dry land of the Tamil Nadu under observed conventional and profit-efficient farming conditions. In this study cotton had been not competitive for most of the period under consideration. EPC estimates showed that it was more than unity like DRC in the most of the study period. However it could be seen that these had been an decreasing trend in the values of EPC and DRC from 2002-2003.Since NPC value are less than unity it indicates that the state had not protected the crop at the farmers level. The estimates of DRC revealed that the state had comparative advantage in cotton export. The main conclusion is that the usefulness of the policy analysis matrix might be substantially enhanced by simulating profitability after efficiency-improving managerial decisions have been adopted.

Key words : Cotton cultivators, DRC, EPC, ERP, Indian agricultural policy, multifunctionality, NPC, policy analysis matrix

This paper evaluates the private and social profitability of farming systems by the use of the policy analysis matrix (PAM). Since the seminal work by Monke and Pearson (1989), the PAM has been widely employed to compute market-driven and social profits for a variety of farming systems under different technological and institutional scenarios. Here, it is shown that important additional insights might be obtained if the farmers’ efficient behaviour is considered, in addition to their observed behaviour. This empirical application responds to the concern over whether or not those Tamil Nadu farming systems that can be deemed multifunctional, because of the important environmental functions performed, will be able to survive in the policy context of the post-2003 common agricultural policy (CAP).

For Indian authorities, the political problem of supporting farmers’ incomes in an increasingly open economic environment has been further compounded by the need to take on board the impact of trade liberalization on the non-commodity outputs of Indian agriculture. There is a growing recognition that, beyond its primary function of supplying food and fibre, agriculture can provide environmental benefits and contribute to the sustainable management of renewable natural resources, as well as to the preservation of biodiversity, and the maintenance of the economic viability of less favored rural areas. These new concerns are frequently summarized under the heading of multifunctional agriculture and have become an integral part of the Indian model of agriculture (EC, 1999, 2000). The research concerning the multifunctional character of agriculture is no longer restricted to international trade policy.

The impact of agricultural policies on farmers’ income might be widely different under observed and efficient behaviors. Likewise, the assessment of private and social profitability for a particular farming system can change substantially after major input adjustment decisions have been adopted in response to the diffusion of best management procedures. Profits obtained after all those adjustments could provide a useful benchmark for current production practices, showing whether enough room exists for an improvement in farms’ financial situation. In this paper efficiency is used in connection with the PAM, refers to a social benchmark for the calculation of costs and revenues based on the adoption of international prices and the removal of the effects of subsidization and taxation.

DATA AND SAMPLE:

Tamil Nadu : The study relied on secondary data pertaining to export of major agricultural commodities in Tamil Nadu. The secondary data included production of the groundnut in Tamil Nadu and India, export and import prices, domestic wholesale and world market prices for the periods between 2004-2005 and 2013-2014 at district and state level. These data were collected from various issues of Seasons and Crop Report of Tamil Nadu, Agro Stat published by different sources and web database of Food and Agriculture Organization and IndiaStat. Value of export of agricultural commodities through Chennai and Tuticorin ports was also collected from the custom houses (Sea Cargo) for the periods of ten years (1996-1997 to 2012-2013).

The price data are monthly quotations for nominal spot price (US $/metric ton) for Cotton were collected from UNCTAD website. The data span from January 2004 to December 2014 was collected. The dataset used in this paper corresponds to a sample of 337 single crop cotton farms located in the Tamil Nadu districts. The data were collected from a comprehensive survey carried out by the authors with support from the Tamil Nadu Ministry of Agriculture and correspond to the year 2014. The dataset provides data for one output and seven inputs. Output is measured in lint of cotton production. The only fixed input is cultivated land, measured in hectares. Variable inputs are: labour (working days), in addition to capital, fertilisers, seeds, herbicides and fungicides, all of which are measured in Indian rupees.

Measures of competitiveness

Nominal protection coefficient (NPC) : The Net Protection Coefficients were estimated for cotton lint under exportable hypothesis for the period from 2004-2005 to 2013-2014 in order to measure the extent to which domestic prices diverge from border equivalent prices. It was estimated as follows.

$NPC = P_d/P_b$

Where,

P_d = the domestic producer price; and

P_b = the border equivalent producer price computed as explained below.

Border equivalent prices or world prices adjusted for transport, marketing and processing costs, were estimated to serve as yardstick to indicate the extent to which domestic prices have been distorted by the various government interventions.

Algebraically,

$P_b = P_w - T_w - T_d - C_d + V_b$

Where,

Pb = Border price

Pw = World price

Tw = Ocean freight and insurance charges

Td = Handling, transport and marketing charges from port to domestic markets

Cd = Transport, processing and marketing charges farm gate to domestic market

V_b = The value of by-products.

An NPC greater than one would show that the domestic market price of the commodity exceeded the border price, which discouraged the export of that particular commodity.

Effective protection coefficient (EPC) : In the present study, Effective Protection Coefficient (EPC) was estimated as the ratio of value added in private prices to value added in social prices. The EPC indicates the combined effects of policies in the tradable cotton markets.

$EPC = VP_d / VP_b$

Where,

VP_d = the value added in domestic price (private price)

VP_b = the value added in border price (social price)

An EPC greater than one would indicate positive incentive effects of commodity policy (an export subsidy to producers), whereas an EPC less than 1 shows negative incentive effects (a tax on producers). Both the EPC and the NPC ignored the effects of transfers in the factor market and therefore do not reflect the full extent of incentives to farmers.

Domestic resource cost (DRC) : To measure the comparative advantage (or) efficiency of Indian cotton in the world market, domestic resource cost coefficient was estimated as given below.

$DRC = SP_d / VP_b$

Where,

SP_d = the shadow price of the cotton; and

VP_b = the value added measured at world prices.

DRCs greater than one would indicate that the value of domestic resources used to produce the commodity exceeded its value added in social prices. Production of the commodity, therefore, does not represent an efficient use of the country's resources. DRCs less than one would imply that a country has a comparative advantage in produce in the commodity. Values less than one would mean that the denominator (value added measured at world prices) exceeded the numerator (the cost of the domestic resources measured at their shadow prices).

Effective rate of protection (ERP) : To measure the structure of protection like tariffs, import bans, quantitative restrictions on Indian rice exports, Effective Rate of Protection coefficient was estimated, which measured the percentage increase above value added in world prices that was permitted by the structure of protection.

$EPC = VAD_p / VAB_p$

$ERP = (VAD_p - VAB_p) / VAB_p$

Where,

VAD_p = Value added at domestic price VAB_p = Value added at border price

ERP = EPC – 1 or EPC = ERP +1

Greater the ERP, higher would be the protection for that commodity to be traded in the world markets and vice versa.

In this paper, the PAM methodology is employed in order to learn about the possibilities of maintaining Cotton cultivation in the Tamil Nadu cotton cultivators.

RESULTS AND DISCUSSION

Details of the competing countries : Details of competing countries and their average market share along with the growth rate for the cotton lint for the period from 1996-1997 to 2012-2013 are furnished in the Table 1. As mentioned elsewhere, the details were collected from the website of Food and Agricultural Organization and growth rate was worked out country wise.

USA enjoyed the prime place in the cotton export and it accounted for nearly 40 per cent of the world's cotton export. Next to USA, Uzbekistan had a share of 10.31 per cent of the world cotton export. However these two countries witnessed a negative growth rate during the period of consideration. India occupied third position in the cotton export and the export dwindled down at the rate of 3.6 per cent/annum of the selected countries only. Brazil exhibited a positive growth rate of 2.3 per cent per annum in cotton export though it shared only five per cent of the world total export of cotton. The growth rate of cotton export at world level showed a marginal decline (- 0.8 per cent/annum).

Export competitiveness : Trade competitiveness of the crops was analyzed using the framework of Policy Analysis Matrix. As mentioned elsewhere, the PAM was constructed taking into consideration of free on board prices. Similarly, for domestic factors which are not internationally traded social cost was calculated using the value of marginal product approach using factor shares of various inputs alongwith the mean values of inputs, output and prices.

Nominal Protection Coefficient (NPC), Effective Protection Coefficient (EPC), Effective Rate of Protection (ERP) and Domestic Resource Cost (DRC) computed to reveal the trade competiveness. Trade competitiveness was

Table 1. Competing countries and their average market share

Commodity	Major exporting countries	Quantity (tonnes)	Per cent to Total	CGR (%)
Cotton	USA	3215218	39.90	-0.5**
	Uzbekistan	830693	10.31	-2.7*
	India	**756216**	**9.38**	**-3.6***
	Australia	435253	5.40	-1.3
	Brazil	395771	4.91	2.3*
	Greece	248303	3.08	-0.4
	World	8057933	100.00	-0.8*

*- Significant at ten per cent level; **- Significant at five per cent level;
***- Significant at one per cent level
Source: www.fao.org/crop/statistics/en/

Table 2. Competitive measures for cotton

Year	NPC	EPC	ERP	DRC
2004-2005	0.81	0.68	-0.32	0.67
2005-2006	0.77	0.66	-0.34	0.64
2006-2007	0.74	1.18	0.18	1.16
2007-2008	0.73	1.22	0.22	1.20
2008-2009	0.69	0.71	-0.29	0.69
2009-2010	0.69	1.22	0.22	1.19
2010-2011	0.70	0.95	-0.05	0.92
2011-2012	0.66	1.23	0.23	1.20
2012-2013	0.63	1.32	0.32	1.28
2013-2014	0.66	1.40	0.40	1.36
Average	**0.71**	**1.06**	**0.06**	**1.03**

estimated using the aforesaid measures for cotton for the period from 2004-2005 to 2013-2014.

Export competitiveness of cotton : The estimates of NPC, EPC, ERP and DRC for cotton lint are furnished in Table 2.

The average NPC was less than unity under exportable hypothesis. The average value of EPC was found to be 1.06, indicating in general that the state had not protected the crop. The DRC cotton revealed that Tamil Nadu had comparative disadvantage in cotton export and it can import at cheaper price. The cheaper availability of international cotton was due to the prevalence of subsidies provided by cotton producing countries especially USA and Brazil.

A relatively better performance of cotton crop in the pre WTO period might be due to expansion in area, availability of improved technologies of cotton production technology and its adoption, remunerative support prices and institutional support. But the production started declining after the establishment of WTO due to decrease in area under cultivation, which could be attributed to import of edible oils and relatively stagnant real prices of cotton.

From the foregoing discussion, it is evident that cotton was found to be disadvantage and efforts have to be taken to avert the situation. The measures will be taken by the Government are in the desired direction.

Conclusion : An efficient PAM has been built on the basis of this information, yielding new estimates of private and social profitability. Now, farms are made negative profits and the society also obtains a net welfare gain from the resources allocated to cotton production. It could be argued, with regard to the lack of social profitability of cotton farms with observed data, that social profitability is too narrowly defined in the PAM context, because it does not include a direct appraisal of the worth of the positive environmental externalities that stem from cotton cultivation. The PAM methodology could be extended by including the valuation of the public goods (landscape and biodiversity among them) jointly produced with the private or commercial output in the social row of the matrix. A trade off could then arise between negative economic returns and the production of non-commercial, *i.e.* multifunctional, outputs. However, this line of thinking has not been pursued in this paper.

The lack of relevant empirical information that could be used for widening the scope of social efficiency prevents us from providing a sound justification of private and social losses grounded on society's quest for non-commodity outputs from agriculture. But differences between private and social profits per hectare can be used to establish a lower threshold for the valuation of the annual supply of public good services jointly produced with cotton output. Instead of pursuing a line of analysis that concentrates on the construction of an environmental PAM, the possibilities offered by computing a virtual PAM, assuming profit maximization on behalf of farmers, is explored. This helps to assess whether there is a way out of the current financial difficulties of cotton cultivators are experiencing that could allow the valuable non-commercial functions currently performed by this farming system to be maintained. The findings point to a negative outcome, both in terms of private and social profits, after farmers should be adopt the best practices of efficient farms.

Finally, it is worth highlighting a couple of the conclusions of this research. On the one hand, it vindicates the potential of the policy analysis matrix to yield fruitful information about particular cotton cultivation. Furthermore, the usefulness of this methodological approach may be substantially enhanced if the analyst can simulate the profitability of the system after all sorts of efficiency improving changes have been adopted by farmers. On the other hand, the results of this research lead to a noteworthy conclusion in terms of economic policy. In order to preserve the nonmarketable function of the Tamil Nadu cotton system linked to the protection of biodiversity and the environment, local and regional authorities need to make a greater effort to spread the adoption of best practices among cotton cultivators, helping them to improve their profit efficiency and financial viability.

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REFERENCES

Deodhar, S.Y., 2001. WTO Agreements and Agriculture: Retrospection and Prospects. CMA Monograph No.191. Oxford and IBH Publishing Co.Pvt.Ltd, New Delhi.

EC, 2000. Agriculture's contribution to environmentally and culturally related non-trade concerns. Indian Commission International Conference on Non-Trade Concerns in Agriculture, Ullensvang, Norway, July 2-4. Discussion Paper Four.

Ministry of Commerce and Industry, 2001. India's Proposals on Agriculture-I: Food Security. India and the WTO, V **l.3** : 2.

Pearson S., Gotsch C., Bahri S., 2003. Applications of the policy analysis matrix in Indonesian agriculture. Available on line in http://www.stanford.edu/group/FRI/

Pearson S., Monke E., 1989. Agricultural policy in Kenya. Applications of the policy analysis matrix. Cornell Univ Press, Ithaca, NY, USA. 328 pp.

Reddy, B., Lalith Achoth, D. R. and Chenappa Reddy, B.V., 1998. Export Competitiveness of Groundnut Empirical Evidence from Karnataka. *Astha Vijnana*, Vol.15 (3): pp. 263-270.

www.fao.org/crop/statistics/en/
www.unctad.com
www.indiastat.com

CROP PROTECTION AND BIOSAFETY

Population dynamics of target and non target pests in transgenic cotton

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ABSTRACT : Performance of transgenic cotton hybrid with *Bacillus thuringiensis* (*Bt*) *Cry* 1Ac+*Cry* 1Ab gene alongwith non-transgenic cultivar of *Gossypium barbadense* was evaluated against pest complex under irrigated condition at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. India for two years during rainy season 2012, 2013 and 2014. The results revealed that there were no difference between the transgenic and non-transgenic hybrid in their relative susceptibility to cotton jassids, *Amrasca biguttula biguttula*, thrips, *Thrips tabcaci*, aphids *Aphis gossypi*, white fly, *Bemesia tabaci* and mealy bug, *Phenacoccus solenopsis* . Thus, the transgenic hybrid does not afford any protection to sucking pests of cotton and their tolerance or resistance is mainly dependent on the morphological or genetic base. Bollworm incidence was completely absent in transgenic cotton hybrid as no square and boll damage was observed. Whereas non-transgenic hybrid recorded higher damage (1.18 to 39.19%) and significantly differed from transgenic hybrid (0.36 to 1.56%). Besides this, significant difference in seed cotton yield was also observed during both the cropping season. Seed cotton yield of transgenic hybrid (18.85 q/ha) was significantly greater than that of the non-transgenic hybrid (13.93 q/ha) under protected condition. The results suggested that transgenic hybrid cannot control sucking pests of cotton and there was no difference in sucking pests incidence in transgenic hybrid and non-transgenic hybrid. The major bollworms *Helicoverpa armigera*, *Earias vittella* and *Pectinophora gossypiella* were effectively controlled in transgenic hybrid. Thus, transgenic hybrid can play a major role in combating pest problem thereby reducing insecticide usage in cotton ecosystem and helps to maintain eco balance by conserving natural enemies.

Key words : Bollworms, *Gossypium,* cotton, *Cry* 1Ac , *Cry* 1Ab, natural enemies, sucking pests

Cotton is an important commercial crop in India playing a major role in agricultural economy. Before introduction of transgenic *Bt* cotton, farmers of India witnessed instability in cotton production due to frequent crop failures because of outbreaks of insect pests. Among the pests problems, bollworms especially American Bollworm, *H.armigera* and Pink bollworm *P.gossypiella* cause considerable damage to the cotton crop. *Helicoverpa* alone cause significant losses to the tune of Rs.1000 crores in the country annually warranting insecticides applications which many a times exceeds 20 sprays especially in epidemic years (Prasad *et al.*, 2009). The excessive and indiscriminate use of insecticides in cotton ecosystem has led to development of resistance to insecticides in *Helicoverpa,* resurgence of minor pests and elimination of natural enemies leading to control failures with insecticides. In order to reduce the dependence on chemical insecticides and resultant effect on non target organisms, tools of biotechnology have been applied to develop cotton that can withstand certain problematic and insecticide resistant pests more efficiently.

Transgenic *Bt* cotton is a new technology in plant protection that enables transgenic cotton plant to express a crystal (Cry) toxin called

Cry 1Ac+*Cry* 1Ab, originally derived from the soil bacterium *B.thuringienesis* which is a natural enemy of bollworm pest and the endotoxins produced by bacteria have proved effective against lepidopteran insects (Kennedy, 2008). When the target pest oviposit on the transgenic plant, the larvae hatching from such eggs feed and ingest Cry protein along with plant tissue. The protein acts immediately on the inner linings of digestive system and the young larvae cease feeding and die within 2 to 3 days. As the pest is killed in its early stage, any potential damage to crop is prevented. Transgenic *Bt* cotton containing *Cry* 1Ac+*Cry* 1Ab gene which offers resistance to major bollworms was first commercially released in the world in 1996 (Gouse *et al.,*2004; Wu KM *et al.*, 2008; Choudhary and Gaur, 2010; Hui-Lin Yu *et al.,* 2011) and during 2002 in India (Prasad and Rao, 2008). In the present study, the second generation transgenic *Bt* cotton which was commercialized in India was studied for their reaction to different pests of cotton.

MATERIALS AND METHODS

The field trials were conducted during 2011-2012 and 2012-2013 to evaluate *Bt* hybrid RCH 2*Bt* along with non *Bt* hybrid of *G.barbadense* DCH-32 at Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra. India under unprotected irrigated conditions for pest incidence and under protected irrigated condition for yield record. The plot size of each hybrid was 2000 sq.m which were sown at a spacing of 90 x 90 cm row to row and plant to plant distance, respectively. The *Bt* cotton genotype RCH 2*Bt* and non *Bt* cotton genotype DCH-32 were sown in the third week of May and all the agronomic practices such as fertilizer application and intercultural operations were similar in these two cotton hybrids. These test hybrids were raised under unprotected condition. Weekly observations on incidence of sucking pests and bollworms were recorded at 10 randomly selected spots on 5 plants along with weather parameters. The sucking pests such as aphids, jassids, thrips and whiteflies were recorded from three leaves, each one from top, middle and bottom canopies of the plant, while the number of mealy bug *P.solenopsis* from 10 cm portion of shoot/5 plants was counted. The american bollworm and spotted bollworm larvae along with per cent square damage and green boll damage were recorded from whole plant. The incidence of pink bollworm larvae was observed through destructive sampling of 20 randomly collected green bolls from each treatment and per cent damage in green bolls were recorded. Thus, the data obtained was subjected to statistical analysis after applying suitable transformations.

RESULTS AND DISCUSSION

Effect of transgenic cotton on sucking pests incidence and natural enemies: Transgenic *Bt* cotton RCH-2*Bt* along with non *Bt* cotton DCH-32 were evaluated against pest complex of cotton under unprotected conditions and the results are presented in Table 1 to 4. The pooled results of two years revealed that the infestation leaf hopper on cotton ranged between 0.40 to 57/3 leaves. The first incidence of aphids was noticed during 27MW (meteorological week). The higher infestation level of 30.80 to 57.00 aphids/3 leaves was observed from 38 to 47MWs, respectively. The population of leaf hopper on cotton ranged between 0.64 to 18.98/3 leaves. The first incidence of jassids was noticed during 27MW. The higher infestation level of 6.44 to 18.98 leaf hoppers/3 leaves was observed from

29 to 42 MWs. The population of jassids crossed the ETL during this period and peaked at 40MW. The incidence of thrips on cotton ranged between 0.18 to 52.88/3 leaves. The first incidence of thrips was observed during 27MW. The high population level of 32.08 to 52.88 thrips/3 leaves was noticed during 33 to 37MW. The population was peaked at 35MW. The infestation whitefly on cotton ranged between 1.78 to 41.52/3 leaves. The first incidence was noticed during 27MW. The higher incidence of 29.66 to 41.52 whiteflies/3 leaves was observed during 44 to 49MW during which population peaked at 49MW. The infestation of mealy bug was first noticed during 35MW in the month of August with the population of 0.83 mealy bugs/10cm shoot. The population varied from 0.83 to 35.35 mealy bugs/10cm shoot. The higher incidence of 35.35 mealy bugs/10cm shoot was noticed during 45MW.

The population of natural enemies *viz.*, *Coccinellids, Chrysopids, Apanteles, Anagyrus, Cryptolaemus,* syrphids and spiders varied from 0.70 to 9.69 predators/plant. The parasitisation due to *Anaseus bambawalei* endoparasitoid caused mummification of mealy bugs.

In the similar type of study Vennila *et al.* (2004) reported that transgenic *Bt* cotton does not afford any protection to sucking pests of cotton and their relative tolerance or resistance is mainly dependent on the morphological or genetic base which is in accordance with Reed

Table 1. Population dynamics of key pests of DCH-32 cotton in relation to climatic conditions.

StandardMW	Sucking pests/3 leaves					Pred-ators/ plant	Abiotic factors				
	Aphids	Jassids	Thrips	Whitefly	Mealy bug/ plant		Temperature (^{0}C)		Relative humidity (%)		Rainfall (mm)
							Maxi-mum	Mini mum	Morn-ing	Even ing	
July 27	30.84	5.12	7.70	2.16	0.00	3.23	31.4	23.1	77.7	61.1	11.8
28	31.74	3.96	7.56	4.60	0.00	1.42	29.9	22.7	78.1	69.1	8.6
29	20.80	5.88	10.02	3.48	0.00	1.27	25.8	21.9	90.3	85.3	65.2
30	20.92	3.76	15.36	2.34	0.00	1.15	29.0	22.6	84.1	66.7	22.8
Aug 31	22.52	4.38	15.04	4.42	0.00	1.25	28.2	21.9	81.0	70.6	21.2
32	19.92	6.68	11.62	3.06	0.00	1.57	29.7	21.9	78.7	64.0	1.0
33	10.08	8.02	20.68	5.28	0.00	1.45	30.2	22.1	78.1	59.0	2.6
34	7.18	5.12	34.80	2.46	0.00	1.27	29.2	21.8	78.7	63.9	13.4
35	27.24	4.66	44.94	11.48	0.83	4.56	31.5	20.4	78.3	50.0	—
Sept.36	0.40	2.84	28.50	9.40	2.24	2.37	32.3	19.7	79.3	49.9	7.7
37	0.72	3.20	14.82	14.70	4.37	4.59	31.4	22.0	81.7	60.1	6.7
38	12.58	4.84	4.40	12.68	6.25	4.13	29.6	21.5	83.7	60.6	6.5
39	10.56	5.32	1.80	10.34	7.58	4.21	30.5	21.1	80.0	56.0	—
Oct. 40	9.26	17.94	1.50	16.74	13.26	5.13	31.9	21.9	81.6	58.0	4.0
41	20.66	4.26	0.66	8.36	14.81	2.69	31.1	20.0	77.1	57.1	9.4
42	21.88	5.82	3.50	14.62	13.10	5.67	32.0	20.1	74.9	46.0	—
43	35.46	1.86	0.40	17.40	20.43	4.36	31.2	19.6	68.4	55.7	5.2
Nov. 44	40.80	3.80	0.28	31.12	18.13	9.67	31.4	16.9	63.3	47.7	—
45	43.82	2.64	0.82	34.78	14.20	9.69	30.6	14.6	65.0	35.6	0.0
46	44.86	2.40	2.64	25.94	19.26	7.29	29.4	12.7	60.4	30.7	—
47	49.54	1.54	0.36	11.12	17.53	3.76	31.0	13.5	67.9	36.6	6.0
48	12.42	1.46	0.42	4.72	12.81	0.87	29.2	6.7	75.1	54.0	—
Dec 49	9.84	0.64	0.18	2.76	7.43	0.84	29.0	9.8	72.3	38.1	—

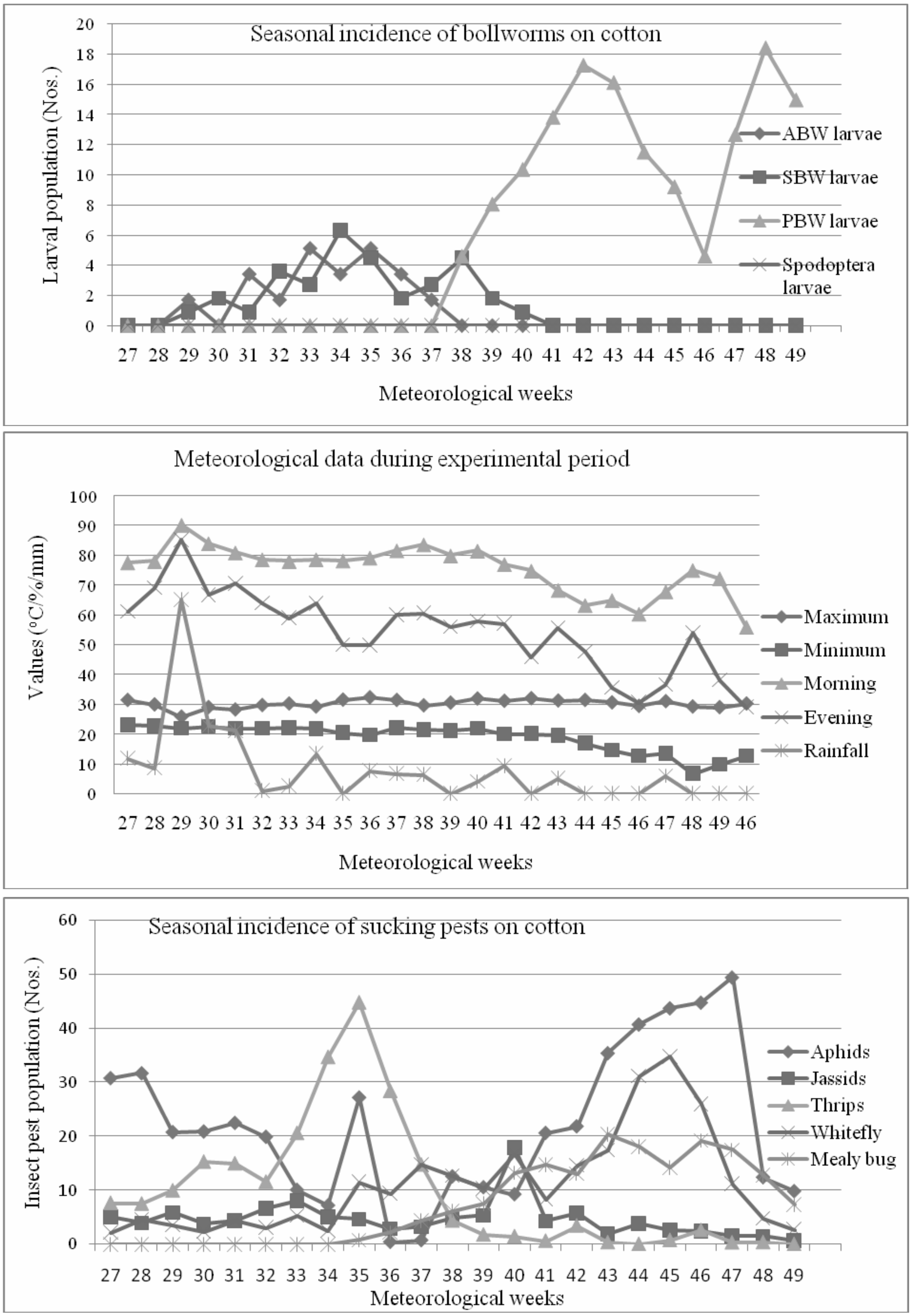

Fig. 1. Seasonal incidence of major pests of cotton and its relationship with meteorological parameters.

Table 2. Population dynamics of key pests of RCH 2 Bt cotton in relation to climatic conditions.

Standard MW	Sucking pests/3 leaves					Pred-ators/ plant	Fruiting body damage (%)	Abiotic factors				
	Aphids	Jassids	Thrips	Whitefly	Mealy bug/ plant			Temperature (^{0}C)		Relative humidity (%)		Rainfall (mm)
								Maxi-mum	Mini mum	Morn-ing	Even ing	
July 27	0.00	4.36	8.15	2.88	0.00	1.32	0	31.4	23.1	77.7	61.1	11.8
28	1.66	3.68	7.87	3.64	0.00	0.70	0	29.9	22.7	78.1	69.1	8.6
29	5.88	9.14	12.06	2.36	0.00	1.24	0	25.8	21.9	90.3	85.3	65.2
30	9.36	6.44	26.56	1.78	0.00	0.70	0	29.0	22.6	84.1	66.7	22.8
Aug 31	22.71	11.60	22.13	4.72	0.00	1.32	0	28.2	21.9	81.0	70.6	21.2
32	26.88	17.84	20.66	4.18	0.00	1.38	0	29.7	21.9	78.7	64.0	1.0
33	11.68	9.66	36.94	8.32	0.00	1.70	0	30.2	22.1	78.1	59.0	2.6
34	21.70	7.40	32.08	6.16	0.00	1.78	0	29.2	21.8	78.7	63.9	13.4
35	32.30	5.84	52.88	14.12	12.22	1.88	0	31.5	20.4	78.3	50.0	—
Sept.36	27.24	3.52	43.52	13.36	9.10	4.84	0	32.3	19.7	79.3	49.9	7.7
37	19.80	7.08	36.26	17.74	15.14	3.97	0	31.4	22.0	81.7	60.1	6.7
38	36.46	11.30	15.40	14.58	13.02	2.72	0	29.6	21.5	83.7	60.6	6.5
39	30.80	16.50	6.24	10.40	11.52	4.31	0	30.5	21.1	80.0	56.0	—
Oct. 40	18.40	18.98	4.32	19.20	17.12	5.83	0	31.9	21.9	81.6	58.0	4.0
41	25.16	8.48	4.50	15.22	8.54	5.35	0	31.1	20.0	77.1	57.1	9.4
42	32.38	12.96	2.86	13.08	15.94	6.28	0	32.0	20.1	74.9	46.0	—
43	47.10	5.06	2.62	28.84	17.18	5.64	0	31.2	19.6	68.4	55.7	5.2
Nov. 44	42.62	4.42	0.48	16.12	31.68	6.81	0	31.4	16.9	63.3	47.7	—
45	49.22	3.26	1.54	23.12	35.35	7.50	0	30.6	14.6	65.0	35.6	0.0
46	55.36	3.38	1.46	22.20	26.40	3.91	0	29.4	12.7	60.4	30.7	—
47	57.00	2.04	1.28	29.66	11.82	2.36	0.36	31.0	13.5	67.9	36.6	6.0
48	29.80	1.40	0.94	38.00	3.54	1.96	1.20	29.2	6.7	75.1	54.0	—
Dec 49	17.26	0.88	0.66	41.52	2.07	1.41	1.56	29.0	9.8	72.3	38.1	—

et al., (2000) and Bambawale *et al.* (2004) who reported that the incidence of sucking pests was more or less similar in both *Bt* and non *Bt* hybrids. However, the present results contradict with findings of Radhika *et al.*, 2004; Abro *et al.*, 2004; Cui and Xia, 2000, who reported that the incidence of sucking pests was high in *Bt* hybrids than their non *Bt* counterparts.

Effect of transgenic cotton on bollworms density and fruiting body damage : The number of *Helicoverpa* eggs recorded on cotton crop varied from 0.46 to 3.22 eggs/5plants. The larval population varied from 1.70 to 5.10 larvae/5plants. The higher incidence of 3.40 to 5.10 larvae/5 plants was noticed during 31 to 37MW. The infestation on green fruiting bodies ranged from 1.18 to 5.27 per cent. The number of spotted bollworm larvae varied from 0.90 to 6.30 larvae/5 plants. But the higher larval incidence of 3.60 to 6.30 larvae/5 plants was noticed during 32 to 38MW. The incidence on green fruiting bodies ranged between 0.72 and 5.32 per cent. The number of pink bollworm (PBW) larvae observed in 20 infested green bolls varied from 4.60 to 18.40 larvae. The higher incidence of 10.35 to 18.40 PBW larvae/20 infested green bolls was observed during 40 to 49MW. The infestation of bollworms on green fruiting bodies was noticed from 29 to 49MW and the higher incidence of bollworms was noticed from 32 to 49MW. The open boll and locule damage varied from 7.46 to 39.19 and 4.08 to 15.10 per cent, respectively. The overall infestation of bollworms on fruiting bodies (squares, bolls and locules) varied from 1.18 to 39.19 per cent.

The *Helicoverpa* moth catches varied from 1 to 5 adults/trap during 31 to 40 MW and the catches of spotted bollworm adults varied from 1 to 81 moths/trap during 30 to 48MW. The population of pink bollworm moth varied from 2 to 140 adults/trap during 32 to 49MW. But the higher catches of pink bollworm moth noticed during 42MW. The *Spodoptera* adult catches varied from 1 to 151/trap but higher catch was noticed during 32 to 35MW. The adults of *S.litura* were trapped in pheromone traps but incidence of larvae was not observed in cotton field throughout the season.

In RCH 2*Bt*, the incidence of american bollworm, *H.armiger*a and spotted bollworm *E.vitella* were completely absent, as no square damage and green boll damage was observed. However, open boll damage was recorded upto 0.36 to 1.56% by pink bollworm *P.gossypiella* which significantly lower than the non *Bt* cotton hybrid DCH-32. Comparatively, the highest green boll damage, open boll damage and open boll damage was observed in DCH-32.

The results clearly indicate that transgenic *Bt* cotton is highly effective against the most problematic pest in cotton which has developed many fold resistance to chemical insecticides. The present findings are in conformity with Krishnamurthy and Subramanian (2004) who reported that fruiting body damage was very low in MECH-12, MECH-162 and MECH-184 *Bt* hybrids over the respective non *Bt* counter parts and Bhatade *et al.,* (2006)

Table 3. Population dynamics of key pests of cotton in relation to climatic conditions.

Standard MW	*H. armigera*/ 5 plants		*Earias* spp larvae/ 5 plants	PBW larvae/ 20 green bolls	*S. litura* larvae/ 5 plants	Fruiting body damage (%)	Trap catches/week			
	Egg	Larvae					*H. armigera*	PBW	SBW	*S. litura*
July 27	0.00	0.00	0.00	0.00	0	0.00	0	0	0	0
28	0.00	0.00	0.00	0.00	0	0.00	0	0	0	0
29	0.92	1.70	0.90	0.00	0	1.18	0	0	0	1
30	0.00	0.00	1.80	0.00	0	3.13	0	0	1	2
Aug 31	1.84	3.40	0.90	0.00	0	4.50	2	0	3	3
32	0.00	1.70	3.60	0.00	0	7.52	0	13	67	80
33	2.76	5.10	2.70	0.00	0	4.94	3	19	69	120
34	1.38	3.40	6.30	0.00	0	7.99	2	13	81	151
35	3.22	5.10	4.50	0.00	0	5.38	3	7	24	150
Sept.36	0.92	3.40	1.80	0.00	0	4.63	5	10	2	10
37	0.46	1.70	2.70	0.00	0	2.66	2	9	5	15
38	0.46	0.00	4.50	4.60	0	8.68	3	13	18	29
39	0.00	0.00	1.80	8.05	0	16.19	3	7	10	15
Oct. 40	0.00	0.00	0.90	10.35	0	14.01	1	5	15	25
41	0.00	0.00	0.00	13.80	0	27.61	0	3	7	16
42	0.00	0.00	0.00	17.25	0	37.37	0	140	3	4
43	0.00	0.00	0.00	16.10	0	32.09	0	2	5	1
Nov. 44	0.00	0.00	0.00	11.50	0	27.14	0	5	2	58
45	0.00	0.00	0.00	9.20	0	23.16	0	8	1	48
46	0.00	0.00	0.00	4.60	0	21.18	0	6	4	23
47	0.00	0.00	0.00	12.65	0	27.14	0	5	6	14
48	0.00	0.00	0.00	18.40	0	39.19	0	3	4	13
Dec 49	0.00	0.00	0.00	14.95	0	31.58	0	5	0	0

findings of 89% reduction in square damage in *Bt* cotton over their non *Bt* hybrids due to *Helicoverpa*. The inbuilt resistance of transgenic *Bt* cotton to *Helicoverpa* was proved by many researchers by reporting very low larval population, low square and boll damage in *Bt* cotton hybrids than their non *Bt* counter parts and conventional cotton (Cui and Xia, 2000; Kranthi, 2002; Gore *et al*., 2003; Vennila *et al*., 2004). Transgenic *Bt* cotton hybrids also offered protection against pink bollworm which is a late season pest in cotton. RCH 2*Bt* has not shown the incidence of pink bollworm upto 150 DAS and superior compared to DCH-32 non *Bt* hybrid in the experiment in which fruiting body damage ranged from 1.18 to 39.19%. The results are in accordance with findings of Hugar *et al.,* (2006) who reported that fruiting damage to pink bollworm was 3.2% in RCH 2*Bt* as against 18.72% in NCH 145 non *Bt* cotton. Pink bollworm is not visible on the plant and completes most of the life cycle in the unopen boll itself and the damage in the form of stained and discoloured kapas is seen only after bursting of the boll. Since the damage is not visible before boll opening it is very difficult to time the application of insecticides for taking control measures. The transgenic *Bt* cotton with *Cry* 1Ac+*Cry* 1Ab toxin can able to control pink bollworm, as toxins are expressed in the plant parts itself and mostly prevents insecticide application and problems of decision making for control options. The resistance of *Bt* hybrids against pink bollworm was proved earlier by many scientists which are

Table 4. Population dynamics of key pests of cotton in relation to climatic conditions.

Std. MW	*H.armigera* av. % infes.on GFB	*E. vittella* av.% infes. on GFB	*S.litura* av. % infes. on GFB and leaves	*P.gossypiella* av. % infes. on		Temperature (^{0}C)		Relative humidity (%)		Rainfall (mm)
				GFB and open boll	Locule	Maximum	Minimum	Morning	Evening	
July 27	0	0	0	0	0	35.6	24.2	55	33	0.0
28	0	0	0	0	0	36.4	23.8	65	39	27.2
29	0	1.18	0	0	0	34.9	23.7	63	38	0.0
30	1.57	1.56	0	0	0	34.8	23.5	67	40	2.2
Aug 31	1.70	2.80	0	0	0	31.5	23.5	74	56	43.4
32	2.20	5.32	0	0	0	32.2	23.4	71	53	4.8
33	1.78	3.16	0	0	0	31.5	23.7	75	58	3.6
34	5.27	2.72	0	0	0	29.7	23.6	73	63	1.0
35	3.18	2.20	0	0	0	29.6	23.4	77	68	23.6
Sept.36	2.46	2.17	0	0	0	30.6	22.7	80	55	0.8
37	1.18	1.48	0	0	0	31.5	21.6	75	57	0.0
38	0	1.22	0	7.46	4.08	32.5	21.9	73	48	0.0
39	0	1.10	0	15.09	7.18	30.2	22.8	79	62	31.4
Oct. 40	0	0.72	0	13.29	6.79	29.6	22.8	81	64	60.2
41	0	0	0	27.61	11.23	30.1	22.2	76	62	15.8
42	0	0	0	37.37	15.10	30.4	21.5	86	57	69.0
43	0	0	0	32.09	11.97	31.6	20.3	82	48	0.0
Nov. 44	0	0	0	27.14	9.34	31.4	21.8	87	62	118.6
45	0	0	0	23.16	7.86	32.1	19.7	79	41	0.0
46	0	0	0	21.18	6.93	32.2	16.9	75	32	0.0
47	0	0	0	27.14	8.82	31.5	19.4	76	39	18.6
48	0	0	0	39.19	13.46	30.0	15.6	63	40	0.0
Dec 49	0	0	0	31.58	10.23	31.7	15.0	62	34	0.0

in accordance with the present results [Gianessi and Carpenter (1999); Henneberry and Jech (2000)].

Effect of transgenic cotton on yield: Seed cotton yield from fully opened bolls was picked up manually, dried in the sun, weighed and expressed as kilogram per hectare. There were 2-3 pickings in each season, depending upon the length of the growing season. Seed cotton yield was recorded separately for the first, second and third pickings. The pooled results of two years reveled that under protected condition, the RCH-2*Bt* produced the highest seed cotton yield (18.85 q/ha); which was significantly greater than non-transgenic cotton hybrid DCH-32 (13.93 q/ha). Under completely unprotected condition, the transgenic RCH-2*Bt* recorded 5.78 q/ha; while non-transgenic cotton DCH-32 produced only 1.24 q/ha seed cotton yield. Thus, there was significant difference in seed cotton yield of *Bt* and non *Bt* cotton under protected and unprotected irrigated condition. The seed cotton yield of *Bt* cotton in all picking were significantly greater than non *Bt* cotton under both unprotected and protected conditions.

CONCLUSION

From the present findings, it can be concluded that *Bt* cotton cannot control sucking pests of cotton and there is no difference in sucking pests incidence in *Bt* and non *Bt* cotton hybrid. The major bollworms *H.armiger*a, *E.vitella* and *P.gossypiella* are effectively controlled in *Bt* cotton hybrids. The transgenic *Bt* cotton can play a major role in combating pest problem, thereby reducing the insecticide usage on cotton ecosystem and helps to maintain eco balance by conserving natural enemies.

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REFERENCES

Abro, G.H., Syed, T.S., Tunio, G.M. and Khuhro, M.A. 2004. Performance of transgenic *Bt* cotton against insect pest infestation. B*iotechnology,* **3 :** 75-81.

Bambawale, O.M., Singh, A., Sharma, O.P., Bhosle, B.B., Lavekar, R.C., Dhandapani, A., Kanwar, V., Tanwar, R.K, Rathod, K.S., Patange, N.R. and Pawar, V.M. 2004. Performance of *Bt* cotton (MECH-162) under Integrated Pest Management in farmers' participatory field trial in Nanded district, Central India. *Curr. Sci,* **86 :** 1628-33.

Bhatade, S .S, Bhosle, B. B., Ghute, V. G., More, D. G, Deshmukh, P. R., Wajerwadekar, S. J. A. and Phad, D. S. 2006. Comparative performance of *Bt* and non *Bt* cotton hybrids under rainfed conditions of Marathwada region of Maharashtra state. Proceedings of national seminar on transgenic crops in Indian Agriculture: status, risks and Acceptance: Souvenir, Extended summaries and Abstracts, 2006 CCS HAU, Hissar pp.25-26 (S.K. Sethi, S.S. Siwach and R.K. Yadav eds.), January 28-29.

Choudhary B and Gaur K. 2010. *Bt* **Cotton in India: A Country Profile. ISAAA Series of Biotech Crop Profiles. ISAAA: Ithaca, NY.**
Cui, J.J. and Xia, J.Y. 2000. Effects of *Bt*

(*Bacillus thuringiensis*) transgenic cotton on the dynamics of pest population and their enemies. *Acta Phytophylacica Sinica,* **27 :** 141-45

Gianessi, L.P. and Carpenter, J.E. 1999. Agricultural Biotechnology: Insect control benefits, National center for Food and Agricultural Policy. http: //www.bio.org/food & ag/ncfap/ag_bio.htm (1999, July 8).

Gore, J., Leonard, B.R. and Jones, R.H. 2003. Influence of agronomic hosts on the susceptibility of *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae) to genetically engineered and non-engineered cottons. *Environmental Entomology,* **32 :** 103-10

Gouse M, Pray C and Schimmelpfenning, D. 2004. The distribution of benefits from *Bt* cotton adoption in South Africa. *AgBioForum* **7 :** 187-94.

Henneberry, T.J. and Jech, L.F. 2000. Seasonal pink bollworm, *Pectinophora gossypiella* (Saunders) infestations on transgenic and non-transgenic cottons. *Southwestern Entomologist,* **25 :** 273-86.

Hugar, P S., ThulasiRam, K. and Mudalagiriyappa. 2006. Performance of transgenic cotton in Thungabadra project area of Northern Karnataka. Proceedings of *National Seminar on transgenic crops in Indian Agriculture: status, Risks and Acceptance*. Souvenir, Extended summaries and Abstracts 28-29 January, 2006, CCS HAU, Hissar, 127-29.

Hui-Lin Yu, YH Li and Kong-Ming Wu. 2011. Risk assessment and ecological effects of transgenic *Bt* crops on non-target organisms. *Journal of Integrative Plant Biology*, "Accepted Article"; doi: 10.1111/j.17447909.2011.01047.

Kennedy. 2008. Integration of insect-resistant genetically modified crops within IPM programs. In: Romeis J, Shelton AM, Kennedy GG, Eds. Integration of Insect-Resistant Genetically Modified Crops With IPM Programs. Springer, Berlin, Germany. pp. 1-26.

Kranthi, K.R. 2002. Modalities of *Bt* cotton cultivation in India: Its Pros and Cons including Resistance Management and Potential Ecological impact. Proceedings of *National Seminar on Bt cotton scenario with special reference to India*. 23rd May, Dharwad, 26-50 PP.

Krishnamurthy, S. V. and Subramanian, S. 2004. Evaluation of transgenic *Bt* cotton hybrids. Abstracts of *National symposium on changing world order cotton Research, Development and Policy in context* August 10-12, 2004, ANGRAU, R.nagar, Hyderabad 35 PP.

Prasad, NVVSD, Rao, M. and Rao N.H. 2009. Performance of *Bt* cotton and non *Bt* cotton hybrids against pest complex under unprotected conditions. *Jr. Biopesticides,* **2 :** 107-10.

Prasad, NVVSD and Rao N.H. 2008. Field evaluation of *Bt* cotton hybrids against insect pest complex under rain fed conditions. *Indian Journal Entomology,* **4 :** 367-70.

Radhika, P., Sudhakar, K., Basha Mohiddin, S. and Prasada Rao, G.M.V. 2004. Relative incidence of pest complex on *Bt* and non *Bt* cotton hybrids under protected and unprotected conditions. Proceedings of *National symposium on "Strategies for Sustainable Cotton Production - A Global vision–* 3. Crop Protection" 23-25, November, 2004, UAS, Dharwad.136-138 PP.

Reed, J.T., Stewart, S., Laughlin, D., Harris, A., Furr, R.,Ruscoe, A. and Dugger, P. 2000. *Bt* and conventional cotton in the hills and delta of Mississippi: 5 years of comparison. Proceedings of *Beltwide Cotton Conference*, San Antonia, USA, **2 :** 1027-30.

Vennila, S., Biradar,V.K., Gadpayle, J.G., Panchbhai, P.R.,Ramteke, M.S., Deole, S.A. and Karanjkar, P.P. 2004. Field evaluation of *Bt* transgenic cotton hybrids against sucking pests and bollworms. *Indian Journal of Plant Protection,* **32 :** 1-10.

Wu KM, Lu YH, Feng HQ, Jiang YY, Zhao JZ.2008. Suppression of cotton bollworm in multiple crops in China in areas with *Bt* toxin containing cotton. *Science* **5896** : 1676-78.

Symposium papers "Future Technologies : Indian Cotton in the Next Decade" 157-164

Population dynamics of cotton insect pests in scarce rainfall zone of Andhra Pradesh

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ABSTRACT : Field experimentswere conducted during *kharif*, 2010-2011 and 2011-2012 at RARS, Nandyal with test hybrid, DCH 32 for the incidence of sucking pests. The results revealed that the leafhopper population attained two peaks differently in both the years. During 2010-2011, leafhoppers attained first peak during47th standard week and the second peak during 1ststandard week of 2011whereas during 2011-2012, leafhoppers attained its first peak during 38th standard week followed by second peak during 44th standard week. However, though the incidence of other sucking pests like thrips, aphids and whitefly was there, their population was below the ETL during both the years. Among bollworms, the incidence of *Helicoverpa armigera* and *Spodoptera litura* larvae was negligible during the cropping period in both the years. However, during 2010-2011, the mean trap catches of *Helicoverpa* were highest during 50th standard week whereas the moth catches attained peak during 39th standard week in the year 2011-2012. The incidence of *Spodoptera litura* was observed throughout the season in both the years. During 2010-2011, the moth catches of *S. litura* were peak during 40th std. week whereas during 2011-12, it was during 38th std. week and the second peak was attained in46th and 51st standard weekduring 2010-11 and 2011-2012, respectively. The highest pink bollworm moth catches were recorded during 4th standard week during 2010-2011 whereas the moth catches attained peak during 47th standard week during 2011-2012. The correlation studies between the leafhoppers, whitefly and aphid population with temperature (both maximum and minimum), relative humidity (both morning and evening) and rainfall was found non significant whereas thrips population showed a significant and positive correlation with both maximum temperature (r = 0.4986) and minimum temperature (r = 0.4645) during 2010-2011. The correlation between the trap catches of *Helicoverpaarmigera* showed a significant but negative correlation with both maximum (r = -0.5644) and minimum temperature (r = -0.5161) during 2010-2011 whereas the correlation was significant and positive with maximum temperature (r= 0.6089) during 2011-2012. The trap catches of pink bollworm showed a significant but negative correlation with minimum temperature (r = -0.7997), morning relative humidity (r = -0.5991) and evening relative humidity (r = -0.8559) during 2010-2011 whereas the correlation between moth catches of pink bollworm and all the weather parameters tested was non significantduring 2011-2012.

Key words: Abiotic factors, cotton, sucking pests

Cotton (*Gossypium*spp.) is the most important commercial crop in India and plays a vital role in agricultural, industrial, social and monetary affairs of the country. About 60 million people of the country are involved directly or indirectly in cotton production, processing, textiles and related activities. India is the only country in the world where all the four cultivated species of cotton, *viz., Gossypium arboreum* L., *G. hirsutum* L., *G. herbaceaum* L. and *G. barbadense* L. along with intra and inter specific hybrids are cultivated. The production and productivity in India is of great concern owing to the demand for cotton all over the world. Insect pests are the major bottle necks for the poor yields in cotton. Cotton is attacked by a herd of insect pests. During the crop growth period, about 148 insect pests have been recorded on cotton, out of which only 17 species have been reported as major insect pests of cotton (Abbas, 2001). Cotton insect pests can primarily be divided into sucking pests and bollworms. After the introduction of *Bt* cotton during 2002, the bollworm attack has drastically reduced and the sucking pests gained major importance. Among the sucking pests, leafhoppers, mirids in south India and whitefly in north India are of immense importance. Weather plays a key role which influence the incidence of the major insect pests. To develop long term forecasting models, the relationship between incidence of the major insect pests and the weather parameters need to be investigated. Therefore, a thorough understanding of interaction between crop growth stage, pest dynamics in relation to meteorological parameters is a pre requisite for weather based pest forecasting model. Hence, the present study was focused on location specific seasonal occurrence of insect pests and their relationship with weather parameters for formulating timely and effective management strategies for mitigating the insect pests of cotton.

MATERIALS AND METHODS

Present investigation on the population dynamics of sucking pests in cotton was carried out on test hybrid, DCH 32 during *kharif*, 2010-2011 and 2011-2012 at Regional Agricultural Research Station, ANGRAU, Nandyal, Kurnool District, Andhra Pradesh. The crop was grown in a plot size of 1000 m^2at a spacing of 90 × 60 cm and the crop was kept unsprayed throughout the cropping season. All agronomic practices as per the recommendations were followed to raise the crop except for crop protection measures. The population of sucking insect pests was estimated from five locations and in each location on 10 plants selected randomly. On each plant, the populations were estimated from three fully formed leaves one each at upper, middle and lower part of the crop canopy before 10 AM everyday throughout the cropping season. For recording bollworm data, sucking pests were managed by spraying monocrotophos @ 1.6ml/l and with *neem* oil @5ml/l. The bollworm moth catches were recorded daily using pheromone traps in the field.

The data obtained were converted to mean population by using the following formula:

Mean (X) = Óx /N

Where N= Number of plants

Óx = Sum of population of all plants

The mean population data obtained from weekly observations were subjected to simple correlation analysis with meteorological parameters, viz. temperature (maximum and minimum), relative humidity(morning and evening) and rainfall.

RESULTS AND DISCUSSION

The resultsrevealed that during 2010-2011, the incidence of leafhoppers was noticed throughout the cropping period with two peaks. First peak during the 47^{th} standard week with 7.85 leafhoppers/3 leaves and the second peak was observed during 1^{st} standard week of 2011 with 9.40 leafhoppers/ 3 leaves. Though the incidence of thrips, aphids and whitefly was observed, it was below ETL during the crop period (Table 1).

The incidence of *Helicoverpa armigera* and *Spodoptera exigua* in the field was negligible during the cropping period. However, the mean trap catches of *Helicoverpa* were highest during 50th standard week of 2010 (1.89 moths/trap/week) followed by 1st standard week of 2011 whereas trap catches of *Spodoptera exigua* were highest during 52nd standard week of 2010(3.29 moths/trap/week). The incidence of *Spodoptera litura* was observed throughout the season with peak mean trap catches during 40th standard week (15.71 moths/trap/week) followed by 46th standard week (15.50 moths/trap/week). The incidence of pink bollworm was started during 44th standard week (0.86 moths/trap/week) and reached a peak during 4thstandard week of 2011 (22.78 moths/trap/week)(Table 1).

The correlation studies between the leafhoppers, whitefly and aphid population with temperature (both maximum and minimum), relative humidity (both morning and evening) and rainfall was found non-significant whereas thrips population showed significant and positive correlation with both maximum temperature (r = 0.4986) and minimum temperature (r = 0.4645). The present findings are in conformity with Shivanna *et al.*, (2011) who reported that thrips population had a significant and positive correlation with maximum temperature. Vennila *et al.*, (2007a and c) reported that high temperature and scanty rainfall aggravate the severity of sucking pests and also reported that *Thrips tabaci* has population peaks during dry spell with high temperature and low humidity which are optimum for population build up.However, the correlation between thrips population and relative humidity (both morning and evening) and rainfall was non-significant(Table 2).

The correlation between the trap catches of *Spodoptera litura* and *S. exigua* and all the weather parameters tested was non-significant. However, the moth catches of *Helicoverpaarmigera* showed a significant but negative correlation with both maximum (r = -0.5644) and minimum temperatures (r = -0.5161) whereas correlation with other weather parameters was non significant. The results are in conformity with Hameed *et al.*, (2015) who reported that there was a significant and negative correlation between moth catches of *H. armigera* and minimum temperature whereas the results are in negation with Yogesh and Rajnish Kumar (2014) who reported that the moth catches of *H. armigera* showed a significant and positive correlation with minimum temperature. Pink bollworm showed a significant but negative correlation with minimum temperature (r = -0.7997), morning (r = -0.5991) and evening (r = -0.8559) relativehumidity (Table 2).

The results obtained during 2011-2012 revealed that the incidence of leafhoppers was noticed throughout the cropping period with two peaks. First peak during the 38th standard week with 6.25 leafhoppers /3 leaves and the second peak was observed during 44th standard week with 6.65 leafhoppers / 3 leaves. Though the incidence of thrips, aphids and whitefly was observed, it was below ETL only during the cropping period (Table. 3).

The incidence of *Helicoverpaarmigera* and *Spodoptera exigua*larvae in the field was negligible during the cropping period. However, the mean trap catches of *Helicoverpa*were highest during 39th standard week (4.80 moths/trap/week) followed by 46th standard week (2.20 moths/trap/week). On the other hand, the incidence of *Spodoptera litura* in the pheromone traps was observed throughout the crop season with peak mean trap catches during 38th standard week (45 moths/trap/week) followed

Table 1. Population dynamics of insect pests of cotton and weather conditions at RARS, Nandyal during 2010-2011

Std. Week	Sucking pests/ 3 leaves				Natural enemies/plant		Bollworm trap catches				Abiotic factors				
	Leaf hoppers	Thrips	White flies	Aphids	Lady birds	Spiders	*H. armigera*	*S. litura*	*S. exigua*	*P. gossy-piella*	Temp. Max. (^{0} C)	Temp. Min. (^{0} C)	RH Mor. (%)	RH Eve. (%)	Rain fall (mm)
39(24thto 30th Sep)	2.41	0.45	0.08	0	0	0.15	1	8	0	0	32.6	24.5	85	78.4	4.4
40(1st to 7th Oct)	4.33	0	0.1	0	0	0.05	0	15.71	0.43	0	33.9	23.8	70.3	59.1	0
41(8th to 14th Oct)	2.96	0.86	0.16	0	0	0.26	0	2.24	0.06	0	34.2	24	85.2	77.2	1.4
42(15th to 21st Oct)	2.36	0.4	0.56	0	0.05	0.05	0	0	0	0	31.6	23.8	89.7	77.7	51.8
43(22nd to 28th Oct)	1.91	0	0.11	0	0	0	0	0	0.04	0	31.19	23.27	88.57	74.57	18.2
44(29th Oct to 4th Nov)	0	0	0	0	0	0	0.43	1.57	0.71	0.86	29.07	22.94	88.29	77.43	7
45(5th to 11th Nov)	6.65	0	1.25	0.5	0	0.2	0.43	6.43	0.57	2.29	30.93	22.84	82	75.29	11.8
46(12th to 18th Nov)	0	0	0	0	0	0	0.8	15.5	0.9	2.1	31.24	21.91	83.09	73.18	71.5
47(19th to 25th Nov)	7.85	0	0.7	0	0	0.25	1.57	7.29	0.71	2	30.9	21.6	83.5	67	48.8
48(26thNov to 2nd Dec)	4.7	0	0.15	0	0	0	1	1.29	1.29	1.29	28.9	20.7	85.7	67.7	0
49(3rdto 9th Dec)	6.05	0	0.25	0	0	0	0.86	7.29	1.57	4.43	30.5	20.4	76	60.7	13.4
50(10th to 16th Dec)	5.63	0	0.4	0	0	0.1	1.89	6.11	0.78	2.89	30.2	14.9	76.8	48.8	0
51(17th to 23rd Dec)	4.65	0	0.25	0	0	0	1.71	2.14	0.71	14	25.05	13.4	74.8	49.5	0
52(24th to 31st Dec)	5.22	0	0.33	0	0	0	1.71	1.71	3.29	7.14	28.52	18.52	80.4	56.8	0
1(1st to 6th Jan 2013)	9.4	0	0.1	0	0.15	0.5	1.75	1	0.63	4.75	29.23	18.23	75.57	55.86	0
2(7th to 13th Jan)	3.35	0	0.15	0.05	0	0	1.44	0.89	0.89	11.89	30.76	14.49	64	32.71	0
3(14th to 20th Jan)	2.35	0	0	0	0	0	0.5	0.5	0	19.17	32.47	15.6	73.71	33	0
4(21st to 27th Jan)	3.21	0	0	0	0.05	0.05	0.11	0	0	22.78	31.8	15.61	75.5	35	0
5 (28th Jan to 3rd Feb)	2.45	0	0.35	0	0	0	0	0	0	11.67	29.23	18.23	75.57	55.86	0

Table 2. Correlation between insect pests and weather parameters during 2010-2011

Pests	Temp (Max)	Temp (Min)	RH (%) (Mor)	RH (%) (Eve)	Rainfall (mm)
Sucking pests					
Leafhoppers	-0.2228	-0.2101	-0.2707	-0.1706	-0.2041
Thrips	**0.4986 ***	**0.4645 ***	0.3941	0.4475	0.0382
Whitefly	-0.0882	0.1594	0.1640	0.2643	0.2076
Aphid	0.0341	0.1547	0.0270	0.1816	-0.0161
Pheromone trap catches					
H. armigera	**-0.5644 ***	**-0.5161 ***	-0.2775	-0.2948	-0.0925
S. liura	0.3391	0.3690	-0.0811	0.2646	0.3990
S. exigua	-0.4434	-0.1634	-0.0801	-0.0621	-0.0605
P. gossypiella	-0.2187	**-0.7997 ***	**-0.5991 ***	**-0.8559 ***	-0.3557

r_{Tab} (0.05,17$_{df}$) = 0.4555

by 51st standard week (30.50 moths/trap/week). In the pheromone traps, the catches of pink bollworm moths started during 38th standard week (1.00 moths/trap/week) and reached the peak during 47th standard week (5.50 moths/ trap/week) (Table 3).

Correlation studies between the sucking pests population and weather parameters indicated a significant and positive correlation between leafhopper population and temperature minimum (r= 0.6181)and relative humidity (evening)(r=0.5394).The present results are also confirm the findings of Laxman *et al.,* (2014) who reported that leafhopper population had a significant and positive correlation with relative humidity (evening). The present findings are also in conformity with Shera *et al.*, (2013), Selvaraj *et al.,* (2011) Shitole and Patel (2009), Kaur *et al.,* (2009) and Prasad *et al.,* (2008) who also reported significant and positive correlation between leafhoppers and relative humidity.The correlation between the other sucking pests and weather parameters tested was non significant.

However, among bollworms, the trap catches of *H. armigera* showed a positive and significant correlationwith temperature maximum(r=0.6089) whereas the trap catches of *Spodoptera exigua* showed a significant and positive correlation (r=0.4851)with relative humidity (evening). The trap catches of other bollworms did not show any correlation with the weather parameters tested (Table 4).

CONCLUSIONS

From the results of this study, it can be concluded that leafhoppers attained two peaks during the season in the test hybrid, DCH 32. The leafhopper population had a significant and positive correlation with temperature minimum and relative humidity (evening) whereas thrips showed a significant and positive correlation with both maximum and minimum temperatures. Moth catches of *H. armigera* had a significant but negative correlation with both maximum and minimum temperatures in one of the years of study and significantandpositive correlation with maximum temperature in the other year of study. Hence, it can be concluded that a long term study can only give complete picture of the dynamics of the insect pests.

Table 3. Population dynamics of insect pests of cotton and weather conditions at RARS, Nandyal during 2011-2012

Std. Week	Sucking pests/ 3 leaves			Natural enemies/plant		Bollworm trap catches				Abiotic factors				
	Leaf hoppers	Thrips	White flies	Lady birds	Spiders	*H. armigera*	*S. litura*	*S. exigua*	*P. gossypiella*	Temp. Max. (^{0} C)	Temp. Min. (^{0} C)	RH Mor. (%)	RH Eve. (%)	Rain fall (mm)
38(17thto 23rd Sep)	6.25	2.3	0.35	0.05	0.80	0.5	45.00	1.00	1.00	32.81	24.93	79.71	58.43	27.8
39(24thto 30th Sep)	4.85	0.7	0.80	0	0.15	4.80	21.00	1.40	1.00	34.83	24.58	68.00	52.78	0
40(1st to 7th Oct)	0	0	0	0	0.10	1.33	5.67	1.67	0.67	33.57	23.81	77.71	64.57	74.6
41(8th to 14th Oct)	4.8	0	1.50	0	0	1.40	2.20	2.00	1.00	33.21	24.6	78.42	65.28	14.2
42(15th to 21st Oct)	5.35	0	0	0	0	0.60	9.40	0.60	0.60	34.00	23.57	74.42	53.00	0
43(22nd to 28th Oct)	5.10	0	0.10	0	0	1.60	8.68	1.32	0.32	33.32	26.08	79.57	69.14	2.4
44(29th Oct to 4th Nov)	6.65	0	0.25	0.05	0	0.33	2.00	0.67	0.50	31.85	22.06	74.33	64.00	2
45(5th to 11th Nov)	4.10	0	0.45	0	0.05	1.00	15.00	2.40	1.00	32.77	18.65	62.71	53.28	0
46(12th to 18th Nov)	3.40	0	0.40	0	0.10	2.20	13.60	1.80	1.00	32.64	19.00	70.00	48.57	0
47(19th to 25th Nov)	3.85	0	0.40	0	0.05	0.75	26.25	2.50	5.50	30.69	20.94	79.70	62.00	13
48(26thNov to 2nd Dec)	2.40	0	0.50	0	0	0.50	22.50	1.00	0.50	30.25	22.43	81.50	69.50	13
49(3rdto 9th Dec)	3.25	0	1.00	0	0	0	14.75	1.25	2.50	32.05	20.54	79.14	56.28	0
50(10th to 16th Dec)	3.60	0	0.45	0.05	0	0.20	6.20	0.40	0.80	32.18	16.86	77.42	50.57	0
51(17th to 23rd Dec)	3.20	0	0.85	0	0	0.17	30.50	0.17	1.33	30.9	22.22	80.14	54.71	0
52(24th to 31st Dec)	2.15	0	0.95	0	0	1.20	27.20	1.60	2.40	31.00	17.04	82.05	45.33	0
1(1st to 6th Jan 2013)	1.75	0	0.50	0	0	1.17	1.67	0.67	2.17	32.70	19.82	77.28	51.14	0
2(7th to 13th Jan)	0.35	0	0.30	0	0	1.50	0.28	0.44	2.69	31.72	18.14	74.14	42.00	4.2
3(14th to 20th Jan)	0.40	0	0.60	0	0	0	1.00	0	0.20	31.06	13.74	73.00	23.71	0
4(21st to 27th Jan)	0.44	0	0.25	0	0	0.20	4.00	0.20	0	32.16	14.38	76.00	37.30	0

Table 4. Correlation between insect pests andweather parameters during 2011-2012

Pest	Temp. Max. (°C)	Temp. Min. (°C)	RH Mor. (%)	RH Eve. (%)	Rainfall(mm)
Sucking pests					
Leafhoppers	0.3299	**0.6181***	-0.0825	**0.5394***	-0.2195
Thrips	0.2498	0.3534	0.0566	0.0896	0.2303
Whitefly	-0.1534	-0.0169	0.1497	-0.0267	-0.2661
Pheromone trap catches					
H. armigera	**0.6089***	0.3528	-0.4264	0.1013	0.0149
S. liura	-0.1918	0.3133	0.2676	0.2460	0.0810
S. exigua	0.1854	0.3359	-0.1729	**0.4851***	0.2696
P. gossypiella	-0.3519	-0.0467	0.2359	0.0785	-0.0421

r_{Tab} (0.05,17$_{df}$) = 0.4555

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REFERENCES

Abbas. M.A. 2001. General Agriculture. Publication emporium . 2nd edition**,** Pakistan, 352.

Hameed, A., Shahzad, M. S., Ahmad, S. and Karar, H. 2015. Forecasting and modelling of *Helicoverpaarmigera* (Hub.) in relation to weather parameter in Multan, Punjab, Pakistan. *Pakistan J. Zool.*, **47**: 15-20.

Kaur, P., Singh, H. and Butter, N.S. 2009. Formulation of weather based criteria rules for the prediction of sucking pests in cotton (*Gossypiumhirsutum*) in Punjab. *Indian J. Agric. Sci.*, **79**: 375-80.

Laxman, P. ,Samatha, Ch and Sammaiah, Ch. 2014. Study on infestation of sucking insect pests on *Bt* cotton and non *Bt* cotton fields in Warangal- Telangana. International *J. Adv, Biol. Res.*, **4** : 172-77.

Prasad, N.V.V.S.D., Rao, N.H.P. and Mahalakshmi, M. S. 2008. Population dynamics of major sucking pests infesting cotton and their relation to weather parameters. *J. Cot. Res. Dev.,* **22** : 85-90.

Selvaraj, S., Adiroubane, D and Ramesh, V. 2011. Population dynamics of leafhopper, *Amrascadevastans*Distant in cotton and its relationship with weather parameters. *J.Ent.,* **8** : 476-83.

Shera, P. S., Vijay Kumar and Anand Aneja. 2013. Seasonal abundance of sucking insect pests on transgenic *Bt*cotton vis-à-vis weather parameters in Punjab, India. *Acta Phytopathologica et Entomologica Hungarica.,* **48** : 63–74.

Shitole, T.D. and Patel, I.S. 2009. Seasonal abundance of sucking pests and their correlation with weather parameters in cotton crop. *Pestology*, **33**: 38-40.

Shivanna, B.K., GangadharaNaik, B., Basavaraja, M. K., Nagaraja, R., KalleswaraSwamy, C.

M. &Karegowda, C. 2011. Impact of abiotic factors on population dynamics of sucking pests in transgenic cotton ecosystem. *Int. J. Sci. Nature*, **2** : 72-74

Vennila, S., Biradar, V.K., Sabesh, M and Bambawale, O.M. 2007a. Know your cotton insect pest whiteflies.*Crop Protection***,** Folder Series: 4

Vennila, S., Biradar, V.K., Sabesh, M and Bambawale, O.M. 2007b. Know your cotton insect pest thrips.*Crop Protection***,** Folder Series: 3

Yogesh and Rajnish Kumar, 2014. Monitoring *Helicoverpaarmigera* through pheromone trap catches under agroclimatic conditions of Eastern U.P. *Trends in Biosciences*, **7**:434-36.

Evaluation of spacing and spray schedule for management of bollworms in HDPS cotton

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ABSTRACT : The field experiment was conducted to evaluate the effective spray schedule for management in bollworms in high density planting system of cotton during *kharif* 2014. The experiment was laid out in FRBD with 3 replications. The non *Bt* cotton variety AKH 081 was sown in three different spacing 45x10 cm, 60x10 cm and 60x15 cm spacing (main treatments) and four insecticidal spray schedule as sub treatments. The experiment was conducted at Akola and Amravati research station. The results revealed that minimum larval population of bollworm (0.13) was observed in treatment S2M2 followed by S2M3. Interaction effect of spacing and modules were found non significant. Module 3 effectively managed larval population of bollworms whereas minimum green fruting bodies damage (2.69 %) was observed in treatment S2M2 at both the locations followed by S2M1. Maximum damage of green fruting bodies (20.83%) was noticed in S1M4 at both the location. Per cent open ball damage data was found significant but their interaction effect were non significant. Minimum open ball damage (2.44 %) was observed in treatment S2M2 schedule whereas maximum open ball damage (21.54 %) was recorded in S1M4 schedule. Data recorded on per cent loculi damage was found significant however their interaction effect found non significant. Minimum loculi damage (0.72 %) was observed in treatment S3M3 followed by S3M2. Maximum seed cotton yield was recorded in S2M2 (1403.27 kg/ha) whereas minimum was recorded in S1M4 (621.19 kg/ha). Thus, application of M3 schedule (flubendamide 480 SC @ 50ml/ac followed by indoxacarb 14.5 SC @ 100 ml/ac followed by fenvalerate 20 EC @ 160 ml/ac) was found superior in management of bollworms resulted in getting higher seed cotton yield and net monetary returns with spacing S2 (60 x 10 cm) in high density system of cotton.

Key words : Bollworms, HDPS, spacing, spray schedule

Cotton is an important crop of India and 60 million people derive their livelihood directly or indirectly from cotton production and its trade. The cotton crop provides fibre, food, feed, fuel, shelter and has a wide variety of medicinal and industrial uses (Siwach and Sangwan, 2012). With nearly 12 million hectares under the cotton crop, India ranks first in the world in respect of area and fourth in total production which has reached the level of 31 million bales (Mayee, 2011). But average productivity in India is quite low (523 kg lint/ha) as compared to worlds average productivity of 760 kg lint/ha (AICRP on Cotton, 2015). In India, cotton is cultivated under rainfed conditions in 60.0 per cent area. Productivity of cotton in these regions is low. Rainfall starts in June and recedes in September in majority of the rainfed cotton zone. Boll formation and retention get negatively affected in long duration varieties and hybrids due to low soil moisture, especially in shallow soils thus resulting in low yield. Major cotton producing countries like China, USA, Brazil, Uzbekistan and Australia continue to harvest high cotton yields through straight varieties adopting high plant population. Over the last few decades, these countries consciously developed dwarf, compact sympodial varieties amenable to high plant density (Venugopalan et al. 2013). The planting geometry is 8-10 cm distance between plants in a row with row to row distance at any of the spacing's at 30/45/60/75/90/100 cm. HDPS is more suitable to Indian conditions by using short duration varieties for improving productivity in rainfed region. Some early maturing compact genotypes have been identified for central region such as Suraj, PKV 081, NH 615 and AKA 07. But all these varieties are non Bt and management of bollworm is must to increase the productivity. Also many earlier workers reported that pest problem is higher in closer spacing than wider. Therefore, the present study was planned to find out suitable spacing and effective insecticidal module for the management of bollworms in high density planting system of cotton in rain fed condition of Vidarbha region.

MATERIALS AND METHODS

The experiment was laid out in FRBD with three replications. The cotton variety AKH 081 was sown at Akola and Amravati location in *kharif* 2014 and regular agronomic practices were followed. Three different spacing's 45 x 10 cm, 60 x 10 cm and 60 x 15 cm along with four different insecticidal spray scheduled were evaluated in this study. The treatments details are as follows:

	Main treatments (Spacing) (cm)
S1 -	45 x 10
S2 -	60 x 10
S3 -	60 x 15
	Sub treatments (Management of bollworm)
M1 -	Quinalphos 25 EC@ 400ml/ ac > Spinosad (45% SC) @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac
M2 -	Flubendamide 480 SC @ 50ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac
M3 -	Flubendamide 480 SC @ 50ml/ac > Spinosad (45% SC) @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac
M4 -	Control

Treatment combinations are - T1- S1M1, T2 - S1M2, T3 - S1M3, T4 - S1M4, T5 - S2M1, T6 - S2M2, T7 - S2M3, T8 - S2M4, T9 - S3M1, T10 - S3M2, T11 - S3M3, T12 - S3M4.

The observations on larval population of *H. armigera* and green fruiting bodies damage were recorded after each treatment spray on randomly selected 5 plants from each net plot on whole plant. The observation on open boll damage and loculi damage by bollworms was recorded at the time of harvest. The picking wise yield of seed cotton was recorded.

RESULTS AND DISCUSSION

a) Effect on larval population of bollworm:

Akola: The data recorded on larval population of bollworm at Akola location was found significant over control. Minimum larval population of bollworm (0.13) was observed in treatment S2M2 *i.e.* in 60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac followed by S2M3 (60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac). However, maximum larval population of bollworm (0.87) was recorded in S1M4 which consisted 45 x 20 cm spacing without any insecticidal application. Interaction effect of spacing and modules were found non significant. Module 3 (application of Flubendamide 480 SC @ 50 ml/ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac) effectively managed larval population of bollworms in HDPS cotton. (Table 1).

Amravati: The data recorded (Table 1) on larval population of bollworm at Amravati location was found significant over control. Minimum population of bollworm (0.04) was observed in treatment S2M3 (60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac) followed by S2M2 (60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac). Maximum larval population of bollworm (0.53) was recorded in S1M4 i.e. control treatment having 45 x 10 cm spacing. Interaction effect of spacing and modules were found non significant.

Table 1. Effect of spacing, module and its interaction on larval population of bollworm

	Akola				Amravati			
	S1	S2	S3	**MEAN**	S1	S2	S3	**MEAN**
M1	0.44(0.97)	0.24(0.86)	0.33(0.91)	**1.01(0.91)**	0.29(0.89)	0.22(0.85)	0.13(0.79)	**0.64(0.84)**
M2	0.47(0.98)	0.13(0.80)	0.27(0.88)	**0.87(0.88)**	0.24(0.86)	0.16(0.81)	0.18(0.82)	**0.58(0.83)**
M3	0.33(0.91)	0.22(0.85)	0.31(0.90)	**0.86(0.88)**	0.22(0.85)	0.04(0.74)	0.29(0.88)	**0.55(0.82)**
M4	0.82(1.15)	0.71(1.10)	0.67(1.08)	**2.20(1.11)**	0.53(1.01)	0.31(0.90)	0.40(0.94)	**1.24(0.95)**
MEAN	**2.06(1.00)**	**1.30(0.90)**	**1.58(0.94)**		**1.28(0.90)**	**0.73(0.82)**	**1.00(0.86)**	
	Spacing	**Module**	**Spacing x Module**	**Spacing**	**Module**	**Spacing x Module**		
F test	**SIG**	**SIG**	**NS**		**SIG**	**SIG**	**NS**	
SE (m)+-	0.03	0.03	0.05		0.02	0.02	0.04	
CD (p=0.05)	0.07	0.09	0.15		0.06	0.07	0.11	
CV (%)	**9.23**				**8.78**			

Figures in parenthesis are square root (x+0.5) transformed values

b) Effect on green fruiting bodies (GFB) damage:

Akola: Minimum green fruting bodies damage (2.69 %) was observed in treatment S2M2 *i.e.* in 60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac at Akola location followed by S2M1 (Quinalphos 25 EC@ 400ml/ ac > Spinosad 45%SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac) however, their effcet were found non significant. Maximum damage of green fruting bodies (20.83%) was noticed in S1M4 *i.e.* control treatment having 45 x 10 cm spacing. (Table 2).

Amravati: Treatment S3M2 which consisted 60 x 15 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac recorded minimum green fruting bodies damage (1.45%) at Amravati location however, their effcet were found non significant. Maximum damage of green fruting bodies (12.88%) was observed in S1M4 i.e. control treatment having 45 x 10 cm spacing. (Table 2).

Table 2. Effect of spacing, module and its interaction on per cent GFB damage

	Akola				Amravati			
	S1	S2	S3	**MEAN**	S1	S2	S3	MEAN
M 1	6.11(14.28)	2.97(9.87)	3.84(11.17)	**4.31(11.77)**	3.81(11.15)	1.65(7.23)	1.83(6.32)	**2.43(8.23)**
M 2	6.56(14.82)	2.69(9.36)	4.21(11.70)	**4.49(11.96)**	4.10(11.67)	2.18(8.43)	1.45(6.88)	**2.58(8.99)**
M 3	4.32(11.93)	3.05(9.70)	4.91(12.78)	**4.09(11.47)**	4.49(12.03)	1.53(7.08)	1.95(8.02)	**2.66(9.04)**
M 4	20.83(27.13)	18.35(25.21)	17.96(25.06)	**19.05(25.84)**	12.88(21.01)	10.70(19.07)	10.45(18.86)	**11.34(19.65)**
MEAN	**9.46(17.04)**	**6.77(13.56)**	**7.73(15.18)**		**6.32(13.96)**	**4.02(10.45)**	**3.92(10.02)**	
	Spacing	**Module**	**Spacing x Module**	**Spacing**	**Module**	**Spacing x Module**		
F test	**SIG**	**SIG**	**NS**		**SIG**	**SIG**	**NS**	
SE (m)+-	0.54	0.63	1.09		0.60	0.69	1.20	
CD (p=0.05)	1.59	1.84	3.18		1.76	2.03	3.52	
CV (%)	**12.32**				**18.13**			

Figures in parenthesis are arc sine transformed values

c) Effect on open ball damage:

Akola: Per cent open ball damage data recorded at Akola location was found significant but their interaction effect were non significant. Minimum open ball damage (2.44 %) was observed in treatment S2M3 *i.e.* in 60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac whereas maximum open ball damage (21.54 %) was recorded in closer spacing *i. e.* S1M4 treatment (Table 3).

Amravati: Data of effect of spacing and module on per cent open ball damage noted at Amravati location was found significant however their interaction effect found non significant. Minimum open ball damage (1.37%) was observed in treatment S3M3 *i.e.* in 60x15 cm pacing followed by application of Flubendamide 480 SC @ 50 ml/ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac whereas maximum open ball damage (18.80%) was recorded in S1M4 treatment (Table 3).

d) Effect on per cent loculi damage

Akola: Data recorded at Akola location on effect of spacing and modules on per cent loculi damage was found significant however their interaction effect found non significant. Minimum loculi damage (0.72 %) was observed in treatment S3M3 (60x15 cm pacing followed by application of Flubendamide 480 SC @ 50 ml/

Table 3. Effect of spacing, module and its interaction on per cent open bolls damage

	Akola				Amravati			
	S1	S2	S3	**MEAN**	S1	S2	S3	**MEAN**
M1	5.54(13.55)	4.85(12.70)	3.57(10.84)	**4.65(12.36)**	5.80(13.88)	3.82(11.25)	3.24(10.33)	**4.29(11.82)**
M2	4.61(12.38)	2.80(9.62)	2.49(9.02)	**3.30(10.34)**	4.63(12.09)	3.36(10.54)	3.62(10.94)	**3.87(11.19)**
M3	4.17(11.56)	2.44(8.96)	2.55(9.10)	**3.05(9.87)**	4.52(12.24)	2.88(9.71)	1.37(5.48)	**2.92(9.14)**
M4	21.54(27.65)	20.38(26.83)	18.84(25.73)	**20.25(26.74)**	18.80(25.69)	16.14(23.65)	15.44(23.14)	**16.79(24.16)**
MEAN	**8.97(16.29)**	**7.62(14.53)**	**6.86(13.67)**		**8.44(15.97)**	**6.55(13.79)**	**5.92(12.47)**	
	Spacing	**Module**	**Spacing x Module**		**Spacing**	**Module**	**Spacing x Module**	
F test	**SIG**	**SIG**	**NS**		**SIG**	**SIG**	**NS**	
SE (m)+-	0.39	0.45	0.78		0.58	0.67	1.16	
CD (p=0.05)	0.14	1.32	2.29		1.70	1.96	3.40	
CV (%)	**9.12**				**14.26**			

Figures in parenthesis are arc sine transformed values

Table 4. Effect of spacing, module and its interaction on per cent loculi damage

	Akola				Amravati			
	S1	S2	S3	**MEAN**	S1	S2	S3	**MEAN**
M1	1.65(1.26)	1.21(1.10)	0.90(0.95)	**1.25(1.10)**	1.66(1.28)	0.96(0.98)	0.81(0.90)	**1.14(1.05)**
M2	1.32(1.15)	1.19(1.07)	0.82(0.89)	**1.11(1.04)**	1.35(1.11)	1.10(1.04)	0.90(0.94)	**1.12(1.03)**
M3	1.49(1.20)	0.86(0.90)	0.72(0.84)	**1.02(0.98)**	1.44(1.19)	0.72(0.85)	0.47(0.55)	**0.88(0.86)**
M4	5.39(2.32)	5.99(2.44)	6.08(2.46)	**5.82(2.41)**	6.58(2.56)	4.76(2.18)	5.54(2.32)	**5.63(2.35)**
MEAN	**2.46(1.48)**	**2.31(1.38)**	**2.13(1.28)**		**2.76(1.54)**	**1.89(1.26)**	**1.93(1.18)**	
	Spacing	**Module**	**Spacing x Module**		**Spacing**	**Module**	**Spacing x Module**	
F test	**SIG**	**SIG**	**NS**		**SIG**	**SIG**	**NS**	
SE (m)+-	0.06	0.07	0.11		0.07	0.09	0.15	
CD (p=0.05)	0.17	0.19	0.33		0.22	0.25	0.44	
CV (%)	**14.22**				**19.42**			

Figures in parenthesis are square root transformed values

ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac) followed by S3M2 *i.e.* 60 x 15 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac. However, maximum loculi damage (6.08 %) was recorded in S3M4 treatment *i.e.* 60 x 15 cm spacing without any insecticidal application (Table 4).

Amravati: Per cent loculi damage due to effect of spacing and modules was found significant at Amravati location however, their interaction effect found non significant. Minimum loculi damage (0.47%) was observed in S3M3 *i.e.* 60x15 cm pacing followed by application of Flubendamide 480 SC @ 50 ml/ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac whereas maximum loculi damage (6.58%) was recorded in S1M4 treatment which is control plot having 45 x 10 cm spacing(Table 4).

e) Effect on seed cotton yield : Maximum seed cotton yield was recorded in 60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac (1501.63 kg/ha) *i.e.* in S2M2 treatment followed by S3M2 (1450.00 kg/ha) *i.e.* 60 x 15 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac whereas minimum was recorded in S1M4 (643.24 kg/ha)

Table 5. Effect of spacing, module and its interaction on Seed Cotton Yield (Kg/ha)

	Akola				Amravati			
	S1	S2	S3	**MEAN**	S1	S2	S3	**MEAN**
M 1	821.89	1178.43	1298.15	**1099.49**	816.45	1011.44	1079.26	**969.05**
M 2	1015.79	1501.63	1450.00	**1322.47**	986.38	1304.90	1187.04	**1159.44**
M 3	959.42	1243.13	1358.89	**1187.15**	966.23	1045.10	1132.96	**1048.09**
M4	643.24	723.85	861.85	**742.98**	599.13	675.82	648.52	**641.15**
MEAN	**860.09**	**1161.76**	**1242.22**		**842.04**	**1009.31**	**1011.94**	
	Spacing	**Module**	**Spacing xModule**	**Spacing**	**Module**	**Spacing xModule**		
F test	**SIG**	**SIG**	**SIG**		**SIG**	**SIG**	**NS**	
SE (m)+-	37.31	43.08	74.62		38.42	43.19	75.82	
CD (p=0.05)	109.41	126.34	218.83		110.70	126.67	219.39	
CV (%)	**11.88**				**13.58**			

at Akola location (Table 5).

Similar trend was also observed at Amravati location recording maximum seed cotton yield in 60 x 15 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac (1304.90 kg/ha) and minimum in control treatment having 45 x 10 cm spacing (599.13 kg/ha) (Table 5).

f) Net profit and ICBR : At Akola location higher net profit was recorded in 60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac treatment (S2M2) (Rs 28097.15/ha) followed by S3M2 (Rs 19356.83/ha) which consisted 60 x 15 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac whereas lowest was recorded in S1M1 (Rs 4811.61/ha) treatment. However, maximum ICBR (1:7.7) was recorded in S2M2 *i.e.* 60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Indoxacarb 14.5 SC @ 100 ml/ac > Fenvalerate 20 EC @ 160 ml/ac followed by S2M3 (1:6.0) (60 x 10 cm spacing with application of Flubendamide 480 SC @ 50 ml/ac > Spinosad 45 SC @ 50 ml/ac > Fenvalerate 20 EC @ 160 ml/ac) (Table 6).

Paslawar *et al.,* (2013) reported that AKH-081 an early and dwarf variety at narrow spacing of 45 x 10 cm showed highest plant height, higher LAI, highest seed cotton (3218 kg/ha), lint and biological yield with highest gross monetary (Rs 125502) and net monetary returns (Rs 86258) with cost benefit ratio of 3.18. However, square dropping and incidence of bollworm complex was more in narrow spacing. Venugopalan *et al.,* (2013) tested several compact varieties and among them AKH 081, NH 615, Suraj, Anjali KC3 (*G. hirsutum*) and AKA7, JK5 and HD123 (*G. arboreum*) planted at 60 x 10 cm, 45 x 15 cm and 45 x 10 cm under rainfed conditions. Further they stated that, by

Table 6 Effect of spacing, module and its interaction and net profit & ICBR at Akola.

Sr. No.	Treatment details	Yield (kg/ha)	Increased yield	Akola Plant Prot. cost (Rs)	Net profit (Rs)	ICBR
T_1	S1M1	821.8919	178.65	2245	4811.61	1: 1.2
T_2	S1M2	1015.791	372.55	3875	10840.62	1: 2.1
T_3	S1M3	959.4186	316.18	2025	10463.92	1: 3.3
T_4	S1M4	643.2435	0.00			
T_5	S2M1	1178.429	454.57	2898	15057.68	1: 3.7
T_6	S2M2	1501.631	777.78	2625	28097.15	1: 7.7
T_7	S2M3	1243.135	519.28	2025	18486.56	1: 6.0
T_8	S2M4	723.8546	0.00			
T_9	S3M1	1298.147	436.30	2898	14335.69	1: 3.5
T_{10}	S3M2	1449.999	588.15	3875	19356.83	1: 3.9
T_{11}	S3M3	1358.888	497.04	2025	17607.94	1: 5.7
T_{12}	S3M4	861.851	0.00			

• Standard spray volume - 500 l water/ha. • Labour charges for spraying - 5 labour/ha @ Rs 180/day for spraying. • 3 Knapsack spray pump rent - @ Rs 25/day = 75 Rs/ha. • Av. market price of cotton - @ Rs 3950/q (MSP 2014-15) • Quinolphos 20 SP @ Rs 370/l • Spinosad 45 SC @ Rs 1123/75 ml • Indoxacarb 14.5 SL @ Rs 140/100 ml • Flubendamide 5 SC @ Rs 682/50 ml • Fenvalerate 20 EC @ Rs 400/l increasing the plant population from 50,000 plants/ha to 1.5 to 2.0 lakh plants/ha, it is possible to realize 1800-2000 kg/ha seed cotton/ ha with the above varieties on marginal soils under rainfed conditions with minimum inputs which is more than twice the average yield of Vidarbha. Ganvir *et al.,* (2013) reported that the spacing 60 x 10 cm produced significantly higher seed cotton yield, gross monetary returns and net monetary returns than spacing 60 x 30 cm and it was *at par* with 60 x 15 cm but benefit cost ratio was higher in 60 x 15 cm of AKH 081. Ahuja *et al.,* (2013) evaluated *G. arboreum* genotypes for HDPS in northern India and on the basis of two years data reported that there was in general higher yield for 67.5 x 20 cm spacing with an increase in yield range of 3 to 8 q/ha (10.1 to 27.8% increase) over normal spacing of 67.5 x 30 cm except for CISA 310 (67.5 x 10 cm, 32.2%).

CONCLUSION

Application of flubendamide 480 SC @ 50ml/ac followed by indoxacarb 14.5 SC @ 100 ml/ac followed by fenvalerate 20 EC @ 160 ml/ ac in 60 x 10 cm spacing was found superior in getting higher seed cotton yield and net monetary returns in High Density Planting System of cotton.

REFERENCES

Ahuja, S. L., Monga D., Meena, R. A., Rishi Kumar and Neha Saxena 2013. Evaluation of *G. arboreum* cotton genotypes for High Density Planting Systems in northern India. National Symposium on *"Technology for Development and Production of Rainfed Cotton"* 24-25 October, 2013, RCRS, NAU, Bharuch : 9.

Ganvir, S. S., Khargkharate, V. K., Ghanbahadur, M. R., Tamgadge, J. B. and Nage, S. M. 2013. Effect of high density planting, nutrient management and In-Situ moisture conservation on productivity of hirsutum cotton. National Symposium on *"Technology for Development and Production of Rainfed Cotton"* 24-25 October, 2013, RCRS, NAU, Bharuch : 85.

Mayee, C.D. 2011. Indian Cotton Welcomes WCRC-5. *World Cotton Research Conference.* The Renaissance Mumbai Hotel and Conservation Center, India: 1-6.

Paslawar, A. N., Patil B. R., Ingole O.V., Nemade P.W. and Deotalu, A. S. 2013. High Density Planting System for AKH-081 and its influence on Growth, Yield and Economics under rainfed cultivation. National Symposium on *"Technology for Development and Production of Rainfed Cotton"* 24-25 October, 2013, RCRS, NAU, Bharuch :74.

Siwach, S. S. and Sangwan, R. S. 2012. Performance of hybrids produced by different systems for yield and quality in *Gossypium hirsutum* L. Silver Jubilee International Symposium on *"Global Cotton Production Technologies vis-à-vis Climate Change"* 10-12 October, 2012, CCS HAU, Hisar :157-162.

Venugopalan, M. V., Blaise D., Tandulkar, N. R. and Shubhangi Lakde. 2013. HDPS- A promising option for Rainfed Cotton. National Symposium on *"Technology for Development and Production of Rainfed Cotton"* 24-25 October, 2013, RCRS, NAU, Bharuch : L-3.

Symposium papers "Future Technologies : Indian Cotton in the Next Decade" 172-177

Status of whitefly (*Bemisia tabaci* Gennadius) population on *Bt* cotton in Marathwada region of Maharashtra under changing climate

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ABSTRACT : The severity of whitefly population is becoming a major concern to transgenic cotton farmers. Keeping this in view scientific survey of whitefly (*Bemisia tabaci* Gennadius) incidence on *Bt* cotton was carried out from last five years (2009-2010 to 2013-2014), in six major cotton growing districts (*viz.,* Parbhani, Hingoli, Nanded, Jalna, Aurangabad and Beed) of Marathwada region of Maharashtra under Crop Pest Surveillance and Advisory Project (CROPSAP) by using ICT tools and total 171 ETL based advisories were issued twice in a week to monitor the pest. On the basis of taluka wise roving survey, the district wise mean data was calculated and showed that during 2009-2010, maximum incidence of whitefly (per three leaves) was recorded in Hingoli (5.92) followed by Jalna (5.20) and minimum in Beed (1.40) district. Similarly during 2010-11, the population was highest in Hingoli (8.72) followed by Jalna (7.72) and lowest in Beed (1.36). During 2011-2012, it was more in Hingoli district (4.20) followed by Nanded (3.48) and minimum in Beed (0.76). During 2012-2013, severe infestation of whiteflies (5.52) observed in Hingoli district followed by Jalna (4.84). Whereas during 2013-2014, Jalna district recorded highest population of whitefly (6.52) followed by Hingoli (5.44) and Parbhani (4.00). The five years data indicated that the severity of whitefly incidence was more during 2010-2011 while it was minimum during 2011-2012. It is observed that Hingoli and Jalna districts of Marathwada are identified as hotspots for cotton whitefly.

Key words: District, incidence, population, survey, whitefly

Cotton is the important cash crop of Marathwada region of Maharashtra state . Cotton is known as one of the most important commercial crop playing a key role in economical, social and political status of the world. In India, more than 60 million people are engaged in cultivation, processing, marketing and other cotton related activities. Cotton is a predominant raw material of Indian textile industry which contributes for more that 14 per cent of the annual value addition of industrial production and more than 30 per cent of the total export with 4 per cent of its gross domestic product. *Bt* cotton technology which was introduced in 2002, has played major role in cotton production and productivity in India. However, sucking pests *viz.,* jassids,thrips and whiteflies are posing a threat to cultivation of *Bt* cotton under climate change. The whitely (*Bemesia tabaci* Gennadious) is assuming a status of major sucking pest on *Bt* cotton. The whitefly may cause 60.2-99.7 per cent loss in seed cotton(Singh *et al.*, 1983). The constant monitoring of whitefly population on *Bt* cotton was carried out through roving survey to know the seasonal and peak incidence of whitefly under agro climatic conditions of Marathwada . The study will be useful to undertake timely management practices against whitefly to the farmers of all the districts of Marathwada region.

MATERIALS AND METHODS

The talukawise survey was carried out in six major cotton growing districts *viz.,* Parbhani, Nanded, Hingoli, Beed, Jalna and Aurangabad of Marathwada to record the status of whitefly under "Crop Pest Surveillance and Advisory Project (CROPSAP)" during 2009-2010 to 2013-2014. During the survey eight fields from each taluka were selected and the incidence of whiteflies were recorded from 10 randomly selected plants from each field. Population of whitefly was recorded from three leaves (bottom, middle and top) of each plant. Average population of whiteflies were worked out for interpretation of data . ETL based advisories were disseminated to the farmers during the study period.

RESULTS AND DISCUSSION

The data on population dynamics of whiteflies during 2009-2010 presented in Table 1 and revealed that in Parbhani district first incidence of whitefly was noticed in 31st MW and it was increased upto 39th MW and attained its peak (7.40). There after it was decreased upto 0.56 in 46 MW. The whiteflies infestation fluctuates in between 0.30 to 7.40 with a average of 3.48. Whereas in Hingoli district whiteflies incidence was noticed in 32nd MW and attains its peak 38th MW thereafter whitefly activity was constant up to end of season with a average of 5.92. In Nanded district whitefly activity was noticed from start of season and it increased from 36th MW and attains its peak in 38th MW. Thereafter it goes on decreasing in the end of season. The whitefly population fluctuates in between 0.04 to 5.96 with a average of 3.24. Similarly in Jalna district the activity of whiteflies was recorded from start of season and it ranges in between 0.10 to 10.40. Infestation starts from 30th MW and attains its peak with severity in 42nd and 43rd MW (10.40 and 10.12) and it remains active throughout season with an average of 5.20. In Aurangabad district comparatively less infestation of whiteflies was

Table 1. Mean population of cotton whiteflies/3 leaves in the districts of Marathwada during 2009-2010

MW	Parbhani	Hingoli	Nanded	Jalna	Aurangabad	Beed
30	0	0	0.04	0.1	0	0
31	0.3	0	0.08	0.14	0.02	0
32	0.12	0.15	0.04	0.38	0.6	0
33	0.25	0.2	0.15	0.86	0.36	0
34	0.27	0.82	0.4	1.6	0.8	0.2
35	1.5	3.5	1.25	2.15	1.2	0.18
36	4.84	5.35	3.86	4.12	1.23	0.2
37	6.32	7.54	4.1	5.52	1.44	0.6
38	7.15	9.2	5.96	6.3	1.44	0.6
39	7.4	9.13	5.42	6.31	1.75	0.84
40	7.32	8.85	5.3	7.9	1.86	0.9
41	6.3	7.45	4.8	9	1.9	1.02
42	4.58	7.35	5.32	10.4	2.03	1.66
43	3.75	6.8	4.00	10.12	2.30	3.04
44	3.2	6.51	4.14	8.7	1.48	3.08
45	1.85	6	4.05	8.8	1.8	1.8
46	0.56	4.24	3	6	1.12	1.65
Mean	**3.48**	**5.92**	**3.24**	**5.20**	**1.44**	**1.4**

noticed. The first incidence was recorded in 31st MW and it attains its peak in 43rd MW (2.30) and it ranges in from 0.02 to 2.30 with a average of 1.44. Whereas in Beed district the infestation starts from 34th MW and its peak activity noticed during 43rd and 44th MW with a average of 1.4.

The data on population dynamics of whitefly during 2010-2011 revealed that(Table 2) in Parbhani district, the population of whiteflies was noticed during 28th MW. The peak population was recorded in 44th MW (14.16). The population ranged in between (0.04 to 14.16) though out the season whiteflies population was above ETL. From 41st MW to 46th MW. With a average of 5.24. In Hingoli district population of whiteflies was noticed in 30th MW and gradually increasing up to 39th MW and attains its peak (21.32) the it goes down decreasingly. But it was above ETL from 38th MW to 47th MW. The population ranged in between, 0.28 to 21.32 with a average population of 8.72. In Nanded district the infestation was recorded in 29th MW (0.12) and population of whiteflies was constant from 38th MW to 44th MW. The population ranges from 0.12 to 9.96 with average of 4.68. In Jalna district the whiteflies incidence was noticed in 28th MW and attains its peak in 43rd MW (15.60).The whiteflies population fluctuates in between 0.04 to 15.60 with a season average of 7.72 whiteflies / 3 leaves. The whitefly infestation was above ETL from 38th MW to 47th MW.

In Aurangabad district incidence of whiteflies was noticed in 28th MW and reaches a maximum population of 5.44 in 41st MW with a average of 2.6.In Beed district the incidence of whiteflies was noticed in 29 MW (0.12) and reaches its highest at 3.28 in 39th MW and population decreasing gradually (Table 2).

The data presented (Table 3) represents population of whiteflies during 2011-2012 and

Table 2. Mean population of cotton whiteflies/3 leaves in the districts of Marathwada 2010-2011

MW	Parbhani	Hingoli	Nanded	Jalna	Aurangabad	Beed
28 MW	0.04	0.00	0.00	0.04	0.28	0.00
29 MW	0.04	0.00	0.12	0.24	0.32	0.12
30 MW	0.12	0.28	0.56	0.32	0.64	0.32
31 MW	0.28	0.80	0.92	0.72	0.88	0.32
32 MW	0.36	1.36	1.08	1.12	1.08	0.32
33 MW	0.68	2.40	1.80	1.56	1.36	0.36
34 MW	0.92	2.76	2.60	1.72	1.56	0.56
35 MW	1.00	3.96	3.12	2.40	1.56	1.00
36 MW	1.56	4.72	3.88	3.08	1.96	1.00
37 MW	1.76	7.40	5.16	7.40	2.28	1.16
38 MW	2.76	12.76	7.48	10.64	3.80	1.48
39 MW	4.64	21.32	9.96	10.92	3.12	3.28
40 MW	9.56	20.08	9.04	14.08	4.92	3.08
41 MW	12.36	16.52	9.00	14.92	5.44	2.88
42 MW	11.56	12.92	9.04	15.00	5.36	2.76
43 MW	12.20	15.76	8.44	15.60	4.64	2.48
44 MW	14.16	13.32	9.56	14.48	4.16	2.04
45 MW	12.20	12.68	5.40	14.84	3.68	1.96
46 MW	11.64	12.28	3.60	12.44	2.64	1.20
47 MW	7.32	13.40	2.92	12.96	2.32	0.76
Mean	**5.24**	**8.72**	**4.68**	**7.72**	**2.60**	**1.36**

Table 3. Mean population of cotton whiteflies/3 leaves in the districts of Marathwada 2011-2012

MW	Parbhani	Hingoli	Nanded	Jalna	Aurangabad	Beed
27	0	0	0	0	0	0
28	0	0	0	0	0	0
29	0	0	0	0	0	0
30	0	0.12	0.04	0	0	0
31	0.04	0.12	0.12	0	0.24	0.08
32	0.24	0.2	1.04	0.24	0.56	0.04
33	0.56	0.84	1.68	0.44	0.72	0.08
34	1.52	1.56	1.48	0.88	0.92	0.28
35	0.92	2.04	2.12	1.64	0.76	0.28
36	1.4	3.76	3.12	2.08	0.88	0.44
37	1.48	6.24	4.12	2.24	1	0.44
38	1.84	6.84	4.56	2.44	1.52	0.68
39	2.16	6.88	4.96	2.6	1.76	0.8
40	2.04	7.56	5.8	3.32	1.84	0.88
41	2.36	8.12	5.72	3.56	1.88	0.96
42	2.36	8.56	6.2	3	1.84	1.64
43	2.32	8	6.96	2.84	1.8	1.84
44	2.56	7.68	6.84	2.76	1.8	1.68
45	1.92	5.8	6	2.88	1.56	1.6
46	2.04	5.28	5.08	3.28	1.36	1.48
Mean	**1.36**	**4.20**	**3.48**	**1.92**	**1.12**	**0.76**

revealed that in Parbhani district incidence of whiteflies was noticed in 31st MW and reaches its maximum in 44th MW (2.56). The population of whiteflies was fluctuates in between 0.04 to 2.56 whiteflies /leaf with a average of 1.36. In Hingoli district, the incidence was started from 30th MW and attains its peak in 42nd MW then its goes down decreasingly. The population of whiteflies ranges from 0.12 to 8.56 with a average of 4.2. Similarly in Nanded district the population fluctuates in between 0.04 to 6.96 with a average of 4.68 where as in Jalna district whitefly incidence was noticed in 32nd MW and reaches its peak (3.56) in 41st MW. During the season, population of whiteflies fluctuates in between 0.24 to 3.56 with average of 1.92. In Aurangabad district the infestation starts from 31st MW and reaches its peak in 41st MW with a average of 1.12.

The trend of incidence was constant from 36 MW to end of season i.e. 46th MW. Similarly in Beed district the infestation starts from 31st MW and attains its peak in 43rd MW with average of 0.76. During the year infestation was competitive more in Hingoli district.

The data (Table 4) revealed that during 2012-2013 in Parbhani district. The population of whiteflies ranged in between 0.28 to 7.40. The first incidence was noticed in 31st MW and attains its peak in 39th MW. There after population decreases gradually up to 46th MW. Whereas in Hingoli district infestation starts whereas from 33rd MW and it goes gradually increasing up to 39th MW and attains its peak (9.76) there after it goes on decreasing gradually. The average incidence of whiteflies was 5.52. In Nanded district the population fluctuates in between 0.08 to 6.20. The infestation starts from 31st MW and attains its peak in 38th MW thereafter it goes on decreasing with a average mean of 3.52 where as in Jalna district infestation starts from 30th MW and goes on increasing up to 42nd MW and attains its peak (8.92) thereafter it goes on decreasing. The population fluctuates in between 0.08 to 8.92 with a mean of 4.84.

In Aurangabad district infestation noticed in 32nd MW, it was moderately increased and constant throughout the season with a peak in 42nd MW (1.84). The average incidence of whiteflies was 1.08 whereas in Beed district infestation starts from 34th MW and it fluctuates up to 40th MW thereafter it goes on increasing up to 43rd and 44th MW and attains its peak (3.16) and thereafter goes down decreasing up to 46th MW with a season average of 1.36. In Parbhani district the activity of whiteflies started from 35th MW to 46th MW. Peak activity of whiteflies was observed during 39th MW (13.8/3 leaves).

The mean seasonal incidence of whiteflies in Parbhani during 2013-14(Table 5) was 6.36/3 leaves. Incidence of whiteflies in Hingoli district peaked in 41st MW (11.28/3 leaves) the population of whiteflies ranged from 6 to 11.26 / 3 leaves during different MW. The mean seasonal incidence of whiteflies in Nanded district was lower as compared to other districts *i.e.* 1.92 leaves. The highest population of whiteflies / 3 leaves was observed during 42 MW (2.48 / 3 leaves). In Jalna district the peak activity of whiteflies was recorded during 40th MW (12.80 / 3 leaves). The mean seasonal population of whiteflies on cotton in Jalna district was highest (9.48 / 3 leaves) as compared to other districts. The population of whiteflies valued between 3.16 and 12.80/3 leaves of cotton.

The present findings are similar with the findings of Rote and Puri (1991) and Patel (1992) who reported that *B.tabaci* was at peak during 2nd week of October to 3rd week of November. Daware *et al.,* (2003) reported first appearance of whiteflies from first week of August (31st MW) and peaked in first week of October to second week of November (40th -46th MW). Prasad *et al.,* (2008) observed that the peak incidence of whiteflies was from 44th to 48th standard week

Table 4. Mean population of cotton whiteflies/3 leaves in the districts of Marathwada 2012-2013

MW	Parbhani	Hingoli	Nanded	Jalna	Aurangabad	Beed
30	0.00	0.00	0.00	0.08	0.00	0.00
31	0.28	0.00	0.08	0.12	0.00	0.00
32	0.12	0.00	0.04	0.36	0.08	0.00
33	0.16	0.24	0.16	0.84	0.32	0.00
34	0.16	1.28	0.44	1.52	0.60	0.32
35	0.96	3.84	1.00	2.08	0.92	0.20
36	4.84	5.68	4.32	4.04	1.16	0.52
37	6.08	8.00	6.00	5.48	1.36	1.12
38	7.08	9.60	6.20	6.28	1.56	1.72
39	7.40	9.76	5.44	6.20	1.68	1.84
40	7.32	9.56	5.32	7.80	1.76	1.40
41	5.24	7.96	5.00	8.60	1.80	1.88
42	3.72	8.20	5.04	8.92	1.84	2.80
43	3.12	7.40	4.40	8.76	1.60	3.16
44	2.00	6.52	4.60	8.20	1.48	3.16
45	1.20	6.04	4.16	7.08	1.36	2.72
46	0.56	4.24	4.16	5.76	1.12	2.48
Mean	**3.12**	**5.52**	**3.52**	**4.84**	**1.08**	**1.36**

Table 5. Mean population of cotton whiteflies/3 leaves in the districts of Marathwada during 2013-2014

MW	Parbhani	Hingoli	Nanded	Jalna	Aurangabad	Beed
35	1.76	6.04	1.16	3.16	0.92	0.56
36	2.32	6.04	1.84	4.92	1.04	0.88
37	3.44	7.56	1.56	12.52	1.04	3.24
38	10.16	8.72	1.76	11.28	1.20	1.20
39	13.80	11.16	1.96	13.12	1.40	1.28
40	13.00	11.12	2.44	12.80	1.52	3.24
41	13.56	11.28	2.00	12.48	1.56	4.32
42	8.96	10.28	2.48	12.20	1.64	4.12
43	4.52	9.12	2.12	10.32	1.36	4.36
44	2.72	9.56	1.96	8.16	1.28	4.72
45	1.44	7.52	1.96	6.84	1.24	3.04
46	0.52	6.00	1.76	5.72	1.08	2.28
Mean	**6.36**	**8.72**	**1.92**	**9.48**	**1.28**	**2.76**

(November). Mohapatra (2008) reported the peak population of *B.tabaci* attained during 44^{th} standard week (October 29 to November 04). Parsai and Shastry (2009) observed the incidence of whitefly from 33^{rd} – 48^{th} SMW with its maximum incidence (21.1-31.1/3 leaves) during 41^{st} SMW. The findings are also supported with those of Sharma *et al.,* (2004) and Pawar *et al.,* (2008). The incidence of whitefly was more in second fortnight of September to first fortnight of October in all the districts of Marathwada and this period should be considered as important to undertake effective the whitefly management practices .

REFERENCES

Daware, D.G., Kurtadikar, J.S., Lavekar, R.C. and Bhosle, B.B. 2003. Achievements in insect pest management in cotton. *State level seminar on pest management for sustainable Agriculture* February 6-7, 2003 MAU, Parbhani: 4-6.

Mohapatra, L.N. 2008. Population dynamics of sucking pests in *hirsutum* cotton and influence of weather parameters on its incidence in western Orissa. *J. Cotton Res. Dev.*, **22** : 192-94.

Parsai, S.K. and Shastry, P.P. 2009. Seasonal incidence of key pests and their natural enemies on cotton. National Symposium on "*Bt-cotton: Opportunities and Prospects*" at ICCR, Nagpur, November 17-18, 2009 : 125-26.

Patel, J.R. 1992. Integrated pest Management in Cotton Hybrid-6. *Ph.D. Thesis* GAU, Anand.

Pawar, A.V., Chavan, S.J., Bhute, N.K. and Kadam, D.R. 2008. Population dynamics of sucking pest complex on cotton at Marathwada region of Maharashtra. *J. Plant Prot. Environ.*, **5** : 150-53.

Prasad, N.V.V.S.D., Rao, N.H.P. and Mahalakshmi, M.S. 2008.. Population dynamics of major sucking pests infesting cotton and their relation to weather parameters. *J. Cotton Res. Dev.*, **22** : 85-90.

Rote, N.B. and Puri, S.N. 1991. Population dynamics of whitefly *B. tabaci* on cotton and its relationship with weather parameters. *J. Cotton. Res. Dev.,* **5** : 181-89.

Sharma, P.D., Jat, K.L. and Takar, B.L. 2004. Population dynamics of insect pests on American cotton (*Gossypium hirsutum* L.) in Haryana. *J. Cotton Res. Dev.*, **18** : 104-06.

Singh, J.,**Butter, N.S. and Madan,V.K.1983**. Assessment of losses due to whitefly, *B. tabaci* in *hirsutum* cotton. *Indian J.ent.* Spl.Issue-**2** : 362-66.

Field performance of *Bt* cotton hybrids against major pests under unprotected conditions in Andhra Pradesh

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ABSTRACT : A field study was conducted to evaluate 59 *Bt* cotton hybrids along with check hybrid (Jaadoo) against sucking pests at RARS, Lam during 2013-14. Among the different sucking pests, leafhopper incidence was moderate to high, where as incidence of aphids and whiteflies was low to medium and the thrips incidence was very low. The incidence of leaf hoppers was ranged from 2.3 to 11.3/ 3 leaves, while whiteflies were ranged from 0.9 to 13.4/3 leaves with significant differences among the different hybrids. The incidence of aphids was ranged from 1.6 to 20.9/ 3 leaves with significant differences, while it was from 0.1 to 2.4/ 3 leaves for thrips among the different test hybrids without significant differences. The incidence of American bollworm is very low which was observed for a very short period only with less than 0.5 % square damage in all the hybrids and incidence of pink bollworm and tobacco caterpillar was nil during the crop growth period. The incidence of leaf hoppers was lowest in the hybrid, Western Nirogi 108 Bg II (2.3/ 3 leaves) and highest was recorded in SCH 777 (11.3/ 3 leaves). The hybrid, Surpass Asha recorded lowest incidence of whiteflies (0.93/ 3 leaves) and the highest incidence of whiteflies was recorded in the hybrid, Ankur 2595 (13.4/ 3 leaves).

Key words: *Bt* cotton hybrids, sucking pests, unprotected conditions

Cotton (*Gossypium hirsutum*) the ‘White Gold’, is one of the most important commercial crop playing a key role in Indian agriculture and economics which is cultivated under varied agro–climatic conditions across the major states of India. The crop is infested by about 1326 insect pests all over the world, however only 166 of them are reported to damage the crop in India (Hargreaves, 1948). However, *Bt* cotton incorporated with *Cry 1 Ac* and Cry 2ab are known to be resistant against major bollworms and several scientists have been already reported the efficacy of *Bt* cotton in India and abroad. However, they attract more sucking pests *viz.,* jassids, *Amrasca biguttula biguttula* (Ishida); thrips, *Thrips tabaci* (Linn.); aphid, *Aphis gossypii* (Glover) and whiteflies, *Bemisia tabaci* (Genn.) from seedling stage to boll development and harvesting stages. Sucking pests are known to cause heavy losses to the tune of 21.20 to 22.86 per cent (Kulkarani *et al.*, 2003 and Satpute *et al.*, 1990) in cotton besides acting as vectors for a number of viral diseases (Sreedhar *et al.*, 1999). The cultural practices such as use of resistant/tolerant varieties is a prime factor to minimise the damage due to insect pests and yield losses which can be used for devising the IPM strategies. Screening results in selection of some promising material with tolerance to sucking insect pests and other biotic stresses besides having good yields. The resistance/ tolerance entries could be taken up for advanced screening to assist in varietal improvement at later stages. In view of the above, the present study was taken up to evaluate the *Bt* cotton hybrids for the incidence of sucking pests under unprotected conditions.

MATERIALS AND METHODS

A field study was conducted to evaluate the *Bt* cotton hybrids against sucking pests at RARS, Lam during 2013-2015. A total of 62 hybrids were evaluated against sucking pests which were replicated twice in a randomised block design (RBD). The test hybrids were sown each in two rows of 8 meters length during the first week of August at a spacing of 105 x 60 cm. All the agronomic practices were followed as per the recommendations of ANGRAU to attain good crop growth. The hybrids were maintained completely under unprotected conditions throughout the crop growth period except against diseases to avoid crop loss due to diseases. The data regarding the Incidence of sucking pests *viz.,* leafhoppers, whiteflies, thrips and aphids per three leaves was recorded from 5 randomly selected plants from each hybrid at 30 and 60 days after sowing.

RESULTS AND DISCUSSION

Among the different sucking pests, leafhopper incidence was moderate to high, where as aphids, and whitefly incidence was low to medium and the thrips incidence was very low. The incidence of leaf hoppers was ranged from 2.3 to 11.3/ 3 leaves, while whiteflies were ranged from 0.9 to 13.4/3 leaves with significant differences among the different hybrids. Similarly the incidence of aphids ranged from 1.6 to 20.9/ 3 leaves among the entries with significant differences. But, there were no significant difference regarding the incidence of thrips among the test hybrids which was ranged from 0.1 to 2.4/ 3 leaves. The incidence of *Helicoverpa armigera* is very low with less than 0.5 per cent square damage in all the entries and incidence of pink bollworm and tobacco caterpillar was nil during the crop growth period. Among the different test hybrids, 30 and 34 hybrids recorded low incidence, whereas 12 and 14 hybrids recorded higher incidence of leaf hoppers and whiteflies, respectively. The incidence of leaf hoppers was lowest in the hybrid, Western Nirogi 108 Bg II (2.3/ 3 leaves) and highest was recorded in SCH 777 (11.3/ 3 leaves). The hybrid, Surpass Asha recorded lowest incidence of whiteflies (0.93/ 3 leaves) and the highest incidence of whiteflies was recorded in the hybrid, Ankur 2595 (13.4/ 3 leaves). The incidence of aphids was lowest in KCH 3041 (1.6/ 3 leaves) and highest was recorded in the DPC 5102 hybrid (20.9 / 3 leaves) (Table.1). However, multi location testing is essential to substantiate the tolerance/ resistance of hybrids.

Several screening studies were conducted by various scientists at different locations with different hybrids/varieties. Earlier, Gupta *et al*., (1997) reported maximum numbers of thrips on cotton cultivars H 4, H 6, JKH 1, DCH 32 and AHH 468 during second fortnight of August. According to Patel *et al*., (2010a), the highest jassid population was recorded in RCH II BG II (5.85) and found most susceptible. Vikram 5 *Bt* (2.12), G.Cot.hy.10 (2.32) and Akka N*Bt* (2.60) recorded significantly lower population than rest of the varieties. NCS 954 *Bt* of Mon 531 event was categorised as the most tolerant against both jassids and mealy bugs among 52 *Bt* hybrids (Patel *et al*., 2010b).

Table 1. Incidence of sucking pests in different Bt cotton hybrids at RARS, Lam during 2013-2014 under unprotected conditions

S.No	Hybrid	Number/3 leaves			
		Leafhoppers	Aphids	Thrips	Whitefly
1	Western Nirogi 108 BG II	2.3 (1.82)	6.5 (2.74)	0.7 (1.3)	8.9 (3.15)
2	NCH 2108	3.1 (2.02)	9.7 (3.27)	1.6 (1.61)	7.3 (2.88)
3	AC H 4	5.0 (2.45)	9.1 (3.18)	0.3 (1.14)	5.9 (2.63)
4	SCH 505	4.1 (2.26)	4.9 (2.43)	1.2 (1.48)	7.5 (2.92)
5	KSCH 207	4.3 (2.30)	3.3 (2.07)	0.5 (1.22)	6.6 (2.76)
6	Bunny	8.6 (3.1)	8.6 (3.1)	0.6 (1.26)	2.8 (1.95)
7	ACH 2	3.7 (2.17)	6.0 (2.65)	1.9 (1.7)	8.5 (3.08)
8	KCH 3011	8.5 (3.08)	7.8 (2.97)	0.7 (1.3)	4.6 (2.37)
9	SWCH 4823	4.9 (2.43)	12.8 (3.71)	0.4 (1.18)	11.7 (3.56)
10	PCHH 4 (Saraswathi)	5.2 (2.49)	4.7 (2.39)	1.1 (1.45)	5.5 (2.55)
11	ACH 1	3.1 (2.02)	6.1 (2.66)	0.7 (1.3)	8.1 (3.02)
12	NBC 101	4.0 (2.24)	7.2 (2.86)	1.3 (1.52)	2.7 (1.92)
13	SCH 311	2.5 (1.87)	10.0 (3.32)	1.9 (1.7)	5.3 (2.51)
14	Mallika	5.9 (2.63)	12.5 (3.67)	0.9 (1.38)	1.7 (1.64)
15	Ankur 2595	3.4 (2.1)	6.9 (2.81)	0.8 (1.34)	13.4 (3.79)
16	Western Niogi 51	3.7 (2.17)	16.2 (4.15)	1.4 (1.55)	6.3 (2.7)
17	ACHH 2	7.6 (2.93)	10.4 (3.38)	1.1 (1.45)	2.3 (1.82)
18	JKCH 8905	6.0 (2.65)	9.6 (3.26)	0.3 (1.14)	3.9 (2.21)
19	KCH 3021	9.3 (3.21)	5.5 (2.55)	0.3 (1.14)	4.3 (2.3)
20	KSCH 232	4.9 (2.43)	6.4 (2.72)	1.1 (1.45)	4.5 (2.35)
21	DPC 5102 (Aravind)	4.2 (2.28)	20.9 (4.68)	1.3 (1.52)	5.0 (2.45)
22	First class	4.1 (2.26)	8.8 (3.13)	0.8 (1.34)	6.3 (2.7)
23	IAHH 4202	7.0 (2.83)	11.3 (3.51)	0.3 (1.14)	3.9 (2.21)
24	DPC 9104 (Aravind)	4.5 (2.35)	12.4 (3.66)	0.8 (1.34)	5.0 (2.45)
25	ACH 104 2	5.3 (2.51)	11.0 (3.46)	0.7 (1.3)	8.5 (3.08)
26	Mallika	5.1 (2.47)	4.7 (2.39)	1.3 (1.52)	1.9 (1.7)
27	KSCH 233	3.9 (2.21)	5.6 (2.57)	1.5 (1.58)	5.9 (2.63)
28	81 SS 33	5.9 (2.63)	1.9 (1.7)	2.2 (1.79)	4.7 (2.39)
29	PCHH 5073 (Meenakshi)	5.3 (2.51)	8.1 (3.02)	0.5 (1.22)	8.6 (3.1)
30	60 SS 66	8.2 (3.03)	6.4 (2.72)	0.3 (1.14)	3.6 (2.14)
31	Ankur 3818	6.6 (2.76)	3.6 (2.14)	0.6 (1.26)	12.6 (3.69)
32	Bunny	5.0 (2.45)	8.3 (3.05)	0.3 (1.14)	3.3 (2.07)
33	KCH 3041	4.2 (2.28)	1.6 (1.61)	0.5 (1.22)	2.4 (1.84)
34	KSCH 209	3.9 (2.21)	10.4 (3.38)	1.8 (1.67)	2.4 (1.84)
35	741 SS 66	6.8 (2.79)	5.5 (2.55)	0.6 (1.26)	8.4 (3.07)
36	Ankur 5464	9.0 (3.16)	2.3 (1.82)	0.1 (1.05)	1.6 (1.61)
37	SP 7585	5.3 (2.51)	11.9 (3.59)	0.4 (1.18)	4.8 (2.41)
38	Ankur 2224	6.4 (2.72)	8.1 (3.02)	1.2 (1.48)	2.4 (1.84)
39	KSCH 229	7.0 (2.83)	14.8 (3.97)	0.8 (1.34)	9.3 (3.21)
40	SCH 234	5.0 (2.45)	5.0 (2.45)	0.9 (1.38)	3.5 (2.12)
41	KCH 3031	5.4 (2.53)	4.5 (2.35)	0.4 (1.18)	4.3 (2.3)
42	RCH 797	5.1 (2.47)	12.7 (3.7)	2.4 (1.84)	3.0 (2)
43	IAHH 178	6.9 (2.81)	5.0 (2.45)	1.4 (1.55)	1.7 (1.64)
44	KCH 3001	7.4 (2.9)	9.4 (3.22)	0.7 (1.3)	6.5 (2.74)

45	Surpass Asha	9.3 (3.21)	3.7 (2.17)	0.4 (1.18)	0.93 (1.38)
46	NCH 1311	4.6 (2.37)	5.2 (2.49)	1.9 (1.7)	6.9 (2.81)
47	Ankur 4858	3.1 (2.02)	7.6 (2.93)	1.8 (1.67)	5.1 (2.47)
48	DPC 7102 (Arind)	5.8 (2.61)	6.0 (2.65)	0.9 (1.38)	3.4 (2.1)
49	63 88 33	5.5 (2.55)	9.1 (3.18)	1.0 (1.41)	6.6 (2.76)
50	NCH 1049	6.1 (2.66)	6.1 (2.66)	1.6 (1.61)	2.1 (1.76)
51	Mallika	8.2 (3.03)	1.8 (1.67)	1.9 (1.7)	1.2 (1.48)
52	RCH 779	4.3 (2.3)	5.5 (2.55)	1.2 (1.48)	10.0 (3.32)
53	NBC 102	5.9 (2.63)	6.7 (2.77)	0.7 (1.3)	6.9 (2.81)
54	Bunny	5.7 (2.59)	2.4 (1.84)	0.8 (1.34)	4.8 (2.41)
55	SP 7517	6.1 (2.66)	11.1 (3.48)	1.45 (1.57)	2.1 (1.76)
56	DPC 9105 (Arind)	4.2 (2.28)	1.7 (1.64)	1.5 (1.58)	5.0 (2.45)
57	KSCH 234	6.6 (2.76)	10.0 (3.32)	0.7 (1.3)	6.2 (2.68)
58	SCH 777	11.3 (3.51)	3.2 (2.05)	0.3 (1.14)	2.7 (1.92)
59	SCH 333	7.7 (2.95)	2.2 (1.79)	0.7 (1.3)	2.5 (1.87)
60	Jaadoo	4.6 (2.37)	11.2 (3.49)	1.2 (1.48)	8.8 (3.13)
	CD (p=0.05)	0.46	0.64	NS	0.94
	CV (%)	11.0	14.8	13.7	18.4

Figures in Parenthesis are Square root (X+1) transformed values

REFERENCES

Hargreaves, H. 1948. List of recorded cotton insects of the world, Common Wealth. Institute of Entomology, London,.: 50.

Gupta, M. P., Sharma, S. and Shrivastava, S. K. 1997. Population buildup of some sap–sucking insect on cotton in M.P. *Jour. Insect Sci.* **10** : 53–56.

Kulkarni, K.A., Patil, S. B. and Udikeri, S. S. 2003. Status of sustainable IPM of cotton pests: A scenario in Karnataka; In Proceedings of National Symposium on *"Sustainable Insect Pest Management"*, Feb 6–7, 2003, ERI, Loyala College, Chennai.:45

Satpute, U. S., Patil, V. N., Katole, S. R., Men, U. B., Bhagwat, V. R. and Thakare, A. Y. 1990. Avoidable losses due to sucking pests and bollworms in cotton. *Jour. App. Zoo. Res.,* **1:** 67–72.

Sreedhar, S., Ulrich, K. and Nedim, U. 1999. Development and fecundity of *Aphis gossypii* Glover (Homoptera: Aphididae) on three malvaceae hosts. *Tribal Jour. Agri. Forest.* **23 :** 637–43.

Patel, S. M. and Bharpoda, T.M. 2010a. Screening of *Bt* cotton varieties for their susceptibility to leaf hopper and mechanism of Resistance. . In Proceedings of National conference on *"Paradigm shift in Cotton Research and Cultivation"*. October 19-21, 2011 pp. 24.

Patel. C.J., Bhadauriya, S., Desai H.R., Maisuria, I.M., Solanki, V.Y. and Kumar, V. 2010b. Reaction of *Bt* cotton hybrids to Jassids, *Amrasca bigitula bigitula* (Ishida) and mealy bug, *Phenococcus solenopsis* Tinsley. In Proceedings of National conference on *"Paradigm shift in Cotton Research and Cultivation"*. October 19-21, 2011. pp. 16-17.

Integrated management of foliar diseases in cotton

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ABSTRACT: Three modules were evaluated to develop integrated management of foliar diseases in cotton. Module I was composed of Seed treatment with *Pseudomonas fluorescens* @ 10g/kg seed and soil application of *P. fluorescens* @ 2.5kg/ha followed by two foliar sprays with *P. fluorescens* (1%) at 60 and 90 days after sowing (DAS). Module II involved seed treatment with *P. fluorescens* @ 10g/kg seed followed by need based foliar sprays with propiconazole (0.1%) for Alternaria leaf spot at 60 DAS and copper oxychloride (COC) @ (0.3%) + Streptocycline (0.01%) for bacterial blight at 90 DAS (or) carbendazim (0.1%) at 60 DAS against grey mildew and propiconazole (0.1%) for Alternaria leaf spot and rust at 90 DAS. Module III included seed treatment with *P. fluorescens* @ 10g/kg seed and soil application of *Trichoderma viride* @ 2.5kg/ha followed by need based foliar sprays with kresoxim methyl @ 1ml/l at 60 DAS and combined product of captan+hexaconazole @ 1.5g/l at 90 and 120 DAS for fungal diseases or COC (0.3%) + streptocycline (0.01%) for bacterial blight at 60 and 90 DAS. Pooled data showed that the modules were significantly superior against Alternaria leaf spot and bacterial blight in Jadoo BG II and RCH BG II. Modules I and II significantly reduced grey mildew in both the hybrids. Module II and III gave best control of rust in Jadoo BG II while module I and III were superior in RCH 2 BG II. All three modules resulted in significant increase in the yield of Jadoo BG II while modules I and II gave superior yields in RCH 2 BG II. Module III resulted in highest Incremental Benefit Cost Ratio (IBCR) of 1.35 in Jadoo BG II followed by module I while module II gave maximum IBCR of 1.30 in RCH 2 BG II.

Key words: Cotton, foliar diseases, integrated disease management

Cotton is an important fibre crop in India, cultivated in 126.55 lakh ha with 400 lakh bales (each bale of 170kg lint) production and a productivity of 537kg lint/ha during 2014-15 season. Andhra Pradesh stood 5th in area (7.36 lakh ha) and 6th in production (21.10 lakh bales) as well as productivity (624 kg/ha) during 2014 – 2015 (Anonymous, 2015). Cotton crop is affected by a number of foliar diseases throughout the season. Altenaria leaf spot, bacterial blight, grey mildew and rust diseases cause significant yield losses under congenial conditions (Monga *et al* 2013). Spraying copper fungicide (0.3%) mixed with streptocycline (0.01%) control foliar diseases. Propiconazole is effective against Alternaria leaf spot and rust diseases (Bhattiprolu and Prasad Rao, 2009, Monga *et al* 2013). Carbendazim is recommended to prevent losses due to grey mildew (Bhattiprolu, 2012). With these recommendations against individual diseases, an experiment was conducted to develop modules for integrated management of foliar diseases in cotton.

MATERIALS AND METHODS

A field trial was laid out at Regional Agricultural Research Station, Lam, Guntur during *kharif* 2011 to 2013. Eight treatments (three modules with two *Bt* hybrids plus controls) were replicated thrice in plots of 50 sq. m by adopting a spacing of 105 x 60 cm in randomized block design. Module I (T1 and T4) was composed of seed treatment (ST) with *Pseudomonas fluorescens* @ 10g/kg seed and soil application (SA) of *P. fluorescens* @ 2.5kg/ha followed by two foliar sprays with *P. fluorescens* (1%) at 60 and 90 days after sowing (DAS). Module II (T2 and T5) involved ST with *P. fluorescens* @ 10g/kg seed followed by need based foliar sprays with propiconazole (0.1%) for Alternaria leaf spot at 60 DAS and copperoxy chloride (COC) (0.3%) + Streptocycline (0.01%) for bacterial blight at 90 DAS (or) carbendazim (0.1%) at 60 DAS against grey mildew and propiconazole (0.1%) for Alternaria leaf spot and rust at 90DAS. Module III (T3 and T6) included ST with *P. fluorescens* @ 10g/kg seed and SA of *Trichoderma viride* @ 2.5kg/ha followed by need based foliar sprays with kresoxim methyl @ 1ml/l at 60 DAS and combined product of captan+hexaconazole @ 1.5g/l at 90 and 120 DAS for fungal diseases or COC (0.3%) + streptocycline (0.01%) for bacterial blight at 60 and 90 DAS. Control plots (Jadoo BG II of T7 and RCH 2 BG II T8) received no protection for diseases. Data on bacterial blight, Alternaria leaf spot, grey mildew and rust were recorded using 0 to 4scale and per cent disease control in each treatment was calculated. Treatment wise yield data and increase in yield over control was recorded. Treatment wise net returns and incremental benefit cost ratio (IBCR) was calculated.

RESULTS AND DISCUSSION

Pooled data showed that all three modules were significantly superior against Alternaria leaf spot and bacterial blight in Jadoo BG II and RCH BG II (Table 1). Modules I and II significantly reduced grey mildew in Jadoo BG II. The disease intensity was low in RCH BG II. Module III recorded the lowest rust intensity (9.96%) in Jadoo BG II, while module II was on par. Module I and module III were superior against rust in RCH 2 BG II (Table 1).

Efficacy of biocontrol agent, *P. fluorescens* as seed treatment followed by foliar applications was found effective against Alternaria leaf spot, bacterial blight and grey mildew (Bhattiprolu, 2010; Chattanavar *et al.,* 2010). Efficacy of seed treatment with endospore forming bacteria against foliar, seed/soil borne diseases of cotton was reported by Medeiros *et al.,* (2015). Module I involving *P. fluorescens* confirms these findings. Efficacy of carbendazim against grey mildew as part of module II and III, in susceptible *Bt* hybrid like Jadoo is in agreement with Bhattiprolu (2012) and Monga *et al.,* (2013). Management of bacterial blight with combination of COC and streptocycline in modules II and III validates the previous works (Bhattiprolu, 2013; Monga *et al.,* 2013). Nunkumar (2006) reported the use of *T. harzianum* against *Phakopsora pachyrhiza* causing soybean rust. Efficacy of Module III using foliar applications with kresoxim methyl and combination of captan and hexaconazole also confirms reports of Bhattiprolu (2010), Chattanavar *et al.,* (2010) and Bhattiprolu (2015). All three modules resulted in significant increase in the yield in the range of 20.34 per cent to 34.75 per cent. Maximum IBCR of 1.35 was recorded with module III followed by module I (1.31) and module II (1.30). Module III resulted in highest IBCR of 1.35 in Jadoo BG II followed by module I while module II gave maximum IBCR of 1.30 in RCH 2 BG II (Table 1). In conclusion farmers are advised to adopt integrated management of foliar diseases using recommended biocontrol agents and/or chemicals.

Table 1. Integrated management of foliar diseases in cotton (Pooled data, 2011-13)

Treatment	Per cent Disease Intensity (PDI)				Reduction in disease (%)				Seed cotton yield (q/ha)	Increase in yield (%)	Incremental Benefit Cost Ratio
	Alternaria leaf spot	Bacterial blight	Grey mildew	Rust	Alternaria leaf spot	Bacterial blight	Grey mildew	Rust			
T1	10.34 (18.72) a	7.49 (15.79)a	12 (20.27)c	13.67 (21.68)b	62.7	54.5	69.23	52.68	13.45a	30.2	1.31
T2	11.24 (19.55) a	9.7 (18.15)a	11 (19.37)c	11 (19.37)a	59.45	41.07	71.79	61. 90	12.90a	24.88	1.25
T3	11.63 (19.91)a	8.7 (17.21)a	15 (22.79)d	9.96 (18.39)a	58.04	46.84	61.54	65.52	13.92a	34.75	1.35
T4	11.33 (19.64)a	7.66 (16.06)a	2 (8.13)a	10.19 (18.58)a	59.2	38.25	73.33	61.86	12.70a	25.37	1.26
T5	10.72 (19.09) a	9.49 (17.90)a	3 (9.89)a	14.17 (22.1)b	61.4	42.1	60	46.99	13.16a	29.91	1.3
T6	11.01 (19.37) a	7.5 (15.89)a	5.9 (14.06)b	11.59 (19.87)a	60.35	54.24	21.33	55.5	12.19b	20.34	1.21
T7	27.72 (31.76)b	16.46 (23.89) b	39 (38.65)e	28.89 (32.49)c					10.33c		
T8	27.77 (31.79)b	16.39 (23.85) b	7.5 (15.89)b	26.72 (31.11)c					10.13c		
CD (p=0.05)	1.26	2.269	3.373	2.824					0.8		
CV (%)	4.7	12.4	16.7	10.40					3.70		

*Figures in parentheses are transformed values. Figures marked with same letters are not significantly different.

T1 and T4 - Seed treatment (ST) with *Pseudomonas fluorescens* @ 10g/kg seed and soil application (SA) of *P. fluorescens* @ 2.5kg/ha followed by two foliar sprays (FS) with 1% *P. fluorescens* at 60 and 90 days after sowing (DAS); T2 and T5 - ST with *P. fluorescens* @ 10g/kg seed followed by need based FS with propiconazole 0.1% for Alternaria leaf spot at 60 DAS and copper oxy chloride (COC) @ 0.3% + Streptocycline @ 0.01% for bacterial blight at 90 DAS (or) carbendazim 0.1% at 60 DAS against grey mildew and propiconazole 0.1% for Alternaria leaf spot and rust at 90 DAS; T3 and T6 - ST with *P. fluorescens* @ 10g/kg seed and SA of *Trichoderma viride* @ 2.5kg/ha followed by need based FS with kresoxim methyl @ 1ml/l at 60 DAS and combined product of captan+hexaconazole @ 1.5g/l at 90 and 120 DAS for fungal diseases or COC @ 0.3% + streptocycline @ 0.01% for bacterial blight at 60 and 90 DAS; T7 and T8 – No protection for diseases. Jadoo BG II (T1, T2, T3 and T7) and RCH 2 BG II (T4, T5, T6 and T8) were the test hybrids.

REFERENCES

Anonymous, 2015. AICCIP Annual Report (2014-15). All India Coordinated Cotton Improvement Project, Coimbatore, Tamil Nadu.

Bhattiprolu, S. L. 2015. Efficacy of Kresoxim methyl against foliar diseases of Cotton. *J. Cotton Res. Dev.* **29** : 112-15.

Chattannavar, S. N., Hosagoudar, G. N. and Ashtaputre, S. A. 2010. Chemical and biological management of major foliar diseases of cotton. *Karnataka J. Agric. Sci.* **23** : 599-601.

Monga, D., Sree Lakshmi, B. and Prakash, A. H. 2013. Crop losses due to important cotton diseases. Central Institute for Cotton Research, Regional Station, Sirsa, India, *Tech. Bull.* No. **1** : 23.

Medeiros, F. H.V.D., Souza, R. M. D., Ferro, H. M,, Zanotto E, Machado, J. D.C., et al. 2015. Screening of Endospore-Forming Bacteria for Cotton Seed Treatment against Bacterial Blight and Damping-off. Adv. Plants Agric. Res. 2 (4): 00056. DOI: 10.15406/ apar.2015.02.00056.

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