Silver Jubilee International Symposium

on

"Global Cotton Production Technologies *vis-a-vis* Climate Change"
October 10-12, 2012

CCS Haryana Agricultural University,
Hisar - 125 004

PROCEEDINGS

Organised by

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

CCS Haryana Agricultural University,
Hisar - 125 001

In collaboration with

Indian Council of Agricultural Research, New Delhi-110 001

***Citation:* In:** **“Global Cotton Production Technologies *vis-a-vis* Climate Change”** (Eds. S. S. Siwach, R. S. Sangwan, M. S. Chauhan and Omender Sangwan), Cotton Research and Development Association, CCS HaryanaAgriculturaI University, *Hisar - 125 004,* India.

DISCLAIMER

Printed at
Ridhi Sidhi Printers
Katla Ramlila, Hisar-125 001
Haryana, India
Ph. 92157-31663

PRINTED IN INDIA

FOREWORD

Cotton is one of the most ancient and very important commercial fibre crop of global importance with a significant role in Indian agriculture, industrial development, employment generation and improving the national economy. It provides employment to about 70 million people and contributes nearly 75 per cent of total raw material to the textile industry in India. It is the back bone of the flourishing textile industry in India. Globally cotton is facing challenges that not only affect sustainability of production but also competitiveness with artifial fibres in the textile industry. The dawn of new millennium is witnessing changes in cultivar preferences, plant protection strategies, fibre quality requirements, displacement of cotton area etc.

India holds the unique distinction of being the only country in the world that grows all the four cultivates species of cotton and their hybrids in the vast diverse agro climatic situation prevailing across the length and breadth of the country. It is cultivated in tropical and sub tropical regions of more than 100 countries. Cotton is grown in the country in different holdings with varied planting dates, soil and water conditions largely under rainfed situation. Sustainability of production, requisite quality standards and rising cost of cultivation, pest management and environmental implications, defective irrigation practices, unstable production and widespread complaints on deterioration of fibre quality are some of the serious challenges for the scientists, developmental department staff, field functionaries and the cotton grower. To achieve this, scientists worldwide are working to meet serious scientific challenges.

Cotton in 2002 on commercial scale marks the beginning of transgenic era in the country. The problems and prospects of *Bt* cotton in the country need to be put in proper perspective. Million of people depend in cotton cultivation, trade transporation, ginning and processing for their livelihood. India is the second largest producer of cotton in the world, next to China only. However, new emerging threats in term of biotic and abiotic factors are to be understood properly and effective strategies need to be put in proper prospective. Climate change has become a major national issue as well as of global concern and such changes will affect coton productivity and environment. Therefore, the crop scientists have a crucial and pivotal role to play in solving the problems so as to benefit the poor peasantry.

With the continued advances in plant breeding, plant genome, genetic engineering and biotechnology research, improved seed have to be evolved for reaping the untapped yield potential. Good quality seed acts as a catalyst for realizing the potential of all other agriculture inputs. Continuous efforts are required to make use of new technology for efficient crop improvement and management.

The papers appearing in this proceeding reflects the achievements made by scientists to attain higher sustainable production and this proceeding will be useful to all the stalkholders *viz.*, researchers, students, developmental department officers, planners, and farmers.

Sd/-
C. D. Mayee
President, Cotton Research and Development Association
CCS Haryana Agricultural University, Hisar and
Former Chairman, Agricultural Scientists Recruitment Board
(ASRB) Govt. of India, New Delhi

Place : Nagpur

Dated : 2 - 1 - 2013

PREFACE

Cotton is an important fibre crop of India and the world as well. Indian farmers produce cotton ranging from coarse and shortest to finest and the longest fibre for all counts of spinning. There is hardly any scope of further expansion of area under cotton which calls for more attention towards improvement in productivity through conventional and unconventional approaches. The decreasing production and higher cost of production are thus, becoming a serious threat to cotton cultivation. The point of immediate concern, is to increase production by saving it from the onslaught of newly emerging pest complex.

Climate Change has become a major national issue as well as of global concern. New projections show that climate change and its consequences *i. e.* increased heat waves, melting glaciers, rise in sea level, change in temperature, ultra violet radiations, increasing carbon dioxide and other gases, depletion of nutrients in soil, erratic and scanty rainfall, declining water resources, changing pests diseases scenario will affect every aspect of life. Such changes will affect cotton productivity and environment.

Cotton is one of the most ancient and very important commercial fibre crop of global importance with a significant role in Indian agriculture, industrial development, employment generation and improving the national economy. It is cultivated in tropical and sub tropical regions of more than 100 countries. It is the back bone of the flourishing textile industry in India. 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.

Although India ranks first in area, its productivity is lowest among major cotton growing countries. The concerted research efforts in crop improvement and development of location specific crop production and protection technologies have increased cotton production. Presently, India is the second largest producer of cotton in the world, next to China only. Crop scientists have a crucial and pivotal role to play in solving the problems so as to benefit the poor peasantry.

The research papers included in this proceeding are related to **"Crop Improvement and Biotechnology", "Crop Production and Post Harvest Technology", "Crop Protection and Biosafety" and "Socio-economic and Development"** which were the theme areas of the symposium. Present compilation on **"Global Cotton Production Technologies *vis-a-vis* Climate Change"** is a compendium of holistic advancements and other relevant information related to cotton covering different disciplines. We hope the information contained in this proceeding will be useful to all the stakeholders *viz.,* researchers, students, developmental officers, planners and farmers. All these manuscripts have been pre reviewed by eminent scientists of the respective disciplines/fields before publishing in this proceedings. 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. C. D. Mayee, President, CRDA for his valuable guidance and directions in the general functioning of CRDA and the International Symposium in particular. We take this opportunity to thank all concerned and hope this proceedings will serves the purpose of cotton research workers for furthering the cause of cotton farmers.

Place : CCS HAU, Hisar

Dated :

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

ACKNOWLEDGEMENTS

The Executive Council of the Cotton Research and Development Association, CCS Haryana Agricultural University, Hisar is gratefully acknowledged the Indian Council of Agricultural Research (ICAR), New Delhi, Council of Scientific and Industrial Research (CSIR), New Delhi and Department of Science and Technology (DST), Govt. of India for the financial assistance provided for printing of "Book of Papers" and "Book of Abstracts" for the Silver Jubilee International Symposium on **"Global Cotton Production Technologies *vis-a-vis* Climate Change"** held at CCS Haryana Agricultural University, Hisar from **October 10-12, 2012.**

Proceedings on "Global Cotton Production Technologies *vis-a-vis* Climate Change"

CONTENTS

LEAD PAPERS

INVITED PAPERS

ABSTRACTS - ORAL PRESENTATION

CROP IMPROVEMENT AND BIOTECHNOLOGY

CROP PRODUCTION AND MECHANIZATION

LEAD PAPERS

Chemical aids for mechanical harvest

D. STEVEN CALHOUN
Bayer Crop Science, International Cotton and Asia Rice Breeding Mgr., Lubbock, TX, USA

When it comes to mechanical harvest (MH) of cotton, India represents a new frontier. India's use of hybrid varieties in wide plant spacing is unique in the world. Experience with MH elsewhere in the world may be of some assistance, but Indian scientists will need to adapt lessons from other regions to find what is applicable here.

Adapting cultivation practices for MH will require a wide range of measures, potentially including changes in genotypes sown, plant spacing, fertilization, insect control practices, irrigation, chemical plant growth regulators (PGR), chemical harvest aids (HA), and even post harvest processing. I will focus on chemical tools helpful for MH, but I don't want to lose sight of the fact that moving to MH requires a holistic, multi disciplinary approach.

All my experience and most global research has been in temperate climates with high plant populations (~100,000 plants/ha). I will present knowledge gained under these conditions, but will attempt to emphasize the TYPE of research that must be done, rather than try to make local recommendations.

Before digging into PGR and HA specifically, I will just touch on a few general considerations for MH. Individual plant architecture, particularly basic plant size, is the primary factor that distinguishes Indian cotton from that in mechanized markets. The tradition here is for very tall, robust plants with vigorous, productive monopodia and long sympodia bearing multiple bolls. "Good chaining" is a term I hear our breeders and agronomists use with great admiration to describe a desirable genotype. The problem with this plant type for MH is that the plants must be made to go through the relatively small picking heads of a mechanical harvester. In general, it is safe to say that the larger plants are, the lower will be mechanical harvesting ease and efficiency.

Plants can be made smaller by a number of means. Simply sowing at a higher density can reduce plant size due to greater moisture and/ or nutrient stress on individual plants. However, starting from point of most commercial Indian hybrids, increased sowing density alone will not adequately reduce plant size; we must make some genetic changes.

Just as we can identify and select genotypes with tall plant stature and long fruiting branches, we can also select genotypes that have shorter main stem internodes and more compact fruiting habit. The art will be in finding the optimum degree of genetic plant size reduction.

Combining the correct genetics with higher plant density has been the core strategy to achieve higher yields in MH markets. This strategy must obviously be supplemented with optimization of other crop management practices. I believe that the greatest challenge and the greatest opportunity for India cotton breeders over the next decade is to achieve two primary objectives:

1) Channel available hybrid vigor into cotton fibre (high value) and away from excessive vegetation (low value)
2) Reduce cost of hybrid seed production using male sterility and other strategies in order to keep high sowing density cost effective.

Now, with apologies for the rather long introductory comments, I will return to the subject mentioned in the title of this talk, chemical aids for mechanical harvest. These fall into two general categories:

1) Plant growth regulators
2) Harvest aids.

Plant growth regulators : The primary purpose and function of PGR is to reduce internode length and thus total plant height in order to achieve more efficient MH, but there are additional, more subtle effects as well. The PGR with longest use history is mepiquat chloride (MQC). MQC inhibits production of gibberellin, the plant hormone responsible for cell enlargement and elongation. As a result, cells in MQC treated plants are generally smaller and/or shorter. Thus, plants themselves are shorter and narrower making mechanical harvest more efficient. In addition, leaves are smaller (though thicker) which makes insecticide application more efficient and often reduces boll rot due to better canopy ventilation. In most studies, Leaf Area Index (LAI) is reduced 5 to 10 per cent and stem dry weight is reduced up to 20 per cent with application of MQC. In theory, reducing vegetative growth with PGR could improve harvest index (shifting photosynthate from vegetation to lint production). However, the genotype and other management practices must be suitable to take economic advantage of any freed up carbohydrates. Interestingly, this cell-shortening effect is not seen in fiber cells. Fibre quality, in particular fibre length, is generally unaffected by MQC.

In many studies, MQC has caused increased boll retention lower on the plant and often decreased boll retention higher on the plant. The explanation for this is beyond the scope of this presentation, but the net effect is generally somewhat earlier maturity, but only small or inconsistent increase in total yield. Under many abiotic stress conditions MQC application can significantly decrease yield which brings us to the four primary factors affecting appropriate MQC use.

The effect of MCQ treatment depends on:

1) rate
2) timing
3) target genotype
4) environmental conditions

Total MQC use rate per season should not exceed 1440 ml/ac. However, this should be split into multiple applications depending on strategy and the other factors mentioned. Typical “low rate multiple applications” (LRMA) are 60 to 360 ml/ac in up to 5 separate applications. High rate applications are up to 720 ml/ac in a single application.

Application timing and rate obviously interact. Earlier applications, when plants are small, require only low rates for significant effects. Later applications, when plants are large, require higher rates to achieve a given degree of reduction in vegetative growth due to dilution effect in the plant. Typically, applications begin with low rates (60 to 120 ml/ac) when early flower buds are 1/3 to ½ grown and continue as needed up until 30 days before harvest.

Different genotypes respond differently to MQC application. Compact, short season, or determinant genotypes require less MQC than more full-season or larger growing genotypes. In India, I have seen very few of the former, so I anticipate relatively high rates of MQC would be needed until significant changes are made in genotypes here.

The environment is the only factor outside our control or even ability to predict with accuracy. We say in Texas that it is best to apply MQC 3 days before a 2 inch rain but disastrous to apply before a 2 week drought. Since we don’t know when, or if, we will get rain in Texas, PGR timing is a little tricky. The need to manage MQC in concert with environmental conditions argues strongly for LRMA. The cost of application for each treatment argues for fewer treatments at higher rates. These competing considerations must be balanced under Indian conditions.

One potential solution to this rate/timing dilemma is Stance®, a second generation PGR from Bayer. Stance is a mixture of MQC and cyclanilide. Use rates are lower (60 to 90 ml/ac) and timing is less problematic. Under most conditions, one application is made at 1/3 grown flower bud, followed by a second application 14 days later if plants are under little or no stress. Effects of Stance are otherwise fairly similar to MQC: shorter and narrower plants, smaller leaves, higher early boll set.

Other modifications of MQC are also available from other companies.

Harvest aids : These fall in to two categories: defoliants and boll openers. HA in general are useful in controlling to some extent the timing of harvest, but are primarily designed to prepare the crop for clean, efficient MH. HA are only AIDS and supplement natural maturation process. For the chemicals to be effective, the crop must be at the proper stage of development.

Defoliants are used to induce leaf abscission and reduce (not eliminate!) the amount of leaf trash in MH cotton. Many materials have efficacy as defoliants. Activity of all is rate dependent and for many temperature dependent. Ideal temperatures are >27° C daytime and >17° C nighttime. These materials are not well translocated, so good spray coverage is essential. On large vigorous plants, multiple applications are needed.

The objective of defoliants is to encourage leaves to drop “naturally” by upsetting the balance of auxin in leaves *v/s* stems. Herbicidal defoliants decrease auxin production in leaves by slowing killing the leaf tissue, resulting in formation of leaf abscission layer. If rates are too high, or conditions are not favorable, leaves can die prior to formation of abscission layer, resulting in poor defoliation. Other defoliants, such as Cyclanilide (found in Finish 6®), stop auxin transport from leaf blades to petioles, causing auxin imbalance and formation of abscission layer without leaf death. These defoliants are generally less error prone than herbicidal defoliants, but they are generally more expensive. Herbicidal defoliants are better at reducing regrowth which can stain lint during harvest.

Boll openers (ethephon or mixes including ethephon) are used to promote opening of green bolls that are near maturity, making them available for MH. Ethephon can also improve performance of certain defoliants. Although once over MH is desirable, it is also possible to MH the earliest 2/3 to ¾ of the crop and collect the remaining in a second MH. Minor damage to green bolls during the first harvest will cause the release of ethylene, which will also promote boll opening.

Correct application of harvest aids is still very much an art since many factors can affect success including stage of the crop, interaction among HA products, rates of various HA poducts, and environmental conditions. A few of the typical tank mixes used in Texas are shown in the table below; however, the best witch’s brew for India needs to be determined under Indian conditions.

Ideally, the optimum combination of correct defoliant and boll opener applied at the right crop stage under favorable conditions will:

- Induce a high rate of leaf drop
- Induce opening of mature but unopened bolls
- Prevent post maturity regrowth

Bayer harvest aid products recommended in Texas, USA

Tank mix	Component description	Rate	Benefits
Finish + Ginstar	Auxin transport inhibitor + ethephon	600-720 ml/A	Leaf drop + boll opener
	Herbicidal defoliant	20-30 ml/A	Leaf drop + regrowth inhibitor
Finish + Def	Auxin transport inhibitor + ethephon	480-620 ml/A	Leaf drop + boll opener
	Herbicidal defoliant	25 ml/A	Leaf drop, economical
Prep + Ginstar	Ethephon	720-960 ml/A	Boll opener + improve defoliation
	Herbicidal defoliant	20-30 ml/A	Leaf drop + regrowth inhibitor
Prep + Def	Ethephon	600 ml/A	Boll opener + improve defoliation
	Herbicidal defoliant	600 ml/A	Leaf drop, economical

CONCLUSION

Conversion to a MH system in India will require a holistic and multi-disciplinary approach. Cornerstones of this conversion will include increased plant density, development of genotypes that tolerate increased plant density and result in more compact plants as well as more bolls per unit area, PGR and HA programs adapted to Indian conditions, and a package of other crop management practices (insect control, fertilization, etc.) designed to maximize economic returns to the local farmers upon whom we all depend. Crop management chemicals alone will not get us to the goal. Cotton genetics alone will not get us to the goal. We can only succeed as we work together—public and private sector; breeders, agronomists, entomologists, pathologists, weed scientists, and mechanical engineer—all working as a team, each cooperating with the other and doing his or her part to propel farming’s future in India.

Although claims are often made for other effects (*e.g.* increased yield, earlier maturity), when measured, these effects are usually modest and/or inconsistent; and when present are often the indirect result of improved harvest efficiency (though my crop protection colleagues might disagree). However, it must be said that controlling excessive vegetative growth under high plant density conditions can reduce shedding of flower buds caused by self shading, and can reduce boll rot that occurs in deep, humid canopy.

In any case, reduction in vegetative mass from use of PGR is relatively small since number of nodes, size of leaves, etc. remain largely unchanged.

Utilizing genetic diversity, molecular breeding and biotech traits to increase sustainability of India cotton production in an era of changing climate and cultural practices

KEIM, DON L
Monsanto, USA

Recent predictions and actual evidence of global climate change have brought to the forefront concerns about predicted effects on crop production. A critical discussion centers around how we as crop scientists can meet the challenges presented in order to maintain or enhance sustainability of crop production systems.

Also of concern are changes in cultural practices necessitated by economics and resource availability, as well as climate change. These changes also affect sustainability of our crop production systems. Of concern at this conference are the effects on India cotton production. This presentation focuses on the changes at the global level with narrowing of the focus to the local level. Also discussed are approaches Monsanto is taking to meet the sustainability challenges presented to Indian cotton agriculture.

Changes in climate and cultural practices : How vulnerable is Indian agriculture to climate change? Predictions by Indian Agricultural Research Institute stated:

- Increased droughts and floods are likely to increase production variability
- Considerable effect on microbes, pathogens, and insects
- Productivity of most crops to decrease only marginally by 2020 but by 10-40 per cent by 2100

A specific temperature prediction sourced from the WorldClim database for the Punjab, Haryana region was of particular interest (ADAPTATION and MITIGATION KNOWLEDGE NETWORK, http://amkn.org). Minimum (nighttime) temperatures during the June, July, August were expected to rise 3.0, 3.1 and 2.8^{0}C by 2050. This rise brings minimum temperatures above the level during cotton flowering period where floral sterility is known to occur (>28^{0}C) (http://cals.arizona.edu/pubs/crops/az1448.pdf). This would suggest to cotton breeders, the need to develop high levels of heat sterility tolerance in commercial hybrids, in order to maintain productivity.

A major concern is the reduced availability of ground water for agriculture use as a result of both climate change and overuse. A recent article in Nature (Gleeson *et al. Nature* 488, 197-200 (2012) doi: 10.1038/nature 11295) described major aquifers in the world and degree of overuse. One major concern is the upper ganges aquifer which serves the Punjab cotton growing region. The Groundwater Footprint far outstrips the recharge rate, thus over time diminishing the availability of water for use in agriculture.

Because cotton production in the Punjab, Haryana region is highly dependent on readily available water, the sustainability of production is threatened. This will certainly lead to growing cotton under more limited irrigation schemes. It could even lead to changing to crops that need less water to sustain minimal levels of production. Actually, cotton is one of those crops.

An example of this outcome would be the Ogallala aquifer depletion in the U.S. on the High Plains of Texas over the past several decades. In 2011, 85 per cent of the cotton production in this region was grown with limited or no irrigation. Also, much of the production acres have shifted from high water use crops such as corn and soybeans to cotton, as a result of dwindling ground water availability.

How will dwindling water availability affect cotton research in the coming years? Certainly, water use efficiency and drought tolerance will receive renewed emphasis.

Another cultural change on the horizon, not related to climate change, is the move toward mechanization of crop production. Economic realities related to the dwindling availability of field labour are necessitating such mechanization. This could impact cotton cultivation from planting through harvest.

Meeting the challenges

Bollgard technology : For many years Monsanto has been involved in the *Bt* technology which has helped dramatically improve the sustainability of cotton production in India. The benefits to the farmer, communities and India, as a whole, have been well documented (Kathage, J. and M. Qaim. 2012 PNAS 109(29):11652-11656 and Choudhary, B. and K. Gaur. 2010. *Bt* Cotton in India: A Country Profile. ISAAA Series of Biotech Crop Profiles).

Because of the protection from certain Lepidopteron pests that *Bt* technology has provided, yield has been dramatically increased. This has helped make India a major exporter of cotton (International Food Policy Research Institute, April 2012 http: / / www.ifpri.org/publication/measuring-contribution-btcotton-adoption-india-s-cotton-yields-leap).

But the story doesn't end here. Our introduction of Bollgard II® technology and ongoing development of Bollgard® III technology are evidence of our commitment to Insect Resistance Management (IRM) and to provide durable insect protection traits. Our IRM strategy also includes wide scale monitoring for resistance. Promoting compliance is critical to sustaining new technologies.

- Reduce the risk of insect resistance to maintain the value of insect protection traits
- Meet regulatory requirements and preserve access to effective technology
- Proper stewardship demonstrates responsible management of technology
- Refuge in the bag offers a potential solution, especially for small holder systems

Roundup Ready® flex technology : A new technology currently in development for India is the Roundup Ready® Flex trait. This would enable the grower to spray Roundup® agricultural herbicides over the top of cotton across a broader window for increased flexibility in managing a broad spectrum of weeds. This would help sustain cotton production during an era of labour shortages.

Breeding : Cotton breeding will play a key role in meeting the challenges of climate change. A unique attribute of the India cotton industry is the commercial utilization of F_1 hybrids. Cotton hybrids have the benefit over pure line varieties of increase yield, more stable yield, early plant vigour and reduced seeding rates.

Essential keys to sustaining the advantages of hybrid cotton agriculture are two-fold. First is the adoption of hybridization technologies that lower the cost of seed production (*i.e.*, genetic male sterility). A second key is the use of molecular tools to assist in the intensive exploitation of heterosis.

Hybrid cotton breeding at Monsanto India leverages a global network of breeding support, expertise and germplasm. Several breeding technologies are utilized to meet the rapidly evolving changes in cotton agriculture. These technologies speed and enhance the incorporation of new traits by utilization of:

- Intensive selection and testing activities in the key production areas
- Molecular breeding technologies
- Rapid generation advance (use of greenhouse and off season nurseries)
- Building broad germplasm base that contain useable diversity for;
  - Disease resistance – CLCuV
  - Insect resistance - jassid
  - Water stress tolerance
  - Enhanced yield and fibre
  - Heat and stress tolerance

Future Technologies - Drought Tolerance : Monsanto is at the forefront of drought tolerance research by using a three pronged approach through:

- Breeding
- Biotechnology
- Agronomic systems

The India breeding effort includes a rainfed breeding programmes to select and evaluate under rainfed conditions in areas that are subjected to periods of water stress.

In addition, Monsanto is testing lead transgenic events in cotton for their performance under moisture stress.

In summary, many challenges for India cotton agriculture lay ahead in light of expected changes brought about by climate and cultural practices. We have a great opportunity as cotton scientists to look ahead and begin efforts to address the challenges. Both private and government efforts are critical to this success. Monsanto is committed to Indian cotton agriculture, as evidenced by our ongoing efforts to meet the needs of the Indian cotton farmer.

Status of emerging pests on *Bt* cotton in Karnataka and their management

B.V.PATIL, M.BHEEMANNA*, S.G.HANCHINAL AND A.C.HOSAMANI
University of Agricultural Sciences, Raichur-584102
**E-mail : bheemuent@rediffmail.com*

Abstract : *Bt* cotton was introduced in the year 2002-2003 in Karnataka and since then area under cotton and yield levels increased drastically. *Bt* cotton has suppressed bollworms which were major threat but at the same time minor sucking pests have become major pests in the recent past. Among them important emerging pests on *Bt* cotton are mealy bug *Phenacoccus solenopsis* Tinsley, mirid bug, *Poppiocapsidea biseratense* (Distant) and yellow mite *Polyphagotarsonemus latus* Bank. Distribution, seasonal incidence, bio ecology and management of these pests are discussed in this article.

Cotton is one of the important fiber crop in Karnataka, where *Bt* cotton is being cultivated both in irrigated as well as dry land conditions and replaced all the non *Bt* hybrids and varieties. After introduction of *Bt* cotton, bollworm menace has reduced drastically and area under cotton increased substantially. This increase in the yield of cotton is not only due to *Bt* technology but also contributed by the good hybrids and efficient systemic insecticides.

In India cotton mealy bug is known to be introduced from Pakistan since the three largest cotton players in Asia are China, India and Pakistan which share common borders that make them vulnerable to insect and disease transfers (Anonymous, 2006).Later it has spread to cotton crop in some districts of Punjab but in 2007 it has spread to throughout major cotton growing districts and caused 30 to 40 per cent loss to cotton yield. Mealy bug infestation was also recorded by Dharajyoti *et al.,* (2008) on *Gossypium hirsutum* in all the nine cotton growing states of India, Punjab, Haryana, Rajasthan, Gujarat, Madya Pradesh, Maharashtra, Tamil Nadu, Andhra Pradesh and Karnataka.

Severe economic damage to *G. hirsutum* was reported in 2007(Dharajyoti *et al.,*2008; Dhawan, 2008) in four major cotton growing districts of Punjab, two districts of Haryana, and low to moderate damage in parts of Maharashtra, Tamil Nadu and Andhra Pradesh. Nearly 2000 acres of cotton destroyed by mealy bug and over 100 acres of mealy bug, infested cotton was uprooted in Bhatinda. In Karnataka mealy bug appeared in isolated patches of cotton growing districts during 2006. Later it was found in the cotton growing districts of Raichur, Bellary, Gulbarga, Haveri, Dharwad and Belgaum during 2007-2008. Mealybug incidence was more in the TBP and UKP project areas which comprises major irrigated cotton (Hanchinal *et al.*, 2009)

Mirid bug damage was severe on cotton during 2005-2006 cropping season and caused dropping of squares and bolls resulted in loss of the yield (Patil *et al.*, 2006). Pest incidence coincided with peak development of fruiting bodies in October/November months in major cotton growing districts of Karnataka (Shalini 2009 and Bheemanna *et al.*,2009). Insecticide usage has also changed, less or no sprays against bollworms but greater sprays against mirid bugs (Lu and Yu,2010).

Polyphagotarsonemus latus belongs to the family Tarsonemidae commonly known by different names as yellow mite, broad mite or white mite. It is an important phytophagous mite with a wide host range including many cultivated crops like cotton, chilli, potato, tomato, egg plant, sweet pepper, guava, passion fruit, citrus and flower crops like chrysanthemum etc. (Gibson and Valenchia, 1978). In the recent past, the incidence of yellow mite on *Bt* cotton is severe in North Karnataka, causing puckering of leaves, reddening and stunted growth (Hosamani *et al.,* 2009).

Mealybug, *Phenacoccus solenopsis* : Roving survey was conducted during 2008-2009, 2009-2010 and 2010-2011 in major cotton growing districts of Karnataka *viz.,* Raichur, Bellary, Gulbarga, Dharwad, Belgaum and Haveri. The observations were recorded at monthly intervals on level of infestation, host range and natural enemies. Incidence of mealy bug was recorded in the scale of zero to four ranges. During survey the flora grown in and around the cotton field was also examined for the presence of mealy bug and to assess the host range.

Mealybug *P. solenopsis* species is apparently a new record as a pest of cotton in Karnataka as Hanchinal *et al.,* (2010) observed only *P. solenopsis* causing extensive damage to the cotton fields in northern districts of Karnataka and reported that, Infestation varied from zero to 3.62 grade in major cotton growing districts of North Karnataka *viz.,* Raichur, Bellary, Gulbarga, Dharwad, Belguam and Haveri. Peak increase in mealybug population was noticed from January and it ranged between 2.15 to 3.34 grade in Raichur, Gulbarga and Bellary districts. Incidence was low and ranged between 0.72 to 2.11 grade in Dharwad, Belguam and Haveri districts during 2009-2010 season (Table 1).

Similar infestation of the cotton mealy bugs, *Phenacoccus* sp., *Ferrisa* sp. and *Maconellicoccus* sp was reported in many districts of Punjab. *P. solenopsis* was also reported on cotton in Punjab, Rajastan, Maharashtra and Gujarat by Tanwar *et al.*,(2007). Mealy bugs, *P. solenopsis* and *M. hirsutus* were found in 50 to 75 per cent fields with damage varied from 1 to 5 per cent in Andhra Pradesh (Durgaprasad *et al.,* 2008). Bhosle *et al.*, (2009) reported that infestation of *P. solenopsis* on *Bt* cotton was maximum in Parbhani with 40.95 per cent leaf infestations and 35.77 per cent of green boll damage. Saini *et al.,* (2009) observed *P. solenopsis* incidence on major cotton growing areas in Haryana

Mean per cent parasitoid cocoons per plant varied from 2.41 to 10.42 in major cotton growing districts of north Karnataka with highest in Bellary district (10.42) followed by Raichur district (8.32). The peak activity of the parasitoids was observed mainly from January to March and the parasitism reached up to 34.15 per cent in March in Raichur taluk during 2009-2010 season (Fig 8). Parasitoid activity was generally low in districts of Dharwad, Haveri and Belguam because of lower mealy bug incidence on cotton which was terminated early during February. In contrary parasitoids activity was maximum during February and March in TBP and UKP districts which coincide with higher population of mealy bug. In these areas majority of the cotton crop was under irrigation and final harvest was done at the end of March.

Examination of plants grown in and around mealy bug infested cotton fields revealed the presence of *P. solenopsis* on more than 15 host plants spread across eight families in cotton growing districts of North Karnataka (Table 2). Among them *Abutilon indicum* L. (Malvaceae) and *P. hysterophorus* L. (Asteraceae) were the major weed hosts found across the north Karnataka. Present findings are also in line with Acharya *et al.*, (2008), who observed that *Parthinium hysterophorus* was the most preferred host and as good as breeding sites for the *P. solenopsis* on canal banks and then migrated to cotton.

Table 1. Mealybug *Phenacoccus solenopsis* incidence on cotton in different locations of north Karnataka

Months	Average of 2008-2009 and 2009-2010 (Zero to 4 scale*)					
	Raichur	Gulbarga	Bellary	Dharwad	Belgaum	Haveri
June	0.00	0.00	0.13	0.00	0.00	0.00
July	0.16	0.00	0.17	0.06	0.00	0.06
August	0.38	0.21	0.23	0.15	0.03	0.58
September	0.54	0.23	0.27	0.19	0.07	1.14
October	0.61	0.34	0.35	0.21	0.08	1.31
November	0.79	0.55	1.05	0.23	1.07	1.30
December	1.52	0.73	1.75	0.27	1.16	1.71
January	2.47	2.15	2.67	0.72	1.68	1.17
February	3.31	3.06	3.34	1.77	1.68	1.65
March	3.42	3.15	3.34	2.11	1.28	1.37
Mean	**1.32**	**1.04**	**1.33**	**0.57**	**0.70**	**1.03**

* Mean of 20 plants

Table 2. Alternate hosts of cotton mealybug at different locations of north Karnataka during 2008-2009 and 2009-2010 seasons

Sl.No	Raichur	Gulbarga	Bellary	Dharwad	Belguam	Haveri
1	*Abutilon indicum* L.	*Abutilon indicum* L.	*Abutilon indicum* L.	*Abutilon indicum* L.	*Abutilon indicum* L.	*Abutilon indicum* L.
2	*Parthenium. hysterophorus* L.	*Parthenium. hysterophorus* L.	*Parthenium. hysterophorus* L.	*Parthinium. hysterophorus* L.	*Parthinium. hysterophorus* L.	*Parthinium. hysterophorus* L.
3	*Helianthus annus* L.	*Helianthus annus* L.	*Helianthus annus* L.	*Lycoperiscum esculentus* L.		
4	*Lycoperiscum esculentus* L.	*Lycoperiscum esculentus* L.	*Hybiscus cannabina*	*Hibiscus rosa-sinensis* L.	*Abelmoschus esculentus*	*Hibiscus rosa sinensis* L
5	*Amaranthus spp*	*Hibiscus rosasinensis* L.	*Hibiscus rosasinensis* L.	*Tectona grandis*	*Hibiscus rosa-sinensis* L.	*Helianthus annus* L.
6	*Vigna mungo*	*Achyranthes aspera* L.	*Abelmoschus esculentus* L.	*Abelmoschus esculentus* L.	*Morus alba* L.	*Abelmoschus esculentus* L.
7	*Ziziphus spp*	*Morus alba* L.				
8	*Physalis minima*	*Abelmoschus esculentus*				
9	*Abelmoschus esculentus* L.					
10	*Leucos spp*					
11	*Achyranthes aspera* L.					
12	*Hibiscus rosasinensis* L.					
13	*Annona squmosa* L.					
14	*Solanum melongera*					

Table 3. Efficacy of different treatments on mealybugs population under irrigated ecosystem during 2009-2010 season

Sl. No	Treatments	Dosage ml/g/ha		Population of mealybugs /10 cm apical shoot					
				First spray			Second spray		
			1 DBS	3 DAS	7 DAS	14 DAS	3 DAS	7 DAS	14 DAS
1	Thiodicarb 75WP	625 g	190.13	50.52	49.85	41.18	12.1	11.89	22.43
			-13.81	(7.81)^{c}	(7.09)^{h}	(6.45)^{c}	(3.54)^{c}	(3.52)^{e}	(4.78)^{e}
2	Profenophos 50EC	1500 ml	194.93	42.43	14.14	35.11	7.5	5.06	9.86
			-13.97	(6.55)^{b}	(3.82)^{b}	(5.96)^{b}	(2.81)^{b}	(2.35)^{b}	(3.20)^{c}
3	Profenophos 50EC	2000 ml	190.58	26.98	6.94	31.45	2.69	1.26	6.29
			-14.11	(5.23)^{a}	(2.72)^{a}	(5.65)^{b}	(1.67)^{a}	(1.27)^{a}	(2.58)^{b}
4	Quinalphos 25EC	2000 ml	189.84	71.98	46.39	64.44	19.89	15.53	29.24
			-13.8	(8.51)^{h}	(6.84)^{g}	(8.05)^{e}	(4.51)^{e}	(4.00)^{f}	(5.45)^{f}
5	Acephate 75SP	2000 g	191.36	50.54	43.92	51.96	10.87	8.7	17.37
			-13.86	(7.14)^{c}	(6.66)^{f}	(7.24)^{d}	(3.36)^{c}	(3.03)^{d}	(4.22)^{d}
6	Chlorpyriphos 20EC	2500ml	193.87	54.26	40	55.95	12.34	14.4	37.61
			-13.91	(7.40)^{d}	(6.36)^{e}	(7.51)^{d}	(3.57)^{c}	(3.86)^{f}	(6.17)^{g}
7	Buprofezin 25 SC	1000 ml	192.12	77.13	30.7	23.36	27.28	6.64	3.92
			-13.83	(8.81)^{i}	(5.58)^{d}	(4.88)^{a}	(5.27)^{f}	(2.67)^{c}	(2.04)^{a}
8	Buprofezin 25 SC	1500 ml	192.02	67.95	25.89	20.58	17.16	5.85	3.45
			-13.88	(8.27)^{g}	(5.13)^{c}	(4.58)^{a}	(4.20)^{d}	(2.51)^{bc}	(1.92)^{a}
9	Neem oil	2000ml	190.22	70.40^{g}	38.57	65.62	28.96	18.76	26.69
			-13.81	(8.42)^{h}	(6.25)^{e}	(8.13)^{e}	(5.42)^{f}	(4.39)^{g}	(5.21)^{f}
10	Neemark1500 ppm	5000 ml	193.84	64.64	44.71	65.09	39.25	29.23	39.34
			-13.94	(8.07)^{f}	(6.72)^{fg}	(8.10)^{e}	(6.30)^{g}	(5.45)^{h}	(6.31)^{g}
11	Fish oil rosin soap	3125 ml	198.84	55.53	39.36	65.56	19.15	13	50.2
			-13.12	(7.48)^{d}	(6.31)^{e}	(8.12)^{e}	(4.43)^{d}	(3.67)^{ef}	(7.12)^{h}
12	*Verticillium lecanii*	2000 g	189.12	182.41	161.89	148.6	143.7	160.96	134.49
			-13.77	(13.52)^{j}	(12.74)^{i}	(12.21)^{f}	(12.01)^{h}	(12.71)^{i}	(11.62)^{i}
13	Un treated Control	—	192.73	198.28	175.97	161.53	156.29	174.95	146.19
			-13.9	(14.10)^{k}	(13.28)^{j}	(12.73)^{g}	(12.52)^{i}	(13.25)^{j}	(12.11)^{j}
SEm +			1.98	0.04	0.05	0.11	0.1	0.07	0.1
CD (p = 0.05)			NS	0.12	0.14	0.33	0.29	0.19	0.3
SEm +			1.98	0.04	0.05	0.11	0.10	0.07	0.10
CD (p = 0.05)			NS	0.12	0.14	0.33	0.29	0.19	0.30

DBS – Day before spraying DAS – Days after spraying

In vertical columns means followed by similar letters are not different significantly (P = 0.05) by DMRT.

* Figures in the parentheses are V (x+1) values.

Similarly Deshmukh *et al.*, (2009) reported a total record of 91 host plants spread across 24 families. *P.solenopsis* was found multiplying on 30 host plants during the cotton growing season and 61 plants exclusively during off-season. Higher population of mealy bug in February and March was due to high temperature prevailing during this period which had probably helped fast multiplication of the mealybug. Maximum temperature showed positive relationship with the mealybug population as reported by (Hanchinal, 2010).

Predatory coccinellids, chrysoperla and spiders population was low in the entire Karnataka. A drosophilid predator, *Gitonides perspicax* Knab appeared in February and March during 2009-2010 season. Another drosophilid *Cacoxenus perspicax* was recorded earlier by Manjunath (1985). Five parasitoids were recorded from the cotton mealy bug, *P. solenopsis*. Among them *Aenasius bambawalei* Hayat was the dominant parasitoid in many fields. Mean per cent parasitoid cocoons/plant varied from 2.41 to 10.42 in major cotton growing districts of North Karnataka (Hanchinal, 2010.)

Management of mealybug using insecticides and biorationals was studied by Hanchinal (2010) Profenophos 50 EC @ 1500 ml/ ha + soap water (1%) and buprofezin 25 SC @ 1000 ml/ha were effective. These two chemicals recorded least incidence of mealybugs after each spray. In general, profenophos at higher doses reduced mealybug incidence to the extent of 5.24 and 6.29 mealy bugs/10 cm apical shoot after second spray during 2009-2010 and 2010-2011 seasons, respectively (Table 3.).

The effectiveness of profenophos 50 EC was also reported by Agarwal *et al.*(2010) where it recorded 93.73 per cent mortality. Similarly Patel *et al.*, (2010) reported more than 95 per cent reduction in mealybug population over control after 3 days after solid in buprofezin at three doses (250,312.5 and 625 g ai/ha) tested. Superiority of profenophos 50 EC was also confirmed by

Table 4. Seasonal incidence of mirid bug *Poppiocapsidera biseretense* on *Bt* cotton

Month	ISW	Population of mirid bug/ 5 squares/plant			
		First sown crop (01/07/2011)	Second sown crop (15/07/2011)	Third sowncrop (01/08/2011)	Fourth sown crop (15/08/2011)
Aug13-19	33	0.0	- -	- -	- -
20-26	34	0.0	- -	- -	- -
27-2	35	0.0	- -	- -	- -
Sep 3-9	36	0.8	0.0	- -	- -
10-16	37	1.2	0.0	- -	- -
17-23	38	1.4	0.8	0.8	- -
24-30	39	1.6	1.0	0.8	- -
Oct 1-7	40	1.8	1.6	1.6	1.6
8-14	41	1.9	1.7	1.9	1.7
15-21	42	2.0	1.9	2.3	1.9
22-28	43	2.1	2.1	2.4	2.4
29-4	44	2.8	2.4	2.6	2.6
Nov 5-11	45	2.9	2.6	2.8	2.9
12-18	46	1.8	2.8	2.9	3.2
19-25	47	1.4	3.2	3.1	3.4
26-2	48	1.0	3.5	3.4	3.8
Dec 3-9	49	- -	3.8	4.3	4.9
10-16	50	- -	2.2	4.5	5.2
17-23	51	- -	1.2	4.8	5.4
23-31	52	- -	1.1	2.0	5.8
Jan1-7	1	- -	- -	1.0	3.0
8-14	2	- -	- -	0.9	2.1
15-21	3	- -	- -	- -	0.9
22-28	4	- -	- -	- -	- -

ISW- Indian Standard week

Table 5. Bio efficacy of different insecticides against miridbug, *Poppiocapsidea biseratense* (after first spray)

Sl. No.	Treatments	Dosage (g.a.i/ha)		Population of bugs/10 square/plant*			
			1 DBS	1 DAS	3 DAS	7 DAS	10 DAS
1	Fipronil 5 SC + (1%) salt	50	4	0.82	0.89	0.9	1.02
			-2.12	-1.15	-1.18	-1.19	-1.23
2	Profenophos 50 EC + (1%) salt	1000	3.94	0.91	0.95	0.99	1.1
			-2.11	-1.19	-1.2	-1.22	-1.26
3	Acephate 75 SP + (1%) salt	750	4.01	0.94	0.98	1.02	1.13
			-2.12	-1.2	-1.22	-1.23	-1.28
4	Thiodicarb 75 WP + (1%) salt	750	3.98	3.54	3.57	3.71	3.86
			-2.12	-2.01	-2.02	-2.05	-2.09
5	Neemguard (1500 ppm) + (1%) salt	51	4	2.75	2.73	2.77	2.91
			-2.12	-1.8	-1.8	-1.81	-1.85
6	Fipronil 5SC	50	4	0.84	0.87	0.91	1
			-2.12	-1.16	-1.17	-1.19	-1.22
7	Profenophos 50 EC	1000	3.97	0.95	0.99	1.04	1.14
			-2.11	-1.2	-1.22	-1.24	-1.28
8	Acephate 75 SP	750	4	0.97	1 .00	1.06	1.16
			-2.12	-1.21	-1.22	-1.25	-1.29
9	Thiodicarb 75 WP	750	4.02	3.61	3.69	3.77	3.9
			-2.13	-2.03	-2.05	-2.07	-2.1
10	Neemguard (1500 ppm)	51	3.99	2.8	2.84	2.9	3.01
			-2.12	-1.82	-1.83	-1.84	-1.87
11	Control	.....	4.01	4.18	4.22	4.3	4.64
			-2.12	-2.16	-2.17	-2.19	-2.27
	S.Em±		0.05	0.01	0.02	0.01	0.02
	CD (p=0.05)		NS	0.03	0.05	0.04	0.06

DBS – Day before spray DAS – Day after spray
NS – Non significant
*Mean of three replications
Figure in the parenthesis are (vx+0.5) transformed values

Suresh *et al.*, (2010)who reported profenophos to be quite effective and caused cent per cent mortality of *P. solenopsis* one day after treatment while imidacloprid, fish oil rosin soap and dimethoate caused cent per cent mortality after two days of the treatment imposition.

Mirid bug, *Poppiocapsidea* (= *Creontiades*) *biseratense* (DISTANT) : Mirid bug incidence was noticed in all the cotton growing parts of Karnataka. Both nymphs and adults were found to suck the sap by piercing their sharp stylet into the plant tissues, squares and small tender bolls. The pierced portion rapidly turns dull in colour, and then feeding punctures turn to black spots. Squares of all sizes and small bolls were most preferred plant parts for feeding. Affected parts gradually turned yellow, sunken and dropped down prematurely.

Seasonal incidence of mirid bug, *P. biseratense* was recorded by Prakash (2012). Irrespective of different dates of sowing, the incidence of mirid bug was very low (0.8 bugs/ 5 squares) on 36th standard week and gradually increased later. The incidence was in the range of 0.8 to 1.6 bugs/5 squares/plant in the month of September. In October the incidence of mirid bug ranged between 1.6 to 2.8 bugs/5 squares/ plant. Whereas in November the incidence ranged between 1.0 to 3.8 bugs/5 squares/ plant and in December, the incidence ranged between 1.1 to 5.8 bugs/5 sqares/plant. Further in the month of January, the incidence ranged between 0.6 to 5.2 bugs/5 squares/plant (Table 4).

According to Prakash (2012), total life cycle of male mirid bug varied from 28 to 36 days with an average of 32.7 ± 3.23 days. Total life cycle of female varied from 30 to 42 days with an average of 40.4 ± 2.27 days. The efficacy of different synthetic and neem based insecticide with and without salt against mirid bug recorded a day before, one, three, seven and 10 days after each spraying revealed that fipronil 5 SC at 50 g a.i. /ha + 1 per cent salt was found to be superior and closely followed by acephate 75 SP + 1 percent salt at 750 g a.i. /ha, profenophos 50 EC + 1 percent salt at 1000 g a.i. /ha. The results obtained with the use of fipronil 5 SC was in close agreement with the findings of Bheemanna *et al.*, (2010), who reported that fipronil 5 SC @ 25g ai/ha recorded lowest mirid population (0.52/15 square) with highest yield (34.31q/ha) which was on par with fipronil 5SC 25g ai/ha + salt. Fipronil 5 SC + 1 per cent salt recorded higher seed cotton yield (32.26 q/ha) followed by acephate 75 SP + 1 per cent salt (31.87 qt/ha) and profenophos 50 EC + 1 per cent salt (30.20 q/ha) (Table 5).

Yellow mite, *Polyphagotarsonemus latus*

Yellow mite incidence on cotton was recorded way back in the year 1962 by Katagihallimath and he observed the activity of *P. latus* during seedling stage of cotton crop and the mite attained peak during November – December months in Karnataka. Ningappa (1972) observed the activity of *P. latus* throughout the year on cotton. The population reached its peak during October and thereafter gradually declined from November onwards reaching the lowest level in May. Seasonal incidence of yellow mite, *P.latus* was studied by Ramya (2012) and she reported the peak activity during August month. In first sown crop (01-07-2011) maximum mite population of both larvae and adult (18.14 and 13.26 per cm^2/leaf respectively) was noticed during first week of September. Similar trend was noticed on second sown crop indicating the peak activity during August month (Table 6).

The total life cycle of adult male was 14.62 ± 0.11 days, while female survived for period of

Table 6. Incidence of yellow mite, *Polyphagotursonemus latus* on *Bt* cotton at different dates of sowing

Month	ISW	Dates of sowing – Number of mites / cm^2 / leaf							
		(01-07-2011)		(15-07-2011)		(01-08-2011)		(15-08-2011)	
		Larvae	Adults	Larvae	Adults	Larvae	Adults	Larvae	Adults
Aug 30-5	31	10.24	10.30	-	-	-	-	-	-
6-12	32	10.45	9.06	10.05	9.89	-	-	-	-
13-19	33	11.32	11.25	10.74	9.63	-	-	-	-
20-26	34	14.09	12.09	10.74	10.17	7.90	1.35	-	-
27-2	35	16.75	12.92	12.06	11.89	13.58	10.18	1.53	0.74
Sep 3-9	36	18.14	13.26	11.31	11.12	14.30	10.93	4.11	0.91
10-16	37	15.68	12.61	9.56	8.65	12.40	7.68	2.82	0.78
17-23	38	14.72	9.39	6.21	6.74	13.80	9.43	0.68	0.13
24-30	39	14.43	11.83	4.90	4.10	13.23	8.43	0.69	0.18
Oct 1-7	40	9.30	8.33	4.33	2.90	9.94	2.08	0.46	0.18
8-14	41	8.43	8.23	1.80	2.08	7.28	1.25	0.22	0.19
15-21	42	4.83	5.33	1.83	1.13	4.55	0.95	0.23	0.20
22-28	43	2.08	2.63	1.28	0.68	2.58	0.75	0.43	0.23
29-4	44	0.70	1.60	1.11	0.63	1.13	0.53	0.15	0.40
Nov 5-11	45	0.83	0.50	0.95	0.80	0.50	0.48	0.50	0.28
12-18	46	0.72	0.40	0.99	0.83	0.63	0.35	0.08	0.18
19-25	47	0.77	0.30	0.90	0.70	0.78	0.13	0.25	0.25
26-2	48	0.50	0.25		0.65	0.53	0.18	0.15	0.33
Dec 3-9	49	0.34	0.21	0.33	0.40	0.35	0.25	0.20	0.35
10-16	50	-	-	0.31	0.40	0.31	0.40	0.20	0.34
17-23	51	-	-	-	-	0.30	0.33	0.18	0.33
23-31	52	-	-	-	-	-	-	0.18	0.33
Mean	**8.12**	**6.87**	**1.32**	**4.39**	**1.25**	**3.09**	**1.00**	**0.35**	**0.66**
SD	6.31	4.97	0.65	4.28	0.61	3.94	0.63	0.22	0.31

ISW-Indian Standard Week

Table 7. Management of yellow mite, *Polyphagotarsonemus latus* through acaricides and insecticides.

Treatments	Dosage (g.a.i/ha)	II spray DBS	(Number of mites / cm² / leaf) 3 DAS	7 DAS	10 DAS	Yield (q/ha)
Dicofol 18.5 EC	232	11.4	8.42	8.02	8.54	25.88
		-3.45	-2.99	-2.92	-3.01	
Propargite 50 EC	500	5.8	3.53	2.94	2.59	27.64
		-2.51	-2.01	-1.85	-1.76	
Fenpyroximate 5 SC	25	4.89	2.1	1.93	1.5	29.14
		-2.3	-1.61	-1.56	-1.41	
Wettable sulphur 80 WP	1500	8.6	6.7	6.2	6.53	26.57
		-3.02	-2.68	-2.59	-2.65	
Ethion 50 EC	500	19.13	16.07	15.98	16.53	26.08
		-4.43	-4.07	-4.06	-4.13	
Lambda cyhalothrin 5EC	12.5	20.17	16.38	16.24	16.72	22.26
		-4.55	-4.11	-4.09	-4.15	
Emamectin benzoate 5 SG	7.5	10.12	7.41	7.64	26.08	
		-3.26	-2.87	-2.81	-2.85	
Rynaxypyr 20 SC	25	22.25	18.62	18.73	18.85	21.29
		-4.77	-4.37	-4.39	-4.4	
Photorhabdus luminescence	4ml	20.95	18.19	18.31	18.36	18.42
broth		-4.63	-4.32	-4.34	-4.34	
Untreated control	-	25.91	23.97	24.16	24.36	15.56
		-5.14	-4.95	-4.97	-4.99	
S.Em±		0.06	0.1	0.08	0.11	0.48
CD @ (p=0.05%)		0.19	0.29	0.25	0.32	1.46

DBS- days before spray DAS-Days after spray
Figures in parenthesis are square transformed (vx+0.05) values0

15.66 ± 0.12 days. The total life span of both male and female ranged from 14.35 to 16.47 days on *Bt* cotton under laboratory conditions.

Management of mites with acaricides was effective and according to Ramya (2012) spraying of fenpyroximate 5 SC @ 25 g.a.i/ha recorded lowest mite population (1.20 and 1.50/cm²/leaf) ten days after spray which was followed by propargite 50 EC @ 500 g.a.i/ha which recorded 1.93 and 2.59/cm²/leaf, respectively (Table 7). Similar findings were made by Biswas *et al.*, (2004) which revealed that fenpyroximate 5 % SC @ 500 ml formulation/ha was found to be the best acaricide among all other pesticides *viz.*, fenazaquin 10 EC, propargite 50 EC, fenpropathrin 10 EC, dicofol 18.5 EC and bifenthrin 10 EC.

These three emerging pests on cotton has made farmers to intervene with insecticides/acaricides sprays in Karnataka and once again use of insecticides and cost is increasing on *Bt* cotton for the management of sucking pests and taking us to non *Bt* era where several insecticide interventions were made to manage both bollworms and sucking pests. The management of mealy bug should be aimed at eco friendly method since much parasitoid activity was found in all the infested fields.

REFERENCES

Acharya, V.S., Prasad, H. and Kappor, C.J., 2008, Record of Mealybug, *Maconellicoccus Sp.* on *Bt* Cotton in northern Rajastan. *Insect Env.*, **14** :18.

Agarwal, N., Vikas Jindal and Vikram Singh, 2009, Evaluation of some new insecticides against mealy bug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Psuedococcidae) on cotton. *Pestology,* **33** : 29-33.

Anonymous,2006. *Bt* cotton in India-A status report. Asia Pacific Consortium on Agricultural Biotechnology, New Delhi, India. P. 34

Bheemanna, M., Hosamani, A.C., Hanchinal, S.G., Patil, B.V. and Sharanabasappa, 2009. Population dynamics of mirid bug *Creontiades biseratense (*Distant) (Miridae: Hemiptera) on *Bt* cotton. *Proc. Of Nation. Symp. On Bt cotton: Opportunities and Prospectus,* Central Institute for Cotton Research, Nagpur, Nov 17-19, pp.150.

Bheemanna, M., Hosamani, A. C., Hanchinal, S. G. and Shivalela., 2010. Bioeffacy of insecticides aganist mirid bug, *Creontiades biseratense* (Distant) in irrigated *Bt* cotton. *Karnataka, J. Agri. Sci.,* **23** : 135-36.

Bhosle, B.B., Sharma, O.P., More, D.G., Bhede, B.V. and Bambawale, O.M., 2009. Management of mealy bug (*Phenacoccus solenopsis*) in rainfed cotton (*Gossypium hirsutum*). *Indian J. Agric. Sci.,* **79** : 199-202.

Biswas, K., Mallikarjunappa, S., Koneripalli N. and Goswami, T. N., 2004, Superiority of Fenpyroximate 5% SC (SEDNA) over other available acaricides against chilli yellow mite, *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae) *Resistant Pest Management Newsletter.,* **19(1)**: 21

Deshmukh, A.J., Vennila, S., Pinjarakar, D.B., Ghodki, B.S. and Kranthi, K.R., 2009. Host range of mealy bug *Phenacoccus solenopsis* Tinsley in cotton + pigeon pea cropping system of central India. *Proc. Nation. Symp. Bt Cotton: Opportunities and Prospects*, CICR, Nagpur. p. 127.

Dharajyoti, B., Surulivelu, T. and Gopalkrishnan, N., 2008, Status of mealy bug on cotton in various parts of India. In: *Proc. Nation. Consultation on Mealybug Management*, CICR, 28-29 Jan. 2008, Nagpur, India. p. 8-10.

Dhawan, A.K., 2008, Historical perspective of various species as cotton pests in India and rest of World and factor affecting occurrence and outbreak on cotton, In: *Proc. Nation. Consultation on Mealybug Management*, CICR, 28-29 Jan. 2008, Nagpur, India. p. 11-14.

Durgaprasad, N., Prasad Rao, G.M.V. and Yellamanda Reddy, T., 2008, Mealy bug an emerging threat to *Bt* cotton. *Tech. Bull. No. 20, Acharya N.G.Ranga Agric. Univ. Hyderabad (India).*

Gibson, R.W. and Valenchia, L., 1978, A survey of potato species for resistance to the mite *Polyphagotarsonemus latus* (Banks), with particular reference to the protection of *Solanum berthaultii* L. and *Solanum tarijnese* L., by glandular hairs. *Potato Res.,* **21** : 217-23.

Hanchinal,S.G.,2010, Bio-ecology and management of cotton mealy bug, *Phenacoccus solenopsis* Tinsley (Pseudococcidae:Homoptera).Ph.D (Thesis), UAS,Dharawad (India).

Hanchinal, S.G., Patil, B.V., Bheemanna, M., Hosamani, A.C. and Sharanabasappa, 2009, Incidence of mealy bug on cotton in Tungbhadra project area. *In : Proc. Dr. Leslie C. Coleman Memorial National Symp. Plant Prot.,* Univ. of Agric. Sci., GKVK, Bangalore. December 4-6.

Hosamani, A. C., Bheemanna, M., Sharanabasappa, Hanchinal, S. G. and Shivaleela, 2009, Incidence of yellow mite on *Bt* cotton. National Symposium on *Bt* cotton: Oppurtunities and Emerging Threats, CICR, Nagpur, pp: 65-69.

Katagihallimath, S. S., 1962, A short note on the sequence time of appearance, duration of infestation and intensity of attack of some of the important insect pests on Laxmi cotton as observed in North Mysore districts. *Indian Cotton Grow. Rev.,* **16** : 13-17.

Lu, Z. X. and Yu, X. P., 2010, Zhejiang Academy of Agricultural Sciences, Hangzhou 310021, China, C. Hu, Institute of Applied Entomology, Zhejiang University, Hangzhou 310029, China.

Manjunath, T.M., 1985, *Maconellicoccus hirsutus* on grapevine. *FAO Plant Prot. Bull.* 32: 74.

Ningappa, M. S., 1972, Studies on the role of *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae) and *Polyphagotarsonemus latus* (Banks) (Acarina: Tarsonemidae) in causing chilli leaf curl and their control. *M. Sc. (Agri) Thesis,* Univ. Agric. Sci., Bangalore. p175.

Patel, M.G., Jhala, R.C., Vaghela, N.M. and Chauhan, N.R., 2010, Bio-efficacy of buprofezin against *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) an invasive pest of cotton. *Karnataka J. Agric. Sci.,* **23(1)**: 14-18.

Patil, B. V., Bheemanna, M., Patil, S. B., Udikeri, S. S. and Hosamani, A. C., 2006, Record of mirid bug, *Creontiades biseratense* (Distant) on cotton from Karnataka, India. *Insect Environ.,* **11(4)** : 176-77.

Prakash 2012. Bio-ecology and management of mirid bug, *Poppiocapsidea* (= *creontiades*) *biseratense* (Distant) (Hemiptera : Miridae) on *Bt* cotton. *M.Sc(Agri) Thesis*,UAS,Raichur

Ramya, 2012, Bio-ecology and management of yellow mite, *Polyphagotarsonemus latus* (banks) on *bt* cotton. M.Sc(Agri) Thesis, UAS,Raichur (India)

Saini, R.K., Pala Ram, Sharma, S.S. and Rohilla, H.R., 2009, Mealy bug (*Phenacoccus solenopsis* Tinsley) and its survival in cotton ecosystem in Haryana. *Proc. National Symp. Bt Cotton: Opportunities and Prospects*, CICR, Nagpur. p. 102.

Shalini, 2009, Survey, crop loss estimation and management of mirid bug *Creontiades biseratense* (Distant) (Miridae : Hemiptera) in *Bt* cotton, *M.Sc (Agri) Thesis,* UAS, Dharwad.

Suresh, S., Jothimani, R.., Sivasubrmanian, P., Karuppuchamy, R., Samiyappan and Jonathan, I., 2010, Invasive mealy bugs of Tamil Nadu and their management. *Karnataka J. Agric. Sci.,* **23(1)** : 6-9.

Tanwar, R.K., Jeyakumar, P. and Monga, D., 2007, Mealybugs and their management. *Tech. Bull.* **No.19**. NCIPM, New Delhi (India).

Ecological impact of cotton textile production

SAROJ S. JEET SINGH*
I. C. College of Home Sciences, CCS Haryana Agricultural University, Hisar – 125 004
**E-mail : sarojsjsingh@gmail.com*

Abstract : Cotton is the most important, popular and versatile natural fibre used in the textile industries worldwide. Its production and processing provide some or all of the cash income of over 250 million people worldwide. In recent years there is an increasing concern about the significant environmental footprint of cotton generating potential environmental and occupational hazards. The impacts of cotton production on the environment are easily noticeable and have diverse faces. Environmental costs originate from the use of agro chemicals during crop production and industrial chemicals in cotton processing. Excessive consumption of water and water pollution is a major concern in both the stages. Cotton processing utilizes a number of chemicals in desizing, mercerizing, bleaching, dyeing, and finishing and thus associated with a number of environmental problems. The main source of pollution is the discharge of untreated effluents into water bodies and soils. Liquid effluents from different processing operations contain organic and inorganic chemicals, as well as suspended solids (such as fibre and grease). These effluents are generally hot, alkaline, smelly, coloured and toxic. The effluents lower dissolved oxygen levels in receiving water bodies threatening aquatic life, and damaging the aesthetic value and quality of water downstream. These problems affect the environment in two ways, those that affect the health of the final consumer and those that affect the local environment in the production process. The former effects are caused generally by particular persistent organic chemicals used in the production process and use of few carcinogenic azo dyes in dyeing of cotton textile. In addition, due to the lack of modern plant and machinery and poor working conditions workers in cotton processing industries get exposed to the risk of lung diseases and asthma. It is imperative to minimize and eliminate the environmental costs of these processes. These concerns have led to a number of measures to induce a change to sustainable alternatives like production of organic cotton, naturally coloured cotton and genetically engineered cotton, agricultural techniques like integrated pest management (IPM) integrated crop management (ICM), low external input sustainable agriculture (LEISA) and biodynamic agriculture. A switch to cleaner production would require the introduction of in-plant control mechanisms as well as end of pipe treatment. Eco friendly and chemical free textile processing like using natural instead of synthetic dyes or bleaches and effluent of quality standards should be used to reduce the affect of production process on environment. The treatment of industrial effluent can be classified into primary, secondary (or biological), and tertiary (or advanced physico-chemical) processes.

Key words : Effluent, environmental costs,environmental footprint, pesticide and processing

Cotton is the most important, popular and versatile natural fibre used in the textile industries worldwide. Today, cotton takes up about 40 percent of textile production, while synthetic fibres take up about 55 per cent. It is the largest revenue earning non food crop produced in the world. Its production and processing provide some or all of the cash income of over 250 million people worldwide, including almost 7 per cent of the available labor force in developing countries. Recent years have seen an increasing concern about the significant environmental footprint of cotton generating potential environmental and occupational hazards in countries involved in cotton production and processing.

Cotton industry involves several distinct steps in the chain from cotton production on field to final product from the textile industries. The two major stages of cotton industry are the agricultural stage (cotton production at field level) and the industrial stage (processing of seed cotton into final cotton products).

Environmental impact of cotton production in field : During agricultural stage, environmental costs originate from the use of agro chemicals and excessive consumption of water and water pollution. The major obstacles to the expansion of cotton yields in the agricultural stage have been the inadequacy of water and attack by insects. Diverse conventional strategies to overcome these obstacles are the source of environmental degradation and creates three types of impact *i.e.* evaporation of infiltrated rainwater for cotton growth, withdrawal of ground- or surface water for irrigation, and water pollution due to the leaching of fertilizers and pesticides. The establishment of irrigation systems has often resulted in rising water tables, water-logging, salinization, and water wastage. Cotton plants are susceptible to a large variety of pests and diseases that can cause stunted growth, poor color, lower yields or even death. Traditional methods of protecting cotton crop from pest and disease infestation included a variety of labour intensive practices like hand picking of pests, inter cropping, crop rotation, and the burning or removal of cotton residues from the soil. Increasingly, however, over the last 100 years, these methods have been largely forgotten, and have been supplemented or transplanted by reliance on chemical pesticides. The term 'pesticides' includes insecticides, nematicides, fungicides, herbicides, defoliants, and desiccants but not fertilisers. In cotton producing countries, the most significant reliance is on insecticides. Use of these pesticides create environmental pollution. Besides this, environmental problems are also associated with prevailing agricultural practices as well as the use of other chemicals in the growing as well as processing stage. More importantly, while the use of chemicals to control pest incidence has dramatically increased yield levels, at least in the short run, it has also been the major contributor to environmental degradation as measured in terms of adverse effects on human health, soil and surface and groundwater quality, local biodiversity, and ecological balance. Water use and common tilling practices effect water quality adversely, and lead to water scarcity, soil erosion, and water logging and salinity. Chemical fertilizers cause soil and water contamination and affect soil fertility.

Another consequence of pesticide use is what is termed as the 'pesticide treadmill'. This refers to the situation whereby higher and higher doses of pesticides are required to control pest populations because of the development of resistance in pests and in the elimination of pest predators. An indication of this is the recurrence and persistence of pest attacks and volatility in yield statistics. Initially, the use of DDT and other organochlorines in the 1940s and 1950s increased yields dramatically for about a decade or so. But this resulted in the development of pest resistance, which induced farmers to use larger and larger volumes of pesticides, thus increasing their costs, further damaging the ecological balance between pests and their natural enemies and increasing pest resistance. The elimination of beneficent insects by excessive use meant that farmers could not afford to step off the treadmill because of anticipated crop losses. On top of this, the increasing demand for pesticides also led to increasing prices, thus raising costs even further. This constitutes an economic argument for reducing or eliminating dependence on pesticides. Given that pesticides raise yields in the short run, only to lower them in the medium run along with an increase in costs due to excessive use, an argument could be made for elimination of pesticides altogether. However, this option is not available to individual farmers, and requires a collective effort on behalf of entire regions in order to be effective.

Although the full impact of pesticides on human health is difficult to measure, the acute toxicity of the substances is not in question. In addition, the World Health Organization (WHO) has concluded that exposure to pesticides is probably carcinogenic as well as toxic. Some pesticides leave persistent residues in soil, groundwater and the food chain, thus exposing the human population to slow and cumulative poisoning. Various studies estimate the impact to be as high as 20,000 people killed and 3 million poisoned every year. Typical pesticide poisoning symptoms include stomach cramps, dizziness, vomiting, and heavy sweating. Pesticides also affect wildlife, domestic animals and biological diversity. Other effects include mortality of birds and aquatic organisms. Finally, human health as well as biological diversity is affected by contamination of surface and groundwater due to agricultural runoffs.

Technological solutions provide alternatives to conventional cotton and promise a more sustainable and environment friendly agriculture. These techniques range from organic cotton, genetically engineered cotton, integrated pest management (IPM) integrated crop management (ICM), low external input sustainable agriculture (LEISA) to biodynamic agriculture which requires cultural as well production change.

Organic agriculture is one of the most environment friendly production methods which are gaining popularity for the production of cotton without the use of any chemical inputs at all and relies on natural processes to increase yields and disease resistance and enhance soil quality. At present, this is the only type that has an internationally recognized, independently assessed label for its products. Producers who do not meet the certification criteria but produce in an environmentally less harmful manner may not call their product organic, although they are allowed to use such other terms as clean, green or natural. In principle, organic cotton can be grown under the same conditions as conventional cotton but there are a number of caveats. First, it requires the farmer to make a considerable investment in studying the ecosystem of the area although this could also be done by an effective and professional extension service. Second, current evidence suggests that organic methods will entail yield reductions to variable degree, which are not likely to be fully offset by the reduction in costs. Third, in some cases the yield reductions might be so large, because of large natural population of pests that organic methods might never be able to compete with conventionally grown cotton. Fourth, even otherwise farmers will have to be prepared to meet initial losses because of a lack of balance in the production area; in particular, natural enemies of pests will not be abundantly available on first switching from conventional, chemical dependent cotton. Finally, farmers will have to invest in crop certification, isolation of organic cotton from conventional produce, and cleaning of machinery and implement before use.

Organic cotton production has been introduced in India through three small-scale successful projects in Madhya Pradesh, Gujarat, and Maharashtra states which have similar institutional and environmental conditions. Although these projects involve yield reductions, these are offset by the guaranteed cost premia of 20 per cent (Madhya Pradesh) and 10 per cent (Gujarat). Although organic agriculture has simpler and more precise definitions and certification arrangements, there is nevertheless some variation across countries and regions, and at least one hundred regional or national standards have been developed so far. The International Federation of Organic Agricultural Movements (IFOAM) has also developed international minimum standards. This is a worldwide umbrella organization of over 570 active member groups in 100 countries. The Global Organic Textile Standard (GOTS) was developed in a common approach by leading standard setters with the aim to define world-wide recognized requirements that ensure organic status of textiles, from harvesting of the raw materials, through environmentally and socially responsible manufacturing up to labeling in order to provide credible assurance to the consumer.

Environmental impact of cotton textile industry : Environmental costs in cotton processing industry originate from the use of chemical, excessive consumption of water and water pollution. Cotton processing start with process of ginning *i.e.* separating fibre from the pods and seeds, their bailing and then sending bails to cotton textile industries.

The cotton textile industry is generally sub divided into three sectors, namely ;

- Spinning
- Weaving
- Processing or composites

Cotton lint separated from seeds is fed into spinning mills which produce yarn. Briefly the spinning stage consists of blowing and mixing, carding, combing, drawing, simplex, ring spinning, and cone winding. This yarn is supplied to weaving mills producing gray cloth. The weaving stage comprises warping, sizing, and weaving. And finally this gray cloth is supplied to processing mills which produces finished cloth utilizing a number of chemicals in desizing, mercerizing, bleaching, dyeing, and finishing of cloth. The finished cloth is used for the garment manufacturing. Alternatively, lint or yarn is supplied directly to composites which are vertically integrated facilities that produce a variety of non woven products ranging from yarn to printed and finished and dyed products. A sector of apparel and knitwear, produces ready made garments, hosiery and other made up products.

As in the case of cotton production, the textile industry is also associated with a number of environmental problems. Industrial pollution can be categorized either according to the medium through which it enters the environment air, water, and soil or to the processing stage. Of the three major industrial processes in textile processing spinning, weaving, and finishing, environmental problems are associated mainly with the last stage. Spinning entails mostly dry processing and virtually no harmful effects are generated. In the weaving process starch is applied to the fabric to impart filter strength and stiffness, resulting in waste waters that contain large amounts of starch with high BOD values. Air pollution and air borne wastes are not a major problem in textile production. The effect of air emissions are fairly limited and localized, although if not properly managed, they can be harmful to the health of workers. These can be classified into four categories: oil and mists, dust and lint, solvent vapors, and odors. Dust and lint problems are peculiar to the spinning stage. To eliminate these problems the yarn spinning sector should be equipped with self contained waste recovery units. These units reduce particulate emissions and health risk to workers, and improve working environment as well as the net profitability of the enterprise. By virtue of such units lint losses in the spinning section can be made virtually nil. Such typical spinning firm can process 60 tonnes of yarn/day, out of which 11 per cent is recoverable as salable yarn waste and another 9 per cent recovered and converted to low grade yarn. Similarly, these units maintain temperature, humidity, and noise levels well within safe limits. Small textile units in the unorganized sector do face a serious air pollution problem, due to the lack of modern plant and machinery. Workers at these units remain exposed to contaminated air and thus to the risk of lung disease and asthma.

Cotton processing is a highly polluting industry. The processing stage covers singeing (burning to remove loose threads), desizing (removing a flexible film, called 'sizes' from the fabric), scouring (immersion in caustic soda to remove impurities), bleaching (using chlorine, hydrogen peroxide or sodium hypochloride to whiten it), heating, washing, drying, mercerizing (immersion in cold caustic soda to improve affinity to dyes), washing, dyeing, washing, drying, printing, drying and finishing (e.g. to obtain wrinkle free or water repellent clothing) and calendering.

The main source of pollution is the discharge of untreated effluents into water bodies and soils. Each step of processing involves environmental costs because of the characteristics of the effluent discharged from it. Liquid effluents from washing, dyeing and bleaching operations contain organic and inorganic chemicals, as well as suspended solids (such as fibre and grease). Effluents are generally hot, alkaline, smelly and coloured by chemicals used in the dyeing process. Some chemicals are toxic. The effluents lower dissolved oxygen levels in receiving water bodies, threaten aquatic life, and damage the aesthetic value as well as quality of water downstream.

There are two types of environmental costs one that affect the health of the final consumer and other that affect the local environment in the production process. The former effects are caused generally by particular persistent organic chemicals used in the production process.

Recent attention has focused on azo dyes, which are favored by textile manufacturers because of their brilliant colours and qualities of adhesiveness. These dyes are believed to cause cancer, and have been banned by a number of European countries. The German government and many other European and western countries have banned the import of products that may be in contact with the skin for prolonged periods such as garments (including outer garments) containing traces of azo dyes.

The finishing stage uses a variety of chemicals, including acids, alkalis, wetting agents, and chemical dyes. These effluents require proper treatment before being discharged to an external drain. Textile processing includes a number of wet processes bleaching, mercerizing, dyeing, and finishing which produce liquid effluent with varying waste composition. Environmental quality standards are most developed in the case of liquid effluent. At present, the majority of the textile mills, including modern, integrated facilities do not have adequate arrangements to treat their effluent before discharging into an external drain. Since in many cases, the external sink is an irrigation canal, the untreated chemicals can affect the quality of irrigation water. Also, textile processing is a heavy user of water. An average integrated textile mill produces 15 tons of finished cloth/day. It uses a total of approximately 3,840 cubic meters of water/day, including 1,680 cubic meters for finishing and processing, another 960 cubic meters for steam generation, and an equivalent volume for serving the workers colony and other domestic uses of water. The water used for finishing and processing results in contaminated liquid effluent of approximately 1,500 cubic meters/day. In addition, the water used for domestic use is emitted with household sanitary wastes.

Different methods are available for minimizing and eliminating the processing environmental cost. A switch to cleaner production would require the introduction of in-plant control mechanisms as well as end of pipe treatment. The latter would be more significant in existing industrial units. The treatment of industrial effluent can be classified into primary, secondary (or biological), and tertiary (or advanced physico-chemical) processes. Primary treatment includes processes such as screening, neutralization, aeration, equalization, and gravity sedimentation.

The purpose of primary treatment is to remove suspended matter (including oil and grease) and to achieve uniform flows and concentrations. As the suspended matter is removed, BOD and COD levels are also reduced. An important component of primary treatment is the use of chemicals to neutralize the effect of other chemicals. Sulfuric acid is used to bring down the pH level of the effluent, and oxidizing chemicals (chlorine, sodium hypochlorite, calcium hypochlorite, and ozone) are used to reduce color through the oxidation of dye molecules. Similarly, lime, ferric chloride, alum, and ferrous sulphate are used to react with dyes and form coagulants, which settle down in the treatment bed.

Secondary or biological treatment involves the development and cultivation of microorganisms on food or substrate available in the effluent to lower its BOD. The process can be aerobic (*i.e.* in the presence of oxygen) or anaerobic. The most popular method is activated sludge treatment. It consists of a primary sedimentation tank, an aeration tank, and a secondary sedimentation tank in a series. Provision is made to recycle settled biological sludge from the under flow of the secondary sedimentation unit into the aeration tank to maintain the desired level of microbial population. Primary and secondary treatment of textile effluent can reduce BOD levels by 94 per cent, and COD levels by 80 per cent.

Tertiary treatment involves a full chemical recovery of the effluent contents. It uses a high rate multi layer granular filtration with flocculation. The system consists of two pressure filters in series (double filtration) and the addition of chlorine, alum, and polymeric flocculation. Each granular layer has three strata consisting of anthracite, quartz sand, and garnet, which differ in density and granule size. Tertiary treatment can reduce BOD by 98 per cent, and COD by 90 per cent. Various in-plant control measures can substantially reduce the generation of wastewater, and thus reduce treatment costs. These measures include shutting off water supply to equipment not in use, installation of automatic shut off valves on water lines, avoidance of spillage and preparation of only the required amount of chemical solutions.

Morpho physiological concept of ideotype in cotton (*Gossypium hirsutum* L.) under rainfed conditions

B. S. JANAGOUDAR*
University of Agricultural Sciences, Raichur
**E-mail : bjanagoudar56@gmail.com*

An ideotype is a biological model which is expected to perform or behave in a predictable manner in a defined environment. Development or identification of such cotton ideotype is possible either by regular breeding programme or by screening from the existing cotton germplasm under rainfed conditions. For the identification of ideotype in cotton, a wide range of cotton cultivars with a genetic diversity for various traits is required (Blixt and Vose, 1984). Application of ideotype concept in cotton with higher photosynthetic rate, higher yield, pest and disease resistance and better fibre character lies in the extent of understanding about plant growth and morpho physiological characters in enhancing yield including the nature of interrelationships between different characters. Water is a limiting resource under dry land conditions, cotton crop improvement and research activities are therefore, compelled to develop or screen high yielding genotypes with low leaf area and higher total biomass under rainfed conditions rather than those producing higher leaf area and higher biomass.

In India about 60 per cent of the cotton is grown under rainfed conditions which seldom suffer from drought at one or the other stage. Drought causes considerable reduction in both yield and quality of cotton. The yield levels of rainfed cotton remain unstable and always fluctuate. Therefore, it would be worthwhile to identify the physiological attributes controlling the productivity of the rainfed cotton from the existing cotton germplasm. Also, understanding these attributes influencing productivity would be the basis for breeding for stable cotton production apart from upgrading their yield levels. Increased drought tolerance has been the major objective of plant breeding programme for regions where rainfall or irrigation supply is limiting. Although, conventional breeding methods have some encouraging successes, overall progress has been slow (Backlund and Hopper, 1984).

Cotton is semi xerophyte and forced annual. Its vegetative growth and duration is linearly related to water supply over a wide input range. However, harvest index is higher at lower water supplies. Thus, a greater proportion of total biomass is apportioned to reproductive structures as water stress is increased. This underlying principles entails that cotton needs only life saving irrigation to circumvent severe stress at the critical boll development stage. One or two life saving irrigations with water harvested and stored, especially after the cessation of rains have proved to increase the productivity by 50 per cent.

In cotton, the important morphological traits associated with drought tolerance include earliness, stomatal characters, leaf characters, rooting pattern and growth habit and physiological traits include high photosynthetic rate, low transpiration rate and higher leaf turgidity. Genetic variability has been found among the germplasm of cotton for growth parameters, lower LA/TDM ratio, higher yield/ LA ratio and higher yield were found to have good correlation under rainfed conditions.

The LA/TDM ratio indicates the mean assimilation rate of the genotype for the entire crop growth period. The observed differences might be due to variation in mean carbon exchange rate (CER) and dark respiration rate. Similarly, the importance of total biomass, LA and their relationship with yield has been reported in *hirsutum* cottons and these characters were considered as important physiological parameters for breeding genotypes for higher seed cotton yield (Bharadwaj *et al.*, 1975 and Singh and Bharadwaj, 1983).

Specific leaf weight (SLW) is an integral of leaf structure and is correlated with photosynthetic rate (Landiver *et al.,* 1983). Significant positive correlation between SLW and seed cotton yield during peak flowering stage has been reported (Janagoudar, 1997).

Plant temperature, particularly leaf temperature, has long been recognized as a potential indicator of plant water stress (Tanner, 1963). Canopy temperatures of cotton are useful indicators of crop water stress (Husman and Garrot, 1992). While studying drought resistance in cotton Lopez (1998) found positive correlation between the drought susceptibility index (DSI) and potential yield. The formula developed by Fisher and Maurer (1978) was used to calculate the Drought Susceptibility Index (DSI) of each entry in which:

DSI = (1-(yd/yp)) / D

Where;

Yd= Seed cotton yield in the non irrigated treatment

Yp= Seed cotton yield in the irrigated treatment (potential yield).

D= Drought intensity

= 1-(mean yd of all genotypes in the non-irrigated treatment / mean yp of all genotypes in the irrigated treatment)

In addition, water use efficiency (WUE) is considered as an important component of drought tolerance. Increasing crop water use efficiency may contribute to improved crop yield in water limited environments. Carbon isotope discrimination has been proposed as an estimate of WUE. This approach is based on discrimination against ^{13}C by leaves during photosynthesis. Analysis of delta have been considered as a valuable selection trait for higher yield. A positive association between delta and seed cotton yield over range of environments and years was found by Gerik *et al.*, (1996).

Initially 228 genotypes were evaluated under rainfed conditions for yield and morpho physiological characters. Based on the results of preliminary investigations, during successive years totally 62 *G. hirsutum* L. genotypes were evaluated in detail for morpho-physiological, biophysical and biochemical parameters apart from growth, yield and yield attributing characters, to identify desirable plant characters for ideotype under rainfed condition. Among the genotypes, Alleppo x Rex, DS 44, DRC 264, IC 376, NA 1269, DRC 19 and CPD-4-4-5 produced significantly higher yield as compared to the checks Abadhita and Sharada. The increase in yield was to the extent of 45 to 70 per cent. Among the high yielding genotypes, DS-44 and IC-376 were categorized as low LA types, because of low LA/TDM ratio's. These genotypes also had high NAR, SLW and TDM/LAD ratio as compared to other genotypes and both the checks. In addition, these genotypes had higher chlorophyll content at all the growth stages indicating better photosynthetic capacity of the leaves which might have resulted in higher dry matter accumulation/unit leaf area. The higher yield obtained in the above mentioned genotypes was ascribed to accumulation of higher total biomass and greater partitioning into reproductive parts as evidenced by the higher degree of association with TDM (r=0.629*) and harvest index (r=0.460*). In addition, the higher yield obtained in these genotypes was associated with higher boll number (r=0.832**), bartlett's index (r=0.278*), LAR at 60 DAS (r=0.317**), SLW at 90 DAS (r=0.289*), RGR (r=0.268*) and NAR (r=0.282*) between 60-90 DAS and the negative association with LAI at 60 DAS (r=-0.312*) and stomatal conductance at 120 DAS (r=-0.368*). All the fibre properties studied in these genotypes were on par with checks Abadhita and Sharada.

Based on the above investigations, it could be concluded that the desirable plant characters for ideotype of plant under rainfed conditions are : low leaf area between 12-18 dm^2 / plant at peak growth stage, NAR of 0.04 to 0.07g/dm^2/plant between 60-90 DAS, CGR of 2.0 to 3.0 g/dm^2/day at 90 DAS, lower stomatal conductance (3 to 4 cm/sec), lower transpiration rate (45 to 50 mg $H_2O/cm^2/sec$) and higher NAR to stomatal conductance ratio (0.0645 to 0.0812) during peak growth period, higher photosynthetic rate (Low LA/ TDM ratio), higher productivity per day, higher yield per unit functional LA, total biomass of 90 to 130 g/plant at harvest, higher HI of 22-35 per cent, and more number of good bolls/plant (6-8) and with medium maturity(160-165 days) and the resultant genotypes identified based on these characters as ideotype cottons are DS 44, IC 376 and CPD 4-4-5.

From the field studies conducted at Dharwad for many seasons the productivity of high yielding rainfed *hirsutum* cotton genotypes was associated with low LA., higher total biomass, high leaf efficiency, higher productivity, higher HI and more number of good bolls per plant (Janagoudar, 1997). From these studies, following cotton ideotype characters have been proposed under rainfed conditions.

- Short compact plant structure with open canopy.
- Smaller leaves well inclined to intercept maximum light and showing heliotropic movements.
- Short multinodal sympodia (2 to 4 nodes).
- Moderate deep root system.
- Semi dwarf stature reaching not more than a meter with amenability to close spacing.
- Leaf anatomy with thick palisade than spongy parenchyma and thinner epidermal layers.
- Crop duration around 130 -150 days.
- Balanced growth, high fruiting coefficient and economic utilization of observed nutrients.
- Higher photosynthetic efficiency and specific leaf weight.
- Low transpiration with higher turgidity of leaves.

Development of ideotypes in cotton (*G. hirsutum*) under rainfed conditions : Since water is a limiting resource under dry land conditions, cotton crop improvement and research activities are therefore, compelled to develop or screen high yielding genotypes with low leaf area and higher total biomass under rainfed conditions rather than those producing higher leaf area and higher biomass. This necessitates the identification and breeding of cotton genotypes with low leaf area and higher total biomass for obtaining higher yield. It would be helpful in identifying the cotton genotypes with higher photosynthetic rate thereby improving the yield potential of cotton genotypes under limited water conditions.

One of the possible approaches is to search for cotton ideotypes with specific and distinct characters or combination of characters that are known to influence the photosynthesis, growth and production of economically important plant parts, as are expected to perform better under adverse environmental conditions. Development or identification of such cotton ideotype is possible either by regular breeding programme or by screening from the existing cotton germplasm under rainfed conditions. In broad sense, an ideotype is a biological model which is expected to perform or behave in a predictable manner in a defined environment.

For the identification of ideotype in cotton, a wide range of cotton cultivars with a genetic diversity for various traits is required (Blixt and Vose, 1984). Application of ideotype concept in cotton with higher photosynthetic rate, higher yield, pest and disease resistance and better fibre character lies in the extent of understanding about plant growth and morpho physiological characters in enhancing yield including the nature of interrelationships between different characters. Seed cotton yield is stagnated for the last 10 years and India's productivity (338 kg/ha) is very low as compared to the world average (478 kg/ha). It appears that, the frequent occurrence of natural vagaries of various kinds of stress, lack of scientific crop production technology and the low yielding nature of present genotypes except hybrid cottons resulted in lower productivity in India. According to the estimates, cotton requirement by 2000 AD and 2050 AD with an estimated population of 1000 and 1600 million would be 185.0 and 282.0 lakh bales, respectively (Narayanan and Bhale, 1987). This could be achieved only through increased productivity under rainfed conditions as it would not be possible to extend the area under cultivation.

In this direction, efforts need to be made in elucidating the principal factors limiting seasonal yield under rainfed conditions. To meet the challenges of productivity, higher *Gossypium hirsutum* offers better scope for genetic improvement among the four cultivated species of cotton. Majority of cotton produced by *G. hirsutum* is medium and long staple and it has very high adoptability with rich diversity for yield and yield related characters.

Initially 228 genotypes were evaluated under rainfed conditions for only yield and morpho physiological characters. Based on this preliminary investigation results in the successive years totally 62 *G. hirsutum* L. genotypes were evaluated in detail for morpho physiological, biophysical and biochemical parameters apart from growth, yield and yield attributing characters, to identify desirable plant characters for ideotype under rainfed condition. Among the genotypes, Alleppo x Rex, DS 44, DRC 264, IC 376, NA 1269, DRC 19 and CPD 4-4-5 produced significantly higher yield as compared to the checks Abadhita and Sharada. The increase in yield was to the extent of 45 to 70 per cent. Among the high yielding genotypes, DS-44 and IC-376 were categorized as low LA types, because of low LA/TDM ratio's. These genotypes also had high NAR, SLW and TDM/LAD ratio as compared to other genotypes and both the checks. In addition, these genotypes had higher chlorophyll content at all the growth stages indicating better photosynthetic capacity of the leaves which might have resulted in higher dry matter accumulation/unit leaf area. The higher yield obtained in the above mentioned genotypes was ascribed to accumulation of higher total biomass and greater partitioning into reproductive parts as evidenced by the higher degree of association with TDM (r=0.629*) and harvest index (r=0.460*). In addition, the higher yield obtained in these genotypes were associated with higher boll number (r=0.832**), bartlett's index (r=0.278*), LAR at 60 DAS (r=0.317**), SLW at 90 DAS (r=0.289*), RGR (r=0.268*) and NAR (r=0.282*) between 60-90 DAS and the negative association with LAI at 60 DAS (r=-0.312*) and stomatal conductance at 120 DAS (r=-0.368*). All the fibre properties studied in these genotypes were *on par* with checks Abadhita and Sharada.

Based on the above investigations, it could be concluded that the desirable plant characters for ideotype of plant under rainfed conditions are with low leaf area between 12-18 dm^2 / plant at peak growth stage, NAR of 0.04 to 0.07g/dm^2/plant between 60-90 DAS, CGR of 2.0 to 3.0 g/dm^2/day at 90 DAS, lower stomatal conductance (3 to 4 cm/sec), lower transpiration rate (45 to 50 mg H_2O/cm^2/sec) and higher NAR to stomatal conductance ratio (0.0645 to 0.0812) during peak growth period, higher photosynthetic rate (Low LA/ TDM ratio), higher productivity per day, higher yield per unit functional LA, total biomass of 90 to 130 g/plant at harvest, higher HI of 22-35 per cent, and more number of good bolls/plant (6-8) and with medium maturity(160-165 days) and the resultant genotypes identified based on these characters as ideotype cottons are DS 44, IC 376 and CPD 4-4-5.

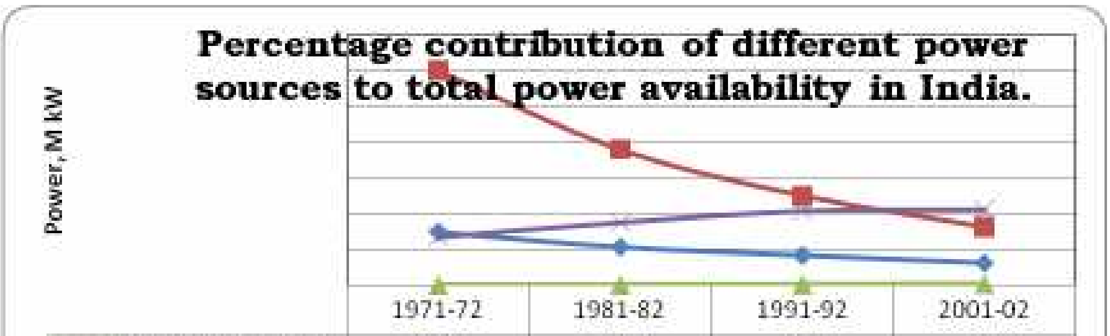
Status of mechanical harvesting of cotton in India: The way ahead

GAUTAM MAJUMDAR*
Central Institute for Cotton Research, Nagpur - 444104
**E-mail : gama62@rediffmail.com*

Abstract : This paper describes the present status of cotton picker development for Indian cotton. Attempts have been made to study imported spindle type cotton picking machine and testing its suitability on Indian fields on one hand and developing a suitable alternative system on the other hand. While developing a cotton picker a history of cotton picker development in the United States of America which has started around 1850 was taken into consideration. Various mechanisms were used before the launching of successful cotton picker. Major types of mechanisms tried were suction type and mechanical type. Mechanical picking mechanisms involved brush type, pin and7 finger type, spindle type, beater type, auger type, bristle type, tooth picking and saw type. After trying various mechanisms finally the spindle type mechanism was found to become very successful to pick seed cotton in Europe and American countries. Presently spindle type cotton mechanism is used in all mechanical cotton pickers which are being run in the above countries. However, another system known as cotton stripping came into popularity wherever Ultra Narrow Row cotton cultivation became popular. Efforts have been made to test a cotton picking machine with Indian cotton. But due to huge initial cost which results into high cost of operation, high trash percentage (20-30%) in machine picked seed cotton and small land holdings in India, the machine still could not be introduced. Alternative attempts are being made to develop a viable cotton picking machine for an Indian condition.

Key words : Mechanical harvesting, spindle type, machanization model, inanimate power

India has made remarkable progress in the development of agricultural mechanization technology. The country evolved a selective mechanization model using a power mix based on animate and inanimate power sources. The animate power sources include the human beings and animals and the inanimate power sources include electro mechanical power sources such as diesel engine, tractors, power tillers and electric motors. One of the globally used Index of Agricultural Mechanization (IAM) is power availability/unit area. Power availability is computed by taking both animate and inanimate power sources. Nearly 80 per cent of the farm power in India at present is contributed by inanimate power sources (Fig.1).



	1971-72	1981-82	1991-92	2001-02
Agricultural workers	15.11	10.92	8.62	6.49
Total animate power	60.37	38.15	25.17	16.38
Power tillers	0.26	0.33	0.4	0.54
Electric motors	13.77	17.78	20.9	21.26

Fig. 1. Percentage contribution of different power sources to total power availability in India. (Source: Verma, S. R. 2007)

Cotton is cultivated in three distinct agro ecological regions (North, Central and South) of the country. Approximately 65 per cent of India's cotton is produced on dry land and 35 per cent on irrigated land. The soils of central zone and some part of south zone contain large proportion of clay thus become very sticky when wet and very hard when dry. Small holdings (Table 1), complex land tenure arrangement and excessive farm fragmentation further limit the scope for sophisticated farm power system more suited to large land holdings of north zones. In small and marginal farms, except for tillage, other operations such as sowing, weeding, cotton picking harvesting and stalk uprooting are normally manually performed. Though, India has abundant labour force in agriculture, non-availability of manpower during peak crop season is a growing problem.

Cotton harvesting in India is done manually whether it is rainfed or irrigated and it is a highly labour intensive operation, also time consuming and drudgerous. Manual picking is not only tedious hard work but also costlier than other agricultural operations. Manual picking of cotton requires around 465 labour h/ha. Due to non-availability of labor in time, cotton picking gets delayed causing around 15 per cent field loss and affecting the overall quality of cotton lint. The change in weather forces the farmers to harvest cotton quickly and non availability of labour and less available time makes it expensive and complex. The cost of operation of the cotton picker is estimated to be high compared to the cost of manual picking of seed cotton because of high initial cost of the picker in India and the associated cost of application of harvest aids *viz.,* defoliants, growth regulators and additional cleaning cost associated with high trash content in machine harvested cotton. However, considering the constraint of availability of labourers during peak season, the adoption of mechanical cotton picking is necessary. The use of mechanical picking machine is, therefore, considered necessary in minimizing drudgery involved in hand picking.

Table 1. Number and area of operational holdings by size group

No. of Holdings: ('000 number)
Area Operated: ('000 ha)
Average size: (ha)

Category of holdings	Number of holdings		Area		Average size of holdings	
	2000-2001	2005-2006	2000-2001	2005-2006	2000-2001	2005-2006
Marginal	75408	83694	29814	32026	0.4	0.38
(Less than 1 ha)	(62.3)	(64.8)	(18.7)	(20.2)		
Small	22695	23930	32139	33101	1.42	1.38
(1.0 to 2.0 ha)	(19.0)	(18.5)	(20.2)	(20.9)		
Semi medium	14021	14127	38193	37898	2.72	2.68
(2.0 to 4.0 ha)	(11.8)	(10.9)	(24.0.)	(23.9)		
Medium	6577	6375	38217	36583	5.81	5.74
(4.0 to 10.0 ha)	(5.5)	(4.5)	(24.0)	(23.1)		
Large	1230	1096	21072	18715	17.12	17.08
(10.0 ha and above)	(1.0)	(0.8)	(13.2)	(11.8)		
All Holdings	**119931**	**129222**	**159436**	**158323**	**1.33**	**1.23**
	(100.0)	**(100.0)**	**(100.0)**	**(100.0)**		

Note : Figures in parentheses indicate the percentage to total
Source : Department of Agriculture and Cooperation, Agricultural Census Division

The cost of operation is high because of the large initial cost of the imported cotton picker. If a cotton picker could be designed and produced in India through combined efforts of R and D organizations, users and manufacturers, then the cost of the machine might be reduced. However, the higher trash content in cotton picked by spindle type cotton pickers and lack of

Table 2. Statewise cotton area in Lakh ha (2011-2012)

State	2011-2012(P)
Punjab	5.60
Haryana	6.05
Rajasthan	5.30
Gujarat	30.23
Maharashtra	40.95
Madhya Pradesh	7.06
Andhra Pradesh	18.54
Karnataka	5.49
Tamil Nadu	1.21
Orissa	1.02
Others	0.46
Total	**121.91**

Source : www.cicr.org.in

pre and post cleaning equipment in Indian ginning factories, prohibits the popularization of spindle type pickers in India. Another issue is the inherent huge size of the spindle type pickers which have huge horse power requirement and pose operational difficulties on Indian farms of small holdings.

Constraints in mechanical cotton picking in India: Because of the staggered blooming characteristics of Indian cotton plants, mechanical pickers were not considered suitable for Indian conditions. Consequently this area of research and development was not taken up extensively anywhere in the country. Barring a few instances, so far a holistic approach has been lacking. As the biological scientists are gearing up to develop suitable plant type amenable to mechanical picking, it is necessary that development / identification of a mechanical picker suitable for Indian conditions is given due consideration to coincide with the advent of such a plant type.

Fig. 2. Statewise farm power availability in India. (Source: Verma, S. R., 2007)

Technology and equipment for cotton harvesting : Current cotton harvesters are of two types, *i.e.*, pickers and strippers. Mechanical pickers are selective in that the seed cotton is removed from the open bolls; whereas green and unopened bolls are left on the plant to mature for later pickings. In high yielding areas and in other areas where serious weather hazards make it important to start harvesting as early as possible, it is common practice to go over the field twice, allowing about 4 to 6 weeks between picking. Under some conditions, a second picking is not economically justifiable. Strippers, on the other hand, are once over machines. All bolls, whether open or closed, are removed from the plant in a single pass. Harvesting with a stripper is, therefore, usually delayed until the plants shed their leaves. Chemical defoliants and desiccants are sometimes applied to permit earlier stripping.

Research efforts in mechanization of cotton picking : Efforts were made by CCSHAU, Hissar during 1972-1977 to develop a knapsack vacuum cotton picker. A laboratory model of blower fan for creating vacuum in the picking zone for the development of a pneumatic cotton picker was fabricated. However, further work could not be taken up as the model ended up picking up a lot of trash. Muthamiselvan *et al.*, 2007. Developed knapsack cotton picker cost economics was worked out as per the 'RNAM test code and procedure for harvesters' to determine the feasibility and economical viability of the machine. The cost of machine was worked out Rs. 5000 and the cost of picking was reported to be Rs. 4.55/kg of cotton. However, the rate of work was found dismally low. In order to improve the above suction type picker, TNAU, Coimbatore developed a trolley mounted suction type picker with many suction hoses (Fig.3). This too could not improve upon the rate of work compared to manual picking.

Fig. 3. TNAU multiple nozzle suction type picker

Development of tractor mounted suction type cotton picker : Suction type cotton picker based on pneumatic principle (Fig.4) comprises of suction valve to pick the cotton bolls. The suction was created by centrifugal blower. The valve could be opened and closed with the hand operated lever. Different picker end diameter had been used to get different suction pressures at picking end of the machine. The picker was tested with American cotton variety F 1861. It has been reported that picking efficiency and output capacity were highest (96.3 %, 6.21 kg/h) at 25 mm picker end diameter with suction pressure of 45 mm of Hg. The trash content was minimum (0.65 %) at 20 mm picker end diameter with suction pressure of 30 mm of Hg. and was highest (5.64 %) at 40 mm of picker diameter with suction pressure of 8 mm of Hg. However, the picking rate could not match that of hand picking and this line of research has been abandoned.

Fig.4: PAU Tractor mounted suction type picker

Design of picking head for mechanical spindle type picker : A tractor operated mechanical spindle type cotton picker was designed and developed at TNAU (Fig.5). The unit consists of major subsystems *viz.*, main frame, hydraulic power pack, mechanical cotton picking head, suction fan assembly, collection tank for cotton and operator work space.

For achieving the best performance of developed mechanical spindle type cotton picker in terms of maximum cotton picking efficiency of 77.9 per cent and fibre length of 33.8 and minimum spilled over cotton of 4.9 per cent and trash content of 17.0 per cent, the optimized levels of selected levels of variables of prototype tractor operated mechanical spindle type cotton picker for Indian conditions are 2000 rpm spindle speed, heavy pressure plate tension, 0.4 mm doffer to spindle clearance and diluted soap solution as spindle moistener.

However the unit was excessively heavy and maneuverability of the developed system was very difficult. Further work needs to be done to refine it and make it workable.

Fig. 5. TNAU Tractor operated cotton picker in operation – front view and rear view

Initial efforts to introduce imported spindle type cotton picker : Initial efforts to introduce mechanical cotton picking system in India were undertaken during 1986-1987. Punjab Tractors Limited, Mohali in collaboration with Punjab State Department of Agriculture, Punjab Agricultural University, Ludhiana and leading cotton growers in Punjab identified need for mechanizing cotton picking. A standard two row Russian cotton picker along with ancillary equipment was obtained on loan from the USSR in 1988 for preliminary field assessment. Cotton crop variety LH 900 was sown at 60 cm row-to-row spacing in the year 1989 at cotton research station, Abhore, PAU for preliminary field assessment. Defoliation of crop was achieved by using Dropp 500 WP at the rate of 175 g/ha at about 140 days after sowing and mechanical picking was done after 15 days from the period of defoliation.

Initial trials revealed encouraging results, however, it was considered appropriate to develop smaller equipment suitable for mounting on Indian tractor. As a part of collaborative programme, two Swaraj tractors were sent to Uzbekistan in 1991 for adoption of Russian cotton picking mechanism on them for further evaluation. A four member team was deputed to Tashkent in October, 1991 to witness trials of newly developed machines and they were satisfied with the technical performance of both single row and double row model of cotton picker mounted on Swaraj tractors. However, team opined that for mechanization of cotton picking, it was necessary to evolve appropriate cotton varieties and agronomical practices as well as cleaning equipment particularly prior to ginning (Singh *et. al.*, 1992).

Testing of two row spindle type mechanical cotton picker under NATP project no. PSR 36 on "Adoption and refinement of a cotton picker and cleaning system" : In the year 2003-2004 a study was conducted on the performance of an imported John Deere 9935 two row self-propelled cotton picker at different locations in India. The performance of cotton picker was evaluated at PAU Ludhiana and CICR, Nagpur. Tests at PAU, Ludhiana were conducted on LH 1556 having average plant height of 112.9 cm. The mean values of forward speed, effective field capacity, total harvesting loss, mechanical picking efficiency and picker efficiency were 2.62 kmph, 0.28 ha/h, 23.62, 75.7 and 76.4 per cent, respectively. The field evaluation of cotton picker at CICR, Nagpur was conducted on seven varieties/genotypes, namely CNH 120 MB, CNH 123, CNH 155, CNH 911, CNH 2713, CNH 4736 and GSH 2. The average height of plant and lower most boll were 85.9 cm, 86.0 cm, 98.1 cm, 81.9 cm, 73.2 cm, 77.8 cm and 86.3 cm and 9.0 cm, 10.9 cm, 21.6 cm, 11.6 cm, 16.4 cm and 12.3 cm for CNH 120 MB, CNH 123, CNH 155, CNH 911, CNH 2713, CNH 4736 and GSH 2, respectively. The mean values of forward speed, effective field capacity, fuel consumption, total harvesting loss, mechanical picking efficiency and picker efficiency were 2.20-3.38 kmph, 0.278-0.563 ha/h, 22.0 - 24.0 l/h, 14.29-31.74, 55.6 - 83.1 and 68.3-85.7 per cent, respectively. Trash content in the machine picked cotton was found to be 22-26 per cent. The cultural practices and staggered blooming characteristics of present Indian cotton varieties poses challenge to engineers in mechanization of cotton picking. With the advent of new genotypes, it may be possible to introduce mechanical cotton pickers successfully. However, the trash content in the machine picked cotton would still pose a problem due to non availability of pre and post cleaners at ginning factories.

Various picking mechanisms explored in western countries : The mechanical type and suction type are the two major mechanisms tried so far. These further consist of the following types

- Brush type of mechanism
- Pins and finger type
- Spindle type
- Brush and beater rollers
- Auger type of mechanism
- Tooth picking
- Saw type mechanism
- Bristle type

The overall development of cotton picker stops with the spindle type of cotton picker. The pickers being used all over the World mostly have spindle type of cotton picking mechanism. The same pickers are being tested in India but suitability of these cotton pickers is questionable as trash percentage in seed cotton is in the range of 20-30 per cent (Prasad and Majumdar, 2007). By nature the spindle type pickers tend to consume large power with huge sizes unfit for small farm sizes of Indian cotton farmers. Evcim 2000, stated that it is possible to pick cotton economically by spindle type pickers if the land size of the farm is more than 150-200 hectares.

High density planting system (HDPS) or ultra narrow row cotton production (UNR) : Ultra narrow row cotton refers to cotton grown on rows that are 25 cm or less wide with plant populations of 200000 plants/ha or more so as to reap more seed cotton per unit area at less cost. The plants tend to be slender with shorter limbs and majority of cotton being set at the first position with few second position bolls and almost no bolls at the third position on a fruiting branch. Narrow row cotton can only be harvested with a stripper harvester therefore, the optimum plant height is 60 to 75 cm only. Cost of cultivation reduces because of quicker canopy closure and a short season which can reduce or eliminate mid to late season herbicide, insecticide, and irrigation water applications (Knowles and Cramer, 1999). With Central Institute for Cotton Research (CICR) experimenting with UNR cotton and a very likely possibility of breaking the yield barriers with a lower cost of production, need for a stripper harvester may arise sooner than expected. A stripper harvester costs a fraction of spindle type picker albeit harvesting almost three times trash as that of latter. The ginning factories will need to have an extra stage of stick cleaner and burr extractor.

Deterrents to popularization of mechanical pickers in India : The current pickers and strippers are suitable for very large size holdings 150-200 ha if not more. Whereas the average land holding in India is 1.23 ha (Table 1). There is a constant fragmentation of land as seen in the Table 1. Maximum area 67 per cent falls in 1 to 10 ha *i.e.*, small to medium category. Maximum numbers of holding (62.3%) have less than 1 ha of land. Therefore, the harvesters need to be redesigned and scaled down to suit the small land holdings of India. Even if custom hiring is resorted to, which eventually will be, the non contiguous land and plethora of varieties and hybrids will pose a problem.

Large initial cost is a major bottleneck for popularization of machine harvesters in India. The self propelled western machines, dedicated to only harvesting cotton will definitely not find favour among Indian cotton growers. No farmer would like his machine to be working only 2-3 months a year and having to maintain and shelter the machine for the rest. A picker attachment to either a tractor, power tiller or pulled by a pair of bullock would be more appealing and viable solution. Any form of mechanization ultimately needs power to take off (Fig. 2) clearly showed the most mechanized state in India has an average farm power availability of 3.5 kw/ha, matching the most mechanized western countries. However, the states of Maharashtra and Gujarat, which together account for 58 per cent of cotton area (Table 2), boast of only 0.7kw/ha average farm power availability. This clearly is a case for smaller machines with smaller power requirements.

Cotton pickers have a very complex mechanism and need highly trained manpower and technicians. A host of adjustments to different components are required before a reasonably efficient picking is realized and losses reduced. These machines need intensive maintenance and repair as the parts wear out quite fast. With the present technical skill of Indian cotton growers such complex systems will remain a distant dream. Repair and maintenance facilities, availability of spares and skilled manpower, technicians and operators at village level need to be put in place.

The bigger issue of higher trash content (20-26% in pickers and 30-40% in strippers) (Prasad and Majumdar, 1999) will have to be addressed in right earnest. As the entire seed cotton in India is manually picked, the ginning factories are not geared to handle this level of trash in machine harvested cotton. These ginning factories will need to be upgraded with a series of pre and post cleaners.

CONCLUSIONS

Scarcity of labour and therefore, the higher cost of picking seed cotton and consequent higher cost of cultivation will eventually pave the way for mechanical harvesting of cotton in India. As shown in the above discussion, cotton is grown in all categories of land holdings and under all sources of power. Therefore, cotton harvesters will need to come in all shapes and sizes, harnessing the available power to satiate the demands of Indian cotton.

References :

Anonymous. Annual Reports of Technology Mission on Cotton TMC MM-1 2007-2012. Central Institute for Cotton Research, Nagpur

Evcim. H.U. 2000. Pamuk Toplama ve Makinalý Hasada Uygun Üretim Tekniði. Ege Bölgesi Pamukçuluðunun Mevcut Durumu. Sorunlarý ve Çözüm Yollarý. (Mechanical Cotton Picking and Production Methods for Mechanical Harvesting. Current Situation of Cotton Production in the Aegean Region: Problems and Solutions) Ege University. Scientific Research Project Report. Project No: 1998/ZRF-019/1. p. 297-299. Izmir. Turkey.

Final Report NATP Project no. PSR-36 "Adoption and refinement of a cotton picker and cleaning system" CIAE, Bhopal.

Knowles, Tim C. and Roc, Cramer.1999. Narrow row cotton production in Vicksberg. Arizona Cotton Report, The University of Arizona, College of Agriculture, index at http://ag.arizona.edu/pubs/crops/az1123/

Muthamilselvan, M., Rangasamy K. and Sampathrajan A. (2007). Feasibility and economic viability of knapsack cotton picker in India. *Indian Jour. Agricul. Res.* **41** (2)

Prasad J. and Majumdar G. 1999. Present practices and future needs for mechanisation of cotton picking in India. Agricultural Engineering

Today. **Vol. 23(5-6)** : 1-20

Singh T.H., Brar A.S., Thind R.J.S., Prakash, Ram and Vithal B.M. 1992. Mechanical Picking of Cotton in Punjab: A preliminary Study. *J. Ind. Soc. Cott. Imprv.,* (March 1992), : 62-67.

Verma, S. R.2007. Farm Mechanization for Diversification of agriculture. Status & recent trends of tractor power in Indian Agriculture. Proceedings of 20th National convention of Agricultural Engineers and National Seminar on *"Farm Mechanization for Diversification of Agriculture"*. January 19-20, 2007, held at PAU, Ludhiana.

Proceedings on "Global Cotton Production Technologies *vis-a-vis* Climate Change" 37-46

Need for breeding system research in improving cotton

SHREEKANT S. PATIL*
Agricultural Research Station, University of Agricultural Sciences, Dharwad - 580 007
**E-mail : sspadvance @indiatimes.com, sspadvance @gmail.com*

The success of varietal development program depends upon magnitude of desirable variability created and the efficiency of the selection strategy practiced in exploiting the variability. The efforts of varietal development in self pollinated crops essentially involve hybridization followed by practicing selection through the method of breeding chosen after hybridization. The success of selection practiced in segregating generations depends upon gene action involved in the loci influencing productivity parameters while the extent of useful variability created through hybridization depends on the diversity existing between the parents. The diversity in question is quantifiable in terms of the number of yield influencing loci for which they compliment with each other. The distribution of these desired alleles between the two parents is another important factor which determines the target genotype set in the task of varietal improvement. While initiating such hybridization work involving the chosen parents breeder should have a clear perception of the constitution of the new varietal genotype aimed to be developed through this program. The idea is to define such a genotype as **"Target Genotype"** in terms of the proportion of alleles retained from two parents chosen for hybridization (it can be defined in terms of multiple parents as well but for simplicity, the case of using only two parents in hybridization is considered). The perception of target Genotype should be clear to the breeder and this enables the breeder to choose right option of breeding method and even make alteration in handling the segregating generations.

The varietal breeding methods of handling genetic material after hybridization can be broadly grouped into

a) Pedigree/ Bulk/ Single seed decent
b) Back cross method of breeding

This distinction between the breeding methods can be made in terms of the proportion of alleles of the two parents (involved in crossing) seen among the segregants in the generations derived (after hybridization) in these methods of breeding. Back cross method of breeding is used when the donor parent has highly undesirable genetic background except for one desirable simply inherited trait . In terms of proportion of alleles required from the two parents, the target genotype would be defined may be as 98:2 or 99:1. The genetic consequences of back crossing and about when to use Back cross breeding, are well explained in different books on Plant Breeding and the procedure followed during back cross breeding precisely increases the chance of occurrence of such a targeted genotype (Allard, 1960). Thus among the breeding methods **Backcross method of breeding is considered as more scientific** especially because this breeding procedure facilitates and enhances the chance of occurrence of the targeted genotype (in terms of proportions of alleles from the two parents). In every backcross generation, the proportion of alleles from the recurrent parent goes on increasing and the undesirable alleles of donor parent are flushed out at high speed. If the breeder keeps track of the desirable trait of the donor parent under transfer and holds that intact in the plants chosen for back crossing, the targeted genotype is produced with great ease.

What is the target genotype set in these two groups of Selfed Generation Breeding (SGB) methods like Pedigree/Bulk/SSD? Are these selfing methods effective in generating a high frequency of this target genotype? How do they compare with Back cross breeding methods in terms of efficiency in generating high frequency of the desired target genotype? Should these methods be rated as less scientific because the target genotype set is not often achieved? Depending on the need can these methods be made more scientific (target oriented) by blending the steps of selfing and backcrossing to increase the efficiency in creating high frequency of the target genotype? These are the important aspects on which lot of information has to be

Procedures of Varietal Breeding and proportions of alleles from the two parents commonly seen among the segregants:

I) Selfed Generation method (Pedigree/ Bulk /SSD Method)

II) Backcross method

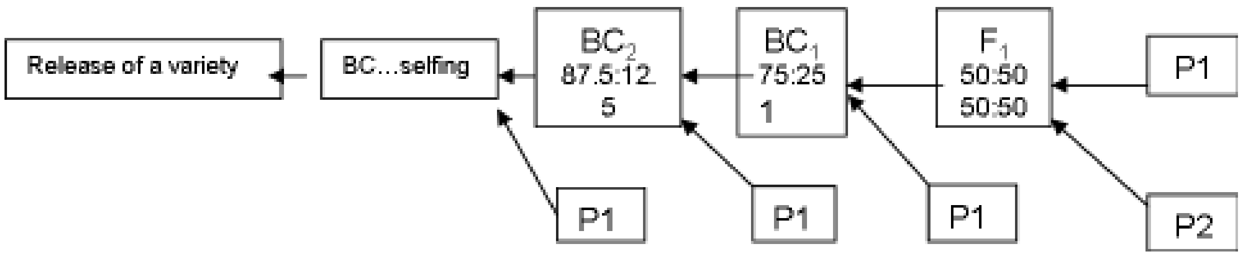


Fig 1. Procedures of handling the material after hybridization in varietal breeding of self pollinated crops and the proportion of alleles from parents

generated through breeding system research but there is a dearth of planned research in this direction.

Consequences of selfing and constitution of selfed generations: An understanding of the constitution of plants in different segregating generations helps in determining what is target (genotype) achievable through SGB approaches. Simple Mendalian expectations of segregation at a locus form the basis for determining the constitution of plants in the segregating populations derived through selfing. A heterozygous F_1 segregates to give two gametic types at each locus. Considering segregation for a quantitative trait like yield which in turn is influenced by many yield components, the F_1 produces an array of 2^n gametic types . At every locus, 3 genotypes are produced in F_2 generation. As the number of loci influencing the ultimate dependent character like yield goes on increasing, the total number of gametic types reaches a very high number. These values of total number of gametic types and genotypes produced in F_2 generation reaches astounding figures. Over 2 million gametic types are produced by F_1 when number of loci increases to just 21, and when these many gametic types coming from male and female sides unite, 10 billions of genotypes are produced. To recover these many genotypes a minimum of 4 trillion population size is required in F_2 generation (Allard, 1960).

If a realistic number of loci (hundreds) governing inheritance of a dependent character like yield are considered, the genotypic classes reach astronomical figures and the population size normally used for handling F_2 segregating generation becomes abysmally low. In fact one of the area of research could be on determination of the acceptable optimum population size and the effect of sampling (F_2 size) on the genetic characterization of F_2 population. The minimal population size by F_6 generation reduces by billions for this scale of segregation and hence this can be a blanket advantage of SSD over pedigree/ bulk methods of breeding. There is immediate attention required on comparing efficiency on SSD over other methods in terms of reduction in minimum population size. Instead of following SSD upto F_6 is not possible, it is interesting to know whether for 1 or 2 selfing generations (F_3 and F_4) SSD approach can be followed. Because distinguishing progeny row right from BC1F_2 helps identifying uniform rows

There are differences in the proportions of each of these genotypes in F_2 and further these proportions keep changing in successive segregating generations. There are different ways of distinguishing the segregants recombining the genotypic constitution of the parents involved in hybridization. It is common to work out genotypic and phenotypic segregation ratios in case of few loci based on Mendelian expectations. When large number of loci is involved in segregation, working out such ratio and distinguishing genotypic classes is not possible.

Proportion of alleles from parents : If the entire population of plants in a segregating generation is considered, it has been shown that the average proportion of alleles of the two parents in $F_{1,}$ F_2 and any subsequent segregating selfed generation is 50:50. As against this , in backcross breeding, the proportion of alleles from recurrent parent goes on increasing with every backcross generation (Table 1).This is always seen as a major difference in the consequence of selfing and backcrossing.

In this paper, another approach is suggested for distinguishing these segregants in terms of proportion of alleles derived from the two parents. The segregants most commonly observed in a breeding approach should match with target genotype set at the beginning of the varietal improvement program. Otherwise the selected approach may not give the desired result. Hence it is necessary to understand what is the target genotype set by the particular pair of parents before embarking on choice of breeding procedure. It is also equally important to understand what are the types of segregants most commonly observed, in a selected breeding approach.

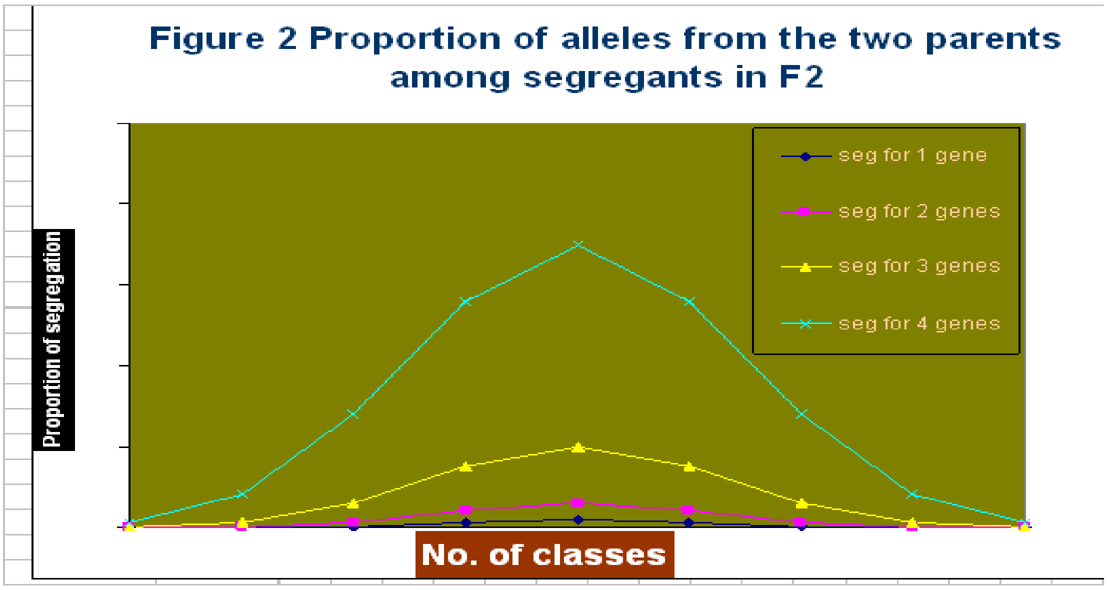
In terms of proportion of alleles from the two parents, a segregation ratio of 1:2:1 is observed in F_2 generation with respect to a locus under consideration. As shown in Table2 when segregation at two loci is considered, a ratio of 1:4:6:4:1 is observed where the segregants with 50:50 allelic contributions from the two parents are most commonly observed. The extreme types and those with unequal contribution of alleles from the two parents are not commonly observed. Extending it to the case of three loci, a ratio of 1:6:15:20:15:6:1 is seen in F_2 and here again segregants with 50:50 or nearly 50:50 allelic contribution from the two parents occur most commonly in an early segregating generation. This pattern of segregation remains same even when large number of loci affecting a quantitative character are considered and this is depicted in Fig. 1 and 2.

In Bulk and SSD methods of breeding artificial selection begins at a stage when population is fixed or nearly fixed at the segregating loci governing inheritance of quantitative traits(may be F_6 generation signifying the fixation of genotypes) and at this stage number of gametic classes and genotypic classes are same(2^n). With the help of Pascle's triangle, the segregation ratios can be worked out in F_2 generation and also in the generation representing fixation.

The segregation ratios worked out in Fig. 3 show that the trend of prominence of 50:50 types among segregants continues even at this stage of fixation. It means that whether it is pedigree or bulk or SSD method of handling segregating populations,50:50 types of segregants are most commonly seen in these populations

Table 1. Average proportion of alleles of parents in selfed/ back cross generations

Selfing generations	Proportion of alleles of parents		Back cross generations	Proportion of alleles of parents	
	P_1	P_2		P_1 (Recurrent parent)	P_2 (Donor parent)
F_1	50	50	F_1	50	50
F_2	50	50	BC_1	75	25
F_3	50	50	BC_2	87.5	12.5
F_4	50	50	BC_3	93.75	6.25
F_5	50	50	BC_4	96.875	3.125
F_6	50	50	BC_5	98.437	1.5625



subjected to artificial selection. As compared to this there is a lower frequency of 70:30 types (or symmetrically 30:70 types) and a still lesser frequency of 95:5(or 5:95) type. It is important to remember for this reason that the target genotype achieved through back cross method of breeding (say 98:2type) is very much available even in F_2 generation but locating such segregants in F_2 becomes a Herculian task and hence it is avoided and the tedious procedure of continuous back crossing is preferred to selecting for the target 98:2 type in F_2 or later segregating generation.

Thus selection practiced in these segregating populations will be successful only if the Target genotype set by the pair of hybridized parents is close to 50:50. This means that if the two parents are perfectly complimenting each other on gene for gene basis or crudely speaking trait for trait basis (component trait) basis, the target genotype set will be 50:50 type. In simpler terms, in any segregating generation (F_2, ...F_6.), the segregants which are 50:50 types (50% alleles from each parents) are the most commonly observed types. If the two parents are complementing each other perfectly by sharing the desirable alleles each at 50 per cent of the total number of loci responsible for yield then the target genotype in case of the parental pair chosen for hybridization is a 50:50type.

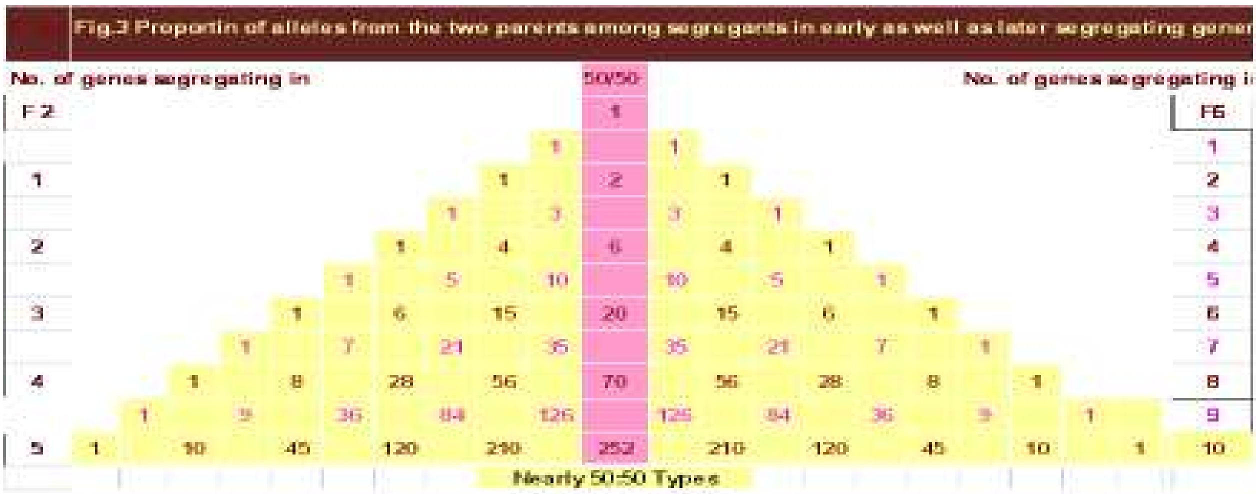


Table 2. Proportion of alleles of two parents among segregants of

a) F_2 generation

Genotypes and proportion of alleles of two parents

One gene case	AA	Aa	Aa
Proportion of alleles of parents	100:0	50:50	0:100
Segregation ratio	1	2	1

Genotypes and proportion of alleles of two parents\

Two gene case	AABB 1	AABb 2 AaBB 2	AaBb 4 AAbb 2 aaBB 2	Aabb 2 aaBb 2	aabb 1
Proportion of alleles of parents	100:0	75:25	50:50	25:75	0:100
Segregation ratio	1	4	6	4	1

b) F_6 generation

Genotypes and proportion of alleles of two parents

Two gene case	AABB 1	AAbb 1 aaBB 1	aabb 1
Proportion of alleles of parents	100:0	50:50	0:100
Segregation ratio	1	2	1

Since the segregating population consists of mainly 50:50 types the job of the breeder is restricted to selecting the **"Best 50:50 type"**. This ultimate best 50:50 type is the target recombinant type and incidentally it is a positive transgressive segregant which blends the desirable favorable alleles equally distributed between the two parents. Among this wide array of 50:50 types of segregants, one can also expect extreme positive transgressive segregants described above and also an extreme negative transgressive segregant perfectly blending only the undesirable alleles distributed equally between in the two parents. Since the population has high frequency of 50:50 types, selecting the best 50:50 among them becomes relatively easy.

Based on this theory, just as it is expected that the these three methods of handling segregating populations after hybridization will be successful when the target genotype is a 50: 50 type it should also be remembered that following these methods will be a an ineffective attempt (if not a wasteful exercise) when the parents reveal un equal distribution of desirable alleles between the parents (say 70:30 or 80:20). It is because frequency of these types in early or later segregating generations is very low. Searching for the best 80:20 in a population full of an array of 50:50 types and a very low frequency of these different 80:20 types is perhaps equivalent to search a pin in a haystack or an un married girl who is above 60 years of age. Very often the breeders fail to find potential transgressive segregants in the segregating generations but how often do they correctly understand that the main reason for failure is that the method of handling the material after hybridization is wrong.

The methods of handling segregating generations are well defined when the target genotype is 50:50 type (Pedigree/ Bulk/ Single seed descent method) or an extreme type such as 99:1 or 98:2 or 100:0 (Back cross breeding). When the target genotype is in between these two, say 70:30 or 80:30 types there is a need to go for limited back cross breeding. In a single back cross derived populations (BC_1F_2, BC_1F_3... etc.,) 75:25 types are most commonly observed and hence it is easier to expect higher frequency of 70:30, 75:25 or 80:20 types (Fig. 4). Here again, the job of the breeder is simplified to the extent of finding which 75 are seen from the first parent and which 25 are seen from second parent. When majority of segregants are 75: 25 types, it becomes easy to pick up the extreme positive transgressive segregants with the required desirable 75 alleles from first parent and 25 from the second parent.

Thus, selection in limited back cross derived population would be successful whenever the parents reveal unequal distribution of desirable alleles between them(say around 75:25) while selfed breeding methods will be more efficient when parents reveal nearly equal distribution of desired alleles between them . The utility of limited back cross approach of breeding has been highlighted earlier by Patil (2007,2011).

It is important to note that limited backcrossing just refers to creation of base population BC_1F_2 with higher frequency of the target genotype. Once such base population is created, breeder has many options of initiating artificial selection right in BC_1F_2. This will be a system of breeding similar to pedigree method of breeding and can be continued by implementing selection schemes described for F_3,F_4 etc.,.in corresponding BC_1F_2, BC_1F_3 etc.,.respectively.The back cross derived population still has considerable heterozygosity and if this is considered as a disadvantage, artificial selection can be delayed up to BC_1F_5 when the proportion of homozygous plants is increased substantially. Either bulk method of advancing or SSD approach can be followed through these early segregating generations. There is a need for research on comparing efficiency of following Pedigree/SSD/Bulk methods in handling segregating generations derived through Limited back cross breeding

Methods for determining the target genotype

Two broad approaches are suggested here for determining the target genotype appropriate for the pair of parents chosen for hybridization.

Comparison of limited back cross and selfed populations

The segregation pattern seen in B_1, B_2 and F_2 populations shows differences in prominent types namely 75:25,50:50 and 25:75 types in them. This becomes genetic basis for explaining differences in means of these populations. If the target genotype set by the pair of parents involved in hybridization matches with prominent segregant type seen in a generation the mean performance of that population will be higher than the remaining two populations. As per this basis of inheritance any of the following three situations shown in can be seen in an evaluation study where these three segregating populations are compared.

Here P_1 parent has higher proportion of desired alleles contributing to higher productivity and as a result of this the decreasing order of performance of populations will be $B_1>F_2>B_2$. In such a case selfed generations of B_1 populations can be subjected to selection either by following pedigree or bulk or single seed decent method of breeding

Here P_2 parent has higher proportion of desired alleles contributing to higher productivity because of which these populations reveal a decreasing order of performance of $B_1>F_2>B_2$. In this situation, selfed generation of B_2 populations can be subjected to selection either by following pedigree or bulk or single seed decent method of breeding.

Here P_1 and P_2 parents have equal proportion of desired alleles contributing to higher productivity of $F_2>B_1 > B_2$ or $F_2>B_2 > B_1$. In this situation advancing selfed F_2 and later segregating generations can be subjected to selection either by following pedigree or bulk or single seed decent method of breeding.

To test this concept, a study was initiated to understand the differences in performance of the three segregating populations and their subsequent selfed generations in cotton at Dharwad. Among the three crosses handled in RAH100 x SAM 4, B_1 population revealed higher mean seed cotton yield/plant and this trend of superiority was continued in next selfed generation, confirming that the trend of observed superiority occurring in this population continued in next selfed generation(Table 4). Many transgressive segregants were noticed in this population. As per the expectations of the genetic basis explained earlier, RAH 100 has many important yield contributing characters including boll number because of which B_1 and the subsequent selfed population revealed improved performance as compared to the remaining two populations. In cross DSC 7 x RAH 53 involving a compact parent and a stay green type, F_2 population was significantly superior to B_2 indicating that the parents were complimenting each other for the yield

Table 3. Comparison of means of segregating populations

Situation I : Decreasing order of performance being $B_1 > F_2 > B_2$

Population	Highest proportion of alleles of parents		Method of breeding	Result of selection in segregating generation
	P1	P2		
B_1 (F_1 x P_1)	75	25	Limited backcross breeding(with P1)	Can be successful
F_2 (Selfing F_1)	50	50	Pedigree/Bulk/SSD	Partially successful/failure
B_2 (F_1 x P_2)	25	75	Limited backcross breeding (with P2)	May be a failure

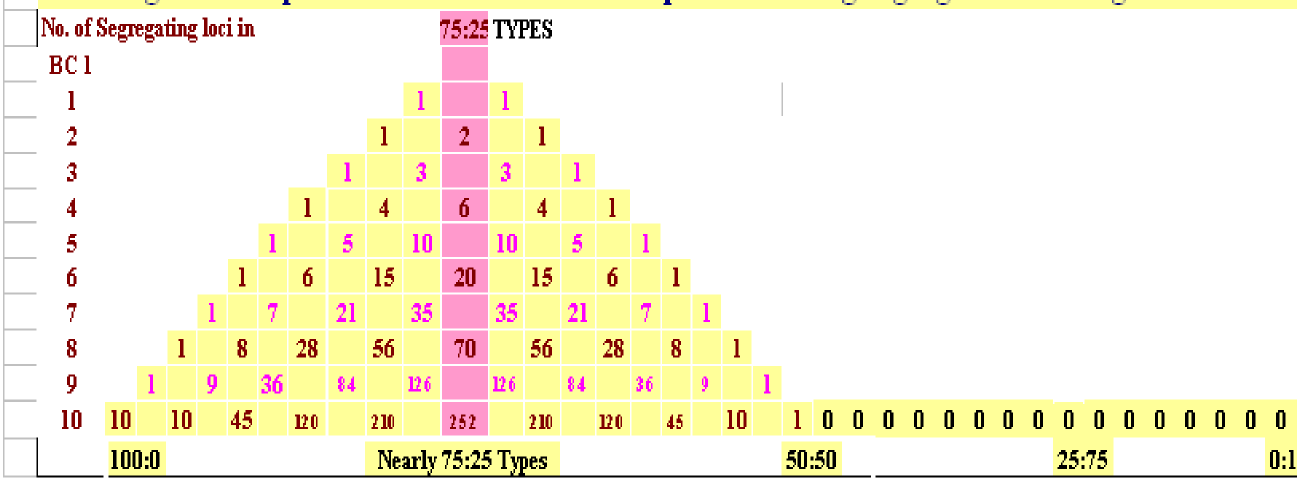
Situation II : Decreasing order of performance being $B_2 > F_2 > B_1$

Population	Highest proportion of alleles of parents		Method of breeding	Result of selection in segregating generation
	P1	P2		
B_1 (F_1 x P_1)	75	25	Limited backcross breeding (with P1)	May be a failure
F_2	50	50	Pedigree/Bulk/SSD	Partially successful/failure
B_2 (F_1 x P_2)	25	75	Limited backcross breeding (with P2)	Can be successful

Situation III : Decreasing order of performance being $F_2 > B_1$ or B_2.

Population	Highest proportion of alleles of parents		Result of selection in segregating generation
	P1	P2	
F_2	50	50	Can be successful
B1	75	25	May be partially successful
B2	25	75	

Figure 4 Proportin of alleles from the two parents among segregants in BC1 generation



influencing loci due to which F_2 revealed superior performance and this trend of superiority continued in F_3 generation . In RAH 111 x RAH 16, B_2 population revealed higher population mean as compared to the other two populations and this trend continued in next selfed generation. The number of transgressive segregants seen in these populations in general matched with the higher mean seen in these populations. Thus different combinations of parents included in the study differed with respect to the pattern of complementation.

The parental genotype used in study were evaluated for an array of yield attributing character including physiological characters related to photosynthesis an overall assement of parents for these many important trait gave some trait about distribution of desirable traits (alleles)between the two parents based on this characterization it was possible to arrive at the possible type genotype in each of these crosses. This assessment matched with the above mentioned conclusion derived from comparing the three segregating generations. This has lead to proposing another approach of arriving at the target genotype.

II Assessments of parental genotype based on yield influencing traits:

It is very crucial to understand the parents thoroughly with respect to different yield and other traits that are desired to be improved by the breeder. This helps in determining how these chosen parents are complimenting each other with respect to the important yield influencing traits. It may be difficult to define the genetic constitution of the parents in terms of distribution of the desirable alleles between them. In a crop like cotton instead they can be characterized in terms of desirable expression revealed by each parent with respect to the list of yield components, fibre quality traits and other priority traits and decide about the target genotype.

Path of Productivity and yield influencing traits : Yield basically results from sum of the expression of boll number and boll weight. If the two parents are to be characterized for only such major yield components it is not possible to correctly arrive at the target genotype. It is necessary to assess the intricate relationship between physiological traits and ultimate yield components. Different plant type traits and physiological processes influence biomass and canopy size, plant harvest index and in turn they create impact on boll number. In addition, there are a set of components influencing boll weight.

All these traits need to be observed for their complementation pattern in the chosen parents, and this helps in deciding the target genotype. In breeding *Bt* cotton varieties and parental lines it is important to improve physiological processes contributing to higher photosynthetic output and productivity, resistance to sucking pests (Fig. 5). Conventional mechanism of tolerance to bollworms would also be helpful in resistance management. Thus based on characterization of parents through an exhaustive list of different traits it is possible to arrive more correctly at the target genotype required to be isolated through selection in segregating generations. There is a need for

Table 4. Comparison of performance of limited backcross and selfed populations for seed cotton yield (g/ plant)

	2007-2008			2009-2010		
I. RAH100 x SAM4	B1	F_2	B2	B1F_2	F_3	B2F_2
NO.OF PLANTS/LINES	154	468	198	96 L	287 L	71 L
RAH 111 x RAH 16						
Mean seed cotton yield(g/plant)	167.1*	144.3	129.8	138.6*	118.5	99.4
II. DSC 7x RAH 53						
NUMBER OF PLANTS/LINES	166	398	184	78 L	243 L	97 L
Mean seed cotton yield (g/plant)	174.8	189.1*	131.7	142.8	154.9*	139.6
III. RAH 111 x RAH 16						
NUMBER OF PLANTS/LINES	165	371	200	77 L	216 L	90 L
Mean seed cotton yield (g/plant)	157.7	150.4	169.0	121.4	146.2	164.1*

Fig5 Path of Productivity in Cotton

focused research on developing these procedures of arriving at target genotype based on assessment of parents for an array of yield influencing traits especially efficiency for physiological processes influencing photosynthetic efficiency and harvest index of *Bt* cotton plant. Apart from this an acceptable limit has to be defined for fibre quality traits. The weightages or importance to be attached to each of the characters in arriving at the target genotype can be worked out and the breeding approach to be followed can be determined. An assessment of target genotype based on this approach can be put to test by comparing the performance of the limited back cross derived populations with selfed segregating generations.

Whenever such thorough characterization of parents and then fixing the target genotype is done, more often than not the target genotype may confirm to be the one with unequal proportion of alleles say a 70:30 or an 80:20 type or it could equally be a 30:70 or 20:80 type where the second parent has more desirable traits to contribute reminding us that in either case our choice of practicing selection in segregating generations (F_2, F_5...etc.,) was a wrong choice of breeding method.

Involvement of more parents in blending the desired traits: In fact, to pool these different traits it may become necessary to involve more than two parents (multiple crossing) in hybridization. The common proportions of allelic contributions involving more parents can be 50:25:25; 25:25:25:25;, 50:12.5:12.5:12.5:12.5 etc... A judicious assessment of a collection of genotype can enable the breeder to identify a set of such parents which account for distribution of the desirable yield influencing traits among them. Based on this an appropriate multiple crossing patterns can be decided upon to garner the required proportion of allele from each of set of selected alleles.

This area of research on characterizing parents and comparing segregating populations for arriving at the target genotype and the choice genotype has to be pursued in cotton as well as other crops. When two parents are systematically characterized and selected for hybridization the perception of target genotype will be fairly clear, once this level of perfection is attained by the breeder it may not be necessary for growing u B_1 F_2 B_2 population for comparision and arriving at target genotype. The breeder will be certain about which population will be advanced or at the most the ambiguity may be about choosing between $B_1$and F_2 or B_2 and F_2. These approaches will definitely improve the efficiency of Breeder (success rate/strike rate) in deriving and selecting potential genotype.

REFERENCES

Allard, R.W. 1960. *Principles of Plant breeding.* John Wiley and Sons, Inc. New York, P.485

Patil, Shreekant. S., 2007. Potential of limited backcross breeding in improving cotton, Proceeding Fourth World Cotton Research Conference held at Lubbock, USA , 1926.

Patil, Shreekant S. 2011. Importance of teaching concepts of population genetics in effective understanding of plant breeding, *Indian J. Genet.* **71** (2) Special issue : 106-14.

Molecular approaches for sustained cotton production under climate change scenario

MUHAMMAD SAEED*, GUO WANGZHEN AND TIANZHEN ZHANG
Department of Botany, Government College University, Faisalabad, Pakistan
**E-mail : saeed242@hotmail.com*

Abstract : Global climate change has adversely affected cotton production worldwide. For sustainable cotton production under post climate change scenario, an integrated approach involving multiple disciplines is needed. Molecular approaches can play a crucial role in screening and development of crop plants better adapted to changed environments. A research study was designed to assess the marker-trait associations for salt tolerance in cotton (*Gossypium hirsutum* L.). Significant markers identified in this study will be helpful for molecular breeding of salt tolerance in cotton.

Key words : Conventional breeding, genomics, mapping, molecular approaches, production, transgenics

Cotton is an important crop worldwide providing natural fibre. Climate change has affected crop production globally (Lobell *et al.*, 2012; Saeed *et al.*, 2011). A pronounced effect of global climate change is the worsening of already existing menace of drought and salt stress in agriculture. As a consequence of human activities, such as deforestation and industrialization, our environment is continuously changing. We have to be prepared to find the solutions of the problems arising from changed environment. An integrated approach addressing the problem is needed. We can take the example of tackling the problem of CLCuV (Cotton leaf curl virus) in Pakistan. It has been addressed by combining different approaches spanning to different disciplines. It can be briefed as:

To find out the resistant sources against CLCuV:

- Conventional breeding approaches
- Molecular breeding/genomic tools
- Transgenics

Controlling the whitefly population

- Entomology
- Agronomy: Shifting of the sowing time of cotton (early sowing in March)

By adopting early sowing of cotton, the incidence of CLCuV attack is minimized and farmers can get better cotton yield. Progressive farmers are getting very good cotton yield of approximately 5000 kg/ha.

Similarly, an integrated approach can be employed for sustainable cotton production under changed environments. Genomic approaches can play their due part in this regard. Various genomic approaches which can be applied for the development of elite cotton cultivars best suited under climate change scenario are:

- Sequencing techniques
- Annotation
- Comparative genomics
- Molecular mapping approaches

A number of research efforts are underway to develop elite cotton cultivars in our research group. These research efforts are addressing different topics of cotton cultivars development. One of the efforts was to develop elite salt tolerant cotton cultivars. First part of this research effort focused on the molecular mapping for salt tolerance in cotton (*Gossypium hirsutum* L.). The objectives of this study were:

- Assess marker trait associations (MTA) having significant relation to salt tolerance in cotton (*Gossypium hirsutum* L.).
- Selection of markers which can be used in marker assisted breeding for development of salt tolerant cotton (*Gossypium hirsutum* L.) cultivars.

MATERIALS AND METHODS

In this study, 109 cotton (*Gossypium hirsutum* L.) genotypes were used. Both salt tolerant and salt susceptible germplasm have used. For genotyping of this cotton germplasm, 98 SSR (simple sequence repeats) primer pairs were used. Marker trait associations were detected by the use of linkage disequilibrium based association mapping approach. Plant material was phenotyped for the morphological traits at the seedling stage against three treatments *i.e.*, control, 100 mM NaCl treatment; and 200 mM NaCl treatment under greenhouse conditions. Data were collected shoot length, root length, plant length, fresh shoot weight, fresh root weight, fresh plant weight, dry shoot weight, dry root weight, dry plant weight and root shoot ratio.

From the genotypic data, number of subpopulations in the cotton germplasm used was detected with the help of STRUCTURE (Pritchard *et al.,* 2000) software. Admixture model under independent allele frequencies with burn in time of 50,000 and number of MCMC repeats at 100,000 with *K* ranging from 1 to 15 was used. With the use of Evanno *et al.,* (2005) method, five subpopulations were detected in this cotton germplasm. For the assessment of marker trait associations, TASSEL software was used.

RESULTS AND DISCUSSION

A number of significant marker-trait associations were found in this study. The significant marker-trait associations under control (T_0) treatment are given below:

Markers associated with the morphological traits under 100 mM NaCl (Table 1) treatment are given below.

Table 1. Markers associated with control treatment and their explained portion of phenotypic variation

Marker	Chr.	SL	RL	PL	FSW	FRW	FPW	DSW	DRW	DPW	RSR
TME03	A1								0.0422		0.0516
NAU458	D1										0.0489
NAU437	A2	0.0751	0.0571	0.0995		0.0432					
NAU2265	A2	0.0571				0.0663				0.0549	
NAU483	A3								0.0479	0.0433	
BNL3089	A4							0.0467		0.0474	
NAU2477	A4		0.053			0.0462					
NAU2162	D4		0.0397	0.0485		0.0763		0.0374			
NAU3095	D5	0.0685									
NAU2679	A6				0.1052		0.0958	0.0658		0.0546	
NAU4946	A6				0.0429						
BNL1694	A7					0.0588					
NAU3608	D7	0.0634		0.0612							
BNL3255	A8										0.0453
NAU1254	A8		0.058			0.0989					0.0561
NAU478	D8										0.0418
NAU2439	D8										0.0433
BNL1672	A9	0.038									
NAU3061	A9		0.0365								
NAU5189	D9				0.057						
TMH05	D11	0.0621				0.052		0.0423	0.1234	0.0829	
NAU5091	D11				0.0704		0.0552				

SL shoot length; *RL* root length; *PL* plant length; *FSW* fresh shoot weight; *FRW* fresh root weight; *FPW* fresh plant weight; *DSW* dry shoot weight; *DRW* dry root weight; *DPW* dry plant weight; *RSR* root shoot ratio

Markers associated with the morphological traits under 200 mM NaCl (Table 2) treatment are given below.

Molecular approaches can play a pronounced role in the sustainable cotton production under changed environmental conditions. For sustainable crop production under climate change, adaptation of crops to changed environment in needed (Wheeler, 2012). Marker trait associations detected in this study will be of significance to develop elite cotton lines tolerant to salt stress. They can also be utilized to understand the underlying molecular mechanisms of salt tolerance in cotton (*G. hirsutum* L.). Efforts are underway to confirm and fine map these markers. After authentication they can be employed in molecular breeding

Table 2. Markers associated with 100mM NaCl treatment and their explained portion of phenotypic variation

Marker	Chr	SL	RL	PL	FSW	FRW	FPW	DSW	DRW	DPW	RSR
NAU3254	A1				0.0569	0.0622	0.0719				
NAU458	D1										0.0514
NAU437	A2		0.0638	0.0445	0.0659		0.0697				
NAU3209	D2	0.107									
BNL226	A3							0.0635			
NAU483	A3	0.0612			0.0567		0.055	0.0546	0.045	0.0766	
NAU3016	D3	0.0683	0.0753	0.109							
BNL3089	A4				0.0426						
NAU2162	D4				0.0683		0.0736				
NAU3529	A5					0.0482					
NAU3092	D5	0.0466			0.0406						
BNL3650	A6					0.088					
NAU2679	A6	0.0521									
BNL3103	D6				0.0481		0.0383				
TMK19	D6							0.0388			
NAU2714	D6				0.0488		0.0493				
NAU2995	A7	0.0704		0.0418							
BNL3255	A8		0.0717	0.0601				0.0595			
NAU1369	A8	0.0622		0.068							
NAU3207	A8								0.0388		
JESPR291	D8							0.06			
NAU478	D8							0.0369		0.0448	
JESPR274	A9		0.068								
NAU462	A9								0.0478		
NAU3414	A9					0.0879	0.054	0.0751			0.0843
BNL3140	D9								0.1032		0.1
NAU4921	A10				0.0699	0.0513	0.083				
NAU5166	A10				0.0439			0.0515		0.064	
JESPR135	A11	0.0353									
TMH05	D11										0.0366
NAU5091	D11					0.0409					
JESPR300	A12					0.0675					
JESPR204	D13										0.0807
NAU2980	D13	0.0748									

SL shoot length; *RL* root length; *PL* plant length; *FSW* fresh shoot weight; *FRW* fresh root weight; *FPW* fresh plant weight; *DSW* dry shoot weight; *DRW* dry root weight; *DPW* dry plant weight; *RSR* root-shoot ratio

programmes. Efforts are concentrated on different aspects aiming at sustainable fibre production. These efforts include finding marker trait associations (MTAs) for drought and salt tolerance; and fibre yield and quality traits. As *G. arboreum* is tolerant to various biotic (CLCuD) and abiotic (drought, salt etc.) stresses, so efforts are aimed to improve its yield and fibre traits. Also efforts are underway to identify CLCuD resistant gene from *G. arboreum*, its characterization and cloning and transformation in *G. hirsutum*.

ACKNOWLEDGEMENTS

We are thankful to Higher Education Commission, Pakistan for providing funds for this research work. Special thanks are for Dr. Yusuf Zafar (Pakistan Atomic Energy Commission (PAEC), Islamabad, Pakistan), Dr. Mehboob-ur-Rahman, (NIBGE, Faisalabad, Pakistan), Ch. Rehmat Ali (CCRI, Multan, Pakistan) and Dr. Saghir Ahmed (CRS, Multan, Pakistan) for their cooperation.

Table 3. Markers associated with 200mM NaCl treatment and their explained portion of phenotypic variation

Marker	Chr	SL	RL	PL	FSW	FRW	FPW	DSW	DRW	DPW	RSR
TME03	A1				0.0499		0.0454				
NAU458	D1					0.0761					
BNL3590	A2					0.0845					
NAU437	A2	0.0385		0.0366	0.0363		0.0385				
NAU2265	A2				0.0724		0.0796			0.0628	
NAU483	A3	0.0426	0.0754	0.0942	0.0753	0.059	0.0846	0.0473		0.0448	
BNL3089	A4			0.0488	0.0503		0.0438				
NAU2477	A4				0.045		0.047				
BNL448	D4				0.0383						
NAU3269	A5	0.0699									
NAU3529	A5	0.0602									
NAU2233	D5										0.0622
NAU2503	D5										0.0706
NAU3092	D5	0.0449						0.0424			
NAU3095	D5				0.0621		0.058				
NAU5005	D5	0.0596		0.0417	0.0448		0.0356	0.0438		0.0362	
BNL3103	D6				0.0437		0.049	0.0584	0.0949	0.0853	
TMK19	D6					0.0628				0.0413	
NAU2687	D6		0.0375	0.0406							
NAU2714	D6	0.0425									
NAU2995	A7	0.0567									
NAU3053	D7						0.0564				
NAU3207	A8								0.0773		0.0753
NAU462	A9		0.0632	0.0476							0.0415
NAU3414	A9							0.0618		0.0639	
BNL3140	D9	0.0403									
NAU2935	A10		0.0625								
BNL1231	A11		0.0723	0.0624							
JESPR135	A11	0.0685	0.0516	0.087							
TMH05	D11			0.0487							
NAU5091	D11				0.0456						
BNL1707	A12							0.0407		0.0368	
JESPR300	A12		0.0678	0.0744							
NAU3084	D12							0.047		0.0395	
BNL3479	A13			0.0363							
NAU2980	D13	0.1041									
NAU3011	D13	0.0741									

SL shoot length; *RL* root length; *PL* plant length; *FSW* fresh shoot weight; *FRW* fresh root weight; *FPW* fresh plant weight; *DSW* dry shoot weight; *DRW* dry root weight; *DPW* dry plant weight; *RSR* root-shoot ratio

REFERENCES

Evanno, G., Regnaut, S. and Goudet, J. 2005: Detecting the number of clusters of individuals using the software STRUCTURE: a simulation study. *Mol Ecol* **14** : 2611-20.

Lobell, D. B., Sibley A. and Ortiz-Monasterio I. O. 2012. Extreme heat effects on wheat senescence in India. *Natural Climate Change* 2 : 186-89.

Pritchard, J. K., Stephens, M. and Donnelly, P. 2000. Inference of population structure using multi-locus genotype data. Genetics 155, 945–59.

Saeed, M, W. Z. Guo, I. Ullah , N. Tabbasam, Y. Zafar, M. Rahman, Zhang, T. Z. 2011. QTL mapping for physiology, yield and plant architecture traits in cotton (*Gossypium hirsutum* L.) grown under well watered versus water-stress conditions. *Electronic Jour. Biotech.* **14 (3)**. doi: 10.2225/vol14-issue3-fulltext-3.

Wheeler, T. 2012. Wheat crops feel the heat. *Nature Climate Change* **2** : 152-53.

INVITED PAPERS

Nematode pests of cotton and their management in India

K. K. VERMA* and R. K. JAIN
Department of Nematology, CCS Haryana Agricultural University, Hisar - 125 004
E-mail : kkv1959@gmail.com

Cotton is a major fibre crop in world agriculture and is used by about 75 per cent of world's population for textile purposes because its fibre is used universally as a textile raw material. In India, it is an important cash and commercial crop valued for its fibre and vegetable oil and thus earning valuable foreign exchange by providing employment to millions of people and hence plays a significant role in national economy. Cultivation of cotton has been considered as an index of the progress of civilization of mankind due to the reasons that cotton is made into more diverse products than any other fibre crop vizly, in addition to clothing, cotton seed is a major source of vegetable oil and cotton cake is a rich source of high quality protein for stock feed.

The area under cotton cultivation during the year 2010-2011 was about 33.2 million ha in the world (Anonymous, 2011) with production estimate of 25.2 million tons. In India, the area under cotton cultivation during 2010 was 10.7 million ha with production around 32.5 million bales. India is the largest cotton growing country in the world with area under cotton around 33 per cent followed by China.

The cultivation of cotton falls into three main groups *viz.*, Egyptian or American Egyptian type, the long staple cotton *i.e., Gossypium barbadense* (allotetraploid), American and African upland medium staple cotton *i.e., G.hirsutum* (allotetraploid) and Asiatic old world short staple cotton i.e. *G.arboreum* (diploid) and *G.herbaceum (diploid). G.hirsutum* accounts for over 80 per cent of global cotton production.

In India, the major cotton growing areas are in the states of Maharashtra, Gujarat, Andhra Pradesh, Punjab, Madhya Pradesh, Rajasthan, Tamil Nadu and Haryana. As regards cotton production, Gujarat is the leading cotton producing state with 106.8 lakh bales while Haryana had cotton in an area of 4.9 lakh ha with production of 17.5 lakh bales during 2010 (Anonymous, 2011).

The successful raising of this crop is hampered by the attack of number of insect pests and diseases. During recent past, phytoparasitic nematodes, which not only cause the disease by themselves directly but, also aggravate the disease caused by fungi, have assumed significance in limiting the production of cotton in many cotton growing areas of country. Because cotton is grown as a cash crop, it is often grown in monoculture system that favours the development of a nematode community that is dominated by one or a few species of plant parasitic nematodes. The important nematode pests of cotton include root knot nematode (*Meloidogyne incognita*), reniform nematode (*Rotylenchulus reniformis*), lance nematode (*Hoplolaimus* spp.) sting nematode (*Belonolaimus longicaudatus*) and a few other nematodes of minor importance such as lesion nematode (*Pratylenchus* spp) and stubby root nematode (*Trichodorus christiei*). (Edward *et al.*,1993). Root-knot nematodes are major problem in many cotton growing areas of India while reniform nematode has regional importance.

Economic importance of plant parasitic nematodes in cotton : On an average, 10.7 per cent loss in cotton yield on world wide basis has been reported due to phytoparasitic nematodes (Sasser and Freckman, 1987). Davis and May, 2005, recorded the yield suppression in cotton which ranged from 18.0-47.3 per cent in 2002 and from 8.5-35.7 per cent in 2003. Similarly, a loss of 17.0 per cent in cotton has been attributed to root-knot nematodes alone in Brazil (Sasser, 1979). Even as high as 40-60 % avoidable yield losses were estimated after application of nematicides in Egypt due to *Rotylenchulus reniformis* (Oteifa, 1970) while Robinson (2007) estimated annual loss to U.S. cotton crop to be $ 130 million and stated that this nematode has replaced the root knot nematode as the major nematode of cotton in few US states. The avoidable losses in cotton yield due to root-knot nematode (*Meloidogyne incognita*) under field conditions in Haryana ranged from 16.8 to 20.0

per cent (Jain *et al.*, 2000).

Root knot nematodes (*Meloidogyne* spp.)

A. Distribution : Among various species of root-knot nematodes, *Meloidogyne acronea and Meloidogyne incognita* are known to parasitize cotton. However, *M.incognita* is the only species which is of consequences to the cotton throughout India. It is worldwide in its distribution. *M.acronea* has so far been found only in some areas of South Africa. The earliest report of root knot nematode on cotton was from USA (Atkinson, 1989). However, in India the first report of its occurrence on cotton was by Luthra and Vasudeva (1939) from Punjab followed by Thirumalachar (1946). Besides India, it has also been reported from Taiwan (Tu *et al.*,1972); Pakistan (Tanveer and Haq 1975); Egypt (Ibrahim *et al.*,1979); USSR (Khurramov,1982); South Africa (Wyk *et al.*,1987); USA (Martin *et al.*, 1994); China (Yang, *et al.*,1992), Kenya (Karuri *et al.*, 2010) and from many other countries.

Prasad (1960) observed *M.incognita* on cotton at IARI, New Delhi. Abu Bucker and Seshadri (1968) reported it, attacking cotton from Tamil Nadu. Darekar *et al.*,(1992) from Maharashtra. Patel (1984) from Gujarat reported *M.incognita and M.javanica* attacking cotton. Sakhuja *et al.*, (1986) reported it from Punjab and race 4 of *M.incognita* infecting cotton in Sirsa district of Haryana was reported first time from India and lator on by others (Bajaj *et al.,*1986; Vats *et al*; 1999, Verma and Jain, 1999).

However, presence of race 3 of *M.incognita* equally capable of damaging cotton has been reported from Tamil Nadu and Karnataka (Krishnappa, 1985).The frequency of occurrence of root-knot nematode (*Meloidogyne incognita* race 4) in major cotton growing areas of Haryana was however high (Vats et *al.*, 1999).

B. Symptoms : The foliar symptoms of root-knot nematode attack on cotton are not very diagnostic. The general symptoms of damage include stunting, chlorosis and temporary wilting and a general unthrifty appearance giving the look of nutritional deficiency symptoms. Cotton is a fairly drought resistant crop by virtue of its long tap root which may reach depths of more than one meter and any damage to this tap root can severely restrict the uptake of water and nutrients, leading to loss of vigour in rest of the plant. Root-knot nematodes attack both tap and lateral roots and leads to formation of galls/ knots thereby causing disruption in meristmatic zone, which may lead to slowing down or even complete cessation of tap root growth depending upon the initial nematode population in the soil. However, galls on cotton are not as big and numerous as on other susceptible crops.

C. Life history : The life cycle of *M. incognita* is slightly prolonged on cotton when compared to other hosts. The second stage juveniles of root-knot nematode penetrate the roots usually in first 2 cms of root tip and thereafter, they migrate to stelar region. The comparative penetration of *Meloidogyne incognita* in cotton and tomato roots showed 11.3 and 17.2 per cent larval penetration respectively. One generation was completed in 30 days on tomato compared to 32 days on cotton (Rai and Jain, 1989). The life cycle lasts for 33-38 days at 25?C on *G. barbadense* and for 32 days on *G.hirsutum* (Rai and Jain, 1989).

The pathogenicity of *M.incognita* on cotton revealed that there was significant decrease in plant growth characters at and above one j_2/g soil (Rai and Jain,1989). Further, the reproduction factor of *M.incognita* infecting cotton under different soil textures showed maximum Rf. value under sand while clay and clay loam soils were least favoured (Verma, 1997), Histopathological changes in cotton roots due to the feeding of *M.incognita* showed that nematode fed on xylem tissue and giant cells were formed in metaxylem. Nematodes were observed lying parallel to stellar region forming multinucleate giant cells with dense cytoplasm (Rai and Jain,1989).

D. Disease complexes : Root knot nematodes like other phytophagous nematodes, are part of soil micro fauna. Besides, inflicting direct damage to the plants, they interact with other microorganisms such as fungi, bacteria, viruses etc. and thus form disease complexes. In all these interactions, there is greater incidence of wilt or seedling disease with greater yield suppression when cotton is exposed to multiple pathogens than when only a single pathogen is present. Interaction of *M.incognita* with root rot fungi *Rhizoctonia solani* revealed that concomitant occurrence of both the pathogens led to higher damage to cotton plants as compared to their individual effect. However, maximum damage was recorded when *M.incognita* was inoculated one week prior to *R.solani* in cotton (Verma, 1997). However, when fungus was inoculated one week before nematode, the nematode penetration was restricted up to cortical region. Carter, 1975 concluded that root-knot nematodes were debilitating parasites which weekened the plants and made it more susceptible to attack by *Rhizoctonia* spp. The posterior end of the nematode body was seen out of the epidermis and fungus presence was seen in the form of sclerotia in the cortical tissue (Tekchand *et al.*, 1992). The severity and incidence of wilt of cotton due to *Fusarium oxysporum* f.sp. *vasinfectum* has also been found to increase in presence of *M.incognita*.

E. Nematode management:

I. Chemical methods : Basically, two types of chemicals *viz.*, fumigants and non- fumigants have been used. Soil fumigation with ethylene dibromide, dichloropropene dichloropropane (DD) and dibromochloropropane (DBCP) proved effective but, DBCP was most promising. However, due to their prohibitive cost, difficulty in application methods, environmental and toxic hazards, their use has been banned in most of the countries including India. Thereafter, non fumigant (non-volatile) chemicals were begun to be used for controlling phytonematodes infecting cotton. These chemicals mainly belong to carbamates (aldicarb and carbofuran) and organophosphates (phorate, phenamiphos etc.) group. In Punjab, application of carbofuran @ 1 kg a. i ./ha at sowing followed by additional dose of 2 kg a. i./ ha 50 days thereafter led to 41 per cent higher cotton yield in root knot nematode affected fields (Sakhuja *et al.,*1987). In order to use the chemical pesticides, judiciously, seed treatment with systemic nematicides has been found to be an effective proposition, which gives protection for 3-4 weeks thereby providing healthy start to the plant. Seed soaking treatment with monocrotophos or carbosulfan each @ 2000 ppm for two h or use of *neem* based pesticides *viz.*, Achook, Nimbicidine etc. @ 1,2 and 4 per cent have shown promising results against *M.incognita* infecting cotton (Vats *et al.,*1997 and 1998) or a novel nematicide, abamectin @ 100g/100 kg seed (Monfort *et al.,* 2006)

Seed dressing treatment with carbosulfan @ 3.0 per cent a.i. (w/w) alone or with soil application of sebufos @ 1.0 kg a. i. /ha at sowing proved effective (Vats *et al.*, 2000). It has been observed that carbamates like aldicarb and carbofuran gave better results than organophosphatic compounds like phorate and disulfoton in controlling nematodes attacking cotton (Kumar and Agarwal,1985).

II. Cultural methods : Harnessing of solar enery in northern part of India, where maximum temperature many a times go as high as 48°C, can help in controlling these noxious soil borne pathogens. Deep summer ploughing of nematode infested fields not only leads to disturbance and instability in nematode community but also causes mortality by exposing the nematodes to solar heat and desiccation.

Azadirachta indica leaves used 20 g/kg soil proved effective in terms of minimum galling (16.7/plant) compared to 118.3/plant in untreated check. Further, of the various organic manures *viz.*, *neem* cake, poultry manure, spent compost, FYM and biogas slurry, proved best in improving growth parameters of cotton (Vats *et al.*, 1998, Verma and Jain, 2001). The crop rotations with wheat, barley and oat and also corn and soybean have shown promising results in containing the build up of root-knot nematode population (Singh *et al.*, 1998, Koenning and Edmisten, 2008).

III. Biological control : Soil application or seed treatment with the number of microorganisms have been found effective to suppress root knot nematode infestations in cotton. Various bio agents like oviparasitic fungi, *Paecilomyces lilacinus* and rhizospheric bacteria have been investigated for controlling *M.incognita* infecting cotton. *Azotobacter chroococcum* used as seed dressing treatment method in cotton in *M.incognita* infested soil (Lakshminaryana *et al.*, 1995) and *Pseudomonas fluorescens* (Timper *et al.,* 2009) mitigated the adverse effect of nematode infection by reducing galling and egg mass production.

Gluconacetobacter diazotrophicus st. 35-47 (rhizobacteria) used as seed treatment accounted for 35-47 per cent higher cotton yield in *M.incognita* infested fields (Bansal *et al.,* 2005). This practice has been included as a recommendation for adoption by the farmers in the "Package of Practices of *kharif"* crops in Haryana. Further, use of vesicular arbuscular mycorrhiza (VAM) fungi (*Glomus fasciculatum*) when applied in *M.incognita* infested soil was effective in increasing plant growth and reducing nematode galling and multiplication (Verma and Jain, 2004). Even a complex of *M. incognita* and root-rot fungus, *R. bataticola* was managed successfully using *Trichoderma viride* (Verma, 2011) while Verma and Nandal, 2009 observed reduction in root knot nematode population on cotton using *T. viride* and 50 kg P/ha.

IV. Host plant resistance : Quite a good number of genotypes have been screened by various workers for resistance against *M.incognita*. But, so far no promising genotypes, which could be used for transfering resistance into commercially cultivated type is yet available. However, the cotton variety Auburn 623 has been found to possess a high level of tolerance to root knot nematode races. Fa LSS and Arkot 9111 have exhibited resistance against *M.incognita* (Dube *et al.*, 1988, Bourland and Jones, 2005). As far as *Bt* cotton is concerned, high degree of susceptibility to root-knot nematode has been reported in all hybrids screened (Verma *et al.,* 2011).

Reniform nematode (*Rotylenchulus reniformis*)

A. Distribution : Reniform nematode was first observed on the roots of cotton in Baton Rouge, Lousiana (Smith and Taylor, 1941). This is the only species of this nematode to cause economic losses in cotton. It is primarily an inhabitant of tropical and subtropical areas including U.S., (Jones *et al.*, 1959), Egypt (Oteifa, 1970) and India (Varaprasad, 1986; Abu Bucker and Seshadri, 1968). Das and Gaur, 2009 have recently reported high frequency of occurrence of this nematode from Punjab (56.5%), U.P. (42.3%) and Haryana (30.0%). Unlike *M. incognita*, *R. reniformis* is favoured by fine textured soils with a relatively high content of silt or clay (Robinson *et al.*, 1987). In addition to all types of cotton, wide spread occurrence of the nematode was reported in *Bt* cotton hybrids (Banu, 2009).

B. Symptoms : The nematode causes dwarfing, chlorosis, premature decay and loss of secondary roots and plant mortality. Injury to cotton becomes evident with reduction in emergence of seedlings. The roots of such plants are smaller , fewer and sometimes show browning. Affected plants bear lesser and smaller bolls. There is delay in maturity, a reduction in size of boll and lint percentage, plant growth, seed index and fibre micronaire value (Jones *et al*; 1959). Stunted patches in field having pale greenish leaves occur due to this nematode infested gardenland cotton in Tamil Nadu.

C. Life history/cycle : Juvenile moults in the egg and comes out as second stage juvenile. The second, third and fourth stage do not feed. After fourth moult, the immature females penetrate the roots and become reniform (kidney shaped) in five days. The nematode shows no specificity to the age of plants roots but they prefer succulent roots on which they feed close to the root tip. They feed on phloem tissues and cause necrosis of phloem and its parenchyma. Damage to epidermal and parenchyma observed near site of infection and feeding is limited. Males also penetrate but do not feed. It took 17-23 days for the completion of one life cycle on cotton (Birchfield, 1962). Life table studies of this nematode revealed that the approximate generation time was 25-45 days. Life cycle duration in *Bt* cotton hybrids and their non transgenic parents was found to be similar (Banu, 2009)

D. Disease complexes : The first indication of the association of *R. reniformis* with *Fusarium* wilt of cotton was observed as early as 1940. This nematode forms disease complexes with *F. oxysporum* f sp. *vasinfectum*, *Verticillium dahliae* and with several seedling disease pathogens in which this nematode increases the incidence and severity of seedling disease on cotton (Brodie and Cooper, 1964).

E. Nematode management:

I. Chemical methods : Soil application of carbofuran @ 0.5 kg /ha gave good results against reniform namatode in Brazil. Its population was significantly reduced by seed treatment with carbofuran @ 2.0 per cent (w/w) coupled with soil application of either carbofuran, phorate, phenamiphos or carbosulfan each @ 1.0 kg/ha which gave maximum reduction in nematode population at 30 days after germination with significantly higher cotton yield over control (Patel *et al.*, 1996). Soil application of FYM @ 25t/ha together with carbofuran @ 1.0 kg/ha managed reniform nematode effectively and increased seed cotton yield. Robinson *et al.*, 2002, had reported that due to the depth of distribution of this nematode in some soils, yield response to fumigation can be improved by deeper placement of 1,3- dichloropropene.

II. Cultural control : Crop rotation has been reported to be effective in suppressing densities of *R. reniformis* despite the nematode's wide host range. Although crop rotation with non-host crops such as corn and soybean are effective in reducing population and damage incurred by this nematode, rotation with these crops are often economically prohibitive (Davis *et al.*, 2003). A number of non host crops are known for this nematode (Varaprasad *et al.,* 1986) but their suitability with reference to the biotype existing in a particular locality and economic considerations remains to be ascertained. Mustard and Sesamum, in cropping sequence, reduce populations in northern India. *Crotolaria juncea* grown as antagonistic crop also suppressed this nematode (Marla *et al.*, 2008)

III. Biological control : Successful suppression of the nematode on cotton by nematophagous, *Pochonia chlamydosporia* was reported by Wang *et al.,* 2005 under green house conditions. A complex of this nematode with root-rot fungus was managed successfully by seed and soil treatment of *T.viride* and *P.fluorescens* (Sivakumar, 2009).

IV. Host plant resistance : Use of culivars resistant to root-knot and reniform nematode would become a major component of nematode management program in cotton. High level of résistance to this nematode has been found in *G.arboreum* Nanking CB 1402, *G. barbadense* Texas 110, *G. somalense* and *G. stocksii* (Carter, 1981).

Lance nematodes (*Hoplolaimus* spp.) : Five species of lance nematode *viz.*, *H. columbus, H. galeatus, H. indicus*, *H. seinhorsti* and *H. aegypti* have been reported to be pathogenic to cotton. In India, *H. indicus* and *H. seinhorsti* were reported by Abu Bucker and Seshadri, 1968 and Verma and Jain, 1999. Field studies in US showed that *H. columbus* could reduce cotton yields upto 19.0 per cent (Noe and Imbriani, 1986). Heavily infested cotton manifests severe stunting, yellowing and almost complete defoliation in *H. galeatus* infestation. All species exhibit both endoparasitic and ectoparasitic feeding habits. The nematodes start feeding on young tap roots of cotton immediately after seedling emergence (Brodie and Cooper, 1964). Cavities are formed on the root cortex due to destruction of cells. The nematodes also penetrate epidermis but do not cause extensive damage as they do in cortex. Tyloses are formed in the affected xylem resulting in plugging of the xylem elements (Lewis *et al,* 1976). The life cycle of *H. indicus* from egg to egg is completed at 27-36 days at a temperature of 28 to 32* C. Hussey (1977) reported control of lance nematode in the southern US by aldicarb or DBCP treatment and or subsoiling to a depth of 5 cm which resulted in deeper penetration by cotton roots.

Futuristic approaches : Besides root knot nematodes, populations of other nematodes is also recorded from some areas. Hence, there is need to carry out intensive surveys for recording other economically important phytonematodes associated with cotton. Other points of future thrusts can be:

- Carry out studies on host parasite relationships.
- Carry out studies on nematode interactions with other co-habiting microorganisms.
- Intensive survey on nematodes on Bt cotton in India has to be carried out.
- Screening of transgenic plants to nematodes.

- Identification of resistance genes to reniform and root knot nematode in cotton.
- Conduct studies on INM in cotton.

REFERENCES

Abu Bucker, A.H. and Seshadri, A. R. 1968. Report on a survey of nematode parasites associated with cotton in Madras State. *Indian J.Agric Sci.* **35** : 470-76.

Anonymous 2011. *Annual Report* (2010-2011), All India Coordinated Cotton Improvement Project, CICR, Nagpur, p. A 1-2.

Bajaj, H.K., Jain, R. K. and Gupta, D. C. 1986. Races of root knot nematode, *Meloidogyne incognita* prevalent in Haryana. *HAU. J. Research* **16:** 399-400.

Banu, J.G. 2009. Plant parasitic nematodes associated with *Bt* cotton. In Proceeding. National Symposium on *"Bt Cotton: Opportunitis and Prospects"* held at CICR, Nagpur from Nov., 17-19, 2009. pp. 100.

Bansal, R.K., Dahiya, R.S., Narula, N. and Jain, R.K. 2005. Management of *Meloidogyne incognita* in cotton using strains of the bacterium, *Gluconacetobacter diazotrophicus*. *Nematologia Mediterranea* **33** : 101-05.

Birchfield, W. 1962. Host-parasite relationship of *Rotylenchulus reniformis* on *Gossypium hirsutum*. *Phytopathology* **52** : 862-66.

Bourland, F.M and Jones, D.C. 2005. Registration of Arkot 9111 germplasm line of cotton. *Crop Sci.* **45** : 2127-28.

Brodie, B. B. and Cooper, W.E. 1964. Relation of parasitic nematodes to post-emergence demping off of cotton. *Phytopathology* **54** : 1023-27.

Carter, W.W. 1975. Effects of soil texture on the interaction between *Rhizoctonia solani* and *Meloidogyne incognita* on cotton seedlings. *Jour. Nem.* **7** : 234-36.

Carter, W.W. 1981. Resistance and resistant reaction of *Gossypium arboretum* to the reniform nematode, Rotylenchulus *reniformis*. *Jour. Nem.* **13** : 368-74.

Darekar, K.S., Shelke, S.S. and Mhase, N.L. 1992. Plant nematodes associated with cotton in Maharashtra state, India. *Curr. Nem.***3 :** 97-98.

Das, D.K. and Gaur, H.S. 2009. Distribution and abundance of *Rotylenchulus reniformis* in cotton growing areas in North India. *Indian Jour. Nem.* **39** : 98-103.

Davis, R.F. and May, O.L. 2005. Relationship between yield potential and percentage yield suppression cause by the southern root-knot nematode in cotton. *Crop ci.* **45 :** 2312-17.

Davis, R. F., Koenning, S. R., Kemerait, C., Cummings, D. and Shurley, W.D. 2003. *Rotylenchulus reniformis* management in cotton with crop rotation. *Jour. Nem.* **35** : 58-64.

Dube,V.P., Charaya, M.U., and Pal, Madan 1988. Screening of some cultivars of cotton against root-knot caused by *Meloidogyne incognita* var. *acrita*. *Indian Phytopath* **41** : 132-33.

Edward, J.C., Sharma, N.N. and Tripathi, S.C. 1993. Plant parasitic nematodes of cotton in India. *Jour. Ind. Soc. Cotton Improve***18**: 5-19.

Hussey, R. S. 1977. Effect of subsoiling and nematicides on *Hoplolaimus columbus* and cotton yields. *Jour. Nem.* **9** : 83-86.

Ibrahim, I.K.A., Khalil, H.A.A. and Rezk, M.A. 1979. Root knot nematode on cotton in northern Egypt. *Jour. Nem.* **11**: 293-317.

Jain, R.K., Singh, J. and Vats, R. 2000. Avoidable yield losses in cotton (*Gossypium hirsutum*) due to (*Meloidogyne incognita*) race-4 *Indian. J. Nematol.***30**: 90-91.

Jones, J.E., Newson, L. D. and Finley, E.L. 1959. Effect of the reniform nematode on yield, plant characters and fibre qualities of cotton. *Agro. Jour.* **51** : 353-56.

Karuri, H. W., Amata, R., Amugune, N. and Waturu, C. 2010. Occurrence and distribution of soil nematodes in cotton production areas of Kenya. *African Jour. Agricul. Res.* **5**:1889-96.

Khurramov, S.K. 1982. Parasitic nematodes in Southern Uzbekistan.*Uzbeskii Biologicheskii Zhurnal* **2** : 43-50.

Koenning, S.R. and Edmisten, K. L. 2008. Rotation with corn and soybean for management of *Meloidogyne incognita* in cotton. *Jour. Nem.* **40** : 258-65.

Krishnappa, K. 1985. In "An Advanced Treatise on *Meloidogyne* volume. I. Biology and Control" (J.N.Sasser and C.C.Carter, eds.) Deptt. of Plant Pathology and U.S.Agency for International Development, N.C. U.S.A. pp. 379-398.

Kumar, K. and Agarwal, R.A. 1985. Effect of systemic granular insecticides on nematodes of cotton. *Pesticides* **19**: 140-43.

Lakshminaryanan, K., Jain, R.K., Bansal, R.K. and Anand, R.C. 1995. Antagonistic effect of *Azotobactor chroococcum* inoculation on the root knot disease of cotton. Paper presented in *16th Annual conference of Association of Microbiologicists of India* CCS HAU,Hisar, November, 8-10,1995. pp 125-126.

Lewis, S.A., Smith, F.H., and Powell, W.M. 1976. Host parasite relations of *Hoplolaimus columbus* on cotton and soybean. *Jour. Nem.* **8** : 264-69.

Luthra, J. C. and Vasudeva, R. S. 1939. The root-knot disease of cotton. *Curr. Sci.* **8**: 511.

Marla, S.R., Huettel, R. N. and Mosjidis, J. 2008. Evaluation of *Crotalaria juncea* populations as hosts and antagonistic crops to manage *Meloidogyne incognita* and *Rotylenchulus reniformis*. *Nematropica* **38**:155-62.

Martin, S.B., Meeler, J.D., Saunders, J.S. and Jones, W.L. (1994). A survey of South Carolina cotton fields for plant parasitic nematodes. *Plant Disease.* **78**: 787-89.

Montfort, W.S., Kirkpatrick, T.L., Long, D.L. and Rideout, S. 2006. Efficacy of a novel nematicidal seed treatment against *Meloidogyne incognita* on cotton. *Jour Nem* **38** : 245-49.

Oteifa, B.A. 1970. The reniform nematode problem of Egyptian Cotton production, *Jour. Parasit.* ***56*** *: 255*

Patel, D.J. 1984. Nematode Problems in Gujarat. Paper Presented for panel discussion on *"Nematological Problems of Economic Importance in North Zone"* held at HAU, Hisar; September, 20-21.

Patel, D.J., Patel, M.B., Patel, B. A., Patel, N. B. and Patel, R.R. 1996. Nematode problems of cotton and their management in India. In:Proceeding National Seminar on *"Centenary of cotton in India"*, Gujarat Agriculture University, Surat, pp.40-51

Prasad, S.K. 1960. Plant parasitic nematodes observed at the Indian Agricultural Research Institute farm. *Jour. Ento.* **22** : 127-28.

Rai, B.S. and Jain, R.K. 1989. Studies on biology, histopathology and reaction of cotton genotypes to root-knot nematode (*Meloidogyne incognita*). Paper presented at National Seminar on *"Futuristic Approaches in Cotton Improvement"*. Feb., 24-28, 1989 held at HAU, Hisar, pp.61

Robinson, A.F. 2007. Reniform in US cotton: when, where, why and some remedies. *Ann. Rev. Phytopath.* **45** : 263-88.

Robinson, A.F., Heald, C.M. Flanagan, S.I. Thames, W.H. and Amador, J. 1987. Geographical distribution of *Rotylenchulus reniformis*, *Meloidogyne incognita* and *Tylenchulus semipenetrans* in the lower Rio Grande Valley as relation to soil texture and land use. *Ann. Appl. Biol.* **1** : 20-25

Robinson, A.F., Cook, C.G., Bradford, J.M., Bridges, A.C. and Bautista, J. 2002. Difference in cotton yield, root growth and *Rotylenchulus reniformis* following deep soil fumigation. In: Proceeding *the Beltwide Conference*, **3**: 564

Sakhuja, P.K., Jhooty, J.S. and Kang, M.S. 1986. Widespread incidence of root-knot nematode, *Meloidogyne incognita* on cotton in Punjab (India). *Curr. Sci. India* **55** : 740-41.

Sakhuja, P.K., Chopra, B.L., Sharma, J.R. and Singh, I. 1987. Evaluation of carbofuran and sebufos against root-knot nematode, *Meloidogyne incognita* on American cotton (*Gossypium hirsutum* L.) *J. Cotton. Res. Dev.* **1**: 213-15.

Sasser, J.N. 1979. Economic importance of *Melodogyne* in tropical countries. In : *Root knot nematodes* (*Meloidogyne* spp.), *systematic, biology and control.* F. Lamberti and C.E. Taylor (eds.), Academic Press.

Sasser, J.N. and Freckman, D.W. 1987. A world perspective on nematology: In : *Vistas on Nematology*, (J.A. Veech and D.W. Dickson eds.) U.S.A. pp. 7-14.

Singh, J., Vats, R and Jain, R.K. (1998). Influence of different crop rotations on cotton yield under *Meloidogyne incognita* infested conditions. International Conference on *Food Security and Crop Science*. Nov., 3-6,1998, Hisar, India, p. 232-33.

Sivakumar, M. 2009. Efficacy of bio-control agents in management of reniform nematode, root-rot complex in cotton. *Ann. Plant Prot. Sci.* **17** : 200-02

Smith, A.L. and Taylor, A.L. 1941. Nematode distribution in 1940 regional cotton wilt plots. *Phytopathology* **31**:771.

Starr, J.L., Carneiro, R.G. and Ruano, O. (2005). Nematode parasites of cotton and other tropical fibre crops. In : *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture.* M. Luc, R.A. Sikora and J. Bridge (eds.), CAB International, Wallingford, UK, pp. 733-50.

Tanveer, M. and Haq, E.U. 1975. Prevalence of nematodes in cotton fields of Pakistan. *Pakistan Cotton* **20**: 45-54.

Tekchand, Jain, R.K. and Chauhan, M.S. 1992. Studies on histopathological changes due to *Meloidogyne incognita and Rhizoctonia solani* in cotton (*Gossypium hirsutum) J. Cotton. Res. Dev.* **6**: 160-65.

Thirumalachar, M.T. 1946. Preliminary note on the eelworm of cotton plants. .*Proceedings of the Indian Science Congress*, 273-78.

Timper, P; Kone, D; Yin, J.F; Ji, P.S; and Gardener, B.B.M. 2009. Evaluation of an antibiotic producing strain of *Pseudomonas fluorescens* for suppression of plant parasitic nematodes. *Jour. Nem.* **41** : 234-40.

Tu,C.C., Cheng, Y.S. and Kuo, F.L. (1972). An investigation of cotton nematicides of Taiwan and preliminary study on the effects of reniform nematode, root-knot nematode and stubby root nematode on cotton. *Plant Prot. Bull. Taiwan* **14**: 95-109.

Varaprasad, K.S. , Sud, U.C. and Swarup, G. 1986. Relationship between *Rolylenchulus reniformis* densities and host damage with reference to tolerance levels. *Ind. Jour. Nem.* **17**:11-16.

Vats, R., Singh,J. and Jain, R.K. 1997. Efficacy of neem based pesticides against root-knot nematode (*Meloidogyne incognita*) infecting cotton (*Gossypium hirsutum*). National Symposium *"IPM. Indian Constraints and Opportunities*". Oct., 23-24, 1997, New Delhi. Abst. p.34.

Vats, R., Singh, J. and Jain, R.K. 1998. Efficacy of a few chemicals as seed dip treatment against root knot nematode in cotton. *Proc. III International Symposium Afro Asian Society of Nematologists,* April, 16-19, 1998, Coimbatore India, p. 187-89.

Vats, R., Singh, J. and Jain, R.K. 2000. Effect of a few organic manures against root knot nematode (*Meloidogyne incognita*) infecting cotton (*Gossypium hirsutum). Proceeding National Symp*osium on *"Rational Approaches in Nematode Management for Sustainable Agriculture"* Nov., 23-25, 1998, GAU, Anand, India, 1998. pp. 10-12

Vats, R., Singh, J. and Jain, R.K. 1999. Prevalence of root-knot nematode (*Meloidogyne incognita*) and identification of its races in cotton growing areas of Haryana. *Indian J. Nematol.* **29**: 199-201.

Verma, K.K. 1997. Role of a few abiotic and biotic factors in root-knot (*Meloidogyne incognita*) disease incidence on cotton. (*Gossypium hirsutum*) in Haryana. (*Ph.D. Thesis*) CCS HAU, Hisar, 1997, pp. 137.

Verma, K.K. 2011. Management of root-knot nematode and root-rot fungus complex in cotton through bioagents. In Proceeding National Symposium on *"Nematodes: A challenge under changing climate and agricultural practices"* held at Kovalam (Kerala) from 16-18th Nov., 2011. pp. 78

Verma, K.K. and Jain, R.K. 1999. Prevalence and distribution of phytoparasitic nematodes associated with cotton in Haryana. *Ind. Jour. Nem.* **29**:192-93.

Verma, K.K. and Jain, R.K. 2001. Role of soil organic carbon on root-knot disease of cotton and uptake of a few biochemical constituents. *Ind. Jour. Nem.* **31**:38-43.

Verma, K.K. and Jain, R.K. 2004. Role of vesicular arbuscular mycorrhiza (VAM) in cotton, *Gossypium hirsutum.* National Symposium on *"Changing World Order-cotton Research, Development and Policy in context"* at ANG Ranga Agri. Univ., Hyderabad, Aug., 10-12, 2004, p.132

Verma, K.K. and Nandal, S.N. 2009. Managing potential of fungal antagonists against root-knot nematode as affected by inorganic fertilizers in cotton. In : Proceeding National Symposium on *"Bt Cotton: Opportunities and Prospects"* CICR, Nagpur 17-19 November, 2009. pp.101.

Wang, K.N; Riggs, R.D; Crippen, D. 2005. Isolation, selection and efficacy of *Pochonia chlamydosporia* for control of *Rolylenchulus reniformis* on cotton. *Phytopathology* **95**:890-93.

WYK, R.J.V., Prinsloo, G.C., Villers, D.A.D. and Meclure, M.A. 1987. A preliminary survey of plant-parasitic nematode genera in the cotton-producing areas of South-Africa *Phytophylactica* **19** : 259-60.

Yang, Y., Dehg, X.M. and Liu, G.Z. 1992. Studies on species and genera of plant parasitic nematodes in cotton fields in Sichaan. *Jour. South West Agri. Uni.* **14** : 292-95.

Avoidable losses due to cotton diseases in India

D. MONGA*, P.S. SEKHON, JAGADISH BENIWAL, DALJEET SINGH, P.V. PATIL, P.K. DHOKE, O.V. INGOLE, R.R. PERANE, S.N. CHATTANNAVAR, B. SREE LAKSHMI, M.S.L.RAO

Central Insitute for Cotton Reserach, Regional Station, Sirsa - 125 055

**E-mail : dmonga2009@gmail.com*

Abstract : Studies carried out under All India Coordinated Cotton Improvement Project over the years at selected locations have demonstrated avoidable losses due to important diseases like cotton leaf curl virus, bacterial leaf blight, Alternaria leaf spot, grey mildew, Myrothecium leaf spot, Helminthosporium and rust.Losses due to Cotton leaf curl virus disease on *Bt* cotton hybrids in north zone during 2009-12 ranged between 25.2-46.6 per cent. In pooled data of three years (2010-2012) at Dharwad, Guntur, Surat and Akola, five sprays of copper oxy chloride and streptocyclin at 35,50,65, 80 and 95 days after sowing showed reduction of bacterial blight PDI from 28.8 to 12.0 and reduction of yield loss upto 22.0 per cent.Alternaria leaf spots can cause loss upto 26.6per cent based on results (2006-2007 to 2008-2009) of study conducted in central India at Rahuri and south zone locations at Guntur and Dharwad. Five sprays of Propiconazole (0.1%) at 35, 50, 65, 80, and 95 DAS decreased percent disease index (PDI) from 31.59 to 20.85 per cent thereby reducing yield loss due to Alternaria leaf spots in variety LRA-5166. In case of grey mildew disease also, a reduction of loss due to grey mildew disease up to 29.2 per cent with the application of five sprays of carbendazim (35,50,65,80 and 95 days after sowing) in *Bt* cotton hybrid Bunny was demonstrated based on a study (2008-2009 to 2010-2011) conducted across central and south zone, (Dharwad, Guntur and Nanded). PDI showed reduction to 8.1 as compared to 20.9 in control.In another important fungal disease, Myrothecium leaf spot, reduction of loss up to 29.1 per cent with the application of five fungicidal sprays of Propiconazole (@ 0.1per cent) at an interval of 35, 50, 65, 80 and 90 DAS in variety JK 4 was observed on the basis of trial in central zone at Khandwa (2007-2008 to 2009-2010). Percent disease index (PDI) showed reduction to 7.4 as compared to 22.5 in control.Losses to the tune of 33.8per cent with 0.1per cent propiconazole spray at 35,50,65,80 and 95 days after sowing due to Helminthosporium leaf spot disease could be avoided in cotton variety LRA 5166 based on (2007-2008 and 2008-2009) studies carried out at Guntur in south zone. Three years pooled results on avoidable losses due to cotton rust disease at Dharwad and Guntur showed four sprays of propiconazole (0.1%) at 15 days interval from 75 days after sowing showed reduction of PDI from 32.8 to 7.7 and 29.0 to 10.7 and reduction of yield loss upto 21.7 and 34.0 respectively. The implications of these studies in disease management are discussed.

Key words : Avoidable losses, carbendazim, copper oxychloride, diseases, propiconazole, streptocyclin

Cotton crop suffers from a number of diseases of air, vector and soil borne nature caused by fungal, bacterial and viral pathogens. Geographical origin, distribution and spread of diseases is influenced by factors like host, pathogen, environment and external boundaries of the region. The cotton disease scenario has shown a continuous change during the past sixty five years since independence (Monga *et. al.*, 2011). Indigenous diploid cottons were mainly grown in fifties and Fusarium wilt, root rot, seedling blight, anthracnose and grey mildew were the major problems. With the large scale cultivation of tetraploid upland cotton (*Gossypium hirsutum*), bacterial blight became the major disease to which indigenous cottons were highly resistant. After the introduction of *Bt* cotton hybrids during 2002 onwards and continuous increase in area under these hybrids to around 90 per cent of total cotton area till date, the disease scenario has also undergone some change. For instance, the grey mildew, once a serious problem for diploid cottons especially in central India has now become a major problem in *Bt* cotton hybrids in central and south zone. The incidence of grey mildew is assuming a serious position in central and southern zone. Majority of released *Bt* hybrids fall in moderately susceptible to highly susceptible category (Hosagoudar *et al.*, 2008). Cotton leaf curl virus disease caused by a single stranded circular DNA Gemini virus and transmitted by *B tabaci* has emerged as an important disease of *G hirsutum* cottons in north zone. Break down of resistance due to emergence of new strains has now been reported. (Chakrabarty *et al.,* 2010). Cotton leaf rust caused by *Phakospora gossypii* and tobacco streak virus belonging to Ilar group are emerging problems of south zone. The early incidence of rust was noted during the last two seasons in Karnataka and Andhra Pardesh (Anonymous, 2010 and 2011) causing significant losses. Studies carried out under All India Coordinated Cotton Improvement Project over the years at selected locations on avoidable losses due to important diseases like cotton leaf curl virus, bacterial leaf blight, Alternaria leaf spot, grey mildew, Myrothecium leaf spot, Helminthosporium leaf spot and rust have been presented.

MATERIALS AND METHODS

Loss estimation studies were carried out for important diseases like cotton leaf curl virus, bacterial leaf blight, Alternaria leaf spot, grey mildew, Myrothecium leaf spot, Helminthosporium leaf spot and rust. The following treatment details were followed for grey mildew, bacterial leaf blight, Alternaria leaf spot, Myrothecium leaf spots, Helminthosporium leaf spot and rust.

- Carbendazim (0.1%) spray at 35 DAS
- Carbendazim (0.1%) spray at 35 and 50 DAS
- Carbendazim (0.1%) spray at 35, 50 and 65 DAS
- Carbendazim (0.1%) spray at 35, 50, 65 and 80 DAS
- Carbendazim (0.1%) spray at 35, 50, 65, 80 and 95 DAS
- Carbendazim (0.1%) spray at 50, 65, 80 and 95 DAS
- Carbendazim (0.1%) spray at 65, 80 and 95 DAS
- Carbendazim (0.1%) spray at 80 and 95 DAS
- Carbendazim (0.1%) spray at 95 DAS
- Water spray

The spray of propiconazole (0.1%) was given in case of Alternaria leaf spot, Myrothecium leaf spots, Helminthosporium leaf spot and rust in place of Carbendazim used in grey mildew loss estimation trial. Whereas in case of bacterial blight copper oxychloride (0.3%) + streptocycline (100 ppm) were used for loss estimation studies. Local popular variety/*Bt* hybrid susceptible to that particular disease was used in the studies. The experiments were conducted for three years at locations as detailed below with RBD design and three replications. Appropriate epiphytotic conditions were created through artificial inoculations and relevant protection against other diseases was suitably followed.

Disease	Variety/*Bt* hybrid	Year of study	Locations
Bacterial blight	Susceptible variety/hybrid	2009-2010 to2011-2012	Dharwad, Guntur, Surat and Akola
Grey mildew	Bunny BG	2008-2009 to 2010-2011	Dharwad, Guntur and Nanded
Alternaria leaf spot	LRA 5166	2006-2007 to 2008-2009	Rahuri, Guntur and Dharwad
Myrothecium leaf spots	JK 4	2007-2008 to 2009-2010	Khandwa
Helminthosporium leaf spot	LRA 5166	2007-2008 & 2008-2009	Guntur
Rust	RCH BG II, Bunny BG	2009-2010 to 2011-2012	Guntur and Dharwad
Cotton leaf curl virus	*	2009-2010 to 2011-2012	Faridkot, Ludhiana, Abohar and Hisar

*Details in table 1

Detailed period and location of yield loss experiments

Observations on disease intensity and yield parameters were recorded and analysed. Data is presented as pooled means over years and locations.

Crop loss estimation due to CLCuD

Loss estimation studies due to CLCuD were undertaken at Faridkot, Ludhiana, Abohar and Hisar districts of Punjab and Haryana on different *Bt* cotton hybrids during 2009-2010 to 2011-2012. The percent reduction of seed cotton yield was worked out based on the seed cotton yield in healthy and diseased plants.

RESULTS AND DISCUSSION

Loss estimation studies due to CLCuD

Table 1. Crop loss due to cotton leaf curl virus disease (Pooled 2010-2012)

Bt cotton hybrid	2009-2010	2010-2011	2011-2012
MRC 7031BG II	-	-	25.2***
SP7007	-	-	46.6
Jai BG II	-	-	43.1
MRC 7017 BG II	-	-	27.0
NS858 BG II	-	-	30.4
RCH 134	45.4*	42.9*	40.8
MRC 6304	41.4	-	-

-not conducted
*Mean of Fdk and Abohar
**Mean of Fdk and Hisar
*** Mean of Fdk, Ldh and Hisar

Table 2. Crop loss due to bacterial blight (Dharwad, Guntur, Surat and Akola; Pooled 2010-2012)

Treatments	PDI	Yield (q/ha)	Yield loss (%)
Copper oxychloride (0.3%) + streptocyclin (SS) (100 ppm) 35 DAS**	24.1	16.5	17.5
Copper oxychloride (0.3%) + streptocyclin (SS) (100 ppm) 35, 50 DAS	20.6	17.3	13.5
Copper oxychloride (0.3%) + streptocyclin (SS) (100 ppm) 35, 50, and 65 DAS	18.0	17.8	11.0
Copper oxychloride (0.3%) + streptocyclin (SS) (100 ppm)35, 50, 65 and 80 DAS	14.1	18.7	6.5
Copper oxychloride (0.3%) + streptocyclin (SS) (100 ppm) 35, 50, 65, 80, and 95 DAS	12.0	20.0	0.0
Copper oxychloride (0.3%) + streptocyclin (SS) (100 ppm) 50, 65, 80, and 95 DAS	13.7	19.6	2.0
Copper oxychloride (0.3%) + streptocyclin (SS) (100 ppm) 65, 80, and 95 DAS	16.6	18.9	5.5
Copper oxychloride (0.3%) + streptocyclin (SS) (100 ppm) 80 and 95 DAS	20.2	17.8	11.0
Copper oxychloride (0.3%) + streptocyclin (SS) (100 ppm) 95 DAS	23.9	17.0	15.0
Control	28.8	15.6	22.0

* COC (0.2%) + SS (100ppm) (Surat), ** COC (0.3%) + SS (500 ppm) (Dhadwad)

Table 3. Crop loss due to grey mildew (Dharwad, Guntur and Nanded ;Pooled 2009-2011)

Treatment	PDI	Yield (q/ha)	Yield loss (%)
Carbendazim (0.1%) at 35 DAS	14.42	17.18	17.98
Carbendazim (0.1%) at 35 and 50 DAS	13.04	17.84	14.83
Carbendazim (0.1%) at 35, 50 and 65 DAS	10.69	18.59	11.27
Carbendazim (0.1%) at 35, 50, 65 and 80 DAS	9.11	19.87	5.13
Carbendazim (0.1%) at 35,50,65,80, 95 DAS	8.10	20.95	0.00
Carbendazim (0.1%) at 50, 65, 80 and 95 DAS	8.79	20.43	2.49
Carbendazim (0.1%) at 65, 80 and 95 DAS	10.27	18.92	9.67
Carbendazim (0.1%) at 80 and 95 DAS	12.98	17.88	14.65
Carbendazim (0.1%) at 95 DAS	14.69	16.88	19.41
Control (water spray)	20.87	14.83	29.20

were undertaken at Faridkot, Ludhiana, Abohar and Hisar districts of Punjab and Haryana. Losses due to Cotton leaf curl virus disease on *Bt* cotton hybrids in north zone during 2009-12 ranged between 25.2-46.6 per cent (Table 1).In pooled data of three years (2010-12) at four centres (Dharwad, Guntur, Surat and Akola), five sprays of copper oxy chloride and streptocyclin at 35,50,65, 80 and 95 days after sowing showed reduction of bacterial blight PDI from 28.8 to 12.0 and reduction of yield loss upto 22.0 per cent. (Table 2).Five sprays of carbendazim at 35,50,65,80 and 95 days after sowing showed maximum reduction of PDI due to grey mildew at all the three locations ie Dharwad, Guntur and Nanded. Pooled data also showed lowest PDI of 8.10 after five sprays as mentioned above as compared to 20.87 in control. There was reduction of loss up to 29.20% with the application of five sprays of carbendazim (Table 3).

Table 4. Crop loss due to Alternaria leaf blight (Rahuri, Guntur and Dharwad; Pooled 2007-2009)

Treatment	PDI	yield (q/ha)	Yield loss (%)
Propiconazole (0.1%) 35 DAS**	28.43	13.30	14.17
Propiconazole (0.1%) 35, 50 DAS	27.34	13.12	15.35
Propiconazole (0.1%) 35, 50, and 65 DAS	26.14	14.13	8.79
Propiconazole (0.1%) 35, 50, 65 and 80 DAS	24.41	14.05	9.37
Propiconazole (0.1%) 35, 50, 65, 80, and 95 DAS	20.85	15.50	0.00
Propiconazole (0.1%) 50, 65, 80, and 95 DAS	20.56	14.56	6.06
Propiconazole (0.1%) 65, 80, and 95 DAS	22.08	13.36	13.80
Propiconazole (0.1%). 80 and 95 DAS	24.01	12.81	17.37
Propiconazole (0.1%) 95 DAS	26.88	12.94	16.47
Control	31.59	11.38	26.59

.

Table 5. Crop loss due to Myrothecium leaf spot at Khandwa(Pooled 2008-2010)

Treatment	PDI	Yield (q/ha)	Yield loss (%)
Propiconazole (0.1%) 35 DAS**	17.22	7.57	22.16
Propiconazole (0.1%) 35, 50 DAS	14.96	7.79	19.91
Propiconazole (0.1%) 35, 50, and 65 DAS	12.80	8.78	9.77
Propiconazole (0.1%) 35, 50, 65 and 80 DAS	8.69	9.36	3.81
Propiconazole (0.1%) 35, 50, 65, 80, and 95 DAS	7.44	9.73	0.00
Propiconazole (0.1%) 50, 65, 80, and 95 DAS	9.15	9.30	4.36
Propiconazole (0.1%) 65, 80, and 95 DAS	12.44	8.75	10.07
Propiconazole (0.1%). 80 and 95 DAS	14.84	8.23	15.44
Propiconazole (0.1%) 95 DAS	16.81	7.63	21.59
Control	22.51	6.89	29.15

Table 6. Crop loss due to Helminthosporium leaf spot at Guntur (Pooled 2008 and 2009)

Treatment	PDI	SCY (q/ha)	Yield loss (%)
Propiconazole (0.1%) 35 DAS**	22.65	10.0	31.11
Propiconazole (0.1%) 35, 50 DAS	15.68	10.64	26.94
Propiconazole (0.1%) 35, 50, and 65 DAS	16.67	11.54	21.19
Propiconazole (0.1%) 35, 50, 65 and 80 DAS	15.00	12.8	11.35
Propiconazole (0.1%) 35, 50, 65, 80, and 95 DAS	14.17	13.8	3.53
Propiconazole (0.1%) 50, 65, 80, and 95 DAS	14.19	13.2	11.41
Propiconazole (0.1%) 65, 80, and 95 DAS	16.67	11.9	18.67
Propiconazole (0.1%). 80 and 95 DAS	18.15	11.29	22.21
Propiconazole (0.1%) 95 DAS	22.50	10.40	26.76
Control	27.52	9.52	33.76

The experiment on loss estimation of Alternaria blight was carried out for three years at three locations (Rahuri, Guntur and Dharwad) and the results were pooled. Based on pooled results it was noted that Alternaria leaf spots can cause loss upto 26.59 per cent. Five sprays of propiconazole (0.1%) at 35, 50, 65, 80, and 95 DAS decreased PDI from 31.59 to 20.85 per cent thereby reducing yield loss due to Alternaria leaf spots in variety LRA-5166 by 26.59% (Table 4).

Table 7. Crop loss due to rust at Dharwad(Pooled 2010-2012)

Treatments	PDI	Yield (q/ha)	Yield loss (%)
Propiconazole (0.1%) 75 DAS	20.36	26.8	18.0
Propiconazole (0.1%) 75 and 90 DAS	16.13	28.0	14.4
Propiconazole (0.1%) 75, 90 and 105 DAS	12.30	30.5	6.7
Propiconazole (0.1%) 75, 90,105 and 120 DAS	7.73	32.7	0.0
Propiconazole (0.1%) 90,105, and 120 DAS	10.90	31.6	3.4
Propiconazole (0.1%) 105 and 120 DAS	13.10	29.6	9.5
Propiconazole (0.1%) 120 DAS	15.77	27.8	15.0
Control	32.80	25.6	21.7

Table 8. Crop loss due to rust at Guntur (Pooled 2010-2012)

Treatments	PDI	Yield (q/ha)	Yield loss (%)
Propiconazole (0.1%) at 75 DAS	19.53	12.27	17.60
Propiconazole (0.1%) at 75 and 90 DAS	16.58	12.87	13.57
Propiconazole (0.1%) at 75,90 and 105 DAS	15.78	13.28	10.81
Propiconazole (0.1%) at 75,90,105 and 120 DAS	10.72	14.89	0.00
Propiconazole (0.1%) at 75,90,105,120 and 135 DAS	13.49	13.87	6.85
Propiconazole (0.1%) at 90,105,120 and 135 DAS	15.57	13.09	10.75
Propiconazole (0.1%) at 105,120 and 135 DAS	18.96	12.77	14.24
Propiconazole (0.1%) at 120 and 135 DAS	19.52	12.40	16.72
Propiconazole (0.1%) at 135 DAS	22.45	11.10	25.45
Water spray	29.0	9.82	34.05

The results indicate that the fungicidal sprays of propiconazole (0.1%) at an interval of 35, 50, 65, 80 and 90 DAS and 35, 50, 65 and 80 DAS and spray at 50, 65, 80 and 95 DAS treatments gave varying levels of *Myrothecium* disease intensity *i.e.* 7.44, 8.69 and 9.15 PDI with 22.51 PDI (%) in the control treatment. The seed cotton yield loss was 0.00, 3.81 and 4.36 per cent respectively with maximum loss of 29.15 per cent when the PDI (22.51 %) was (Table 5).

Losses to the tune of 33.76 per cent with propiconazole (0.1%) spray at 35,50,65,80 and 95 days after sowing due to Helminthosporium leaf spot disease could be avoided in cotton variety LRA 5166 based on (2007-2008 and 2008-2009) studies carried out at Guntur in south zone (Table 6).Three years pooled results at Dharwad showed reduction of PDI from 32.8 to 7.73 and reduction of yield loss upto 21.7 with four sprays of propiconazole (0.1%) at 15 days interval from 75 days after sowing showed (Table 7) . Results of a similar experiment at Guntur Andhra Pardesh also showed four sprays of propiconazole (0.1%) at 15 days interval from 75 days after sowing showed reduction of PDI from 29.0 to 10.72 and reduction of yield loss upto 34.05(Table 8). These studies have clearly established that significant losses are caused due to various diseases in cotton and can be avoided by suitable interventions.

REFERENCES

Annonymous, 2010. *Annual Report* 2009-2010. All India Coordinated Cotton Improvement Project, Coimbatore, Tamil Nadu.

Annonymous, 2011 - *Annual Report* 2010-2011, All India Coordinated Cotton Improvement Project, Coimbatore, Tamil Nadu.

Chakrabarty, P.K., Sable, S., Kalbande, B., Vikas, Monga, D. and Pappu, H.R. 2010. Molecular diversity among strains of CLCuV prevalent in north west India and approaches to engineering resistance against the disease. Invited paper presented at Conference on *“Whitefly and thrips transmitted diseases”* held at University of Delhi South Campus on August 27-28, 2010 p.17.

Hosagoudar, G. N., Chattannavar, S. N., and Kulkarni, S. 2008. Survey for foliar diseases of *Bt* Cotton Karnataka - *J. Agric. Sci.*, 21: 139-40.

Monga, D., Kranthi, K. R., Gopalakrishnan, N. and Mayee, C. D. 2011. Changing scenario of cotton diseases in India-The challenge ahead. Lead Paper presented at WCRC-5 held at Mumbai from 7-11 November . Paper published in Book of papers p: 272-80.

Multitier cropping systems and its weed control methods for higher resource utilization, profitablity and sustainability in *Bt* cotton

K. SANKARANARAYANAN*, P. NALAYINI, AND K.RAJENDRAN
Central Institute for Cotton Research, Regional Station, Coimbatore - 641 003
**E mail: sankaragro@gmail.com*

Abstract: Climate change and its likely impact on cotton crop is fast gaining momentum because of fact an importance of cotton in national economy for providing livelihood security to 60 million people including all the stake holders of cotton value chain. Thus, keeping in view of climatic vulnerability, market fluctuation and better resources use, cotton based multi tier vegetable intercropping system was evaluated with integrated weed management. A field trial was conducted during 2009-2010 and 2010-2011 at Central Institute for Cotton Research, Regional Station, Coimbatore. The experimental soil was clay loam in texture, low in available N (214 kg/ha), medium in available P (14.6 kg/ha) and high in available K (741.2 kg/ha) with a pH of 8.3. The experiment was laid out in a factorial randomized block design with three replications. The treatment combinations comprised of three systems (S_1.cotton+coriander+vegetable cowpea +cluster bean,S2.cotton+radish+beet root+ coriander and S_3.sole cotton) combined with three weed control methods (W1.Hw @15,30 &60 DAS,W2.Pendimethalin @0.75 kg/ha +HW 30DAS+Pendimethalin@1.25 kg/ha (lay by) and W3.Pendimethalin@0.75kg/ha+HW30DAS+ Quizalofop-ethyl @50g/ha). *Bt* cotton hybrid (RCH 20Bt) was planted at spacing of 120 x 45 cm. Two ridges at 60 cm apart were formed making 120 cm. Cotton, and multi intercrops (three) were planted on 4 sides of the 2 ridges in sequence.

Pooled results revealed that seed cotton yield was not significantly influenced by multi-tier systems as compared to sole cotton. Amongst weed control, hand weeding thrice at 15,30 and 60 DAS had been harvested significantly highest seed cotton yield (2332 kg/ha), which was on par with by pre emergence application of pendimethalin @ 0.75 kg / ha followed by hand weeding at 30 DAS and application of pendimethalin @ 1.25 kg ./ ha as lay by method (2229 kg/ha). The economics of multi tier system revealed that multi tier system of , cotton intercropped with coriander, radish and beet root had been arrived with the significantly highest net return of Rs1,36,235/ha . Amongst weed control methods the highest net return (Rs1,02,806/ha) had been calculated with weed control by pre emergence application of pendimethalin @ 0.75 kg / ha followed by hand weeding at 30 DAS and application of pendimethalin @ 1.25 kg / ha as lay by method for weed control. Nutrient uptake had been significantly higher with multi tier systems and significantly highest soil available nitrogen status (182.2 kg/ha) was analyzed by cotton+ coriander+ vegetable cowpea +cluster bean.

Key words : Integrated weed management, multitier cropping, net return, pendimethalin, quizalofop-ethyl, seed cotton yield

Demand for agricultural commodity is growing world over and to meet the ever increasing targets, productivity needs to be raised further. This is possible through intensive cropping involving crop mixers. In multiple cropping systems, the possibility of more efficient use of resources like sunlight, nutrient and water, which leads to increased biological diversity and higher production stability. Monocropping is exception while mixture (of species) is the rule of nature. Reviewing cropping system in South Asia, it was observed that intercropping is a well established practice covering over 12 m ha (Woodhead *et al.,* 1994). Since cotton is a crop of relatively longer duration, its slow initial growth offers a vast scope for cultivation of suitable vegetable intercrops. India is the second largest producer of vegetables in the world, with an annual production of 101.43 m t from an area of 6.75 m ha. Our requirement of vegetables has been increased to about 127.2 million tones to meet the nutritional requirement of an estimated 1200 million population expected by 2020-2021. Although the productivity levels of vegetables have increased manifolds, it won't be sufficient to feed ever increasing population as a result of increased demands. This will complicate the issue of price rise further leading to increased costs of vegetables. In addition, although vegetables have high production potentials, yet biological risk, perishablity, fluctuating price are the limitation that pose major constraints in vegetable production in the country. Thus, keeping in view climatic vulnerability, market fluctuation and better resources use, cotton is chosen as a candidate crop and cotton based system with multiple intercrops is aimed for sustainable production of cotton and vegetables. However, multitier systems are labour intensive with respect to weeding because of difficulties in using animal drawn implements. Hence, integrated weed management is proposed along with system evaluation.

MATERIALS AND METHODS

A field trial was conducted during fall season (August to February) of 2009-2010 and 2010-2011 at Central Institute for Cotton Research, Regional Station, Coimbatore. The experimental soil was clay loam in texture, low in available N (214 kg/ha), medium in available P (14.6 kg $_{P2O5}$/ha) and high in available K (741.2 kg K_2O/ha) with a pH of 8.3. The experiment was laid out in a factorial randomized block design with three replications. The treatment combinations comprised of three *Bt* cotton based vegetables intercropping systems (cotton + coriander + vegetable cowpea +cluster bean (S1), cotton + radish + beet root + coriander (S_2) and sole cotton (S_3). tried in a multitier in an additive series under irrigated condition combined with three weed control methods(Hand weeding thrice (15,30 and 60DAS) (W_1), Pre emergence application of pendimethalin @ 0.75 kg/ha followed by hand weeding at 30DAS and lay by application of pendimethalin @ 1.25 kg/ha (W_2) and pre emergence application of pendimethalin @ 0.75 kg/ha followed by hand weeding at 30DAS and post emergence application of Quizalofop-ethyl @ 50g/ha (W_3). Cotton *(Gossypium hirsutum* L.) hybrid RCH 20 *Bt,* coriander (C*oriandrum sativum* L.) cultivar 'SURABHI', radish *(Raphenus sativus* L.) cultivar 'PUSA CHETKI', beet root *(Beta vulgaries* L.) cultivar 'DDR', cluster bean (C*yamopsis teragonolaba* L.) cultivar PUSA NAVBAHAR, and vegetable cowpea *(Vigna unguiculata* L.) Walp) *cultivar* CO2 were included in the trial. Cotton equivalent yields were worked out by equating prices of component crops' yield as suggested by De *et al.,* (1976).

The field was ploughed once with tractor drawn mould board plough and then harrowed twice. *Bt* hybrid 'RCH 20' was planted at 120 x 45 cm where two ridges at 60 cm apart were formed, and various intercrops (three crops) were planted on 4 sides of the 2 ridges in sequence (Fig.1 and Plate 1). Radish, coriander and others vegetables (beet root, cluster bean and vegetable cowpea) were planted at intra-row spacing of 10, 15 and 20 cm respectively after one week of pre emergence application. Lay by application of pendimethalin @ 1.25 kg/ha and post emergence application of quizalafop-ethyl @ 50 g/ha were imposed after the h7arvest of coriander and radish. Weed species were counted and dry matter production was estimated at 15, 30, 60 and 90 DAS. Growth characters, seed cotton and intercrop yields were recorded during the course of investigation. Pooled analysis was made from two years data to have a reliable assessment. Gross return, net return and benefit: cost analysis was also derived on the basis of prevailing market price of inputs and outputs.

RESULTS AND DISCUSSION

Weed dry matter production : The weed flora observed in the experimental trial consisted of *Trianthema portulacastrum, Amaranthus viridis, Datura metal, Cyprus rotundus, Panicum repens, Parthenium hysterophorus, Cynodon dactylon, Cleome gynandra* and others. Cotton (especially hybrids) is a widely spaced crop in India and it takes at least 90 days to cover the land area. The interspaces between cotton rows are occupied by weeds and compete with crop for nutrient, moisture, light and space and also act as alternate host for pest and disease. One of the best approaches for reducing problems caused by weeds is increasing the crop density either of sole crop or intercrop. Shading the top soil and competition for water and nutrients will certainly suppress weed germination and growth (Altieri and Liebman, 1986). Weed dry matter production recorded at 30, 60 and 90 DAS had influenced significantly by multitier system. The significantly least weed dry matter production of 204.6, 202.8 and 354.6 kg/ha registered by the multitier system involving *Bt* cotton with

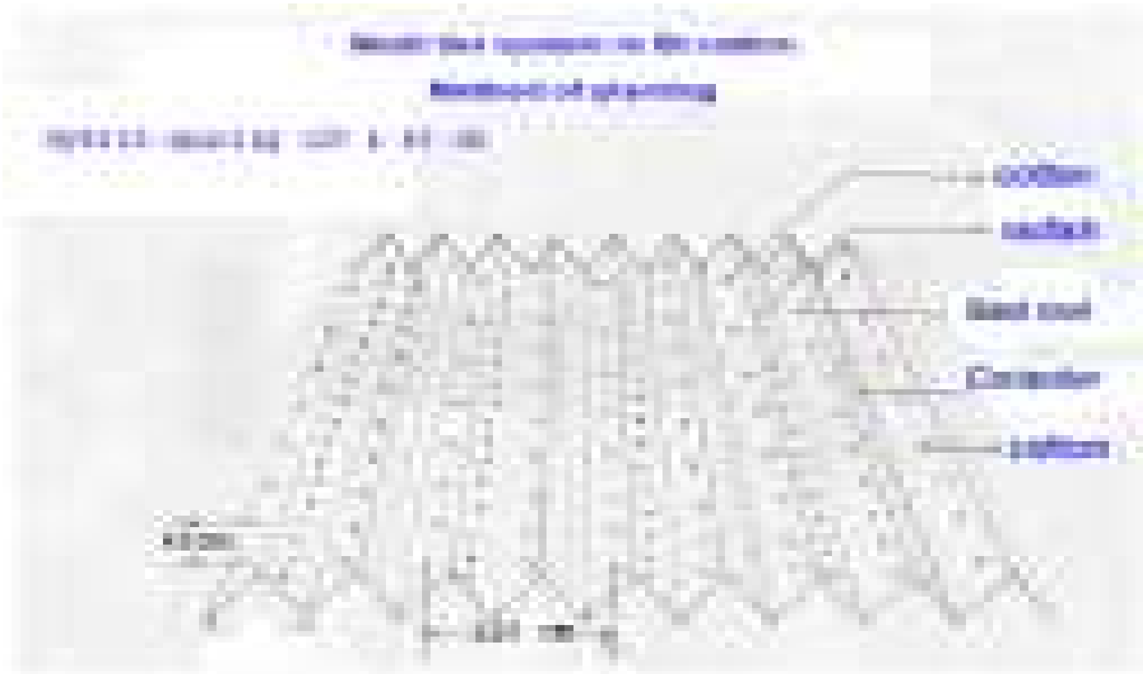


Fig. 1. Method of planting in multitier cropping system

intercrops of coriander, vegetable cowpea and cluster bean (Table 1) . High foliage producing capacity of vegetable cowpea, cluster bean and coriander resulted in high light interception and suppressed underground weed growth. Green gram as intercrop in cotton had higher weed smothering efficiency (Sivakumar and Subbian (2010). Legumes are often used for cover because they are less competitive with cotton can also be an effective approach to weed control (Entz *et al.,* 1995).

Dry matter production of weeds had been significantly affected by weed control methods. Application of pre emergence pendimethalin@ 0.75 kg/ha had the least weed dry matter production at 15 days after sowing. However hand weeding imposed plot at 15 DAS had been registered the significantly least weed dry matter production at 30 DAS (243.1 kg/ha).At 60 and 90 DAS, pre emergence application of pendimethalin @ 0.75 kg/ha followed by hand weeding at 30 DAS and lay by application of pendimethalin@ 1.25 kg/ha registered the significantly least weed dry matter production of 263.9 and 278.2 kg/ha, respectively (Table 1). Pendimethalin @ 1.0 kg / ha followed by a hoeing at Faridkot (Punjab), pendimethalin @ 1.5 kg/ha as pre plant along with one hand weeding (HW) at 35 DAS for controlling *Trianthema* spp at Sriganganagar (Rajasthan) were optimum for higher yield and net return (AICCIP, 2004).The highest weed dry matter production of 678.3 kg/ha had been registered by pre emergence application of pendimethalin @0.75 kg/ha followed by hand weeding at 30 DAS and post emergence application of quizalofop ethyl @50 g/ha. The post emergence, quizalofop ethyl is selective weedicide for graminae control, which had not effective in controlling of broad leaved weeds, but which were major proposition in the experimental field, thus subsequently resulted in higher weed dry matter production. Koshiya (2010) reported that quizalofop ethyl was found only effective against monocot weeds.

Seed cotton yield : Analysis of pooled data on seed cotton yield (Table 1) showed that the selected multitier systems (cotton + coriander + ver. cowpea +cluster bean (S_1) and cotton + radish + beet root + coriander (S_2) had produced significantly *on par* seed cotton yield as compared to sole cotton. The results revealed that the selected intercrops, method of planting did not suppress the growth of base crop of cotton,

Table 1. Weed dry matter production (kg/ha), seed cotton yield (kg/ha) and vegetables yield (kg/ha) as influenced by multitier systems and weed control

Treatments	Weed dry matter production (kg/ha)				Yield					
	15 DAS	30 DAS	60 DAS	90 DAS	Seed cotton (kg/ha)	Coriander (kg/ha)	Vegetable cowpea (kg/ha)	Cluster bean (kg/ha)	Beet root	radish (kg/ha)
A. Multitier system										
S_1- Cotton + coriander + vegetable cowpea + Cluster bean	125.3	204.6	202.8	354.6	2006	3211	929	2358		
S_2 - Cotton + radish + beetroot + coriander	136.0	236.3	330.2	382.2	2251	4622			1486	3523
S_3 - Sole cotton	146.9	379.6	489.7	591.5	2237					
SEd,	14.7	19.9	39.6	174.2	124					
CD (p=0.05)	NS	42.1	84.0	369.2	NS					
B.Weed control										
W_1- HW @15,30 and 60 DAS	366.6	243.1	353.4	371.8	2332	3053	987	1991	2473	3632
W_2 - Pendi.0.75 kg/ha +HW + Pendi1.25 kg/ha	18.2	297.3	263.9	278.2	2229	4523	986	2726	934	3013
W_3- Pendi.0.75kg/ha+ HW + Quizalofop-ethyl . @ 50 g /ha	23.4	280.1	405.4	678.3	1934	4373	817	2357	1051	3925
SEd	14.7	19.9	39.6	174.2	124					
CD (p=0.05)	31.5	NS	NS	369.2	260					

which resulted on production of equivalent seed cotton yield. Since the component vegetable intercrops viz., coriander within 30- 45 DAS, radish at 45 DAS, vegetable cowpea, cluster beans and beet root within 75 DAS were harvested, none of the above crops competed with the main crop of cotton during the peak growth periods. Thus, intensive cropping systems through crop mixer was successful as the components in the system have different nutrient and moisture requirement, varied feeding zones in the soil profile, differential growth duration for enabling the utilization of natural resources optimally. It was also reported that seed cotton was not adversely influenced by intercropping with cowpea and onion (Chowdhury and Singh, 1983).

Amongst weed control methods, hand weeding thrice at 15,30 and 60 DAS had recorded the significantly highest seed cotton yield (2332 kg/ha),which was *on par* with pendimethalin 0.75 kg/ha as pre emergence followed by hand weeding at 30DAS and lay by application of pendimethalin 1.25 kg/ha (2229 kg/ha). The effective control of weeds resulted in reduced crop weed competition thus helped to produce higher seed cotton yield. The significantly least seed cotton yield (1934 kg/ha) was recorded by pre emergence application of pendimethalin @0.75 kg /ha + hand weeding at 30 DAS followed by quizalofop-ethyl @ 50 g /ha as post emergence. The methods had higher weed dry matter production because of non broad spectrum weed control by quizalofop-ethyl (only controlling graminae weeds) , which leads to ineffective control of late emerging broad leaved weeds resulted in less seed cotton production. Quizalofop- ethyl was found only effective against monocot weeds (Koshiya, 2010).

Intercrop : Analysis of intercrop yield harvested from multi tier systems plots revealed that the highest coriander yield (4622 kg/ ha) had been produced under cotton+ radish+ beetroot + coriander system. In another multi tier system, coriander growth may be suppressed by intercropping of tall and high foliage vegetable cowpea and cluster bean, resulted in less yield (3211 kg/ ha). Application of pre emergence, pendimethalin @ 0.75 kg/ha followed by hand weeding at 30 DAS and lay by application of pendimethalin @1.25 kg/ha produced the highest coriander (4523 kg/ha) and cluster bean (2726 kg/ha) yield.

Soil available nutrient and uptake : Multitier intercropping system is highly intensive in nature and their impact on nutrient status of the soil and uptake needs to be assessed. The multitier system had intercropping of coriander, vegetables cowpea and cluster bean along with *Bt* cotton had recorded the significantly highest soil available nitrogen (182.2 kg/ha), uptake of nitrogen (128.8 kg/ha), phosphorous (28.9 kg/ha) and potassium (142.6 kg/ha). Distinctive feature of most members of the fabaceae (pulses sub family) is the capability to fix atmospheric N_2 biologically by prime modulators. It helped to estimate significantly higher available N (182.2 kg/ha) in a multi tier system involved with cotton with two legumes (cluster bean and vegetable cowpea S_1, Table 2). Thus, growing of legumes, as an intercrop was beneficial to soil health and soil fertility (Basu, 1992). The ability of intercropping system to make more efficient use than sole crops was evident both for soluble and non soluble nutrients. Because of different root growth pattern of component species, intercropping also explores the entire soil mass in the rooting zone. Similarly, maximum N, P and K uptake were under cotton + blackgram than sole cotton (Harisudan, 2004).Weed control methods did not significantly influence phosphorus and potassium uptake and soil available nutrient status of major nutrients.

Economics : The multitier system had significantly influenced gross, net return, seed cotton equivalent yield and benefit cost ratio of cotton production system. The significantly highest gross return (Rs 1, 82,735 /ha), net return (Rs 1, 36,235/ha), seed cotton equivalent yield (42.8 q/ha), and benefit cost ratio (3.93) realised by multi tier intercropping of cotton + radish + beet root + coriander (S_2). The system (S_2) was more efficient as it enhanced gross return, net return, seed cotton equivalent yield and BCR, @ 198.9, 226.2, 191.3 and 135.4 per

Table 2. Economics, nutrient uptake (kg/ha) and soil available nutrient status (kg/ha) as influenced by multi tier systems and weed control

Treatments	Gross return (Rs/ha)	Net return (Rs/ha)	SCEY (q/ha)	B/C ratio	Nutrient uptake (kg/ha)			Soil available nutrient (kg/ha)		
					N	P	K	N	P_2O_5	K_2O
A. Multitier system										
S_1 - Cotton + coriander + vegetable cowpea + cluster bean	149210	92696	28.8	2.59	125.3	28.9	142.6	182.2	17.3	805.4
S_2 - Cotton + radish + beetroot + coriander	182735	136235	38.1	3.86	128.8	28.9	135.6	163.7	18.3	809.8
S_3 - Sole cotton	91866	60225	19.2	2.87	99.6	19.3	102.7	171.3	17	828.6
SEd	11406	9398	2.4	0.13	7.1	2.4	9.6	6.2	1.5	25.2
CD (p=.05)	23953	19736	5.0	0.27	14.9	5.0	20.2	13.1	NS	NS
B.Weed control										
W_1- HW @15,30 and 60 DAS	142600	96302	29.1	3.06	125.8	28.4	134.9	169.3	17.2	798.8
W_2- Pendi.0.75 kg/ha + Hw + Pendi1.25 kg/ha	148194	102806	29.9	3.23	124.5	26.3	130.7	170.7	16.9	813.1
W_3- Pendi.0.75kg/ha+ HW + Quizalofop-ethyl @ 50 g/ha.	133018	90047	27.0	3.05	103.4	22.4	115.3	177.2	18.5	831.9
SEd	11406	9398	2.4	2.40	7.1	2.4	9.6	6.2	1.5	25.2
CD (p=0.05)	23953	19736	5.0	5.04	14.9	5.0	20.2	13.1	NS	NS

cent respectively in comparison to those in sole cotton. Intensification of crop on time and space dimension in the system (S_2) by selecting short duration, non competitive crops and method of planting adopted could not suppress growth of the base crop and produce statistically as much as equal seed cotton yield (2251 kg/ha) as that of sole crop (2237 kg/ha) in addition to supplementing it by vegetable yield. These included production of 3523 kg/ha of radish, 1486 kg/ha of beet root and 4622kg/ ha of coriander, which favoured for higher economic return. Sole cotton registered the lower values of gross return (Rs 91,866/ha), net return (Rs 60,225/ha), BCR (2.90) and seed cotton yield (2237 kg/ha). On the similar lines, cropping system did not influence seed cotton yield but additional yield of intercrops make system more remunerative over the sole cotton (Seema Sepat and Ahlawat, 2010).This may be also attributed to differential growth peaks in the selected crops in the intercropping involving radish, beet root and coriander that coincided with lag phase of the cotton and helped in avoiding competition among the components and main crop resulted in higher production and economic return. Non-competitiveness amongst components of an intercropping system was corroborated by Mohammad *et al,*. (2001). All these resulted in higher cotton equivalent yield under rotation and intercropping system compared to monocropped cotton as reported by Jagvir singh *et al.,* (2004) and Giri *et al.,* (2006).

The economic returns had not been significantly influenced by weed control methods; amongst the weed control methods, pre emergence application of pendimethalin @ 0.75 kg /ha followed by hand weeding at 30 DAS and lay by application of pendimethalin @ 1.25 kg/ ha had numerically higher returns.

Multitier cropping systems are dynamic interactive practices aimed at better use of the production components such as soil, water, air space, solar radiation and all other inputs on sustainable basis. Highest gross return, net return, per day profitability and seed cotton equivalent yield were obtained with the multi-tier system of cotton +radish+ beet root+ coriander. The introduction of non competitive, short duration, multi intercrops into sole cotton, salvaged the risk perturbed by mono-cropping. Higher production, economic return and resource utilisation realised with multi-tier system of *Bt* cotton+ radish+ beet root +coriander were advantageous in more than one ways. Weed control by pre emergence application of pendimethalin @0.75 kg/ha , followed by hand weeding at 30 DAS and subsequent lay by application of pendimethalin @ 1.25 kg/ha for late emergence weed control is better option under labour scare situation , the study suggested.

REFERENCES

AICCIP, 2004. *Annual Report*. All India Coordinated Cotton Improvement Proj ect.Central Institute for Cotton Research, Coimbatore.

Altieri, M.A. and Liebman, M. 1986. In *"Multiple Cropping System"* (C.A. Francis Eds.), pp.1 83-2 1 8,Macmillan,New York.

Basu, A.K.1992.Integrated nutrient supply system in cotton based cropping system.*Fert.News* **37:** 47-54.

Chowdhury, R.K. and Singh, B.P. 1983. Intercropping of pulses – A good bet. *Field Crop Abstracts* **30** : 900.

DE, R., Gupta, S., Singh, S. P., Pal, M., Singh, S.N., Sharma R.W. and Kowsik S. K. 1978. Intercropping maize, sorghum and pearl millet with short duration grain legumes. *Indian Jour. Agri. Sci.* **48 :** 132-37.

Entz., M. H., Bullied, W. J. and Katepa-Mupondwa, F. 1995. Rational benefits of forage crops in Canadian Prairie Cropping system. *Jour. Prod. Agri.* **8 :** 521-29.

Giri, A.N., Deshmukh M.N. and Gore S. B. 2006. Nutrient management in cotton *(Gossypium hirsutum)* based cropping systems. *Indian Jour. of Agro.* **51:** 116 -18

Harisudan, C. 2004. Nutrient management in cotton + Black gram intercropping system. *M. Sc (Thesis)*, Tamil Nadu Agricultural University, Coimbatore.

Singh, Jagvir, Venugopalan, M.V., Mayee, C.D., Deshmukh, M. S. and Tandulkar, N. R. (2004) Effect of manure and cotton based cropping systems on productivity and micronutrient availability in rainfed vertisols. *Jour. Indian Soc. Cotton Improve.* **29 :** 100-05

Koshiya, D. J. 2010.Management of narrow leaf weeds in cotton with a post emergence herbicide,Targa super 5 EC. National conference on *"Paradigm shift in cotton research and cultivation"*,October 19-21,2010 organised by Navasari Agricultural university, Surat and Indian Society for cotton improvement,Mumbai.

Mohammad, Bismillah Khan, Mahboob Akhtar and Abdul, Khaliq 2001. Effect of planting patterns and different intercropping systems on the productivity of cotton *(Gossypium hirsutum L.)* under irrigated conditions of Faisalabad. *International Jour. Agri. Biology* **3:** 432-35.

Seema, Sepat and Ahlawat I.P.S. 2010. Effect of cropping system, phosphorus sources and level on phosphorus uptake and yield of cotton *(Gossypium hirsutum)*. Extended summary **In:** XIX National Symposium on *"Resource Management approaches Towards Livelihood Security"* 2-4 Dec. 2010 Bengaluru, Karnataka, organised by Indian Society of Agronomy, Indian Council of Agricultural Research and University of Agricultural sciences

Sivakumar, C. and Subbian, P. 2010. Weed smothering efficiency of pulses and allelopathic potential of parthenium on weeds in irrigated cotton (MCU 5). Abstract **In:** National conference on ' *Challenges in weed management in agro-ecosystem- Present status and future strategies"* Nov.30 and Dec. 1 organised by and held at Tamil Nadu Agricultural University, Coimbatore

Woodhead, T., Huke, R. and Huke E. 1994. Areas, location and on-going collaborative research for the rice wheat system in Asia, Bangkok, Thailand. *FAO Bullet.* **68** : 97.

Impact of intercropping technology transfer on knowledge, adoption and net profit of cotton farmers in Vidharbha region of Maharashtra

S. M. WASNIK* AND S. USHA RANI
Central Institute for Cotton Research, Nagpur- 440 010
**E-mail : wasniksm2012@gmail.com*

Abstract : Results obtained at research stations and demonstrations conducted on farmer's fields have proved that intercropping with cotton is beneficial over growing of cotton alone. Cotton being a long duration crop and having a slow growth in early growth stages is ideally suited for growing of scientifically sound and practically feasible intercrops *viz.* mungbean, cowpea, soybean, etc. However, the technology are not being adopted at the rate at which these are being generated by the researchers though the intercropping system has several advantages like enhancing productivity of land, suppressing weeds in the inter row spaces, enriching soil fertility, additional production and increasing income/unit area. However, the grower apprehensive of yield reduction in both cotton and intercrops due to problems in intercultural operations. Also the other problems encountered were lack of awareness and sufficient knowledge of intercropping, training, access to credits and farm inputs. Keeping the idea in view and to popularize intercropping technology among farmers, a comprehensive programme of transfer of intercropping technology through 'farmer to farmer' technology dissemination was introduced at farmer's field in Vidharbha rainfed region of Maharashtra State. The farmers were motivated and educated about worth of intercropping technology. They were also provided on-farm technical support. Since soyabean is extensively grown in Vidharbha region, the crop was chosen as intercrop with cotton varieties NHH 44 and Bunny *Bt* Soyaben variety JS 335 was selected as suitable variety for intercropping (1:1) and laid out trial at farmer's field. The study showed very encouraging results in motivation, diffusion and promotion of cotton intercropping. The results show that there was significant improvement in knowledge, adoption and net profit due to implementation of programme. The increase in knowledge and adoption was 44.32 and 56.79 per cent as a consequence of intercropping technology transfer. Further there has been significant gain in profit as the farmers were able to get 32 per cent additional yield and 26 per cent additional returns over the years in intercropping system from same piece of land compared to sole cotton. The neighbouring young and educated farmers of the area were positively influenced towards intercropping mainly due to economic profitability. Further they themselves started convincing other farmers for adoption of intercropping technology to strengthen their economy.

Intercropping in cotton is of significance because of higher profit and stabilized yield advantage, especially under adverse weather conditions since cultivating cotton as a sole crop is usually found to be risky and less remunerative. Many researchers pointed out the benefits of intercropping. Balasubramanian, 1987 observed that intercropping in cotton could exploit the environment in better way besides providing insurance against the inclement weather situation and consequent crops. Increased productivity with higher market value and enhanced profitability when pulses were intercropped with cotton observed Sivakumar, 2003. Intercropping of legumes is an important aspect for biological farming systems not only for weed control, but also in reducing the leaching of nutrients, pest control and in reducing soil erosion (Prabu Kumar and Uthayakumar, 2006). Intercropping of cotton + soyabean (1:1), cotton + *moong*/ *urid* (1:1), cotton + cowpea (1:1), cotton + groundnut (1:1), cotton + pigeonpea strip intercropping (6:2) or (8:2), etc. is advocated as one of the ways to improve food security and soil fertility while generating cash income of rural poor. In spite of advantages in intercropping system, the area in cotton based intercropping is very less is a matter of serious concern considering the emerging stiff problems of non-remuneration of cotton farming. This has necessitated cotton growers to strive towards adopting various production systems. Farmer's participatory endeavours need to be encouraged in intercropping system to provide a holistic in technology dissemination process. Keeping the idea in view and to popularize intercropping technology among farmers, a comprehensive programme of transfer of intercropping technology action research of innovative extension model *i.e.* farmer to farmer technology dissemination was implemented at farmer's field in Vidharbha rainfed region of Maharashtra State. The farmers were motivated and educated about worth of intercropping technology. They were also provided on farm technical support to improve and enhance the grower's confidence, capability and skills in cotton intercropping.

MATERIALS AND METHODS

Central Institute for Cotton Research (CICR) Nagpur initiated technology transfer of cotton intercropping system through innovative extension model 'Farmer to Farmer' participatory dissemination in village Weni in Hinganghat tahsil of Wardha district in Vidharbha rainfed region of Maharashtra state at selected farmer's field. The identified farmer participated in designing, laying out of intercropping trials of soyabean and cowpea along with cotton (1:1), collection of data for yield and net income and trained him in dissemination of the technology to other farmers. To ensure validity, regular field visits and meeting with growers were held. Motivated due to economic benefits in intercropping at selected farmers field several farmers came forward from villages Jununa, Pohana, Pipri, Badner, Khairi , Rampur, Pachgaon, Weni, Pimpalgaon and near about around 97 farmers adopted intercropping of cotton + soybean. Thus, all intercropping practicing 97 farmers were selected as respondents for the study.

Measurement of impact : The impact of technology transfer of cotton intercropping system through the farmer to farmer dissemination module was measured in terms of gain in knowledge, adoption and net profit in cotton intercropping for before and during programme implementations. A structured schedule was developed for the purpose and data was collected by personal interview.

The study also attempted the relevance of farmer to farmer dissemination module in terms of appropriateness of strategy and also identifying the bottlenecks in cotton intercropping system

RESULTS AND DISCUSSION

Dissemination of intercropping technology through introduction of 'Farmer to Farmer' model : The farmer to farmer extension approach was introduced with a view to conduct their own field studies, sharing knowledge, experiences ,learning with each other and using the field as a primary learning base to encourage the farmers involvement in cotton intercropping system. The farmers "learn by doing" through comparing different management practices. Consequently they become experts on the particular practice they are investigating. Such farmers can therefore serve as farmer's promoters or farmers scientist. Accordingly, a farmer namely Vinod Raut was identified from village Weni in Hinganghat tahsil of Wardha district (2009-2011). He was trained and motivated by conducting on his own farm the technique of cotton+soyabean and cotton + cowpea in one acre each. It was encouraging to note that the adopted farmer harvested 15 q/seed cotton yield and 9 q/soyabean, he also sold cowpea for Rs.30, 000/-. Despite there was heavy and continuous rains during crop season and also record cold waves in first week of January due to which heavy crop losses was observed in most of farmers fields. However, participating farmer managed his field excellently and earned benefits of more than 1 lakh rupees by adoption of technology due to which many farmers from his villages and adjoining villages visited his field personally. State Agril Deptt. officials also visited these trials in large number and convinced other farmers about benefits of technology. The farmer's participatory approach helped to promote cotton intercropping technology with assistance and support from CICR as well as extension workers of State Agril Deptt.

Spread of intercropping technology : The farmer to farmer technology dissemination helped to popularize intercropping technology as indicated from the spread and adoption of cotton intercropping specially cotton + soyabean particularly among young and educated farmers. Motivated due to its economic gains, around 97 farmers have practiced the cotton + soyabean intercropping in around the ten villages of project areas as shown in Fig 1.

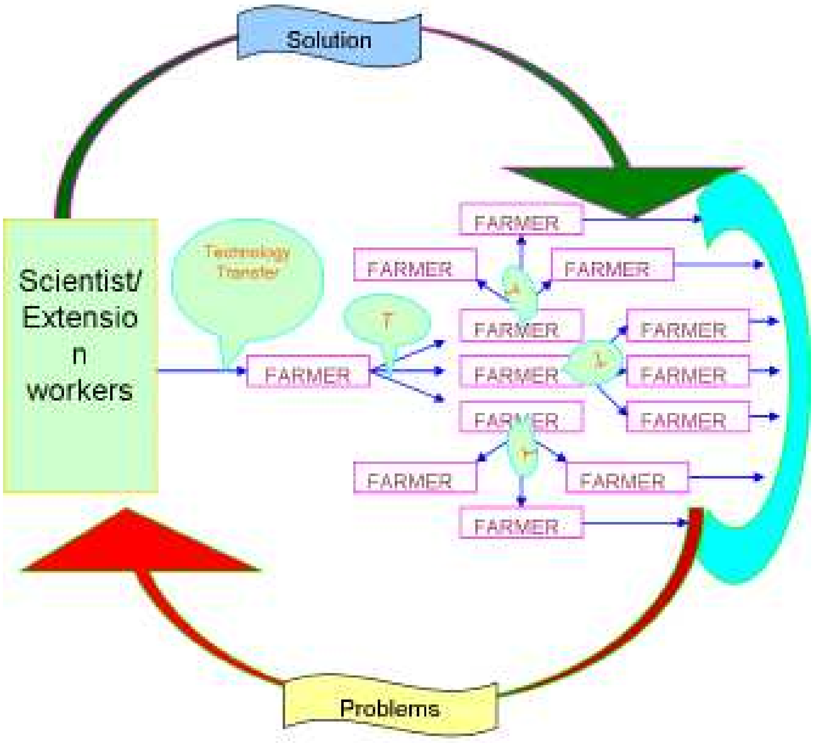


Fig 1. Farmer to Farmer technology transfer

Gain in knowledge and adoption level of intercropping : The knowledge levels and adoption of respondents on cotton intercropping was measured through the knowledge and adoption tests developed for the purpose. The knowledge level of respondents was measured prior to before the programme and during the programme (Table 1) show that there was significant improvement in knowledge and adoption of recommended practices of cotton intercropping system. The values presented shows that the overall mean scores of knowledge and adoption of cotton intercropping was recorded to 43 and 28.64 out of total permissible score of 100 prior to launching of programme, while it was 81.36 and 66.36 scores after launching of farmer to farmer dissemination project. Thus, as a consequence of FF dissemination the increase in knowledge and adoption was 44.32 and 56.79 per cent, respectively. The difference between knowledge levels and extent of adoption of intercropping technology before and during implementation of project was found to be highly significant (t=15.12)***in respect of knowledge while (t=14.5)***in respect of adoption. It indicates that the 'farmer to farmer' participatory approach have helped to spread intercropping among farmers and have a potential to increase the knowledge and adoption level by two times.

Economic gains achieved : There has been significant gains in profit due to implementations of intercropping technology through farmer to farmer dissemination (Table 2).Data presented in Table clearly indicates that farmers achieved higher profitability during the programme. The average income before programme due to sole cotton was Rs.21, 616/-, which was increased to Rs.34, 790/-an increase of profitability by Rs. 13174/-(25.52%) after the programme. These farmers' innovators are likely to represent important source of information amongst other farmers and the intercropping technique results in benefits, it is likely that the technology will spread throughout the

Table 1. Knowledge and adoption gain due to FFTD

Intercropping technology	Average scores Pre	During	Increase (%)	"t" value
Knowledge	48.3	81.36	44.32	15.12***
Adoption	28.6	66.36	56.79	14.5***

locality/areas. Since informal emerging method farmer to farmer dissemination emphasizes to accelerate farmers access by linking them to research supported by an extensionist for testing the practices in their local conditions will be more effective and viable method of dissemination. It is characterized of the farmer to farmer extension approach that farmers learn from other farmers about agricultural technology and practices. Hence such type of dissemination approach must be strengthened and can be taken up extensively to advice adoption and profitability in intercropping systems.

Relevance of farmer to farmer dissemination module : An attempt was made to investigate the relevance of farmer to farmer dissemination module in terms of appropriateness of strategy followed .Relevance refers to appropriateness of module in terms of influencing other farmers with respect intercropping system.

The data in Table 3 shows that farmer to farmer dissemination modules were perceived to be highly relevant to influence the farmers in intercropping system. The score of relevance (out of the possible maximum score of 10) for the six modules ranged from 8.5 to 8.9.The highest score was received by module skill improvement in carrying out field operations in intercropping (8.9) followed by skill improvement in weed control and skill improvement in nutrient management (8.8), skill improvement and motivation towards planting of intercrops (8.6), skill improvement in plant protection measures (8.5). The overall picture with regards to relevance shows that farmer to farmer dissemination module is highly relevant.

Bottlenecks in cotton intercropping : Despite having potentialities to enhance economy from same piece of land by taking intercrops with the main crop, there are several hindrances, which farmers usually face while adoption of certain technologies (Table 4). An effort was therefore made to measure the

Table 2. Economic gains due to FFTD

Monetary gains achieved	Yield (kg/ha)	Net returns	Income (Rs)	Net profit during programme	Increase profitability (%)
Before programme (Sole cotton)	1358.33	51616.54	21616.54	13174.21	25.52
Before programme (Sole soybean)	950 .0	20425.00	10925.0		
After programme (cotton + soybean)	1262.29 + 782.5	64790.75	34790.54		

different types of constraints faced by the farmers in adoption of cotton intercropping practices. The main technological constraints of meagre adoption of cotton intercropping as expressed by the growers were difficulty in intercultural operation followed weed problem, fear of more insect attack, fertilizers shortage, no interest in cotton intercropping, traditional belief, scarcity of labours, non availability of seeds of appropriate crop/varieties, farmers mindset, lack of proper understanding on methods of sowing of main and intercrop, fear of more insect attack, fear of low yields, stunted plant growth, lack of training and exposure towards intercropping were problems felt by the respondent farmers. This is probably due to wide variation in knowledge in terms of their extension contacts and least exposure to intercropping system suggesting to imparting more training on intercropping. Some respondent expressed of unsure about more income and fear of more expenditure. Respondents overall observed technical constraints ranking topmost bottleneck in adoption of intercropping followed by financial, situational and HRD constraints.

Table 3. Relevance of FFDM

FFDM	Relevance score*
Skill improvement and motivation towards planting of intercrops	8.6
Skill improvement in weed control	8.8
Skill improvement in plant protection measures	8.5
Skill improvement in nutrient management	8.8
Skill improvement in carrying out field operations in intercropping	8.9
Average score	**8.53**

Range1-10

Table 4. Bottlenecks in adoption of intercropping technology

Technical problem	Ranks
Difficulty in intercultural operations	1
Fear of more insect pest attack	4
Fear of low yield	3
Labour problems	2
Seed of appropriate varieties	7
No interest in intercropping farming	5
Risky	8
Traditional beliefs	6
Stunted plant growth	10
Problem in ventilation	9
HRD/ Training	**Ranks**
Lack of expert advice	2
Lack of motivation	3
Propaganda about losing crop	1
Lack of innovativeness	4
Financial constraints	**Ranks**
Unsure about more income	1
Fear of more expenditure	2
Costly labors	3
Costly inputs	4
Cost of cultivation more	5

Hence concerned agencies should make appropriate arrangements for improving the adoption of cotton intercropping

CONCLUSION

Farmer to farmer's participatory research and dissemination of intercropping indicated more diffused impact by changing their perception about technology and its management to achieve profitability and livelihood security. Further, participating farmer gained thorough knowledge about intercropping technology which he can disseminate among other fellow farmers. The model 'Farmer to farmer' dissemination provided opportunity for the farmers to develop their capability and build- up their confidence in adopting technologies. The model showed very encouraging results in motivation, diffusion and promotion of cotton intercropping. There has been significant gain in knowledge, adoption and net profit as a consequence of programme. The neighbouring young and educated farmers of the area were positively influenced towards inter cropping mainly due to economic profitability and they themselves started convincing other farmers in project location. Also, the perception of farmers highlighted the obstacles in adoption of intercropping techniques related to problems like difficulty in intercultural operations, fear of yield loss, labour problem, unsure about more income, lack of knowledge and motivation and propaganda about losing both intercrop and main crop as reported by the farmers can be overcome by forging better communication linkages. The farmer to farmer dissemination modules were perceived to be highly relevant to influence the farmers in intercropping system in terms of improving motivation, solving field problems and dissemination of technology. The study suggests that there is a great need of educating the farmers about cotton intercropping; it was therefore suggested for taking pro- active sustainable extension intervention to train and motivate the growers in adoption of cotton intercropping. The risk taking ability of the farmers needs to be enhanced with some policy initiatives to encourage cultivation of intercropping system by many farmers

REFERENCES

Balasubramanian, T.N. 1987. *Ph.D. Thesis*. Tamil Nadu Agric. Univ., Coimbatore, india

Kesavan R. 2005. *Kisan World* **32(11)** : 52-53.

Prabu Kumar G. and Uthayakumar B. 2006. *Agric. Rev.*, **27(3)** : 208-15.

Sivakumar, S.D. 2003. *Ph.D. Thesis*. Tamil Nadu Agric Univ., Coimbatore, India

Impact of exclusion of solar UV-B/UV-A radiation on growth, photosynthesis and yield of cotton (*Gossypium hirsutum* L.) varieties

SUNITA KATARIA*, P. DEHARIYA, K.N. GURUPRASAD AND G.P. PANDEY
School of Life Sciences, Devi Ahilya University, Indore – 452 017
**E-mail: sunitakataria@hotmail.com*

ABSTRACT : The influence of solar UV-B or UV-A radiation on the growth, photosynthesis and yield of four varieties of cotton (*Gossypium hirsutum* L.); JK 35, IH 63, Khandwa 2 and Vikram was investigated by the exclusion of solar UV-B/UV-A radiations. Cotton plants were grown from seeds in specially designed UV exclusion chambers, which were lined with selective UV filters to exclude either UV-B (280-315 nm) or UV-A/B (280-400 nm) from solar spectrum under filed conditions. Excluding UV-B and UV-A/B significantly increased plant height, leaf area, dry weight accumulation and yield parameters (number and weight of bolls and length of fibres) in all the four varieties of cotton. The photosynthetic pigments were significantly enhanced while UV-B absorbing substances were significantly decreased by the exclusion of solar UV-B and UV-A/B. Enhancement in the vegetative growth and yield of the plants could be related to the enhanced rate of photosynthesis in all the varieties of cotton. UV exclusion also enhanced the stomatal conductance and intercellular CO_2 concentration and reduced the stomatal resistance. Total soluble proteins were also higher after UV exclusion in all four varieties of cotton. Considerable variation in the sensitivity to ambient solar UV-A/UV-B exists between the varieties and according to UV sensitivity index, the sensitivity can be arranged in increasing order as; JK 35>IH 63>Khandwa 2>Vikram. Thus Vikram was the most sensitive and JK-35 the least sensitive to current level of solar UV radiation at Indore, Experiments indicated the suppressive action of ambient UV on carbon fixation and yield of cotton plants. Exclusion of solar UV proved to be beneficial in enhancing the growth and yield of cotton plants.

Key words : Biomass, cotton, photosynthesis, Pigment system II, UV exclusion, yield

The stratospheric ozone decrease has heightened concern over the ecological implication of increasing solar UV-B (280-315 nm) radiation on agricultural production and natural plant ecosystems (McKenzie *et al.,* 2007). Numerous investigations concerning the influence of UV-B radiation on different plant species have been conducted, and most have shown negative effects (Kakani *et al.,* 2003a). Plant species and even genotypes within species can differ greatly in their responses to UV-B radiation. Intraspecific responses to enhanced UV-B in maize and wheat (Biggs and Kossuth, 1978), broad bean (Bennett, 1981), cucumber (Murali and Teramura, 1986), soybean (Teramura and Murali, 1986; Sullivan and Teramura, 1990), rice (Teramura *et al.,* 1991; Dai *et al.,* 1994) have been reported.

Many indoor studies have shown that UV-B can impair all of the three main processes of photosynthesis: the photophosphorylation reaction, the CO_2 fixation reactions and stomatal control of CO_2 supply, with photosystem (PS) II appearing to be particularly sensitive (Teramura and Sullivan, 1994; Allen *et al.,* 1998). Some studies utilizing filters to compare near ambient and reduced UV-B radiation indicate that current ambient UV-B inhibit photosynthesis (Xiong *et al.* 2002; Albert *et al.,* 2005). The impairments in photosynthesis in the upper mesophyll has been associated with enzymatic, rather than PS II, limitations (Xiong and Day, 2001). Other studies indicate that the inhibition of biomass accumulation in response to UV-B primarily is due to reductions in leaf area but not damage to photosynthesis (Ballare *et al.,* 1996; Xiong and Day, 2001). Keiller and Holmes (2001) found that UV-B enhancements over five years led to inhibition of carbon assimilation in five tree species, in the absence of any apparent PS II damage.

The deleterious effects of UV-B on photosynthesis have been observed mostly under unrealistically high doses of UV-B. In cotton plants high doses of UV-B (14 KJ m^{-2}/day) decreased net photosynthesis in the leaves associated with decrease in chlorophyll *a* fluorescence (Fv/Fm) at optimum and high temperature but with decreased stomatal conductance and intercellular CO_2 under low temperature (Reddy *et al.,* 2004). Most of the UV-B research in the past two decades has been conducted as short term experiments in growth chambers and greenhouses, where an unnatural spectral balance of radiation may have substantially changed plant sensitivity to UV-B. It is important in experiments to maintain a realistic balance between various spectral regions, since both UV-A (315-400 nm) and visible (400-700 nm) radiation can have ameliorating effects on responses of plants to UV-B radiation (Caldwell *et al.,* 1995). Unfortunately, only 15 per cent of the reported studies have been conducted under field conditions. While laboratory and glasshouse studies provide information on mechanisms and processes of UV-B action, only field studies can provide realistic assessments of what will happen as the stratospheric ozone layer thins (Caldwell *et al.,* 1995). Only few studies have been conducted under field conditions, on the other hand, until now, only a few studies have determined the effects of prevailing ambient solar UV-A/UV-B radiation on plants using the methods of UV-B or UV-A/B exclusion especially on intraspecific responses of crop plants in field conditions (Kataria and Guruprasad, 2012 a,b).

The aim of the present study is to evaluate the possible contribution of ambient UV-B and UV-A in the regulation of growth, photosynthesis and yield of cotton varieties and to evaluate the intra specific variations in the sensitivity of these responses in four cotton (*Gossypium hirsutum*) varieties; Jawar Kisan 35, Indore *Hirsutum* 63, Khandwa 2 and Vikram. Cotton is a major economic crop of India and the experiments were done at indore (22.4$^{?}$ N) located in the western part of the state of Madhya Pradesh. Cotton (*Gossypium hirsutum L.*) is grown extensively in the southern/western districts of Madhya Pradesh.

MATERIALS AND METHODS

Site description : Seeds of cotton (*Gossypium hirsutum)* varieties; Jawar Kisan 35 (JK 35), Indore *Hirsutum* 63(IH-63), Khnadwa 2 and Vikram were collected from Cotton Improvement Project Agriculture College, Indore and treated with recommended fungicides *viz.,* Bevistin and Diathane M at 2 g/kg seeds. Field experiments under natural sunlight were conducted in the Botanical garden of School of Life Sciences, Indore (22.4^{0}N) India. The experiments were carried out during February to May 2011 and repeated in February to May

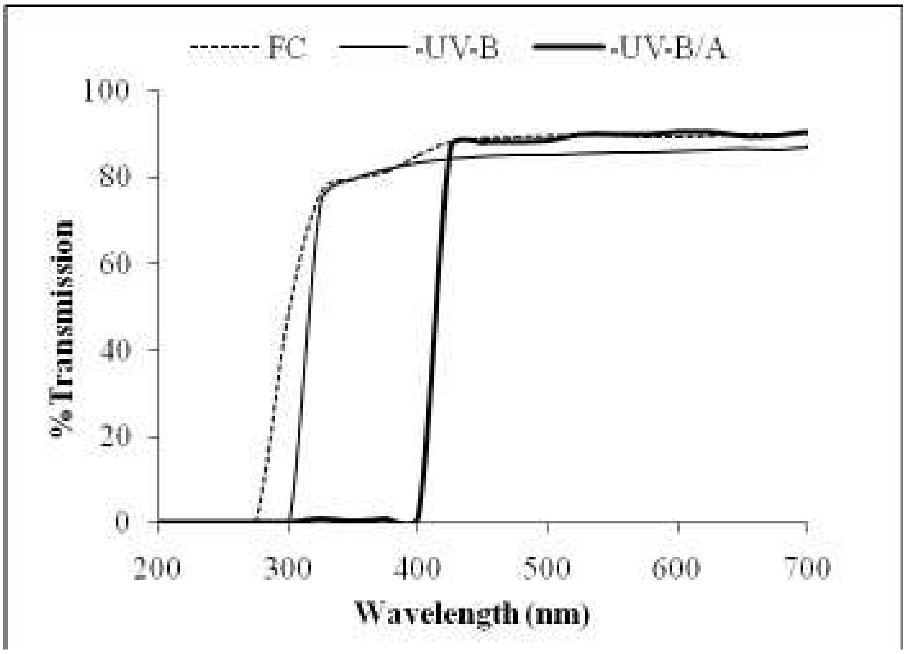


Fig. 1. Transmission spectra of UV cut off filters used in growth chambers for raising cotton varieties under natural conditions.

2012, when the average daily solar UV-B dose is around 10 KJ/ m^2 which is approximately 50 per cent higher than the average daily dose received in the temperate region. Seeds were sown in the field area of 160 x 160 cm in 120 cm rows planted 23cm apart with 5cm plant spacing within the row under iron cages of dimensions [4 feet L x 4 feet W x 5 feet H]. Iron cages with UV cut off filters (Garware polyester Ltd., Mumbai) that selectively cut-off UV-B (< 315 nm) and UV-B/A (< 400 nm) radiation. Two types of control were taken for the present study; plants were grown either in the cages covered with polythene film that transmits all the ambient solar radiation, (filter control FC) or in soil directly exposed to natural solar radiation (Open control OC).

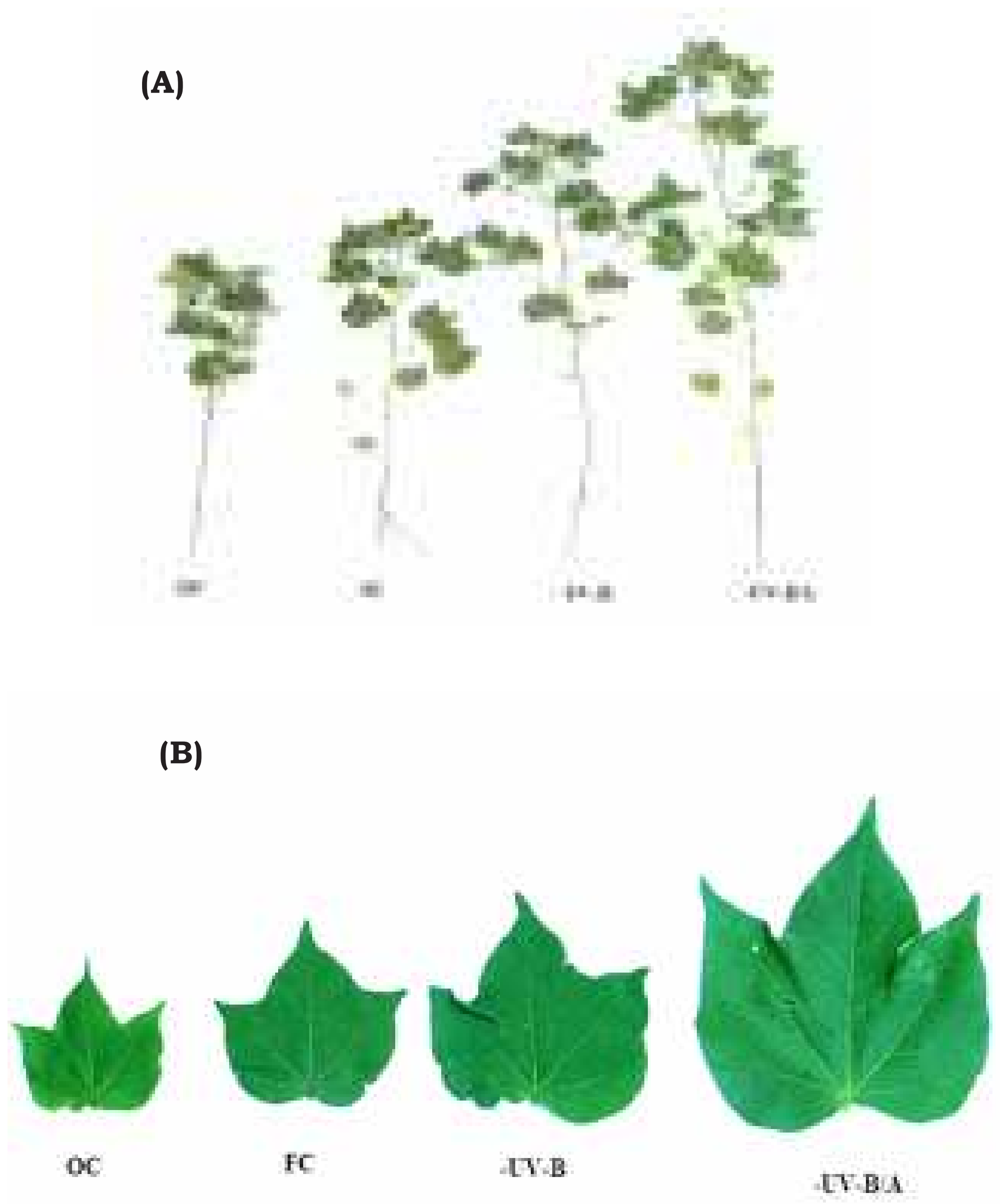


Fig. 2. Photograph of cotton plants var. Vikram grown in open control, filter control and UV excluded sunlight and these plants were used to measure plant height (A) leaf (9th) lamina size (B) of cotton seedlings var. Vikram.

Transmission characters of these filters were measured by Shimadzu (UV-1601) spectrophotometer (Fig.1).

Radiation measurement : Absolute solar irradiances in all treatments were measured using a Radiometer (IL 1350, International light Inc) USA. The ambient solar irradiance during experimental period at midday was 382 µ mol m?^{2} s?^{1}, the loss in light intensity at midday by UV-B exclusion filter was 43 per cent (219 µmol m?^{2} s?^{1}) and 44 pere cent (214 µmol m?^{2} s?^{1}) under UV-B/A exclusion filter and 7 per cent (356 µmol m?^{2} s?^{1}) under polythene filter transmissible to UV (filter control).

Growth analysis : Plant height and total dry weight accumulation were taken at 120 days after emergence of seedlings (DAE) and area of 9th leaves were measured at 80 DAE using portable laser leaf area meter CI-202 scanning planimeter (CID Inc., USA). For dry weight accumulation determination, the total plants parts were dried at 60°C for 72 h.

Pigment analysis : Photosynthetic pigments were extracted from the leaves with 80% acetone. Absorbances of pigment extract were measured at 470, 646 and 663 nm with Shimadzu UV/VIS 1601 spectrophotometer. Equations of Wellburn and Lichtenthaler (1984) were used to calculate the chl a, chl b, total chl and carotenoids concentrations. Chlorophyll content and carotenoids were expressed as mg/ gms leaf fresh weight. Accumulation of UV-B absorbing compounds in leaves was determined spectrophotometrically from acidified methanol extract by the method of Mazza *et al.,* (2000).

Net photosynthesis : Net photosynthesis (Pn), intracellular CO_2 concentration (Ci), stomatal conductance (gs) and stomatal resistance (rs) of a topmost fully expanded leaf (9th leaf) was analyzed by using IRGA (Li- 6200 LI-COR Inc., Lincoln, Nebraska, Serial No. PPS 1332 USA) on intact plants growing in the fields in normal sunlight or UV excluded sun light.

Total soluble protein : Leaf total soluble proteins were estimated by the method of Lowry *et al.,* (1951) using bovine serum albumin as standard.

Yield : Yield parameters bolls/plant, weight of total bolls/plant (gm) and length of fibre (cm) were measured at the time of harvest in all the four varieties of cotton.

UV sensitivity Index (UV-SI) : Differences in the UV sensitivity of the four varieties of cotton at maturity were ascertained by a UV sensitivity index (UV-SI) which was calculated according to the following equation (Kataria and Guruprasad, 2012a):

$$\text{UV-SI} = \frac{\text{Plant height +UV}}{\text{Plant height -UV}} + \frac{\text{Dry weight +UV}}{\text{Dry weight -UV}} + \frac{\text{Yield +UV}}{\text{Yield -UV}}$$

An UV-tolerant plant has an UVSI of 3 whereas; UV-SI values below 3 indicate an UV-sensitive plant. (+UV= Filter control, -UV= Either UV-A/B excluded or UV-B excluded plants)

RESULTS AND DISCUSSION

Growth parameters : A significant increase was observed in all growth parameters like plant height, leaf area and biomass accumulation in all four varieties of cotton plant (var. JK 35, IH 63, Khandwa 2 and Vikram) grown under UV B or UV A/B excluded solar radiation (Fig. 2A, B). All the growth parameters were significantly enhanced after the exclusion of UV-B and further promoted by the UV-A/B exclusion in all the four varieties (Fig. 3A, B, C). However the magnitude of the growth responses was more in var. Vikram and KH 2 as compared to other varieties JK 35 and IH 63. The maximum enhancement in plant height was found in cotton var.Vikram and an increase of 56 per cent by UV-B exclusion and 64 per cent increase after UV-A/B exclusion (Fig. 3A).

Maximum difference in dry weight accumulation was found in var. Vikram; an increase of 20 per cent by UV B exclusion and 65 per cent by UV A/B in dry weight of was recorded at 120 DAE (Fig. 3B). Similar trend was found in enhancement of leaf area after UV A/B exclusion (Fig. 3C).

Photosynthetic pigments and UV absorbing substances : Since the biomass was enhanced by exclusion of UV-A/B, it was of interest to analyse the changes in components

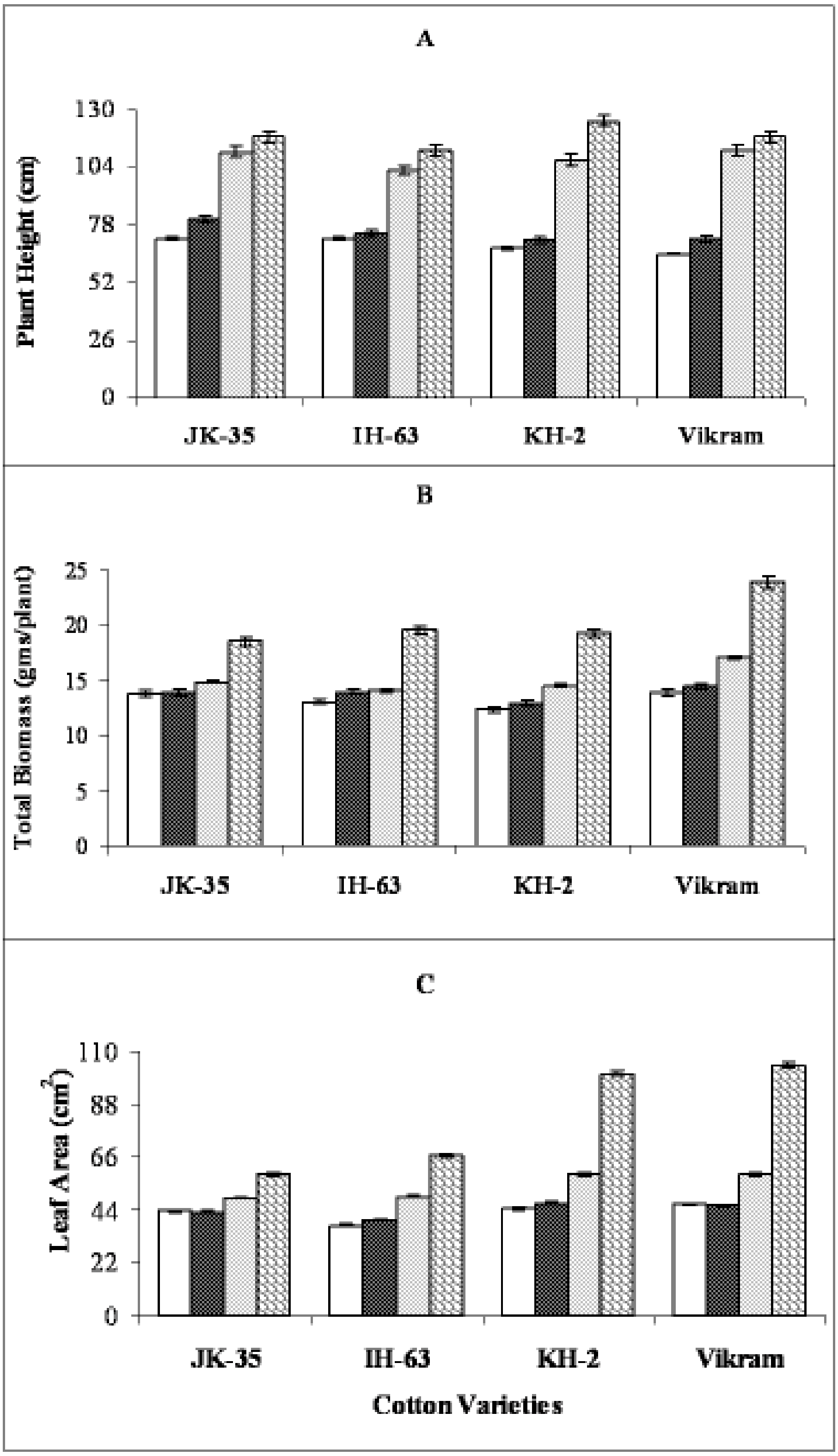


Fig. 3. Plant height (A), total dry weight (B) and leaf area of 9th leaves (C) in open control, filter control, UV-B and UV-B/A excluded cotton varieties. The vertical bar indicates ±SE for mean.

of photosynthesis after UV exclusion. Exclusion of ambient UV enhanced the amount of Chl *b* in particular (Table 1) compared to Chl *a* (Table 1). Exclusion also resulted in higher amounts of carotenoids in the leaves (Table 1). In contrast to photosynthetic pigments, UV exclusion reduced the level of UAS significantly in the leaves (Table 1).

Rate of photosynthesis, stomatal conductance, stomatal resistance and intercellular CO_2 : Differences in growth in area and dry weight of leaves indicate that the exclusion of solar UV components results in additional fixation of carbon in cotton. To obtain a direct evidence for the enhancement in the CO_2 fixation, measurements were done by using IRGA (Li Cor) on the leaves of intact plants growing in the fields in normal sun light or UV excluded sun light. A dramatic increase in the net photosynthesis rate (Pn) was observed in the leaves of UV excluded plants of all the four varieties (Fig.4A). This was concomitant with an increase in stomatal conductance (gs) and intercellular concentration of CO_2 (Ci) and decrease in stomatal resistance (rs) (Fig. 4 B and 5A, B). Enhancement in these parameters were much higher in the presence of UV-A (-UV-B) than in its absence (-UV-A/B). However the magnitude of the response was more in var Vikram as compared to other varieties. The maximum enhancement in net photosynthesis of leaves was by 57 per cent (-UV-B) and 43 per cent (-UV-A/B) in var Vikram.

Total soluble proteins : Total soluble proteins were higher in the leaves of plants grown under the exclusion of UV-B (Fig. 6). Exclusion of both UV-B and UV-A reduced this enhancement. Presence of UV-A seems to enhance protein synthesis in the leaves of cotton plants.

Yield : Yield parameters analysed in terms of number of bolls, total boll weight (weight of fibre + seeds) and fibre length in all the four varieties. A significant enhancement in all these

Table 1. Exclusion of solar UV-B and UV-B/A radiation induced effects on UAS, chlorophyll *a, b,* total chlorophylls and carotenoids in cotton varieties. Data are the means of ± S.E.M. of fifteen plants (n=15).

Cotton Varieties	UAS (Units/mg FW)	Chl *a* (mg/gm FW)	Chl *b* (mg/gm FW)	Total Chl (mg/g FW)	Carotenoids (mg/g FW)
1. JK 35					
OC	0.089	1.672	0.453	2.125	123.41
FC	0.093	1.641	0.453	2.094	119.17
- UV-B	0.074	1.678	0.456	2.134	129.69
- UV-A/B	0.068	1.604	0.455	2.059	118.73
2. IH 63					
OC	0.09	1.658	0.072	1.729	122.37
FC	0.088	1.712	0.052	1.764	137.04
- UV-B	0.071	1.809	0.150	1.959	164.26
- UV-A/B	0.068	1.830	0.138	1.969	147.67
3. KH 2					
OC	0.076	1.108	0.250	1.358	140
FC	0.081	1.125	0.260	1.385	148.5
- UV-B	0.069	1.250	0.400	1.650	168
- UV-A/B	0.065	1.390	0.468	1.858	155
4. Vikram					
OC	0.071	1.186	0.300	1.487	164
FC	0.078	1.080	0.256	1.199	152
- UV-B	0.054	1.342	0.425	1.768	178
- UV-A/B	0.051	1.597	0.500	1.941	168

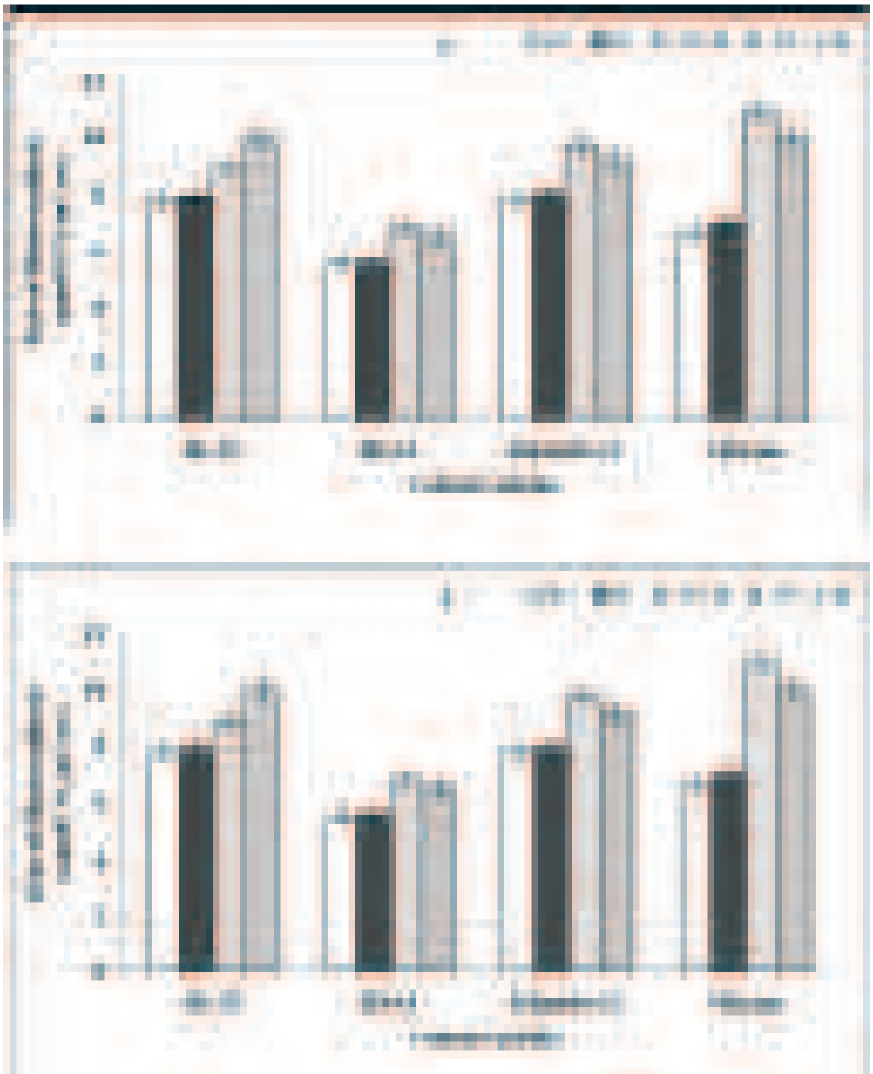


Fig. 4. Net photosynthesis (A) and stomatal conductance (B) in open control, filter control, UV-B and UV-B/A excluded cotton varieties. The vertical bar indicates ±SE for mean.

parameters was evident in the plants grown under UV exclusion compared to the exclusion of UV-B in all the four varieties of cotton. Exclusion of both UV-A/B enhanced the parameters to a greater extent (Fig.7A,B,C).

UV Sensitivity index (UV-SI) : UV Sensitivity Index (UV-SI) varied between the varieties and it was less than 3 in all the four varieties of cotton tested in the present study. The sensitivity index was numerically lower for Vikram (2.0) and higher for JK_2 35 (2.5) to ambient level of UV-B. Vikram showed SI's (1.65) and JK 35 showed SI's (2.30) to ambient level of UV-A/B (Fig. 8).

In the present study, exclusion of UV from solar spectrum led to an enormous enhancement in growth parameters and biomass accumulation in all the four varieties of cotton plant when compared to filter control conditions (+UV-B/UV-A). Our results have shown that vikram and khandwa 2 were potentially more sensitive to ambient UV than JK 35 and IH 63. Negative impact of supplemental UV-B on the growth of field grown cotton plants has earlier been established in the variety Sukan 103 grown in Nanjing China (Gao *et al.,* 2003). Shorter plant height of cotton due to shorter average internodal

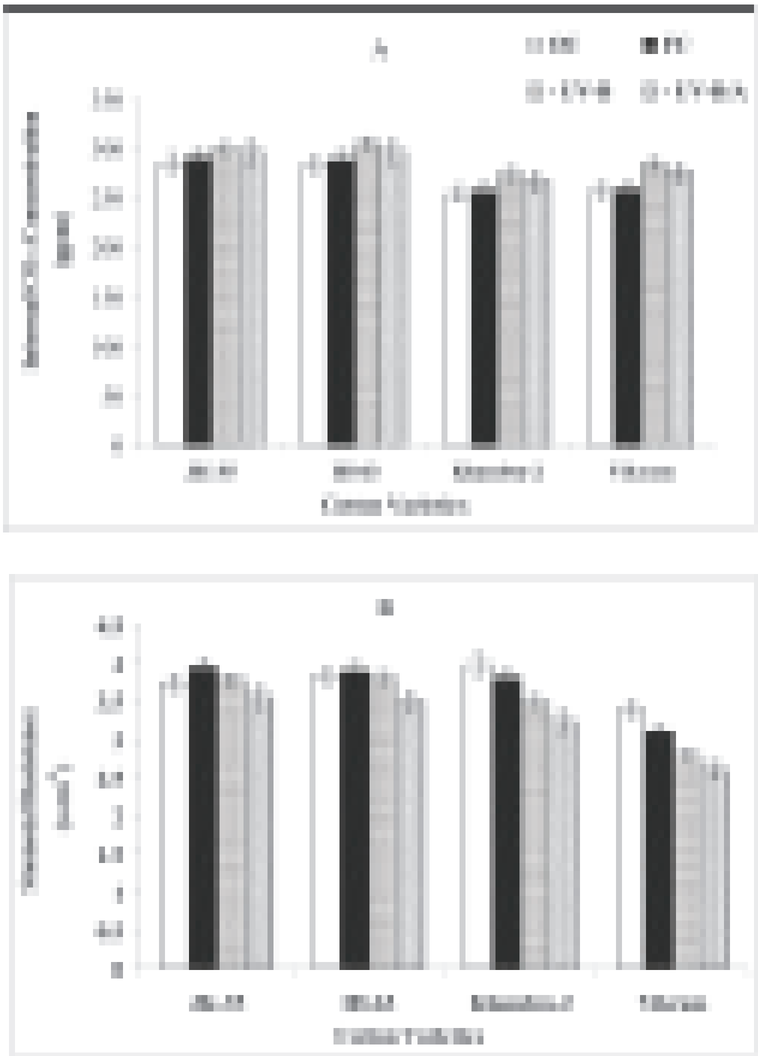


Fig. 5. Internal CO_2 concentration (A) and stomatal resistance (B) in open control, filter control, UV-B and UV-B/A excluded cotton varieties. The vertical bar indicates ±SE for mean.

length was observed in the experiments with supplemental UV-B used inside sunlit plant growth chambers (Reddy *et al.,* 2004; Kakani *et al.,* 2003b). Cotton plants exhibit reduction of plant height as a result of shortening of internodes under supplemental UV B irradiance (Zhao *et al.,* 2004; Kakani *et al.,* 2003b). Changes in morphological traits like reduction in height, biomass accumulation and leaf area when exposed to increased UV B radiation is a general response of many plant species sensitive to UV B (Correia *et al.,* 1999; Yang *et al.,* 2005). The present report on the exclusion of ambient UV supports the earlier observations by providing data on the enhancement of plant height and biomass in the absence of ambient UV. In addition, unlike the earlier experiments on the cotton confined to the impact of only UV-B, the present report indicates the significance of UV A in the ambient solar radiation in reducing the plant height and biomass of cotton. The increase in plant height was accompanied by high stem dry weight and increase in internodal length by UV-B and UV-A/B exclusion (data not given). The increase in plant height, leaf area and biomass accumulation has been observed previously in mung bean, pea, soybean, barley, *Cymopsis* and wheat (Pal *et al.,* 1997, 2006, Amudha *et al.,* 2005; Guruprasad *et al.,* 2007, Kataria and Guruprasad, 2012a) after exclusion of solar UV-B and UV-A.

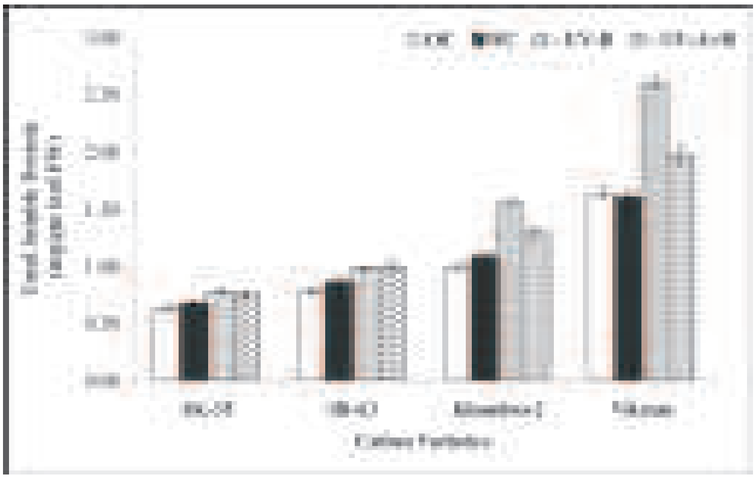


Fig. 6. Total soluble protein of cotton varieties in open control, filter control, UV-B and UV-B/A excluded condition. The vertical bar indicates ±SE for mean.

Changes in biomass accumulation are an important measure to asses UV-B sensitivity since this parameter reflects the cumulative effect of many small disruption of plant functions. The present investigation showed more damaging effect of ambient level of UV-B and UV-A radiation on biomass accumulation of all the four varieties of cotton. Agarwal and Rathore (2007) found that the biomass of mung bean was reduced by supplemental UV-B in field conditions. Ghissi *et al.,* (2002) also found reduced fresh weight and dry weight of UV-B exposed barley plants. Teramura *et al.,* (1991) showed reduction in total biomass of 6 out of 16 rice cultivars screened for UV-B sensitivity. Response of plants to solar UV-B include alteration in photosynthesis, growth and yield as well as great variety of changes in physiological and morphological parameters (Day and Neal, 2002; Kakani *et al.,* 2003b).

An extensive study on the impact of supplemental UV-B on leaf growth and morphology of cotton plants indicated reduction in leaf area and appearance of chlorotic and necrotic patches on leaf surface (Kakani *et al.* 2003b). In the present study ambient UV reduced the leaf area and exclusion enhanced the expansion of leaves. Thus the primary effect of absence of ambient UV seems to be an enhancement in the rate of growth of the leaves. Coleman and Day (2004) have reported that individual leaves as well as total plant leaf area become smaller in cotton plants as the UV-B dose approaches ambient levels compared to suboptimal levels of UV-B.

Enhancement of growth and accumulation of biomass has been linked to enhanced rate of photosynthesis and carbon fixation in soybean (Guruprasad *et al.,* 2007). Similarly, in cotton also the enhancement in the area of leaves may contribute to enhanced photosynthesis. The primary effect of ambient UV is on the photosynthetic apparatus that reduces rate of photosynthesis and fixation of CO_2. In cotton, exclusion of ambient UV enhanced total chlorophyll especially chlorophyll *b*. A decreased chlorophyll *b* concentration has been identified as a more common symptom of UV-B stress (Ranjbarfordoei *et al.,* 2006; Shweta *et al.,* 2006) attributed to inhibition of biosynthesis of pigments under UV-B (Charles *et al.,* 2002). An increase in total chlorophyll has also been reported in *Cymopsis* (Amudha *et al.,* 2005), Beech samplings (Laposi *et al.* 2008), *Helianthus annus* (Cechin *et al.,* 2007) and sorghum (Kataria and Guruprasad, 2012b) after the exclusion of solar UV-B.

A decrease in UV absorbing substances after the exclusion of ambient UV has consistently been reported in several plant species and the cotton plants also exhibit the same response. Enhancement in the UV absorbing substance mainly flavonoids in response to supplemental UV has been observed in many plants like soybean, sorghum etc. (Mazza *et al.,* 2000; Dubey and Guruprasad, 1999).

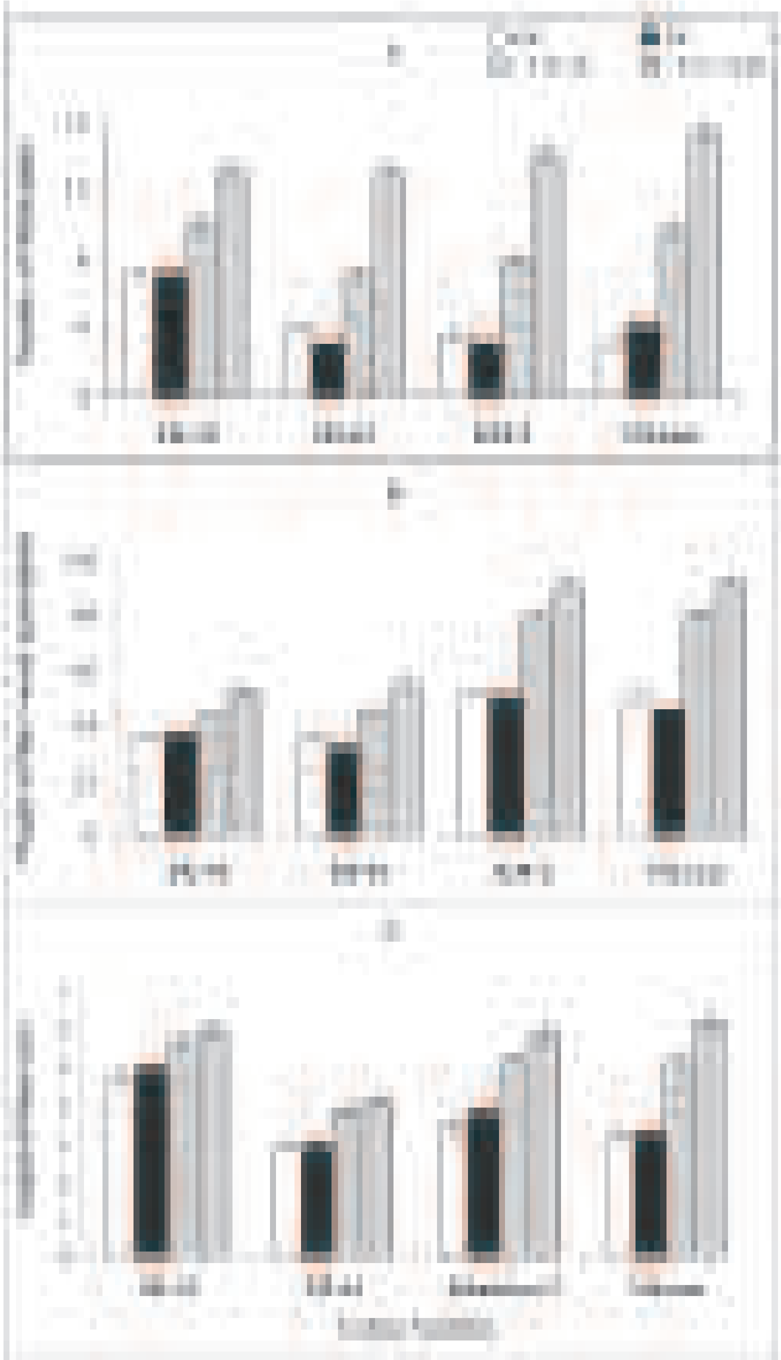


Fig. 7. Yield parameters of cotton varieties in open control, filter control, UV-B and UV-B/A excluded conditions: number of bolls per plant (A), weight of bolls per plant (B) and length of fibres (C). The vertical bar indicates ±SE for mean.

In the absence of ambient UV; reduction in the synthesis of these secondary products can save the carbon that can be channelized to primary metabolism.

In cotton plants assimilation of CO_2, stomatal conductance and net photosynthesis are enhanced significantly and stomatal resistance was decreased by UV exclusion. Net rate of photosynthesis is inversely correlated with stomatal resistance. A similar observation of

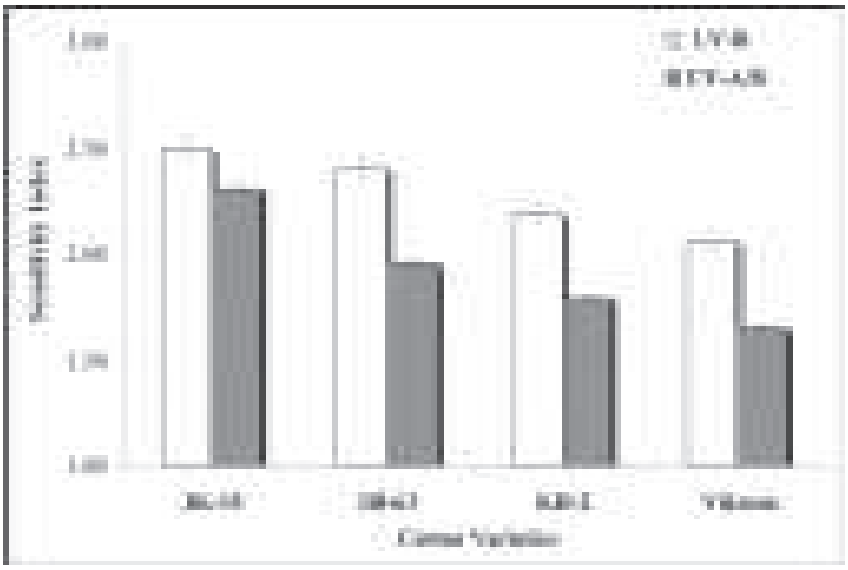


Fig. 8. UV sensitive index for sensitivity of *Gossypium hirsutum* varieties to ambient level of UV radiation by the exclusion of solar UV-B and UV-B/A. The vertical bar indicates ±SE for mean.

enhancement in the net rate of photosynthesis has been made in *Populous* (Schumaker *et al.,* 1997), maize and mung bean (Pal *et al.,* 1997), wheat and pea (Pal *et al.,* 2006) and sorghum (Kataria and Guruprasad, 2012b). A direct effect of UV-B on stomatal conductance has been reported in pea, *Commelina communis* and *Brassica napus* (Nogues *et al.,* 1999).

Although inhibition of photosynthesis by supplementary UV-B was reported earlier in cotton (Reddy *et al.,* 2004), there was no assessment of the impact of ambient UV on carbon assimilation rate. The present data establishes the influence of ambient UV on carbon fixation and assimilation in four varieties of cotton. The rate of photosynthesis is enhanced in cotton plant after the exclusion of ambient UV by enhancing the fixation of CO_2. Correlation has been observed earlier between Rubisco activity and higher yield in plants (Martinez *et al.,* 1992). Although we have not measured the activity of Rubisco, but there is an enhanced amount total leaf soluble protein in all the varieties of cotton tested in the present study. Rubisco is a key enzyme in C_3 cycle of photosynthetic fixation of CO_2 and is a remarkably abundant protein making upto 65 per cent of total soluble leaf proteins in C_3 plants (Furbank and Taylor, 1995).

Does enhancement in net rate of photosynthesis owing to UV exclusion channel the additional CO_2 fixation to the yield of cotton? The data on yield parameters indicate a significant enhancement in all the parameters tested like boll weight and number; fiber length and weight by exclusion of ambient UV. It is important to note that these parameters are enhanced to a greater extent by the exclusion of both UV-A and UV-B compared to exclusion of UV-B alone. Both enhancement in leaf area and net photosynthesis/unit area of leaf seem to contribute towards increase in the yield under the exclusion of both UV-A and UV-B. The net photosynthesis rate shows a slight decrease after exclusion of both UV-B and UV-A compared to exclusion of UV-B alone but the yield is higher inspite of this decrease owing to enhancement in the area of leaf. Reduction in fruit dry weight of cotton by supplemental UV-B has earlier been observed by Kakani *et al.,* (2003b), this reduction has however been related to higher fruit abscission or fewer bolls retained per plant and not to decrease in net photosynthesis.

Sensitivity indices have been established as useful indicators of plant sensitivity to UV-B radiation (enhanced or ambient) (Saile Mark and Tevini, 1997; Kataria and Guruprasad, 2012a). In the present study, sensitivity indices of four cotton varieties were calculated in terms of plant height, total dry weight accumulation and yield and it could reflect the overall sensitivity of cotton varieties to current level of UV radiation. The UV sensitivity index of all the varieties was significantly less than 3, which means that all of them are UV sensitive to some extent. This is the first report of intraspecific responses of Indian varieties of cotton plants to ambient solar UV in terms of growth, photosynthesis and yield by the exclusion of solar UV components. Our result reveals that Khandwa-2 and Vikram are the most sensitive and the JK-35 and IH-63 are the least sensitive variety to current level of UV (280-400 nm) radiation. Excluding UV-B (280-315 nm) and UV-A/B (280-400 nm) significantly increased plant height, leaf area, dry weight accumulation and rate of photosynthesis in all the varieties tested. But the considerable variation in the sensitivity to ambient UV-A/UV-B exists between the varieties and according to UV sensitivity index, the sensitivity can be arranged in increasing order as: JK 35 >IH 63>Khandwa 2> Vikram.

Results of experiments presented indicate the extreme sensitivity of cotton plant (*Gossypium hirsutum)* var Vikram to ambient UV. As presented here cotton plants are sensitive not only to UV-B part of the solar spectrum but also to UV-A part in terms of reduction in the height of the plants, leaf area and biomass. In conclusion exclusion of ambient UV enhances photosynthesis in cotton and channelizes the additional fixation of carbon towards improvement of yield. The data would be beneficial in testing the feasibility of using this technique for improvement of yield in cotton.

ACKNOWLEDGEMENTS

Financial support from Department of Science Technology (WOS- A Scheme- SR/WOS-A/LS101/ 2009) to S. Kataria is thankfully acknowledged. Thanks to Professor Gaikwad, Agriculture College, Indore.

REFERENCES

Agrawal, S.B., Rathore, D. 2007. Changes in oxidative stress defense system in wheat (*Triticum aestivum* L.) and mung bean (*Vigna radiata* L.) cultivars grown with and without mineral nutrients and irradiated by supplemental ultraviolet-B. *Environ. Exp. Bot.* **59** : 21-33

Albert, K.R., Mikkelsen, T.N., Ro-Poulsen H. 2005. Effects of ambient versus reduced UV-B radiation on high arctic Salix *arctica* assessed by measurements and calculations of chlorophyll-*a* fluorescence parameters from fluorescence transients. *Physiol. Plant.* **124** : 20-26.

Allen, D.J., Nogues, S. and Baker, N.R. 1998. Ozone depletion and increased UV-B radiation: is there a real threat to photosynthesis. *J. Exp. Bot.* **49** : 1775-88.

Amudha, P., Jayakumar, M., Kulandaivelu, G. 2005. Impacts of ambient solar UV (280-400 nm) radiation on three tropical Legumes. *J. Plant Biology* **48** : 284-91

Ballare, C.L., Scopel, A.L., Stapelton, A.E., Yanovsky, M.J. 1996. Solar ultraviolet-B radiation affects seedling emergence, DNA integrity, plant morphology, growth rate and attractiveness to herbivore insects in *Datura ferox*. *Plant Physiol.* **112** : 161–70.

Balakrishnan, V., Venkatesan, K., Ravindran, K. C., Kulandaivelu, G. 2005. Protective mechanism in UV-B treated *Crotalaria juncea* L. seedlings. *Plant Protect Sci* **41** : 115–20

Barsig, M., Malz, R. 2000. Fine structure, carbohydrates and photosynthetic pigments of sugar maize leaves under UV-B radiation. *J. Environ. Exp. Bot.* **43** : 121-34

Bennett, J. H. 1981. Photosynthesis and gas diffusion in leaves of selected crop plants exposed to ultraviolet-B radiation. *J. Environ. Qual.* **10** : 271-75.

Biggs, R. H., Kossuth, S. V. 1978. Impact of solar UV-B radiation on crop productivity. Final report of UV-B biological and climate effects research. *Terrestrial FY* **77** : 11-77.

Bornman, J. F. 1989. Target sites of UV-B radiation in photosynthesis of higher plants. *J. Photochem. Photobiol.* **4** : 145–58

Caldwell, M. M., Teramura, A. H., Tevini, M., Bornman, J.F., Bjorn, L.O., Kulandaivelu, G. 1995. Effects of increased solar ultraviolet radiation on terrestrial plants. *Ambio.* **24** : 166-73.

Cechin, I., Fumis, T.D.F., Dokkedal, A. L. 2007. Growth and physiological responses of sunflower plants exposed to ultraviolet-B radiation. *Ciencia Rural* **37**: 85-90

Charles, F.M., Samson, B.M.C., Felix, D.D. 2002. Effects of elevated ultraviolet-B radiation on native and cultivated plants of Southern Africa. *Annals Botany* **90**: 127-37

Correia, C.M., Torres Perira, M.S., Torres Pereiara, J.M.G. 1999. Growth, photosynthesis and UV-B absorbing compounds of Portuguese Barbela wheat exposed to ultraviolet-B radiation. *Environmental Pollution* **104** : 383-88

Coleman, R.S. and Day, T. A. 2004. Response of cotton and sorghum to several levels of subambient solar UV-B radiation: a test of the saturation hypothesis. *Physiol. Plant.* **122** : 362-72

Dai, Q., Peng, S., Chavez, A.Q., Vergara, B.S. 1994. Intraspecific response of 188 rice cultivars to enhanced ultraviolet-B radiation. *Environ. Exp. Bot.* **34** : 433-42.

Day, T. A. and Neale P. J. 2002. Effects of UV-B radiation on terrestrial and aquatic primary producers. *Annu. Rev. Ecol. Syst.* **33** : 371-96.

Dubey, A. and Guruprasad, K. N. 1999. Induction of anthocyanin synthesis by UV-B in *Sorghum bicolor* seedlings-Dependence on *de novo* synthesis of phenylalanine ammonialyase. *J. Plant Biol.* **26** : 225–29

Gao, W., Zheng, Y., Slusser, J. R., Heisler, G. M., Grant, R. H., Xu, J. Douliang, He 2004. Effects of supplementary ultraviolet-B irradiance on maize yield and qualities: a field experiment. Photochem. *Photobiol.* **80** :127-31.

Germ, M., Kreft, I. and Osvald, J. 2005. Influence of UV-B exclusion and selenium treatment on photochemical efficiency of photosystem II, yield and respiratory potential in pumpkins (*Cucurbita pepo* L.). *Plant Physiol. Biochem.* **43** : 445-48

Ghisi, R., Trentin, A.R., Masi, A. and Ferretti, M. 2002. Carbon and nitrogen metabolism in barley plants exposed to UV-B radiation. *Physiol. Plant.* **116** : 200-05.

Guruprasad, K., Bhattacharjee, S., Kataria, S., Yadav, S., Tiwari, A., Baroniya, S., Rajiv, A. and Mohanty, P. 2007. Growth enhancement of soybean (*Glycine max*) upon exclusion of UV-B and UV-A components of solar radiation: characterization of photosynthetic parameters in leaves. *Photosyn. Res.* **94** : 299-06

Kakani, V.G., Reddy, K.R., Zhao, D. and Sailaja, K. 2003a. Field crop responses to ultraviolet B radiation. *Ann. Rev. Agric Meteor* **120**: 191-218

Kakani, V. G., Reddy, K.R., Zhao, D. and Mohammed, A.R. 2003b. Effects of ultraviolet-B radiation on cotton (*Gossypium hirsutum* L.) morphology and anatomy. *Ann. Bot.* **91**: 817-26.

Kataria, S. and Guruprasad, K.N. 2012a. Solar UV-B and UV-A/B exclusion effects on intraspecific variations in crop growth and yield of wheat varieties. *Field Crops Res.* **125**, 8-13.

Kataria, S. and Guruprasad, K. N. 2012 b. Intraspecific variations in growth, yield and photosynthesis of sorghum varieties to ambient UV (280-400nm) radiation. Plant Sci. http://dx.doi.org/10.1016/*j. plantsci.* 2012.07.011

Keiller, D.R. and Holmes, M.G. 2001. Effects of long-term exposure to elevated UV-B radiation on the photosynthetic performance of five broad-leaved tree species. *Photosynth. Res.* **67** : 229-40

Laposi, R., Veres, S. and Meszaros, I. 2008. Ecophysiological Investigation of UV-B tolerance of Beech saplings (*Fagus sylvatica* L.). *Acta Silv. Lign. Hung.* **4**: 7-16

Lowry, O.H., Rosebrough, N.J., Farr, A.L. and Randall, R.J. 1951. Protein measurements with the follin phenol reagent. *J. Biol. Chem.* **193**: 165-275

McKenzie, R.L., Aucamp, P.J., Bais, A.F., Bjorn, L.O. and Ilyas, M. 2007. Changes in biologically active ultraviolet radiation reaching the Earth's surface. *Photochem. Photobiol. Sci.* **6** : 218-31.

Martinez-Barajas E, Villanueva V.C., Molina Galan J., Loza Tavera H. and Sanches de Jimenez, E. 1992. Relation of Rubisco to maize grain - yield improvement - effect of water restriction. *Crop Sci.* **32**: 718-22

Martz, F., Sutinen, M.L., Derome, K., Wingsle G., Julkunen-Tittoo, R. and Turunen, M. 2007. Effect of UV-exclusion on the seasonal content of photosynthetic and UV screening pigments of scot pine needles. *Global Change Biol.* **13** : 252-65

Mazza, C.A., Boccalandro, H., Giordano, C.V., Battista, D., Scopel, A.L. and Bailar, C.L. 2000. Functional significance and induction by solar radiation of UV-absorbing sunscreens, in field grown soybean crops. *J. Plant Physiol.* **122** : 117-25

Melis, A., Nemson, J.A. and Harrison, M.A. 1992. Damage to functional components and partial degradation of photosystem II reaction centre proteins upon chloroplast exposure to ultraviolet-B radiation. *Biochem. Biophys. Acta* **1109** : 312–20

Murali, N.S., Teramura, A.H. 1986. Effectiveness of UV-B radiation on the growth and physiology of field-grown soybean modified by water stress. *Photochem. Photobiol.* **44**: 215-19.

Nogues S., Allen, D.J., Morison, J.I.L., Baker, N.R. 1999. Characterization of stomatal closure caused by ultraviolet-B radiation. *J Plant Physiol.* **121**: 489–496

Pal, M., Sharma, A., Abrol, Y.P. and Sengupta, U.K. 1997. Exclusion of solar UV-B radiation from normal spectrum on growth of mungbean and maize. *Agri Eco Environ.* **61**: 29-34

Pal, M., Zaidi, P.H., Voleti, S.R. and Raj, A. 2006. Solar UV-B exclusion effects on growth and photosynthetic characteristics of wheat and pea. *J. New Seeds* **8**: 19-34

Ranjbarfordoei, A., Samson, R. and Van Damme P. 2006. Chlorophyll fluorescence performance of sweet almond (*Prunus dulcis* (Miller) D. webb) in response to salinity stress induced by NaCl. *Photosynthetica* **44**: 513-22

Reddy, K. R., Kakani, V. G., Zhao, D., Koti, S. and Gao, W. 2004. Interactive effects of ultraviolet-B radiation and temperature on cotton physiology, growth development and hyperspectral reflectance. *J Photochem. Photobiol.* **79**: 416–27

Saile-Mark, M., Tevini, M. 1997. Effects of solar UV-B radiation on growth, flowering and yield of central and southern European bush bean cultivars (*Phaseolus vulgaris* L.). *Plant Ecol.* **128** : 115–25.

Schumaker, M.A., Bassman, J.H., Robberecht R., Radamaker, G.K. 1997. Growth, leaf anatomy and physiology of *Populus* clones in response to solar ultraviolet-B radiation. *Tree Physiology* **17** : 617-26

Shweta, M., Agrawal, S.B. 2006. Interactive effects between supplemental ultraviolet-B radiations and heavy metals on the growth and biochemical characteristics of *Spinacia oleracea* L.Brazilian *J Plant Physiol.* **18** : 307-14

Sullivan, J.H., Teramura, A.H. 1990. Field study of the interaction between solar ultraviolet-B radiation and drought on photosynthesis and growth in soybean. *Plant Physiol.* **92** :141–46.

Teramura, A.H. and Murali N.S. 1986. Intraspecific differences in growth and yield of soybean exposed to ultraviolet-B radiation under greenhouse and field conditions. *Environ. Exp. Bot.* **26**: 89–95.

Teramura, A.H. and Sullivan, J.H. 1994. Effects of UV-B radiation on photosynthesis and growth of terrestrial plants. *Photosynthesis Research* **39** : 463-73.

Teramura, A.H., Ziska, L.H., Sztein, A.E. 1991. Changes in growth and photosynthetic capacity of rice with increased UV-B radiation. *Physiol. Plant.* **83** : 373–80.

Wellburn, A.R. and Lichtenthaler, H. 1984. Formulae and programme to determine total carotenoids and chlorophylls *a* and *b* of leaf extracts in different solvents. In: Sybesma C (ed) *Advances in Photosynthesis Research,* Martinus Nijhoff/Dr. W. Junk Publishers, Boston pp 9-12

Xiong, F.S., Day, T.H. 2001. Effect of solar ultraviolet-B radiation during springtime ozone depletion on photosynthesis and biomass production of Antarctic vascular plants. *J. Plant Physiol.* **125** : 738–51.

Xiong, F.S., Ruhland, C.T., Day, T.A. 2002. Effect of springtime solar ultraviolet-B radiation on growth of *Colobanthus quitensis* at Palmer Station, Antarctica. *Global Change Biol.* **8** : 1146-55.

Yang, Y., Yao, Y., Xu, G., Li, C. 2005. Growth and physiological responses to drought and elevated ultraviolet-B in two contrasting populations of *Hippophae rhamnoides*. *Physiol Plant* **124**: 431–40

Zavala, J.A., Botto, J.F. 2002. Impact of solar UV-B radiation on seedling emergence, chlorophyll fluorescence and growth and yield of radish (*Raphanus sativus*). *Funct Plant Biol.* **29** : 797-804

Zhao, D., Reddy, K.R., Kakani, V.G., Mohammed, A., Read, J.J., Gao, W. 2004. Leaf and canopy photosynthetic characteristics of cotton under elevated CO_2 and UV-B radiation. *J. Plant Physiol.* **161** : 581-90

Quality assessment of indian cotton harvested using spindle picker *vis-a-vis* effectiveness of cleaners in its processing

S. K. SHUKLA*, P. G. PATIL, JYOTI M. NATH, V. G. ARUDE AND G. MAJUMDAR
Ginning Training Centre, Central Institute for Research on Cotton Technology, Nagpur – 440 023
**E-mail : skshukla2000@gmail.com*

Abstract : Present study assesses the quality of machine picked cotton and evaluates the performance of pre cleaners specially developed at GTC, Nagpur to process the machine picked cottons. The moisture content and temperature in cotton were 5 per cent and 39°C, respectively. The trash content present in the control sample was separated manually so as to avoid its damage in the ginning machinery. A set of pre cleaning machinery consisting of a cylinder type pre cleaner, a 3-stage stick removal machine and a saw band cleaner has been used for pre-cleaning of machine picked cotton. A double roller gin was used for ginning of the pre cleaned cotton. The fibre quality at each stage of machine operation was measured using HVI. The percentage of trash content present at each stage of processing was determined using an indigenous trash separator. The performance of a cleaner was assessed by its cleaning efficiency *i.e.* the percentage of trash content removed from the cotton. The trash content present in the machine picked cotton using spindle type picker can be classified into four major groups *i.e.* green and dry leaves, burs, sticks, immature seeds/mote. The analysis of results suggested that the machine picked cotton contains around 19.26 per cent total trash content among which the dry leaves is highly significant (*i.e.* 13.45%) compared to the large foreign matters (such as sticks and burs). The length and diameter of sticks present in the machine picked cotton varies from 2-40 mm and 1-25 mm, respectively. The overall cleaning efficiencies of pre-cleaner, stick machine and saw band cleaner have been found as 20.45, 41.86 and 23.59 per cent, respectively. The average percentage of trash content present in the machine picked cotton has been brought down to 3.11 per cent using saw cylinder cleaner in combination with the cylinder cleaner and stick machine. The analysis of fibre parameters suggest that the pre-cleaning operations do not make any significant difference in the fibre properties.

India ranks first in area under cotton cultivation and is the second largest producer of cotton fibre in the world after China with 34.25 million bales (*i.e.*170 kg each) production in 2011-2012. Unlike developed cotton growing countries (*i.e.* USA, Australia, Israel, etc.) where cotton is harvested using sophisticated machines, entire cotton in India is picked manually (Shukla *et al.*, 2006). The cost of cotton picking in India (*i.e.* around Rs. 10/kg cotton) has quadrupled in last 4-5 years, mainly due to high inflation rate, migration of landless farm labours to cities and implementation of the *National Rural Employment Guarantee Act* (*NREGA*). Moreover, delay in the cotton harvesting due to the shortage of labours results in the delay in sowing of the next crop leading to low yield (Prasad and Majumdar, 1999). In order to meet the scarcity of labour and to reduce the cotton picking cost, efforts need to be concentrated on mechanization of cotton harvesting (Shukla *et al.*, 2006).

The average farm holding in India is less than 2 hectare and size of Indian cotton fields is very small (Anonymous, 2012). The machine pickers available in the world market are very large in size and capacity (Corley and Stokes, 1964), hence they are unsuitable for cotton pickings in small Indian cotton farms. Dedicated work at different Indian Cotton Research Institutes and by Indian as well as foreign agricultural machinery manufacturers is going on for past one decade towards development of a suitable cotton picking machine for small sized Indian farms. Researchers have tried different picking methods (*i.e.* pneumatic suction, pneumatic suction cum picking brushes, sensor techniques, conventional spindle type pickers, etc.) for harvesting of cotton (Muthamilselvan *et al.*, 2007). However, most of these methods did not perform well under field conditions (Asola, 1996). The major stumble blocks in the success of these methods are availability of a suitable cotton hybrid/variety for mechanical picking (maximum height and width of cotton crops for mechanical harvesting are 4 and 2 feet, respectively), practice of multiple pickings, non-standardization of defoliant application technology, development of suitable cleaning systems, etc.

It has been observed by the numerous researchers that among the different methods tested for cotton picking, the conventional spindle type picker based mechanism appeared to be working satisfactorily for picking of cotton. This method was also evaluated in Indian cotton farms by cotton pickers imported from then USSR (Singh *et al.*, 1992). However, further progress in this direction was constrained by the fall of former USSR. Efforts have been made by the researchers and agricultural machinery manufacturers for attaching the cotton picking heads on the side of existing tractors so as to avoid high initial investment in purchasing a self-propelled spindle type picker. It is widely reported in literature (Anthony and Mayfield, 1994, Muthamilselvan *et al.*, 2007, Sandhar, 1999, Singh *et al.*, 1992, Sui *et al.*, 2010) that the machine picked cotton contains around 10-15 per cent trash content, which includes burs, sticks, leaves, grasses, motes, etc. However, the non-standardization of defoliants under Indian conditions has resulted in around 20-25 per cent trash content in machine picked cotton. A set of special machines is required to pre clean the machine picked cotton. Such machines are not readily available in local market and import is unviable and very costly. Ginning Training Centre (GTC) of CIRCOT, Nagpur is working in tandem with the cotton picker research group towards development of a cleaning system suitable for pre cleaning of machine picked cotton.

The aim of this paper is twofold. The first part presents the statistics of trash content present in the machine picked cotton supplied by M/s. John Deere India from its Aurangabad (MS) farm. This cotton was harvested using conventional spindle picker attached at the side of a tractor in 2011-2012. The second part is devoted towards the performance evaluation of cleaning machines developed at GTC of CIRCOT, Nagpur for pre-cleaning of machine picked cotton. Fibre quality evaluation at each stage of cleaning operation is also presented in this work.

MATERIALS AND METHODS

In the present work, a spiked cylinder pre-cleaner, a three stage stick remover machine and a saw band cleaner were used to pre-clean the machine picked cotton. These machines were developed at GTC of CIRCOT, Nagpur for processing of machine picked cotton. The stick remover machine mainly utilizes the sling off action of saw cylinders for removal of trash content while the spiked cylinder cleaner mainly uses the centrifugal action of spiked cylinders for trash content removal. However, the saw band cleaner employs both the centrifugal action of spiked cylinders and sling off action of saw cylinders for removal of fine trash content from machine picked cotton. The sequence of the cleaning machinery adopted in this work for processing of the machine picked cotton is given in Fig. 1.

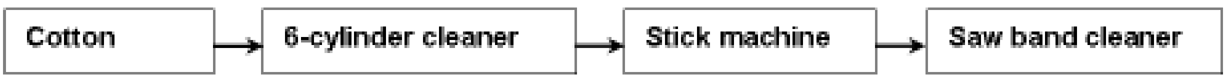
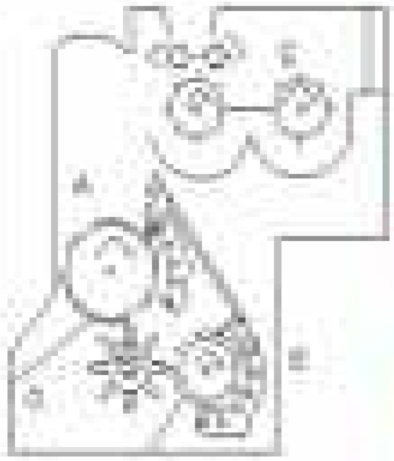


Figure 1. Sequence of machines employed for pre-cleaning of the machine picked cotton

The details of stick remover machine and spiked cylinder cleaners can be found from published work of Shukla *et al.,* (2006) and Patil *et al.,* (2008), respectively. The saw band cleaner consists of a hopper, feeder rollers, opening cylinders, saw band cylinders, doffing brush cylinders, loading brushes, grid bars and deflectors (Fig.2). The cylinder cleaning stage of the machine employs two numbers of spiked cylinders for opening and cleaning of the cotton. Then, the cotton is kicked to the saw band-cleaning stage. In the saw band stage of cleaning a saw band cylinder is used to clean the cotton with the help of combing and centrifugal actions of its cylinders. From there, the cotton is fed to reclaiming stage of machine. In the reclaiming stage of the machine a saw band cylinder is used to recover the good fibres from waste of the first stage. The trash content removed in each stage and cleaned cotton was routed directly out of the



A-Main Saw Cylinder; O-Doffing Brush Cylinder; E-Reclaimer Cylinder; C-Spiked Cylinders

Fig. 2. Interval details and picture of saw band cleaner

machine.

Since the machine picked cotton contains a significant amount of the dry leaves, which are broken and completely mixes with the lint and cottonseed during ginning operation, it becomes very difficult to determine the trash content in the machine picked cotton by usual procedure (*i.e.* ginning of cotton and determination of trash content using trash separator). Therefore the trash content of the machine picked cotton was evaluated employing labourers, who separated the foreign matters from the machine picked cotton manually. Three samples weighing 300 g each of the machine picked cotton were analysed for their trash content.

Due to limited availability of the machine picked cotton, the present study was limited to only one trial of 200 kg for performance evaluation of cleaning machines. The cotton was fed manually and uniformly to each machine. Three samples of 600 g each was collected after passing from each machines. The cleaned cotton obtained from each machine and the control were ginned on a double roller gin. The lint samples obtained after ginning were analysed on MAG-SITRA trash separator for fine trash content and on High Volume Instrument (HVI) for its fibre properties. The moisture content and temperature during each cleaning operation was maintained at 5 per cent and 39°C, respectively.

RESULTS AND DISCUSSION

Analysis of trash content : The constituents of the of trash content in the machine picked cotton as its average weight in gram and as average percentage of the lint are given in Table 1. It can be seen from this table that the machine picked cotton contains around 19.26 per cent total trash content where the percentage of dry leaves is highly significant (*i.e.* 13.45%) compared to the large foreign matters (such as sticks and burs), which requires special machines for its separation. In contrast to the previous study, the percentage of large trash content present in the machine picked cotton is significantly on the lower side as depicted in Table 1. Analysis of fibre parameters of the machine picked cotton is given in Table 2.

The length and diameter of the sticks separated from the samples of 300 g machine cotton have been given in Table 3 and Table 4. It can be seen from Table 3 that the length of the sticks present in the machine picked cotton

Table 1. Constituents* of trash content in the machine picked cotton

cotton (g)	Lint (g) (g)	Cotton seed	Trash content	Bracts/ burs	Sticks	Green leaves	Immature seeds/ motes	Dry leaves	Total trash content
300	105	195	(g)	3.96	0.7	0.85	0.32	14.34	20.17
			(%)	3.83	0.7	0.93	0.35	13.45	19.26

* Average value of three samples

Table 2. Fibre parameters of the machine picked cotton without any treatment

2.5 per cent span length (mm)	Micronaire value (g/inch)	Bundle strength (g/tex)	Uniformity ratio (%)
29.9	3.2	22.3	46

Table 3. Length and number of sticks present in the machine picked cotton

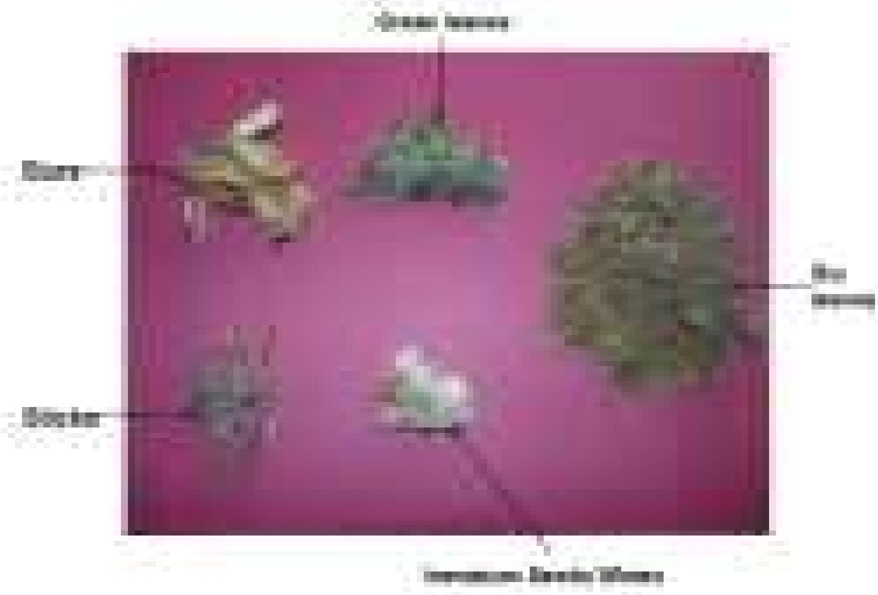
Length of sticks (mm)	2-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	2-40
Number of sticks	2	7	10	6	7	1	3	3	39

Table 4. Diameter and number of sticks present in the machine picked cotton

Dimensions of sticks (mm)	0.1 to 0.50	0.50 to 1.00	1.01 to 1.50	1.51 to 2.00	2.01 to 2.50
Number of Sticks	1	15	17	5	1

varied from around 2 to 40 mm. However, the majority of the sticks were in the range of 2 to 25 mm length. Similarly, the measurement of diameter of the sticks shows that sticks lies in the diameter range of 0.1 to 2.5 mm. It can be concluded from this measurement that the sticks present in the machine picked cotton are very small in size. Separated foreign matters from a sample of 300 g machine picked cotton are depicted in Fig. 3.

Performance evaluation of cleaning machines : Data in Table 5 showed the average



weight of trash content and percentage of trash content to the lint of the control and after each cleaning treatment. It can be seen from this table that the total trash content present in the control is around 8.8 per cent, which is much below the 19.26 per cent trash content depicted in Table 1 for the machine picked cotton. It is mainly due to the reason that the dry leaves which are dominantly present in the machine picked cotton get crushed and finely mixed during ginning leading to separation of finely mixed particles partly through the grids along with the cottonseed and partly along with the lint, which could not be even separated using the trash separator.

Data in Table 5 showed that the average percentage of foreign matter content present in cotton is reduced to 7.0 from 8.8 per cent after processing in the six cylinders cleaner. Thus, the overall cleaning efficiency of this machine is found to be 20.45 per cent as depicted in Table 6. Hence it is evident that the cylinder cleaner is very efficient in removing fine trashes from the machine picked cotton. On the contrary, the stick and burs removal efficiencies of this machine have been found as 10.17 and 15.38 per ent only. This phenomenon can be explained with the working principle of the cylinder cleaner. The cylinder cleaner removes the trash content by scrubbing and beating the cotton over its grid bars. Hence the fine trash content and the heavy particles which are not tightly entangled with the fibres are separated while the trash content, which are present in the inner lock of the cotton and particles which are tightly entangled with the fibres could not be separated in this machine. In addition to the removal of fine trash content, the cylinder cleaner opens the wads of the cotton resulting in the separation of the large trash particles in the next cleaning machines

Table 5. Constituents of trash content of machine picked cotton at various cleaning machines

	Cotton (g)	Lint (g)	Trash content	Bracts/ burs	Sticks	Green leaves	Immature seeds/ motes	Dry leaves	Total
Control	600	241	(g)	6.9	1.4	5.21	0.3	7.4	21.21
			(%)	2.86	0.59	2.16	0.12	3.07	8.8
Cylinder cleaner	600	238	(g)	5.77	1.27	2.93	0.1	6.6	16.67
			(%)	2.42	0.53	1.23	0.04	2.77	7
Stick machine	600	230	(g)	2.06	0.72	1.38	0	5.2	9.36
			(%)	0.9	0.31	0.6	0	2.26	4.07

Table 6. Effectiveness of cleaning machines in percentage for removing trash content from machine picked cotton

	Bracts/ burs	Sticks	Green leaves	Immature seeds/motes	Dry leaves	Total
Cylinder cleaner	15.38	10.17	43.06	66.67	9.77	20.45
Stick machine	62.81	41.51	51.22	100	18.41	41.86
Saw band cleaner	51.11	100	13.33	0	4.87	23.59

Table 5 shows that the average percentage of trash content present in the machine picked cotton has been reduced to 4.07 per cent after processing in the stick machine in combination to inclined cylinder cleaner. Hence, the overall cleaning efficiency of this machine is 41.86 per cent as shown in Table 6. In addition, the burs removal, sticks removal and green leaves removal efficiencies of this combination have been found as 62.81, 41.51 and 51.11 per cent, respectively. It is evident from this data that the stick machine is very efficient in removing large foreign matter content from machine picked cotton. It is mainly due to reason that the combing and sling off actions of this machine dislodge the large trash content from the cotton leading to their separation.

Table 5 further depicted that the average percentage of foreign matter content present in the machine picked cotton has been brought down to 3.11 per cent using saw cylinder cleaner in combination with the cylinder cleaner and stick machine. Hence, the overall cleaning efficiency of this machine is 23.59 per cent. In addition, this machine is very efficient in removing the burs from the machine picked cotton. It can be observed from the data Table 5 that all the sticks present in the machine picked cotton have been successfully removed using the specified sequence of machinery. It is evident from Table 6 that the saw band cleaner is almost equally efficient for removal of all type of foreign matter content.

Fibre properties measured by High Volume Instrument (HVI) : Fibre properties of machine picked cotton at different stages of processing and the control are presented in Table 7. It is evident from this table that the pre cleaning operations have not made any significant difference in the fibre properties represented by 2.5 per cent span length (SL), uniformity ratio (UR), micronaire value and bundle strength. The pictures of the machined picked cotton and cleaned lint is given in Fig. 4.

CONCLUSIONS

This study presents the statistics of trash content present in the machine picked cotton and evaluates the performance of pre cleaners (*i.e.* spiked cylinder pre cleaner, stick remover machine and saw band cleaner) specially developed at GTC, Nagpur in cleaning the machine picked cotton. The sequence of cleaning machines for cleaning of machine picked cotton used in this work were spiked cylinder pre-cleaner, stick remover machine and saw band cleaner. Following conclusions can be presented:

- The machine picked cotton analysed in this work contained around 19.26% total trash content among which the percentage of dry leaves is highly significant (*i.e.* 13.45%) compared to the large foreign matters (such as sticks and burs).
- The length and diameter of sticks present in the machine picked cotton varied from

Fig. 4. Pictures of the machine picked cotton and cleaned lint obtained

Table 7. Fibre parameters of the machine picked cotton at each cleaning machine

	2.5 per cent span length (mm)	Micronaire value (µg/inch)	Bundle strength (g/tex)	Uniformity ratio (%)
Control	29.9	3.2	22.3	46
Cylinder cleaner	29.4	3.1	23.7	49
Stick machine	29.0	3.1	22.1	49
Saw band cleaner	29.8	3.1	22.0	48

2-40 mm and 0.1-2.5 mm, respectively.

- The overall cleaning efficiencies of pre cleaner, stick machine and saw band cleaner have been found as 20.45, 41.86 and 23.59 per cent, respectively.
- The average percentage of trash content present in the machine picked cotton has been brought down to 3.11 per cent using saw cylinder cleaner in combination with the cylinder cleaner and stick machine.
- The analysis of fibre parameters suggest that the pre cleaning operations did not make any significant difference in the fibre properties.

REFERENCES

Anonymous, 2012. Agriculture in India. Wikipedia (status Sept 21, 2012), http://en.wikipedia.org/wiki/Agriculture_in_India.

Anthony, W.S. and Mayfield, W.D., 1994. *Cotton Ginners Handbook*. The United States Department of Agriculture (USDA).

Asola, C.N., 1996. Field performance evaluation of a manually opearted cotton picker. Agricultural Mechanization in Asia, Africa and Latin America (AMA), **27(4)**: 24-26.

Corley, T.E. and Stokes, C.M., 1964. Mechanical cotton harvester performance as influenced by plant spacing and varietal characteristics. Transaction ASAE, **7(9)** : 281-86; 96.

Muthamilselvan, M., Rangasamy, K., Ananthakrishnan, D. and Manian, R., 2007. Mechanical picking of cotton - a review. *Agric. Rev.,* **28(2)** : 118-26.

Patil, P.G., Shukla, S.K. and Manojkumar, T.S., 2008. Effects of spiked cylinders and saw band cleaners on trash removal efficiency and fibre properties of cotton. *Jour. Agricul. Engin.* **45 (2)**.

Prasad, J. and Majumdar, G., 1999. The present practices and future needs for mechanization of cotton picking in India. Agricultural Engineering Today **23(5-6)**: 1-20.

Sandhar, N.S., 1999. Present practices and future needs of mechanization of cotton picking/harvesting in India, Indo-Uzbek Workshop on Agricultural Research, CIAE, Bhopal, MP, India.

Shukla, S.K., Patil, P.G. and Arude, V.G., 2006. Design development and performance evaluation of saw cylinder cleaner for mechanically picked cotton. Agricultural Mechanization in Asia, Africa and Latin *America (AMA)* **37(1**): 30-34.

Singh, T.H., Brar, A.S., Thind, R.J.S., Prakash, R. and Vithal, B.M., 1992. Mechanical picking of cotton in Punjab: a preliminary study. *J. Indian Soc. Cott. Improv.*: 62-67.

Sui, R., Thomasson, J.A., Byler, R.K., Boykin, J.C. and Barnes, E.M., 2010. Effect of machine fibre interaction on cotton fibre qulity and foreign matter particle attachment to fibre. *Jour. Cotton Sci.*, **14**: 145-53.

Symposium papers "Global Cotton Production Technologies *vis-a-vis* Climate Change" 102-107

Performance of hybrids produced by different systems for yield and quality in *Gossypium hirsutum* L

S. S. SIWACH* AND R.S.SANGWAN

Department of Genetics and Plant Breeding, CCS Haryana Agricultural Unviersity, Hisar - 125 004
**E-mail : profsssiwach@gmail.com*

Abstract : Cotton is an important commercial crop of India. *Gossypium hirsutum* is the most commonly grown species among the four cultivated species. Noticeable heterosis has been reported in cotton. Hybrid seed in most of the cases is produced by conventional method. The cost of hybrid seed produced by the conventional method is high because of high labour requirement in the process of emasculation and secondly setting per cent of crossed bolls is also low. Hybrid seed production cost in cotton could be reduced significantly by using the male sterility approach. Performance of cotton hybrids produced by different breeding methods was compared for seed cotton yield, ginning outturn (%), 2.5 per cent span length (mm), fibre strength (g/tex) and micronaire value (ug/in) for three years. Overall mean performance of 191 cytoplasmic genetic male sterility based hybrids; 123 genetic male sterility based hybrids and 155 conventional hybrids revealed that conventional hybrids produced the maximum seed cotton yield (2225 kg/ha) followed by genetic male sterility based hybrids (2157 kg/ha). The cytoplasmic genetic male sterility hybrids performed poorly with mean values of 1406 kg/ha. The ginning out turn, 2.5 per cent span length, fibre strength and micronaire values of all the hybrids produced by different methods were almost similar.

Key words : Cytoplasmic genetic male sterility, heterosis, fibre length, micronaire value

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. The genus *Gossypium* has four cultivated species (two each of diploid and tetraploid). India is the only country where all the four species are commercially cultivated. Flowers of cotton plant are bisexual. Pollen of cotton being heavy and sticky and is not wind blown. Pollination is predominantly autogamous with some entomophyllous cross pollination. Allogamy is usually 0 to 5 per cent depending upon honey bee's population. Anthesis takes place around 9.00 a.m. to 12.00 noon with some variation depending upon the climatic conditions. By and large, both male and female organs of flowers mature at the same time. Mehetre, (1992) observed very low natural out crossing in cotton. Patel and Mehta (1985) recorded 11.3 per cent cross pollination in CMS lines. Bhale and Bhatt (1989) and Avtar *et al.,* (1994) studied honey bee population under controlled conditions and reported the overall efficiency and superiority of hand pollination over natural pollination.

A noticeable heterosis for seed cotton yield has been reported by many workers (Khadi *et al.*,1993, Wang and Li 2002), although it is not widely utilized in cotton as compared to pearl millet and maize due to difficulty in producing cheap commercial hybrid seed. The major reason of not widely utilizing heterosis in cotton is the high cost of hybrid seed production due to hand emasculation and pollination as it involved high amount of skilled manpower (Raut,1998). For better exploitation of heterosis, the hybrid seed production, should be easy cheap and economical.

There are four approaches of hybrid seed production *i.e.* the removal of male reproductive organ by hand emasculation or introducing male sterility by different means *i.e.* chemical hybridizing agents or genetic male sterility (GMS) or cytoplasmic genetic male sterility (CGMS). The chemical hybridizing agents' method is not feasible in cotton due to long flowering period. Most of hybrid seed production in major cotton growing countries like India and China is done by hand emasculation and pollination. The cost of hybrid seed produced by this method is very high because of high labour requirement in the process of emasculation and setting per cent of crossed bolls is also low It varies from 20 to 40 per cent depending upon location, genotype, wind direction and speed, skill of labour and climatic conditions.

Genetic male sterility system (GMS) : In *hirsutum* cotton loci ms 5 ms5 ms6 ms6 behaving as duplicate recessive genes results effective and usable genetic male sterility. The potential female parent of a hybrid can be converted into GMS line by backcrossing programme and finally selecting a line for sterility which is heterozygous for one locus. GMS line is maintained by mating the sterile plants with fertile heterozygote within the same GMS population and hand pollination is practiced. The identification of sterile and fertile plants is easy as anther lobes of sterile plants will be shriveled and devoid of pollen grains but in fertile plants anther lobes will be fluffy and full of pollen grains. Thus fifty per cent plants *i.e.* fertile heterozygote can be rogued out easily and sterile plants will be used as female parent for hybrid seed production. This method is costly as compared to cytoplasmic genetic male sterility (CGMS) system but far better to conventional method. By using GMS system the cost of hybrid seed production can be reduced to more than 50 per cent of conventional method.

Use of cytoplasmic genetic male sterility (CGMS) in cotton hybrid seed production appears to be advantageous in several ways. Meyer (1975) reported that transfer of the *G. hirsutum* genome into *G. harknessii* produces complete male sterility.. Maintenance of CGMS population for seed production is easier as compared to genetic male sterility. Shroff (1980), observed the expression of male sterility (CMS-A) to be stable at different temperature, day length and no effect of ageing in various hybrids. Sometime problem of fertility restoration in A x R hybrids have been observed (Unpublished reports). This may be caused by specific climatic conditions which restrict the R line to restore the fertility and such situation may be specific to genotype and environmental conditions and it needs further investigation to confirm. Cytoplasmic male sterile lines in *G. harknessii* background had reduced flower, petal and anther size and less number of anthers than their counterpart fertile line. Such markers can be used in establishing identity of parental lines and genetic purity. Cross of female line with fertility restorer line again restores the flower size and number of anthers. In various studies it was reported that *G. harknessii* cytoplasm has detrimental effect on yield and yield components (Weaver, 1986; Wei *et al.,* 1995, Lather *et al.,* 2001). Although only few wild species are involved in the development of CMS lines in cotton, the vast array of wild species in cotton offers great scope for development of cytoplasmic genetic male sterility through diversified sources to avoid danger of monoculture.

Narayanan *et al.,* (2004) reported *G. harknessii*, *G. anomalum* and G. *aridum* as important sources of sterile cytoplasm for *hirsutum* cotton. Thus, the development of hybrid based on male sterility system is the necessity to reduce the cost of hybrid seed.

Higher seed cotton yield is the prime target in any breeding programme. Hence concerted efforts were made to compare the seed cotton yield of hybrids developed by different methods *i.e.* conventional, cytoplasmic genetic male sterility and genetic male sterility.

MATERIALS AND METHODS

The experiment was conducted continuously for three years to compare the performance of cotton hybrids produced by conventional method, cytoplasmic genetic male sterility and genetic male sterility system. A gene pool of promising genotypes was developed to be used as male parents. Superior genotypes for different traits were identified and converted into cytoplasmic male sterile lines (A) and genetic male sterile lines.

Majority of CMS (A) lines had sterile cytoplasm of *harknessii*. The fertile counterpart of CMS (A) lines were used as maintainer lines (B); the potential restorer lines were identified for restorability of fertility of CMS A lines to produce the fertile hybrid. During the year 2002-2003, 2003-2004 and 2004-2005 forty one diverse CMS (A) lines namely RS 875, RS 2013, SH 175, H 1117, HS 182, H 1180, Super okra, RS 810, CAK 053, CAK 8835 (*aridum*), CAK 3456 (*aridum*), CAK 1234, Supriya, Suman, Laxmi (C), Akola 442, LRA 5166, LRK 516, PKV Rajat, LCMS 3, LCMS 509, LCMS 2, LCMS 5, RCMSA 2, RCMSA 3, DMSA 20, J 205, CIR 59, GSCMS 24, GSCMS 31, L 89, L 603, LCM 501, LCMS 511, RCMS 5, RCMS 6, HCMS 11, CAK 2160, CAK 8801, CAK 8, NH 258 were used in the development of hybrids. The restorers used as male parents for restoration of fertility of CMS (A) lines were Athens, AKH 073, AKH 07, DHY 286-1, GSR-6, GSR-22, AKH 98-81, AKH 98-8, AKH 39, GSRH 24, DR 4, DR 104, DR 2, AKH 0816, AKH 186, LR 103, GSRH 41, GSRH 26, CIR 6, DR 8 and DR 7, HGMS-1, HGMS 2, HGMS 3, HGMS 4, HGMS 5, HGMS 6, HGMS 7, HGMS 17, H. Super Okra, H 1117, H 999, H 974, MCU 5, Gregg-1 and Gregg 2. The number of hybrids developed by cytoplasmic genetic male sterility, genetic male sterility and conventional methods were 68, 21 and 68 in the year 2002-2003; 15, 33 and 41 in the year 2003-2004 and 108, 69 and 46 in the year 2004-2005 respectively and same were tested in different trials.

The material was grown in randomized block design with three replications followed by all the recommended cultural practices. Seed cotton yield was recorded in kg/plot and converted into kg per hectare in each year and mean yield of different hybrids attempted by different breeding methods was recorded and finally overall mean of 3 years was obtained. Similar observations were also recorded for fibre traits *viz.* ginning per cent, 2.5 per cent span length (mm), fibre strength (g/tex) and micronaire value (ug/in).

RESULTS AND DISCUSSION

The mean performance of hybrids developed by cytoplasm genetic male sterility hybrids was compared with genetic male sterile and conventional hybrids (Table 1). The mean seed cotton yield of conventional hybrids (68) was 2208 kg/ha during 2002-2003 and it ranged from 958 kg/ha to 2921 kg/ha. The GMS based hybrids produced the mean seed cotton yield 2167 kg/ha with a range of 1042 kg/ha to 2809 kg/ha. The CMS based hybrid performed poorly with mean seed cotton yield of 1446 kg/ha that ranged from 444 kg/ha to 2553 kg/ha. The studies conducted during the year 2003-2004 revealed the superiority of conventional hybrids (2148 kg/ha) over the CMS (1905 kg/ha) and GMS (1819 kg/ha) based hybrids for seed cotton yield. Similarly the studies conducted during 2004-05 also showed the superiority of GMS based hybrid (2450 kg/ha) for seed cotton yield over the conventional hybrids (2324 kg/ha) as well as CGMS based hybrids (1332 kg/ha).

Observations on ginning outturn (%) of hybrids developed by cytoplasm genetic male sterility, genetic male sterility and conventional methods were compared (Table 2). There was not much variation in mean values of hybrids tested in the year 2002-2003, 2003-2004 and 2004-2005 for ginning outturn of the hybrids developed by different methods.

Similarly for fibre quality parameters *i.e.* 2.5 per cent span length, fibre strength and micronaire values of cotton hybrids based on

Table 1. Mean seed cotton yield (kg/ha) and range of hybrids tested in different years

Character	Year	Parameter	CMS	GMS	Conventional
2002-2003	Seed cotton yield (kg/ha)	**Mean**	**1446 (68)**	**2167 (21)**	**2208 (68)**
		Range	444 -2553	1042 -2809	958 - 2921
		Conventional check	2331	2467	2496
2003-2004		**Mean**	**1905 (15)**	**1819 (33)**	**2148 (41)**
		Range	926 -2732	183 - 2932	370 -3601
		Conventional check	2469	2291	2145
2004-2005		**Mean**	**1333 (108)**	**2450 (69)**	**2324 (46)**
		Range	164 -3018	247 -3395	206 -3740
		Conventional check	3072	2630	2481
2002-2005	Mean seed cotton yield (kg/ha) over the year	**Mean**	**1406 (191)**	**2157 (123)**	**2225 (155)**
		Range	164 -3018	183 -3395	206 -3740
		Conventional check	2624	2463	2374

Table 2. Mean and range of ginning outturn of hybrids tested in different years

Character	Year	Parameter	CMS	GMS	Conventional
2002-2003	Ginning per cent	**Mean**	**33.0**	**34.0**	**33.0**
		Range	28.4 -36.0	28.0 -38.0	28.0 -38.0
		Conventional check	36.6	32.0	31.0
2003-2004		**Mean**	**32.5**	**33.0**	**34.0**
		Range	30.2 -34.7	29.0 -38.0	30.0 -39.0
		Conventional check	32.8	33.0	33.0
2004-2005		**Mean**	**33.5**	**34.0**	**35.0**
		Range	24.8 - 40.7	30 - 37	31- 40
		Conventional check	36.6	33.0	35.0
2002-2005	Mean ginning per cent over the years	**Mean**	**33.3**	**34.0**	**34.0**
		Range	24.8 - 40.7	28.8 - 38.0	28.0 - 40.0
		Conventional check	35.3	33.0	33.0

Table 3. Mean and range of 2.5 per cent span length of hybrids tested in different years

Year	Character	Parameter	CMS	GMS	Conventional
2002-2003	2.5 per cent span length (mm)	**Mean**	**27.8**	**27.6**	**29.7**
		Range	25.3 -30.0	22.0 -33.0	19.3 -30.4
		Conventional check	27.4	26.8	26.0
2003-2004		**Mean**	**-**	**27.6**	**28.0**
		Range	-	22.5 -30.0	22.0 -32.4
		Conventional check	-	26.3	26.9
2004-2005		**Mean**	**-**	**29.1**	**27.0**
		Range	-	22.7-33.1	24.5 -28.5
		Conventional check	-	27.1	25.9
2002-2005	Mean 2.5 per cent span length over the years	**Mean**	**-**	**27.9**	**27.5**
		Range	-	22.0 -33.1	19.0 -32.4
		Conventional check	-	26.7	26.3

CMS, GMS and conventional method were almost similar in mean and range. These findings indicated that sterile cytoplasm of *G. harknessii* had no adverse effect on fibre quality characters as the hybrids produced by different methods were almost similar for fibre quality.

Overall mean performance of 191 CGMS; 123 GMS and 155 conventional hybrids revealed that conventional hybrid produced the maximum seed cotton yield (2225 kg/ha) followed by GMS based hybrids (2157 kg/ha). The CGMS hybrids performed poorly with mean values of 1406 kg/ha. The ginning per cent, 2.5 per cent span length, fibre strength and micronaire values of all the hybrids produced by different methods were almost similar.

Cytoplasmic genetic male sterility based hybrids consistently showed poor performance for seed cotton yield in different years. The main reason may be the sterile cytoplasm of *G. harknessii* in female parent resulted reduction in seed cotton yield. Similar reduction in seed cotton yield in CMS based hybrids was also reported by earlier workers (Yagya Dutt *et al.,* 2004, Lather *et al.,* 2001). Weaver (1986) and Zhu *et al.,* (1998) observed detrimental effects of sterile cytoplasm on yield and its contributing traits in *hirsutum* cotton. The probable reason for low yield in hybrids with sterile cytoplasm (A x R) might be due to lower viability of pollen grains resulting low boll setting as compared to hybrids with normal cytoplasm.

The *G. harknessii* CMS source by and large is not very ideal because this cytoplasm suppresses the yield, ginning out turn, fibre fineness (Bhale 1999) and contradictory findings were observed by Shroff *et al.,* (1988). In the present investigation the ginning out turn and fibre quality of CMS A x R hybrids was comparable to GMS and conventional hybrids. Similar observations were observed in all categories of hybrids, whereas contradictory observations were

Table 4. Mean and range of fibre strength (g/ tex) of hybrids tested in different years

Year	Character	Parameter	CMS	GMS	Conventional
2002-2003	Fibre strength (g/tex)	**Mean**	**21.9**	**22.5**	**22.3**
		Range	19.7-23.9	19.3 -23.6	17.8 -24.8
		Conventional check	23.2	21.8	22.0
2003-2004		**Mean**	**-**	**22.8**	**22.5**
		Range	-	18.0-26.5	19.2 -27.6
		Conventional check	-	22.3	23.4
2004-2005		**Mean**	**-**	**23.7**	**22.0**
		Range	-	19.7-27.8	20.2 -23.4
		Conventional check	-	22.8	20.8
2002-2005	Mean fibre strength (g/tex) over the years	**Mean**	**-**	**22.8**	**22.4**
		Range	-	18.0 -27.8	17.8 -29.8
		Conventional check	-	22.3	22.1

Table 5. Mean and range of micronair value of hybrids tested in different years

Year	Character	Parameter	CMS	GMS	Conventional
2002-2003	Micronair value	**Mean**	**4.4**	**4.4**	**4.8**
		Range	3.4-5.1	3.0-5.2	3.4-5.8
		Conventional check	4.4	4.6	4.2
2003-2004		**Mean**	**-**	**5.0**	**5.0**
		Range	-	4.0-5.6	4.0-6.5
		Conventional check	-	4.8	5.1
2004-2005		**Mean**	**-**	**4.6**	**5.0**
		Range	-	4.1-5.1	4.2-5.1
		Conventional check	-	4.8	4.9
2002-2005	Mean micronair value over the years	**Mean**	**-**	**4.7**	**4.9**
		Range	-	3.0-5.6	3.4-6.5
		Conventional check	-	4.7	4.7

recorded by Bhale (1999) for these traits.

The comparison of genetic male sterility based hybrids with conventional hybrids indicated that the seed cotton yield of both classes of hybrid were almost similar. This indicated the possibilities of exploitation of GMS based hybrids at commercial scale without any risk of restoration and detrimental effect of CMS-A can also be avoided.

GMS system results significant reduction in cost of hybrid seed production than that of conventional method because of elimination of process of emasculation otherwise that requires high labour cost. Moreover in male sterility system there is no damage to the floral parts ultimately resulting more setting of crossed bolls with less labour cost. Experimental findings at this centre also indicated that the cost of hybrid seed production can be lower down to 25 per cent by using genetic male sterility as that of conventional hybrids. Wide range was observed for seed cotton yield (164 to 3740 kg /ha) in different years in all the 3 categories of hybrids. Possibilities of development of CMS A x R hybrids can't be ruled out as yield produced by a CMS A x R hybrid was as high as 3018 kg/ha against 3072 kg/ha of conventional check hybrid in the year 2004-2005. Further it was also observed that potential yield level attained by a hybrid can not be realized in successive years indicated more role of environmental condition on this character.

There is need for diversification of CMS A x R system to counter the negative effect of *G. harknessii* by using of sterile cytoplasm from other sources like *G. aridum* or *G. anomalum* and other alternative is to develop cotton hybrids based on genetic male sterility. Number of such hybrids were superior for seed cotton yield to conventional check hybrid indicated the possibilities for the development of hybrid with reduced hybrid seed production cost. The efforts made in this direction resulted in the development of first GMS hybrid in north India *i.e.* HHH 287. This hybrid had good yield potential, early maturity, resistance to cotton leaf curl virus disease and good fibre quality parameters and number of other GMS based hybrids are in advance stage of testing.

REFERENCES

Avtar, R., Chhabra, B. S. and Lather, B.P.S. 1994. Hybrid seed production cytoplasmic male sterile lines of upland cotton (*Gossypium hirsutum*) *Indian J. agric Sci.* **64** : 459.

Bhale, N. L. 1999. *Heterosis breeding in cotton, Hand Book of Cotton in India.* pp 57-78. *Indian Soc. Cotton Improve.*, Mumbai.

Bhale, N. L. and Bhatt, M. G. 1989. Use of honey bees as pollinator in hybrid seed production of male sterile lines of upland cotton (*Gossypium hirsutum*). *Indian J. agric Sci.* **59** : 74

Khadi, B. M., Janagoudar, B. S., Katageri, I. S. and Eshanna, M. R. 1993. Some superior upland cotton hybrid combinations for rainfed conditions. *J. Indian Soc. Cotton Improve.* **18**. 47-49.

Lather, B.P.S, Chhabra, B.S., Sangwan, R.S. and Siwach, S.S. 2001. Hybrid Cotton in North India-Future Prospects. Presented in National Seminar on, *"Sustainable cotton production to meet the requirement of industry"* held on 3-4 Oct. 2001 at CIRCOT, Mumbai.pp 1-6.

Mehetre, S.S. 1992. Natural crossing in cotton (*Gossypium* sp.). Its significance in maintaining varietal purity and production of hybrid seed using male sterile lines. *J. Cotton Res. Dev.* **6** : 73-79.

Meyer, V.G. 1975. Stable cytoplasmic male sterility in cotton. *J. Hered.* **66 (1)** : 22

Narayanan, S. S., Singh, V. V., Mohan, Punit, Vinita, Gotmare and Baitule, S. J. 2004. Cotton genetic resources and crop improvement priorities. Presented International symposium on *"Strategies for Sustainable Cotton Production-A Global vision"* I. Crop Improvement. 48 -55.

Patel, J. C. and Mehta, N.P. 1985. Identification and transfer of restorer gene(s) to cotton strains for use as pollinator. *Cotton Dev.* **14** : 49-50.

Raut, R. S. 1998. Male sterility in cotton hybrid seed production. Hybrid Cotton. *News Letter* **7(2)**:3.

Shroff, V.N. 1980. Cytoplasmic male sterility in Cotton *J. Indian Soc. Cotton Impr.* **5** : 40-41.

Shroff, V.N., Pandey, S.C., Mandloi, K.C. and Nigam, S.K. 1988. Use of genetic and cytoplasmic male sterility for developing cotton hybrids. *J. Cotton Res. Dev.* **2 (1)** : 56-61.

Weaver, Jr., J.B. 1986. Performance of open pollinated cultivars and CMS upland x upland restorer lines. *Proc. Beltwide Cotton Prod. Res. Con.* pp 98-99.

Weaver, Jr., J.B. and Weaver, D.B.. 1977. Inheritance of pollen fertility restoration in cytoplasmic male sterile lines of upland cotton. *Crop Sci.* **17** : 497-99

Wang, X. D. and Lim, Y. Y. 2002. Development of transgenic restorer of cytoplasmic male sterility in upland cotton. *Agricultural Sciences in China* : 381-87.

Wei, Z. G., Li, Z.Y., Hua, J. P. and Yi, X.D. 1995. Studies of effects of the male sterile cytoplasm of G. harknessii. *Acta Gossypii Sin.* **7** : 76-81

Yagya, Dutt, Xue, Wang and Nirania, K.S. 2004. Effect of sterile cytoplasm on lint yield and contributing traits of F_1 hybrids in cotton (*Gossypium hirsutum* L.). Presented International symposium on *"Strategies for Sustainable Cotton Production-A Global vision"* I. Crop Improvement 216-19.

Zhu, X. F, Wang, X. D; Sun, J.; Zhang, T. Z. and Pan, J. J. 1998. Assessment of cytoplasmic effects of male sterile liens in upland cotton. *Plant Breeding* **117** : 549-52.

Effect of spinning mechanism on blended fabric

K. KHAMBRA* AND CHANCHAL

College of Home Sciences, CCS Haryana Agricultural University, Hisar – 125 004
**E-mail : krishnakhambra@yahoo.com*

Abstract : The raw material jute and acrylic were blended in different proportions. Yarns were spun on ring and rotor spinning mechanisms and converted into plain knit fabrics. Pilling resistance was experimented in different blended fabrics and it was found that 100 per cent acrylic had more pilling tendency as compared to jute blends. As the percentage of jute increased in the blend, the number of pills decreased. The yarn made up on ring had lesser diameter and tenacity than yarn spun on OE. The yarn made up on ring spun yarn had more fabric count than of OE yarn thus resulting in less weight, thickness and number of pills. Natural fibre (jute) reduces pilling tendency of blended fabrics to a great extent.

MATERIALS AND METHODS

The raw material included the processed jute (*Colechorus olitorius*) of white variety (TD-3) and acrylic. The yarn of different blends was spun on rotor (open end) and ring spinning mechanisms. Plain fabrics of different blends were knitted on round circular machine 9" diameter (without dial). The fibre, yarn and fabric properties were tested by standard test procedures fibre length (BS 4044), fibre tenacity and elongation (BS 3411), yarn diameter (BS 2085), yarn tenacity and elongation (ASTM D2256-88), fabric count (BS 2862), fabric weight (ASTM D 3776-90), fabric thickness (ASTM DL 777-64) and pilling resistance. All the fabrics were tested for pilling. The number of pills was counted on each specimen using magnifying glass. The samples were also shown to group of 15 textile experts for subjective analysis of rating. For this, BIS standards were used for comparison. The results were finally statistically analyzed.

RESULTS AND DISCUSSION

The properties of both the fibres used in the blends are presented in Table 1. The fibre length, tenacity and breaking elongation of jute fibres are 201 mm, 29 g/ tex and 1.1 per cent, respectively. The corresponding values for acrylic fibres are 99 mm, 40 g/tex and 21.5 per cent, respectively.

Table 1. Fibre properties

Fibre properties	Jute	Acrylic	"t"values
Fibre length (mm)	201	99	45.73
Tenacity (g/tex)	29	40	0.79
Breaking elongation (%)	1.1	21.5	11.11

The results showed that the jute fibre had very low breaking extension as compared to that of acrylic fibre. Besides it was about three times coarser and had a lower tendency at break, thus jute had fewer tendencies to pill because of less modulus. The results are in accordance to the finding of Chaudhari and Das (1991) who blended jute fibre with man made or other natural fibres which were finer than jute, had better spinnability and less pilling resistance.

The data presented at Table 2 showed that the finest diameter of RS yarn with a mean value of 0.145 mm was observed in the case of 100 per cent acrylic. The diameter increased significantly (CD = 0.017) with the increase in ratio of jute in the blend and was maximum under 60:40 J/A proportion (0.209 m). Similar trend was observed in case of mechanism where the mean diameter of hundred per cent acrylic was 0.210 mm and increased significantly (CD = 0.0172) with increase in proportion of jute in the blends and was maximum under 60:40 J/A proportion (0.209 m). Similar trend was observed in case of mechanism where the mean diameter of hundred per cent acrylic was 0.210 mm and increased significantly (CD = 0.0172) with increase in proportion of jute in the blends and was maximum under 60:40 J/A blend (0.358 mm). It is clear from the data that the yarn prepared by RS is finer than OE spun yarn.

The maximum tenacity of RS yarn was observed in 100 per cent acrylic (48.5 g/tex) which decreased significantly (CD = 0.158) with the increase in ratio of jute in the blend and was

Table 2. Specification of yarn construction

Yarn of different blend proportion	Spinning technique	Opening speed (rpm)	Roter speed (rpm)	Spindle speed (rpm)
0:100 to 60:40 jute-acrylic	RS	-	-	1000
proportion	OE	6000	3500	-

Effect of blended yarn parameters on spinning mechanism

J/A blends	Diameter (mm)		Tenacity(g/tex)		Elongation (%)	
	RS	OE	RS	OE	RS	OE
0:100	0.145	0.210	48.5	105.2	22.53	20.63
10:90	0.150	0.222	27.09	95.50	22.82	22.40
20:80	0.174	0.287	18.60	91.27	19.90	18.09
30:70	0.181	0.289	14.44	86.19	18.78	15.0
40:60	0.197	0.344	11.10	80.42	16.49	10.99
50:50	0.200	0.347	9.49	75.79	14.78	9.74
60:40	0.209	0.358	7.20	70.4	12.84	7.25
CD	0.017	0.172	0.158	0.147	0.20	0.28

RS = Ring spun
OE = Open end

minimum under 60:40 J/A blend (7.20 g/tex). Similar trend was observed in the yarns of OE mechanism but it is evident from the data that RS yarn being fine had lesser tenacity than OE yarn which had higher diameter. Sharma *et al.,* (1992) also reported that tenacity of 100 per cent jute yarn was lesser than half the tenacity of the 100 per cent acrylic yarn.

The yarn elongation of RS was 22.53 per cent in 100 per cent acrylic and decreased significantly (CD = 0.20) with the increase in the ratio of jute in the blends having lowest under 60:40 J/A (12.84%). Similar trend was observed in the case of OE yarn. It is clear from the data that RS yarn being soft in texture had more elongation than OE spun yarn. The decrease in elongation with increased jute in blend proportion was due to much lower extension of jute fibre as compared to acrylic fibre. These results are in agreement with those of Ghosh and Bagchi (1987) who worked on same characteristics of jute propylene blended yarn and concluded that all propylene yarns had significantly high strength with high extension compared to all jute yarns.

A perusal of data (Table 3) showed that irrespective of the fabric structure and the mechanism of fabrication, the number of wales/ cms decreased with increasing content of jute in the blends. However, of the two mechanisms, the RS plain fabric had 12 wales/cms as compared to OE plain having 9 wales/cms in 100 per cent acrylic which decreased to 8 (RS) and 5 (OE) against 60:40) J/A blend. The data also show that number of course/cms decreased with increase of jute in both types of fabrics knitted under RS and OE. When compared, the RS fabric had more width (12 number of courses/cms) as compared to OE (8.0 number of courses/cms) against 100 per cent acrylic which increased with the increase of jute in the blends. It is clear from the data that higher the number of counts of different fabrics knitted under both the mechanisms with increasing proportions of jute in the blends. It is clear from the data higher the number of counts of different fabrics knitted under both the mechanisms with increasing proportions of jute in the blends could obviously be attributed to the coarseness of jute fibre which increased the size of the loop which have higher significant positive correlation between fabric count and stitch length (r = 0.3815), stitch density (r = 0.9883), tightness factor (r = 0.6690) of RS plain nitted fabric. Same trend was observed in OE plain knitted fabric.

The data in Table 3 also showed that the weight of the fabric increased with increasing content of jute in the blends. However of the two mechanisms, the RS fabric had 204 g/m^2 weight

Table 3. Effect of blends on fabric parameters

J/A blends	Wales/cm		Courses/cm		Fabric weight (g)		Fabric thickness (mm)		Number of pills	
	RS	OE	RS	OE	RS	OE	RS	OE	RS	OE
0:100	12	9	12	8	204	290	2.28	3.2	17	20
10:90	12	8	11	8	206	310	3.24	3.8	15	18
20:80	11	8	10	7	261	314	3.39	4.1	14	17
30:70	11	8	10	7	266	318	4.39	4.4	14	15
40:60	10	7	9	6	269	321	4.83	4.7	11	13
50:50	9	6	9	5	271	327	5.4	4.9	10	12
60:40	8	5	8	5	283	330	5.9	5.1	8	10
CD (p=0.05)	0.24	0.41	0.28	0.38	0.82	0.79	0.20	1.10	0.71	0.68

against 100 per cent acrylic but the weight increased to 283 g/m^2

And (RS) and 330 g/m^2 (OE) knitted 60:40 J/A blend. Similar tend is observed in case of fabric thickness (Table 3). The data show that irrespective of the fabric structure and mechanism of fabrication, the thickness of RS plain knitted fabric was 2.28 mm in the case of 100 per cent acrylic. With the increase in jute content in the blend, it was 5.9 mm against 60:40 jute acrylic blends. Similar trend was observed in OE plain knitted fabrics.

It is evident from the data that with the increase of jute in the blend proportion the thickness of the fabric prepared under both mechanisms increased because of coarseness of jute and thus there was increase in fabric weight. The findings of Pierce and Shinn (1957) supported the study by reporting their finding that thickness of any fabric is fully dependent only on yarn diameter. It was also supported by the findings of Ganguli et al. (1980). They developed products from blends of jute and naural/synthetic fibres and reported that jute (100%) fabric weighed 480 g/m^2 and jute/rayon blend fabric weighed 426 g/m ^{2} .

The data showed that RS plain knitted fabric had less number of pills (17) on the roller than OE plain knitted fabric (20) agains 0:100 J/A blend. It is clear that the number of pills decreased with the increase of jute content in the blends. RS knitted fabric had 8 and OE had 10 numbers of pills against 60:40 J/A blends. It could be due to more jute fibre and lesser acrylic in the blends. Acrylic had tendency to form balls/pills on the surface due to friction as proved by Knapton (1965).

Effect of fibre on pilling : Acrylic fibre had more tendencies to pill than jute fibre as it is evident from Table 1. This is because of high modules of acrylic fibre. A significant difference in pilling was observed between acrylic and jute by "t"-test (Table 1).

In blends as the percentage of jute increased, pilling decreased (Table 3). This reveals that fabric made up by RS yarn had less number of pills than OE fabrics. As the percentage of jute increased the number of pills decreased in the blends, the difference was found significant at 5 per cent level. In blended fabrics, the blends with less thickness and weight had less number of pills (Table 3). The difference was found significant at 5 per cent level.

CONCLUSION

From the above results, it was concluded that the problem of pilling could be reduced by using more of natural fibre (jute) than synthetics (acrylic) for knit wear. Pilling can also be minimized by ring spun yarn than OE. OF acrylic and jute acrylic blends, acrylic showed more pills, it may be because of high modulus of acrylic. With the increase of jute in the blends the pilling decreased. The blended fabrics with less weight and thickness had less number of pills.

REFERENCE

Annual Book of Standards ASTM 1976. Standards Test Methods for Tenacity and Elongation (ASTM D2256-88), fabric weight (ASTM D3776-90, fabric thickness (ASTM DL 777-64).

BIS Handbook of Textile Testing 1982. for Fibre length (BS 4044), fibre tenacity and elongation (BS 3411), yarn diameter (BS 2085 Chaudhari, A. and Das, A. (1991), Blending of jute fibre with natural and synthetic fibres, Indian Text. J. 101 (**3**):22.

Ghosh, S.K. and Bagchi, N.N. 1987, Evaluation of some characateristics of jute prolylene blended yarn, *Man Made Textiles* in India, **30(2)** : 73.

Ganguli A.K., Aditya R.N. and Som, N.C. 1980, Development of products from blends of jute and natural/synthetic fibres on jute processing system, *Man made Textiles* in India, **23(7)** : 329.

Vasantha, G. and Jacob, M. 1993, Blending of jute with polypropylene and acrylic, *India Text. J.* **103 (3)** : 28 : 31.

Assessment of cotton fibre attributes for trade and export

CHITRANAYAK*, A.YADAV, V. PRASAD, R.S. PRABHUDESAI AND D.N. MOON
Central Institute for Research on Cotton Technology (ICAR), Matunga, Mumbai-400 019
**E-mail : chitranayaksinha@yahoo.com*

Abstract : Indian textile products have been well accepted throughout the world market and had already established a substantial market base. These all could become possible as the quality of these products remained world class and superior in many ways. The export as well as the demand of Indian textile products have been rising successively in the world market, so maintaining the world class quality of these products is of prime importance. Apart from that with the globalization of economy and the need to meet stringent quality norms particularly for export, the cotton trade and spinning industry have come to realize the importance of objective testing of raw material.

Keywords: Cotton fibres, export, micronaire, quality evaluation, span length, tenacity

The quality of textile products lies in the quality of its raw materials as cotton, silk, jute, ramie, other natural fibres and the man made fibres as polyester, nylon, rayon etc. Accepting the demand from textile industry and trade, it was desired to evaluate the cotton quality where information on essential fibre quality attributes for various cotton varieties collected from different centers and parts of the country would be analysed. India is the only country where all four genotypes of cotton are cultivated commercially under the vast varying agro climatic conditions from Punjab of north to Tamil Nadu of south and Gujrat of west to Odisha of east, apart from the widely distributed central region of MP and Maharashtra. However, the share of *G.hirsutum* variety in India is the largest one followed by *G.arborium* cottons.

MATERIALS AND METHODS

The fibre samples of various cotton varieties received from the cotton growing locations have been tested for fibre quality parameters. The data have to be presented and analysed statistically then the frequency distribution curves for some selected cotton varieties have also to be drawn for these fibre quality parameters from their minimum to maximum values of 2.5 per cent span length (SL) of fibre in mm, uniformity ratio (U.R.) in percentage, micronaire (MIC) value in microgram/inch and bundle tenacity (3.2 mm) in g/tex. The samples belong to various locations of the three main cotton growing zones such as north, central and south of the country. In general screening of initial breeding material, cotton germplasm, are tested for quality parameters at the respective regional units. The regional testing laboratories in the cotton growing areas participate in quality evaluation of cotton strains developed and tested for their various parameters. With a view to improve cotton productivity and quality of fibre through coordination of research, by various institutes, Agricultural Universities, State Departments of Agriculture and other related agencies were involved in research pertaining to quality evaluation of cotton lint, its mechanical behaviour at various stages of processing upto spinning of yarn and evaluation of its characteristics. Breeding materials, Initial Evaluation Trials and Preliminary Varietal Trials constitutes the initial stages of cotton breeding programme. The samples under Initial Evaluation Trials or Preliminary Varietal Trials are tested only for fibre quality parameters by using the High Volume Instrument (HVI) in ICC mode, whereas samples of Coordinated Varietal Trial are evaluated for spinning performance and seed coat fragments, trash content, yarn uniformity besides fibre parameters. Finally, before releasing the cotton variety / hybrid for commercial cultivation, it's full spinning potential is checked. This is to ensure its acceptance by Indian and international textile industry once it is released and cultivated on a large scale in farmer's field.

RESULTS AND DISCUSSION

As per the results and the technological data generated so far, it could be stated that the present Indian cotton varieties / hybrids cover a wide spectrum of fibre quality and spinnability ranging from 20s to 120s count. Most of the traded samples of cotton have good fineness and their value had mostly fallen in the range of 3.0 to 5.0 microgram/inch except for a few whose values were above 5.0 or below 3.0 microgram / inch. The varieties developed so far ranges from short staple cotton of 18.0mm to Extra Long Cotton (ELS) up to 39.0mm length, which include very coarse to very fine cottons. Cotton cultivation in India is carried out under three prominent zones as north, central and south under different agro climatic conditions. The

Table 1. Promissing strains of cotton from north zone

St. no	Trial	Location	Variety	2.5 per cent SL	UR	MIC	S(3.2mm)
1306	Br 04 (a)	Sriganganagar	CSH 3129	30.8	50	3.9	25.9
1962	Br 04 (a)	Ludhiana	F 2228	30.3	51	4.4	24.9
1970	Br 05 (a)	Ludhiana	CSHH 3008	31.3	52	4.6	25.1
1981	Br 05 (a)	Ludhiana	LHH 1424	29.9	53	4.6	24.4
2007	Br 05 (a)	Bhatinda	MRC 7365	31.4	50	4.3	25.8
2342	Br 05 (a)	Kanpur	Local Check	29.9	51	4.3	24.9
1410	Miscellaneous	Sirsa	—	30.0	51	4.3	24.2
1413	Miscellaneous	Sirsa	—	30.0	52	4.6	24.8
1624	Miscellaneous	Sirsa	—	29.7	52	4.0	24.4
1783	Miscellaneous	Sirsa	—	31.0	51	4.7	25.4
1786	Miscellaneous	Sirsa	—	29.1	52	4.4	23.6
1837	Miscellaneous	Sirsa	—	29.0	52	4.6	25.1
1473	Miscellaneous	Sriganganagar	—	31.6	49	3.9	26.9
1489	Miscellaneous	Sriganganagar	—	30.2	53	4.4	25.7

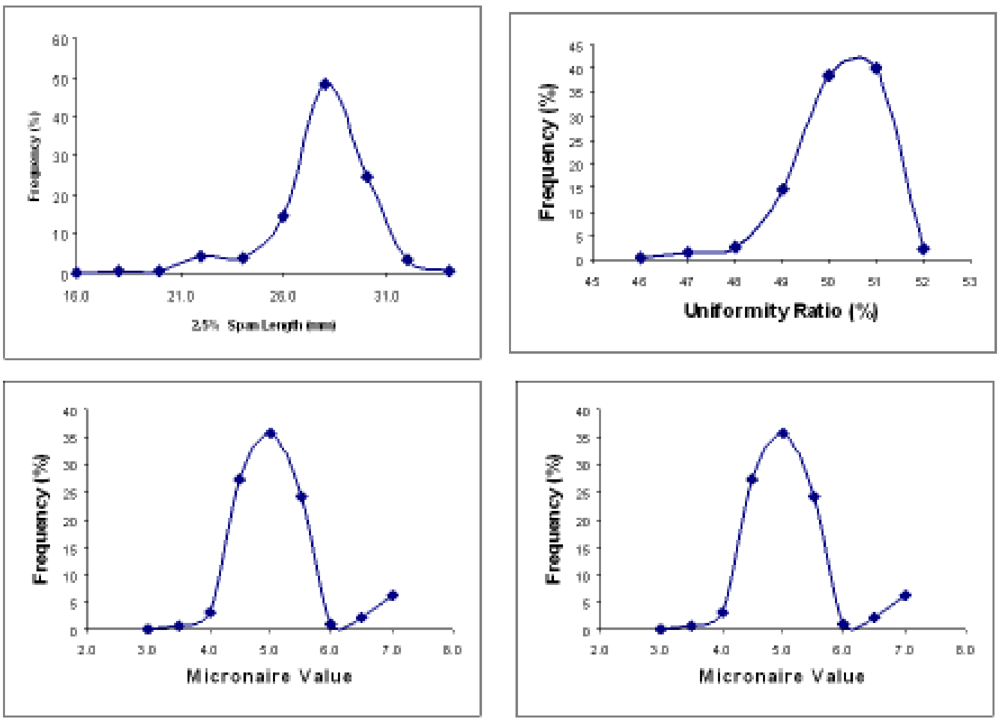


Fig. 1. Frequancy distribution analysis of the cotton fibre quality parameters, 2.5 per cent span length, uniformity ratio, micronaire and the tenacity of the fibres.

states Punjab, Haryana, Rajasthan, Uttar Pradesh and New Delhi are the main cotton growing states in north zone, Madhya Pradesh, Maharashtra, Gujarat and Odisha are in central zone while Andhra Pradesh, Karnataka and Tamil Nadu are the main cotton producing states in south zone. Apart from the rising export of various textile products the export of Indian raw cotton is also increased from 68.80 lakh bales during 2010-2011 season to 84 lakh bales during 2011-2012 season so far, which shows the acceptabily and demand of the Indian cotton in world market. The results have been obtained and shown in the table below belong to the cotton fibre samples received from the cotton breeders. These are some good quality cotton samples, showing good quality parameters belonging to the north zone area.

CONCLUSIONS

The ranges of the various quality parameters of the samples shows that the span length is varying between 21.00 to 31.5 mm, but most of the samples belong to the range of 26.00 to 31.00 mm. This range of cotton fibre length falls in the group of medium long to long staple category and presently most of the cotton peoduced in the country fall in this range only, so there may be a shortage of other length fibres such as short staple and extra long staple category.

ACKNOWLEDGEMENT

The authors are indebted and wish to thank their Director, Dr. S. K. Chattopadhyay for permitting to submit the paper for presentation and publication and Head QEID, Dr. R. P. Nachane for his valuable guidance and support.

REFERENCES

Anonymous, 2011. Annual Cotton Quality Update-2011, CIRCOT (ICAR), Mumbai.

Anonymous, 2012. AICCIP Annual Technological Report, 2010-2011, CIRCOT (ICAR), Mumbai.

Agronomic strategies for sustainable use of poor quality irrigation water in *Bt* cotton wheat cropping system

G. S. BUTTAR*, K.S. SEKHON, H.S. THIND, ANUREET KAUR, B.S. SIDHU, M.S. AUJLA
Department of Agronomy, Punjab Agricultural University Regional Station, Bathinda 151 001
**E-mail : buttargs@rediffmail.com*

Abstract : A field experiment was conducted for three years on calcareous soil in semi-arid area to evaluate the response of each furrow and alternate furrow irrigation in hybrid *Bt* cotton - wheat cropping system using irrigation waters of different qualities. Irrigation was applied to each and alternate furrow on bed-planted wheat followed by ridge planted cotton for comparison with standard check-basin method of irrigation to both the crops. Three water qualities namely good quality water (GW), saline-sodic water (SSW) and pre-sowing irrigation to each crop with GW and all subsequent irrigations with SSW (GWpsi+SSW) were evaluated under three methods of irrigation (check basin, each furrow and alternate furrow). The pooled results over 3 years revealed that wheat grain yield was not affected significantly with quality of irrigation water. However, significant wheat yield reduction was observed in alternate bed irrigation in all the water qualities. In hybrid Bt cotton, saline sodic water (SSW) significantly reduced the seed cotton yield in all the three methods of planting. The pre-sowing irrigation with GW and all subsequent irrigations with saline sodic water improved the seed cotton yield as compared to the application of saline sodic water alone. However, in alternate furrow the yield increase was significant and the yield obtained was equal to the yield under alternate furrow in GW. Reduced use of irrigation water under alternate furrow resulted in 21, 21 and 25 per cent higher water use efficiency in wheat under GW, SSW and GWpsi+SSW, respectively. The corresponding increase under Bt cotton was 28, 19 and 36 per cent.

Key words : *Bt* cotton, wheat, good quality water, saline sodic water, wheat

The development of *Bt* cotton represents a significant technological landmark in the global cotton research. India, adopted this technology in 2002-2003 and amongst those countries that adopted *Bt* cotton, it derived the greatest benefit from the insect resistance trait. Prior to the introduction of *Bt* cotton, about 40,672 t of pesticides were sprayed on this crop which occupied only 5 per cent of the cultivated area (Bambawala and Jeyakumar, 2009). In the post *Bt* cotton era, between 2002 and 2006, there was a reduction in the insecticide to the tune of 9,000 t valued at Rs 17,500 million (ISAAA, 2009). Recent survey indicated multiple benefits from the adoption of *Bt* cotton including increase in yield, decreased production costs, reduction in pesticide use and plant-protection costs, improved population of beneficial insects, substantial environmental and health benefits to farmer along with socio-economic benefits (Monga, 2008). However, to sustain the benefits of *Bt* cotton, effective management of irrigation water would be crucial.

In Indo Gangetic plains where the soils of cotton growing region are light in texture and underground water is brackish, drip irrigation to cotton is at experimental stage (Thind *et al.*, 2008; Aujla *et al.*, 2008). At present farmers' grow cotton in rotation with wheat by applying four to five irrigations to each crop through flood irrigation method (check basin). In this region the only source of good quality water for irrigation is river water supplied through canals. There is great need for judicious use of canal water because excess usage causes deep percolation resulting in high water table and secondary salinization (Boumans *et al.*, 1988; Datta and de Jong, 2002). The judicious use with minimal deep percolation of available canal water and sustainable use of underground poor quality water is the need of the hour for sustaining the land resources. Surface irrigation (check basin) with poor quality waters usually lead to build up of salinity and sodicity problems and thus causes reduction in crop yields (Choudhary and Ghuman, 2008). It has been emphasized that when poor quality waters are used for irrigation due attention should be given to minimize root-zone salinity. It has also been advocated that there is great need for selection and use of appropriate irrigation systems and practices that will supply just sufficient quantity of water to the root zone to meet the evaporative demand and minimize salt accumulation in the root-zone (Munns, 2002). Higher yield potential and water use efficiency was obtained under alternate furrow irrigation than each furrow irrigation in cotton (Stone *et al.,* 1982). Under such situations water was saved by reducing evaporation from the soil surface and as dry part of the crop root system sends a soil drying signal (abscisic acid or others) from roots to shoots where shoot physiology such as stomatal opening and leaf expansion can be restricted (Davies and Zhang, 1991).

Irrigation with sodic waters high in carbonates and bicarbonates leads to an increase in soil pH and sodium saturation of soils. Under such situations, it is suggested that for successful use of saline/ sodic waters, crops that are semi-tolerant to tolerant (wheat, cotton, mustards) as well as those with low water requirement should be grown (Minhas *et al.*, 2004). When using poor quality waters, the period of germination and emergence of the seedlings is the most critical stage of crop growth and crops can tolerate higher salinity once good quality water was substituted for pre-sowing irrigation to leach out the salts of seeding zone (Boumans *et al.*, 1988). Furthermore, the deleterious effects of poor quality water are reduced in calcareous soils as Na saturation of the soil is retarded due to higher amount of inherent $CaCO_3$ (Choudhary *et al.*, 2011). Lal *et al.,* (2008) concluded that $CaCO_3$ was one of the major sources that released Ca and bicarbonate ions in the solution when sodic waters are applied. They also reported that using sodic water in alkali soils rich in Ca+Mg bearing minerals like feldspars and $CaCO_3$ could maintain proportionately higher (Ca+Mg)/ Na ratio in the soil solution than in the applied irrigation water. Calcium ions might also be produced from dissolution of silicate minerals (plagioclase feldspars) or $CaCO_3$ of metastable form, which was more soluble than pure silicate minerals present in the soil (Curtin *et al.*, 1995). Ahmed *et al.,* (2006) concluded that smaller amounts of gypsum are required for reclamation of calcareous saline sodic soil than non-calcareous saline sodic soil.

Therefore, there is need to adopt specialized and efficient methods of irrigation which can help in attaining the twin objectives of higher productivity and rational use of poor quality water. The present investigation was undertaken to evaluate the response of each and alternate furrow irrigation in *Bt* cotton and wheat using good quality canal water and saline-sodic groundwater in a calcareous soil.

MATERIALS AND METHODS

Experimental site and soil : A 3-year field study was conducted at Research Farm of the Punjab Agricultural University Regional Station, Bathinda, India (30°9' N and 74°56'E; altitude 211 m a.s.l.) from 2005-06 to 2007-08. The experimental site forms a part of the Indo-Gangetic alluvial plains which were formed with varying pleistocene and recent alluvial deposits of the rivers of Indo Gangetic system. The site is semi-arid (dry), with mean rainfall of 401 mm. Rainfall is monsoonal in nature, 70 to 80 per cent is received during the months of July, August and September which coincide with the active growing season of *Bt* cotton. The soil of the experimental field belongs to the Gehri Bhagi series (mixed, hyperthermic, Ustochreptic Camborthid) and has loamy sand texture. Some physical and chemical properties of the soil are presented in Table 1. The organic carbon content of the surface soil layer (0-15 cm) was 0.28 per cent (Nelson and Sommers, 1996) and $CaCO_3$ 4.46 per cent. Soil pH and electrical conductivity determined in 1:2 soil water suspension was 8.48 and 0.145 dS/m, respectively. The available phosphorus (Olsen *et al.*, 1954) and available potassium (Knudsen *et al.*, 1982) in the surface layer were 14.2 and 361 kg/ha, respectively. The soil in the experimental field had no salinity or drainage problem and the water table was deeper than 8.0 m; thus, it does not interfere in the root zone.

Experimental treatments and procedures *:* In wheat, flat sowing was compared with bed planting where each furrow or alternate furrows were irrigated. Similarly, in cotton, flat sowing was compared with ridge planting where each and alternate furrows were irrigated. The experiment was laid out in split plot design with three water qualities in main plots and three

Table 1. Physical and chemical characteristics of soil profile of experimental field.

Soil depth (cm)	pH	EC* (dS/m)	Volumetric moisture (%) at		Available soil water (mm)	Bulk density (g cm^{-3})
			1/3 bar	15 bar		
0-15	8.48	0.145	25.1	7.1	27	1.51
15-30	8.35	0.134	27.2	8.3	28	1.55
30-60	8.74	0.135	26.9	9.2	52	1.41
60-90	8.51	0.131	28.2	9.3	55	1.43
90-120	8.43	0.136	27.1	9.7	52	1.51
120-150	8.39	0.135	28.2	7.9	54	1.52
150-180	8.40	0.131	27.9	8.8	53	1.54
					321	

*EC = Electrical conductivity measured at 25^0 C

methods of irrigation in sub plots with three replications. Three water qualities in main plots were; good quality canal water (GW), saline-sodic underground water (SSW) and pre-sowing irrigation (psi) to each crop with GW and all subsequent irrigations with SSW (GWpsi+SSW) and three methods of irrigation in sub plots were; check basin (CB), each furrow (EF) and alternate furrow (AF). Three water qualities as main plots were randomized in three replications and three methods of irrigation were randomized within main plots in all the replications. Under check-basin method of irrigation, the irrigations were based on 0.9 and 0.4 ratio between fixed depth (7.5 cm) of irrigation water and net cumulative pan evaporation since previous irrigation (PAN-E minus rainfall) in wheat and cotton , respectively (Prihar and Sandhu, 1987). In check-basin irrigation, 7.5 cm irrigation water was applied for each irrigation by using Parshall flume, however, the water depth was 5.5 and 4.0 cm in EF and AF on total area basis in all the water qualities.

Wheat was planted with bed planter, in which two wheat rows were sown 22.5 cm apart on 37.5 cm wide bed. The width of furrow between two beds was 30 cm. After wheat harvest these beds were converted to ridges spaced 67.5 cm and *Bt* cotton was planted with cotton planter by keeping plant to plant spacing of 90 cm. Sub plot size was 5.40 x 19.80 m and area harvested was 4.05 x 18.0 m. After cotton harvest, fresh beds were prepared for wheat after ploughing the field. The amount of rainfall received during each crop, water quality of SSW and GW, quantity of irrigation water applied, varieties of wheat and cotton sown during different years along with dates of sowing and harvesting are detailed in Table 2. The recommended amounts of fertilizers applied to wheat and cotton were 120 kg N and 26 kg P/ha and 150 kg N and 13 kg P/ha, respectively, and these amounts were applied to all the plots. All the phosphatic fertilizers were drilled before sowing of wheat and cotton crop. In wheat, half N was applied at sowing and remaining half at the time of first irrigation at crown root initiation (CRI) stage. In *Bt* cotton, half N was applied by broadcasting at the time of first irrigation (42 days after sowing) and the remaining half at 50 per cent flowering stage of the crop. Recommended practices were followed to control weeds and pests. Wheat grain yield and seed cotton yield (lint + seed) were recorded in each plot after maturity of the crop. Surface (0-15 cm) soil samples were collected and analyzed for salinity (EC) and sodicity (pH) after each crop rotation. Soil pH and EC were measured in the 1:2 soilwater suspension.

Water use efficiency : Water use efficiency (WUE) was calculated from total water use and economic yield. Water use is the sum of irrigation water, soil profile water used and rainfall received during the season as the possibility of deep percolation was negligible under experimental conditions (Prihar and Sandhu, 1987). For determining soil water used by the crop, soil profile water content was measured at the time of sowing and at harvest in 0- 180 cm soil by thermo-gravimetric method in each crop. For soil water determination, soil samples were collected from 0-15, 15-30, 30-60, 60-90, 90-120, 120-150 and 150- 180 cm depths. For each soil sample, the soil was collected

Table 2. Rainfall, irrigation water quality and irrigation water applied during different years of experimentation.

	Year of experimentation			Mean
	2005-2006	2006-2007	2007-2008	
Rainfall (mm)				
Wheat season	63	135	33	**77**
Cotton season	371	245	345	**320**
Water quality				
Saline sodic water (SSW)				
EC (dS/m)*	2.30	2.20	2.20	**2.23**
RSC($mmol_c$/L)**	5.81	5.89	5.85	**5.85**
Good quality water (GW)				
EC (dS/m)*	0.49	0.55	0.52	**0.52**
RSC($mmol_c$/L)**	0.0	0.0	0.0	**0.0**
Irrigation water applied (mm)				
Wheat				
Check basin (CB)	300	225	375	**300**
Each furrow (EF)	220	165	275	**220**
Alternate furrow(AF)	160	120	200	**160**
Bt cotton				
Check basin (CB)	300	300	300	**300**
Each furrow (EF)	225	225	225	**225**
Alternate furrow(AF)	160	160	160	**160**
Crop varieties, dates of sowing and harvesting				
Wheat				
Variety	PBW 502	PBW 502	PBW 502	-
Date of sowing	03.12.05	15.11.06	20.11.07	-
Dateof harvesting	09.04.06	09.04.07	11.04.08	-
Bt Cotton				
Variety	RCH 134 *Bt*	RCH 134 *Bt*	RCH 134 *Bt*	-
Date of sowing	24.04.06	01.05.07	13.05.08	-
Date of harvesting	02.11.06	02.11.07	03.11.08	-

* EC = Electrical Conductivity

** RSC= Residual Sodium Carbonate= $(CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+})$
(all cations and anions in $mmol_c$/L)

randomly from three locations representing top of ridge, middle of ridge and center of furrow in each plot and mixed together for each depth, and a representative sample for each depth was taken for determination of soil water content in each replication to take care of variation in soil water content among plots. The profile water used by these crops was calculated by the difference method (available water at sowing minus available water at crop harvest) in 0-180 cm soil profile. For computing WUE, economic yields (air dried wheat grain yield and seed cotton yield)/ ha were divided by total water use and expressed as kg m.

Statistical analysis : The experiment was laid out in split plot design with three replicates. Three water qualities as main plots were randomized and three methods of irrigation were randomized within main plots in three replications. Results were statistically analysed using standard procedures for split plot design. Means were compared using least significant differences (LSD) at the 5 per cent probability level.

RESULTS AND DISCUSSION

Wheat grain and seed cotton yield : The results pooled over 3 years revealed that wheat grain yield was not significantly different in check basin (CB) and each furrow (EF) under all the three water qualities (Table 3). However, alternate furrow (AF) irrigation significantly reduced the wheat grain yield as compared with respective CB and EF irrigation under all the

Table 3. Wheat grain yield and seed cotton yield (kg/ha) during different years of experimentation as influenced by irrigation water quality and methods of irrigation.

Treatments* Qualities	Methods	Year of experimentation 2005-2006	2006-2007	2007-2008	**Mean**
		Wheat			
GW	CB	3694	3814	3248	**3585**
	EF	3432	3721	3058	**3410**
	AF	2186	4002	3290	**3159**
SSW	CB	3233	3794	3830	**3619**
	EF	3224	3760	3683	**3556**
	AF	2206	3782	3417	**3135**
GWpsi+SSW	CB	3234	4247	3115	**3532**
	EF	2818	4160	3146	**3375**
	AF	2497	3631	2998	**3042**
LSD(0.05)		322.8	111.4	83.4	184.0
		Bt cotton			
GW	CB	3405	2158	2760	**2774**
	EF	3567	2124	3108	**2933**
	AF	3431	2153	2973	**2852**
SSW	CB	3164	1505	2479	**2383**
	EF	3386	1229	2682	**2432**
	AF	2846	1511	2518	**2292**
GWpsi +SSW	CB	3227	1414	2595	**2412**
	EF	3454	1551	2997	**2667**
	AF	3541	1929	2760	**2743**
LSD (0.05)		303.2	202.6	NS	209.1

* GW = Good water; SSW = Saline sodic water; GWpsi+SSW = Pre-sowing irrigation with GW & subsequent irrigations with SSW, CB = Check basin; EF = Each furrow; AF = Alternate furrow

three water qualities. The wheat yield reduction in AF as compared with CB was 11.9, 13.4 and 13.9 per cent in GW, SSW and GWpsi+SSW, respectively. However, the wheat grain yield was not affected with quality of irrigation water under all the three methods of irrigation. On the other hand, mean seed cotton yield was not affected significantly by methods of irrigation under respective irrigation water quality in GW and SSW. But the use of SSW to cotton significantly reduced the seed cotton yield in all the methods of irrigation as compared with these treatments under GW. However, a significant yield increase was observed under EF and AF as compared with CB when both waters were used in combination (GWpsi+SSW). The yield obtained in AF under GWpsi+SSW was comparable with yield obtained under GW in all the methods of irrigation. The results revealed that AF in cotton, when irrigated with GW and SSW, produced similar seed cotton yield as produced in CB and EF under respective irrigation water quality. In AF, one row of cotton is grown on each furrow thus each row received the water from one side, which proved to be sufficient for its requirement. The results showed that under these water qualities (GW and SSW) about the same seed cotton yield can be obtained in AF with 47 per cent less irrigation water than was applied in CB and with 25 per cent less than in EF. Tang *et al.,* (2005) also observed that AF required up to 30 per cent less irrigation water as compared with EF irrigation without significant reduction in seed cotton yield. They further observed that stomatal conductance was lower in AF irrigation of cotton than in EF irrigation in early days after each irrigation but leaf water potential was comparable between both the treatments during whole crop season thus seed cotton yield was comparable with both the treatments. The results revealed that higher rainfall during wheat season 2006-2007 (Table 2) improved the wheat grain yield whereas as reduced rainfall in subsequent cotton season caused a spectacular decrease in seed cotton yield. The results of wheat further indicated that without causing significant yield loss, 27 per cent less irrigation water can be applied in EF than in CB. However, when 47 per cent less irrigation water was applied in AF than in CB, significant reduction in wheat grain yield was recorded under GW (12%) as well as under SSW (13%). This significant reduction might be due to water stress experienced by two rows adjacent to un-irrigated furrow as EF was having two rows of wheat crop. It is evident that use of poor quality irrigation water failed to adversely affect the wheat grain in this calcareous soil. Recently, Choudhary *et al.,* (2011) also observed that wheat yield was not affected significantly up to nine years in a calcareous soil irrigated with sodic water having even higher sodicity (residual sodium carbonate 10 $mmol_c/L$). Pre sowing irrigation with good quality water (in GWpsi+SSW treatment) improved the seed cotton yield as compared to SSW alone. This might be due to leaching of salts with good quality pre sowing irrigation and thus providing favorable conditions for seed germination and seedling establishment, and enabling the cotton to withstand unfavorable conditions during subsequent crop growth period (Boumans *et al.*, 1988). Under GWpsi+SSW, AF irrigation produced similar seed cotton yield compared to CB but applied only 53 per cent SSW. Lower salt-load in AF irrigation under GWpsi+SSW might be the reason for significantly higher seed cotton yield as compared with SSW and equal with GW. The combined use of GW and SSW (GWpsi+SSW) under AF fulfills the twin objectives of higher WUE and sustainable use of saline sodic water.

Changes in soil pH and electrical conductivity : The application of SSW caused a spectacular increase in soil pH and electrical conductivity (EC) (Table 4). The increase was highest in CB followed by EF and AF irrigation, which followed the pattern of quantity of irrigation water applied. On the other hand, EC has increased progressively during all the years of saline-sodic water application although the small changes suggest equilibration in the soil. The deleterious effects of SSW were significant in cotton although cotton crop is grown during monsoonal rainy season which received large amounts of rainwater (Table 2). Suarez *et al.* (2006) observed that under a combined rain-irrigation water use, the soil may go from relatively saline condition to a non-saline condition in the upper part of the profile after a significant rain. Under such conditions the decrease in sodium adsorption ratio (SAR) will be slower than the decrease in EC. This condition causes a potential sodium hazard leading to dispersion, loss of aggregate stability and decrease in infiltration rate during the rain event. However, the extent to which a sodic soil adversely responds to deionized water does not depend upon the quantity of rainfall alone but is also related to the extent to which the soil can maintain an elevated EC as a result of mineral dissolution, primarily presence and reactivity of $CaCO_3$ (Shainberg *et al.*, 1981). Thus, it seems

Table 4. Effect of irrigation methods and quality of water on pH and electrical conductivity of the surface (0-15 cm) soil layer after each year of cropping.

Treatments*		pH#			EC (dS/m)#		
Qualities	Methods	2005-2006	2006-2007	2007-2008	2005-06	2006-2007	2007-2008
GW	CB	8.51	8.52	8.53	0.148	0.179	0.172
	EF	8.51	8.52	8.52	0.149	0.175	0.168
	AF	8.50	8.52	8.52	0.156	0.178	0.173
SSW	CB	8.62	8.66	8.72	0.302	0.335	0.349
	EF	8.60	8.64	8.70	0.291	0.315	0.322
	AF	8.59	8.62	8.65	0.289	0.309	0.315
GWpsi+SSW	CB	8.60	8.63	8.65	0.274	0.290	0.310
	EF	8.59	8.61	8.63	0.263	0.281	0.294
	AF	8.58	8.60	8.61	0.256	0.276	0.285

* GW = Good water; SSW = Saline sodic water; GWpsi+SSW = Pre sowing irrigation with GW and subsequent irrigations with SSW
CB = Check basin; EF = Each furrow; AF = Alternate furrow
# Measured in 1:2 soil water ratio

that monsoonal rainfall during cotton growth may be responsible for higher yield reduction than occurs with wheat owing to sodium hazard that exists when irrigated with saline sodic water (Suarez *et al.*, 2006) but the presence of $CaCO_3$ might have reduced the adverse effects. Small increase in soil pH may be ascribed to mobilization of Ca from inherent $CaCO_3$ present in the soil. The saline-alkali water being used for irrigation was of marginal alkalinity, residual sodium carbonate (RSC) varied from 5.81 to 5.89 $mmol_c/L$, which might have enabled the soil to maintain the Ca concentration in soil solution within nutritionally adequate amounts for crops (Pratt and Suarez, 1990). Minhas *et al.,* (1995) pointed out that alkali water irrigated soils undergo cyclic precipitation of $CaCO_3$ during irrigation to wheat crop and its dissolution with rainwater depends upon rainfall received during monsoons. They further observed that sustained yields are possible when irrigation is practiced with alkali waters (RSC > 4.0 $mmol_c/L$) in areas having annual rainfall of 500 mm.

Water use efficiency : The total water use under different treatments was calculated from profile water use (Table 5), irrigation water applied and rainfall received (Table 2), and is presented in Table 6. The mean total water use in wheat was highest in CB followed by EF and AF under all the three water qualities. The pattern of total water use was similar in cotton , however, it was almost double in cotton than wheat. High total water use in cotton is mainly attributed to higher rainfall in the cotton season (Aujla *et al.*, 2008; Thind *et al.*, 2008). In wheat,

Table 5. Profile water use (mm) during different years of experimentation as influenced by irrigation water quality and methods of irrigation.

Treatments* Qualities	Methods	Year of experimentation 2005-2006	2006-2007	2007-2008	**Mean**
		Wheat			
GW	CB	21	72	80	**58**
	EF	31	93	90	**71**
	AF	25	91	94	**70**
SSW	CB	27	81	77	**62**
	EF	33	89	90	**71**
	AF	33	97	88	**73**
GWpsi +SSW	CB	37	75	75	**62**
	EF	26	70	65	**70**
	AF	24	82	100	**69**
LSD (0.05)		4.8	6.9	8.7	**5.6**
		Bt Cotton			
GW	CB	115	218	287	**207**
	EF	124	164	289	**192**
	AF	124	206	304	**211**
SSW	CB	132	238	291	**220**
	EF	121	250	267	**213**
	AF	142	204	278	**208**
GWpsi +SSW	CB	138	233	283	**218**
	EF	115	239	259	**204**
	AF	149	258	281	**229**
LSD (0.05)		11.4	18.3	23.4	**12.7**

* GW = Good water; SSW = Saline sodic water; GWpsi+SSW = Pre-sowing irrigation with GW & subsequent irrigations with SSW
CB = Check basin; EF = Each furrow; AF = Alternate furrow

Table 6. Total water use (mm) during different years of experimentation as influenced by irrigation water quality and methods of irrigation.

Treatments* Qualities	Methods	Year of experimentation 2005-2006	2006-2007	2007-2008	Mean
		Wheat			
GW	CB	384	432	488	**491**
	EF	314	393	398	**401**
	AF	248	346	327	**330**
SSW	CB	390	441	485	**488**
	EF	316	389	398	**401**
	AF	256	352	321	**324**
GWpsi +SSW	CB	400	435	483	**486**
	EF	309	370	373	**376**
	AF	247	337	333	**336**
		Bt Cotton			
GW	CB	786	763	932	**935**
	EF	720	634	859	**862**
	AF	655	611	809	**812**
SSW	CB	803	783	936	**939**
	EF	717	720	837	**840**
	AF	673	609	783	**786**
GWpsi +SSW	CB	809	778	928	**931**
	EF	711	709	829	**832**
	AF	680	663	786	**789**

* GW = Good water; SSW = Saline sodic water; GWpsi+SSW = Pre-sowing irrigation with GW & subsequent irrigations with SSW
CB = Check basin; EF = Each furrow; AF = Alternate furrow

mean WUE increased significantly in EF as compared with CB and although it further increased in AF but increase was not significant in all the three water qualities (Table 7). The increase in mean WUE under EF as compared with CB was 12 (from 0.84 to 0.94 kg m^{-3}), 17 and 21% under GW, SSW and GWpsi+SSW, respectively. The corresponding increase in AF over CB was 21, 21 and 25%. On the other hand, WUE was not significantly affected with the quality of water in wheat because grain yield was not influenced with water quality. The WUE in cotton also increased significantly in EF as compared with CB in all the water qualities. However, further increase in AF was significant only in GWpsi+SSW. The application of SSW significantly reduced the WUE as compared with GW in all the methods of sowing. However, the application of GW as pre-sowing irrigation and all other irrigations with SSW (GWpsi+SSW) improved WUE over SSW. In cotton the extent of increase in WUE in EF and AF was higher than wheat. In AF increase in WUE as compared with CB was 28 (from 0.32 to 0.41), 19 and 36 per cent under GW, SSW and GWpsi+SSW, respectively. The higher WUE with reduced irrigation water use suggest that there was comparatively lower reduction in yield than reduction in irrigation water applied. Similarly higher WUE was observed in furrow irrigation than CB in transplanted *Brassica napus* (Buttar *et al.*, 2006) and in eggplant (Aujla *et al.*, 2007). The mean WUE of hybrid *Bt* cotton grown in this experiment is about 2.5 times higher than non *Bt* non hybrid varieties grown in the same location in previous years (2003 and 2004) in CB method of irrigation (Thind *et al.*, 2008). The reduced use of saline sodic irrigation water with pre-sowing irrigation with GW reduced the deteriorating effects on yield and soil. Traditionally farmers of semi-arid region grow wheat and *Bt* cotton using check-basin method of irrigation. However, for judicious use of precious water, farmers are advised to follow bed and ridge planting in wheat and *Bt* cotton, respectively. A significant number of farmers are practicing furrow irrigation in canal irrigated areas to save limited water so that larger area can be brought under irrigation. Thus by adopting alternate furrow irrigation in *Bt* cotton, sustainable yields and higher water use efficiency can be obtained by applying pre-sowing irrigation with good quality water and subsequent irrigations with saline sodic water under these light textured calcareous soils of semi arid environment.

Table 7. Water use efficiency (kg m^{-3}) during different years of experimentation as influenced by irrigation water quality and methods of irrigation.

Treatments* Qualities	Methods	Year of experimentation 2005-2006	2006-2007	2007-2008	**Mean**
Wheat (kg grain yield/m)					
GW	CB	0.96	0.88	0.67	**0.84**
	EF	1.09	0.95	0.77	**0.94**
	AF	0.88	1.16	1.01	**1.02**
SSW	CB	0.83	0.86	0.79	**0.83**
	EF	1.02	0.97	0.93	**0.97**
	AF	0.86	1.07	1.06	**1.00**
GWpsi+SSW	CB	0.81	0.98	0.61	**0.80**
	EF	0.94	1.12	0.84	**0.97**
	AF	1.02	1.08	0.90	**1.00**
LSD (0.05)		0.091	0.084	0.079	**0.081**
***Bt* cotton (kg seed cotton yield/m)**					
GW	CB	0.39	0.28	0.30	**0.32**
	EF	0.46	0.34	0.36	**0.39**
	AF	0.52	0.35	0.37	**0.41**
SSW	CB	0.36	0.19	0.27	**0.27**
	EF	0.44	0.18	0.32	**0.31**
	AF	0.40	0.25	0.32	**0.32**
GWpsi+SSW	CB	0.37	0.18	0.28	**0.28**
	EF	0.45	0.22	0.36	**0.34**
	AF	0.49	0.29	0.35	**0.38**
LSD (0.05)		0.039	0.031	0.037	**0.032**

* GW = Good water; SSW = Saline sodic water; GWpsi+SSW = Pre sowing irrigation with GW & subsequent irrigations with SSW
CB = Check basin; EF = Each furrow; AF = Alternate furrow

CONCLUSIONS

In *Bt* cotton, the application of saline-sodic water significantly reduced the seed cotton yield in all three methods of planting. The pre-sowing irrigation with good quality water and all subsequent irrigations with saline-sodic water increased the seed cotton yield over saline-sodic water alone. However, the increase was significant only in each furrow and alternate furrow irrigation methods, which was equal to the yield obtained in good quality water. The results revealed that wheat grain yield was not affected significantly with quality of irrigation waters but significant yield reduction was observed in alternate furrow irrigation under all the three water qualities. Each furrow and alternate furrow irrigation resulted in 25 and 47 % saving in irrigation water in *Bt* cotton, whereas the corresponding potential "saving" in wheat was to the tune of 27 and 47 per cent, respectively. The reduced use of irrigation water under alternate furrow resulted in 21, 21 and 25 per cent higher water use efficiency in wheat under GW, SSW and GWpsi+SSW, respectively. The corresponding increase under *Bt* cotton was 28, 19 and 36 per cent, respectively. The reduced use of saline sodic water with pre sowing irrigation with GW reduced the deteriorating effects on yield and soil. Thus by adopting alternate furrow irrigation in *Bt* cotton, sustainable yield and higher water use efficiency can be achieved by applying pre-sowing irrigation with good quality water and subsequent irrigations with saline sodic water on calcareous soils under good drainage conditions in semi-arid regions.

REFERENCES

Ahmed, S., Ghafoor, A., Qadir, M., Abbas Aziz, M. 2006. Amelioration of a calcareous saline-sodic soil by gypsum application and different crop rotations. *International Jour. Agri. Bio.* **42** : 142-46.

Aujla, M.S., Thind, H.S., Buttar, G.S. 2007. Fruit yield and water use efficiency of eggplant (*Solanum melongema* L.) as influenced by different quantities of nitrogen and water applied through drip and furrow irrigation. *Scientia Horticulturae* **112** : 142-48.

Aujla, M.S., Thind, H.S., Buttar, G.S. 2008. Response of normally sown and paired sown cotton to various quantities of water applied through drip system. *Irri. Sci.* **26** : 357-66.

Bambwala, O.M., Jeyakumar, P. 2009. In: *International conference on emerging trends in production and utilization of natural fibres,* 16-18 April, 2009 Mumbai, India. Book of papers Vol. 1, pp 155-161.

Boumans, J.H., van Hoorn, J.W., Kruseman, G.P., Tanwar, B.S. 1988. Water table control, reuse and disposal of drainage water in Haryana. Agri. *Water Manag.* **14** : 537-45.

Buttar, G.S., Thind, H.S., Aujla, M.S. 2006. Methods of planting and irrigation at various levels of nitrogen affect the seed yield and water use efficiency in transplanted oilseed rape (*Brassica napus* L.). *Agri. Water Manag.* **85** : 253-60.

Choudhary, O.P., Guman, B.S., Bijay Singh, Buresh, R. J., Thuy, N. 2011. Effects of long-term use of sodic water irrigation, amendments and crop residues on soil properties and crop yields in rice wheat cropping system in a calcareous soil. *Field Crops Res.* **121** : 363-72.

Choudhary, O.P., Ghuman, B.S. 2008. Cyclic use of sodic and non sodic canal waters for irrigation in cotton wheat cropping system in semi-arid region. *Jour. Sus. Agri.* **32** : 269-86.

Curtin, D., Seelers, F., Steppuhn, H. 1995. Sodium-calcium exchange selectivity as influenced by soil properties and method of determination. *Soil Sci.* **159** : 76-84.

Datta, K.K., de Jong, C. 2002. Adverse effect of water logging and soil salinity on crop and land productivity in northwest region of Haryana, India. *Agri. Water Manag.* **57** : 223-38.

Davies, W.J., Zhang, J. 1991. Root signals and the regulation of growth and development of plants in drying soil. *Ann. Rev. Plant Physio. Plant Mole. Bio.* **42 :** 55-76.

ISAAA, 2009. *Biotech crops in India: the dawn of new era.* ISAAA Brief No. 39. ISAAA South Asia Office, New Delhi, India. p 34.

Knudsen, D., Peterson, G.A., Pratt, P.F. 1982. *Lithium, sodium and potassium.* In Page A.L., Miller, R.H., Keeney, D.R.(eds) Methods of soil analysis. Part 2, 2nd edn. Agron. Monogr. 9. ASA and SSSA, Madison, WI, 225-46.

Lal, K., Khan, I. Yadav, G. 2008. Irrigation water and release of ions from soil mineral weathering. In: Lal, K., Meena, R.L., Gupta, S.K., Singh, Gajendar and Singh, Gurbachan Singh (Eds) *Diagnosis and management of poor quality water and salt affected soils.* Central Soil Salinity Research Institute, Karnal, pp116-121.

Minhas, P.S., Sharma, D.R., Chauhan, C.P.S. 2004. Management of saline and alkali waters for irrigation. In: Advances in Sodic Land Reclamation. International Conference on *"Sustainable Management of Sodic Lands",* 9-14 February 2004, Lunknow, India. P 121-62

Minhas, P.S., Sharma, D.R., Singh, Y.P. 1995. Response of rice and wheat to applied gypsum and farmyard manure on an alkali water irrigated soil. *Jour. Ind. Soc. Soil Sci.* **43** : 452-55.

Monga, D. 2008. Problem and prospects of cultivation of Bt hybrids in the North India cotton zones. *ICAC Recorder* **24** : 8-9.

Munns, R. 2002. Comparative physiology of salt and water stress. *Plant Cell Envir.* **25** : 239-50.

Nelson, D., Sommers, L.E. 1996. Total carbon, organic carbon and organic matter, SSSA Book Ser.5. In: Sparks, D.L., et al (eds). *Method of soil analysis.* Part 3. SSSA, Madison, WI, 961-1010.

Olsen, S.R., Cole, C.V., Watanabe, F.S., Dean, L.A.1954. *Estimation of available phosphorous by extraction with sodium bicarbonate.* USDA. Circ., 939.

Pratt, P.F., Suarez, D.L. 1990. Irrigation water quality assessment. In: *Agricultural Salinity Assessment and Management* (Ed, K. K. Tanji,). American Society of Civil Engineers, New York, p 220.

Prihar, S.S., Sandhu, B.S. 1987. *Irrigation of field crops: principles and practices.* Indian Council of Agricultural Research, New Delhi. P. 142.

Shainberg, I., Rhoades, J.D., Suarez, D.L., Prather, R.J. 1981. Effect of mineral weathering on clay dispersion and hydraulic conductivity of sodic soil. *Soil Sci. Soci. Amer. Jour.* **45** : 287-91.

Stone, J.F., Reeves, H.E., Garton, J.E. 1982. Irrigation water conservation by using wide-spaced furrows. *Agri. Water Manag.* **5** : 309-17.

Suarez, D.L., Wood, J.D., Lesch, S.M. 2006. Effect of SAR on water infiltration under a sequential rain-water management system. *Agri. Water Manag.* **86** : 150-64.

Tang, L.S., Li, Y., Zhang, J. 2005. Physiological and yield responses of cotton under partial root zone irrigation. *Field Crops Res.* **94** : 214-23.

Thind, H.S., Aujla, M.S., Buttar, G.S. 2008. Response of cotton to various levels of nitrogen and water applied to normal and paired sown cotton under drip irrigation in relation to check-basin. *Agri. Water Manag.* **95** : 25-34.

ABSTRACTS - ORAL PRESENTATION

Proceedings on "Global Cotton Production Technologies *vis-a-vis* Climate Change" 127-132

CROP IMPROVEMENT AND BIOTECHNOLOGY

Study of heterosis for fibre quality characters in GMS based diploid cotton hybrids

SEKHAR BABU GEDDAM*, B.M. KHADI, RAJESH S. PATIL., L. SEKHAR, NAGAPPA HARIJAN., SUMA C. MOGALI AND I. S. KATAGERI

Department of Genetics and Plant Breeding, University of Agricultural sciences, Dharwad - 580 005

**E-mail : sekharbabug.iari@gmail.com*

Abstract : The investigation was carried out during *kharif,* 2009-2010 at Main Agricultural Research Station, UAS, Dharwad. A total of nine genetic male sterility based hybrids were tested for heterosis over mid parent, better parent and checks for fibre quality characters. All the parents and hybrids recorded significantly higher fibre length over the hybrid check AAH 1. Six crosses showed positive significant heterosis for fibre length over varietal check GSaV-1056. Except the cross, MSD 7 nkd × Jayadhar, all the entries showed significantly higher fibre strength over the check AAH 1. Two crosses MSD 7 nor × ARBH 35 and MSD 7 nor × DDhc 11 exhibited significant heterosis in desirable direction over mid parent, better parent and both the checks for fibre strength. For fibre fineness all the hybrids recorded significantly lower micronaire values than the hybrid check. All the crosses over GSaV-1056 exhibited significant heterosis for fibre uniformity ratio. The crosses MSD 7 nor × RAhS 14 and MSD 10 × RAhS 14 for fibre length, MSD 7 nor × DDhc 11 and MSD 7 nor × ARBH 35 for fibre strength, fibre fineness and fibre elongation (%), MSD 11 × DLSa 102 and MSD 7 nkd × Jayadhar for uniformity ratio were found superior.

Key words : Diploid cotton, fibre quality, genetic male sterility, heterosis

Cotton, the most important fibre crop of the world often called as the 'White Gold' belongs to the genus *Gossypium*. In cotton, mainly two types of male sterility systems *viz.*, Cytoplasmic Genetic Male Sterility (CGMS) and Genetic Male Sterility (GMS) systems are used for hybrid seed production. GMS is preferred than CGMS as it overcomes the drawbacks of cytoplasmic effect and problem of fertility restoration. GMS character in tetraploids is conditioned by double homozygous recessive alleles, ms_5 ms_5 ms_6 ms_6 whereas in diploids it is controlled by single recessive alleles, ams_1 ams_1 (Singh and Kumar, 1993). The availability of Genetic male sterility system (GMS) in diploid cotton resulted in release of GMS based diploid hybrids *viz.*, AAH 1, CISAA 2, AKDH 7 and G.cot MDH 11 (Patel *et al.*, 2004) for commercial cultivation in India. The objective of the present experiment was to study the heterosis for fibre quality parameters in GMS based diploid hybrids.

MATERIALS AND METHODS

A total of nine GMS based diploid cotton hybrids (five interspecific and four intraspecific) were developed by making crosses between four GMS lines of *Gossypium arboreum viz.,* MSD 7 nor, MSD 7 nkd, MSD 10 and MSD 11 using as female parents and three varietal lines of *G. herbaceum* and two varietal lines of *G. arboreum* as male parents during *kharif,* 2008-2009. Hybrids along with parents and two checks (GMS based diploid hybrid AAH-1 and *G.arboreum* variety GSaV 1056) were evaluated under RCBD with three replications maintaining each row of three meter length during *kharif,* 2009-2010 at MARS, Dharwad. The spacing of 90 cm between rows and 60 cm between plants was used. All the "Package of Practices" recommended for diploid cotton were adopted from time to time to raise the healthy crop. Observations were recorded on five randomly selected plants from each treatment and replication for the fibre quality traits *viz.,* fibre length, fibre strength, fibre fineness, uniformity ratio and fibre elongation percentage.

The data was analyzed using the standard statistical package to find extent of heterosis over mid parent, better parent and standard checks. Heterosis was expressed in percentage.

RESULTS AND DISCUSSION

The analysis of variance showed that the parents and hybrids differed significantly for all the characters under study indicating presence of considerable genetic variability between the genotypes. The mean performance the parents, their hybrids and checks and heterosis expressed by the hybrids for each trait is presented in Table 1 and Table 2 respectively and discussed in the following sub headings.

Number of bolls/plant : The mean number of bolls in case of females, males and hybrids was 11.97, 13.61 and 23.14, respectively. None of the hybrids showed higher mean than the check AAH 1. But, all the crosses showed significantly higher mean over the check GSaV 1056. The range of mid parent heterosis was from 20.31 (MSD 11 × ABBH 35) to 130.27 per cent (MSD 7 nor × RAhS 14). All the crosses except one MSD 11 × ABBH 35 showed significant mid parent heterosis. The magnitude of heterosis over better parent was from –5.51 (MSD 11 × ABBH 35) to 102.08 per cent (MSD 7 nor × RAhS 14). A total of 7 crosses recorded significant and positive heterobeltiosis. None of the crosses showed significant positive heterosis over the check AAH 1. All the crosses except one MSD 10 × RAhS 14 showed significant positive standard heterosis over GSaV 1056 an varietal check with a range from 36.22 (MSD 10 × RAhS 14) to 97.96 per cent (MSD 7 nor × RAhS 14). The findings of heterosis for this trait are in agreement with the reports of Govindaraju (2002) and Maisuria *et al.,* (2007).

Ginning outturn (%) : The mean GOT of 28.31 per cent, 31.01 per cent and 34.94 per cent was exhibited by the female, male parents and hybrids, respectively. None of the parents and hybrids had significantly higher percentage of ginning outturn over hybrid check AAH 1 (40.73%). However all the crosses exhibited significantly higher mean for GOT over the check GSaV 1056. Except the cross MSD 7 nkd × DLSa 102, all the crosses had significant positive mid parent heterosis. The cross MSD 7 nor × RAhS 14 (33.70%) had highest mid parent heterosis. Six hybrids recorded significant heterobeltiosis with a range from 2.65 (MSD 7 nor × DDhc 11) to 27.72 per cent (MSD 11 × ARBH 35). None of the crosses exhibited significant standard heterosis over AAH 1 in desirable direction. The range of heterosis over the check GSaV 1056 ranged from 5.65 (MSD 7 nkd × DLSa 102) to 29.72 per cent (MSD 7 nor × RAhS 14) and all the crosses except two (MSD 7 nor × DDhc 11 and MSD 7 nkd × DLSa 102) exhibited significant useful heterosis in desirable direction. These findings are in conformity with the reports of Tuteja *et al.,* (2000) and Karande (2004).

Seed cotton yield (g / plant) : Among the females, MSD 7 nkd, among the males ARBH 35 and among hybrids MSD 7 nor × RAhS 14 ranked first for seed cotton yield/plant *i.e.*, 22.86, 32.03 and 73.07 g/plant, respectively. None of the hybrids showed significant higher seed cotton yield over check AAH 1. However all hybrids over GSaV 1056 had significantly higher mean seed cotton yield per plant. The heterosis over mid parent ranged from 89.32 (MSD 11 × ARBH 35) to 294.92 (MSD 7 nor × RAhS 14). The heterosis over better parent ranged from 47.09 (MSD 11 × ARBH 35) to 220.61 per cent (MSD 7 nor × RAhS 14) and all the hybrids showed significant positive heterosis over better parent. The standard heterosis over AAH 1 ranged from -62.57 (MSD 10 × RAhS 14) to -25.82 per cent (MSD 7 nor × RAhS 14), none of the crosses showed significant positive heterosis. The hybrids showed a range of 88.75 (MSD 10 × RAhS-14) to 274.06 (MSD 7 nor × RAhS 14) per cent standard heterosis over GSaV 1056 and all the hybrids showed significant positive heterosis. The results are in agreement with those of Patel and Pethani (1998), Kajjidoni *et al.,* (1999) and Maisuria *et al.,* (2007).

2.5 per cent span length (mm) : The mean fibre length at 2.5 per cent span ranged from 21.60 (MSD 7 nkd × Jayadhar) to 28.10 mm (MSD 7 nor × RAhS 14) in hybrids. The mean fibre length of was 25.10 and 24.30 mm in females and males, respectively. All the parents

Table 1. Mean performance of parents, hybrids and checks for important yield component traits and fibre quality parameters in diploid cotton

Sl. No	Entries	Bolls/ plant	Ginning outturn (%)	Seed cotton yield (g/plant)	2.5 per cent span length (mm)	Fibre strength (g/tex)	Micronaire value (10^{-6} g/inch)	Uniformity ratio (%)	Fibre elongation (%)
Females									
1	MSD 7 nor	12.80	26.80	22.79	23.7	16.5	5.9	48	5.5
2	MSD 7 nkd	12.33	28.20	22.86	25.6	18.7	6.0	51	5.6
3	MSD 10	10.33	28.82	15.24	26.0	20.4	5.7	51	5.5
4	MSD 11	12.40	29.42	17.74	25.1	17.9	5.2	48	5.6
	Mean	**11.97**	**28.31**	**19.66**	**25.1**	**18.3**	**5.7**	**49**	**5.5**
Males									
1	ARBH 35	21.73	28.50	32.03	24.8	19.3	3.5	49	5.4
2	DLSa 102	12.60	29.25	20.69	25.6	19.6	3.5	52	5.6
3	Jayadhar	12.13	30.97	15.01	25.4	18.5	5.5	50	5.5
4	DDhc 11	11.93	31.37	19.42	22.5	16.4	5.4	51	4.6
5	RAhS 14	9.67	30.44	14.21	23.1	17.8	4.8	49	5.4
	Mean	**13.61**	**30.10**	**20.27**	**24.3**	**18.3**	**4.5**	**50**	**5.3**
Crosses									
1	MSD 7 nor × ARBH 35	22.40	35.85	58.32	25.3	21.6	4.2	49	5.9
2	MSD 7 nor × DDhc 11	24.20	32.20	66.28	24.6	22.5	4.7	50	6.1
3	MSD 7 nor × Jayadhar	25.73	35.09	67.37	25.1	18.0	5.2	51	5.2
4	MSD 7 nor × RAhS 14	25.87	38.27	73.07	28.1	19.9	4.8	49	5.6
5	MSD 7 nkd × DLSa 102	24.73	31.17	53.23	23.3	18.0	5.2	52	5.5
6	MSD 7 nkd × Jayadhar	23.57	36.90	57.19	21.6	14.9	6.6	54	5.2
7	MSD 10 × RAhS 14	17.80	33.27	36.87	26.5	21.0	5.5	53	5.4
8	MSD 11 × DLSa 102	23.47	34.11	52.00	22.0	17.5	5.2	53	5.7
9	MSD 11 × ARBH 35	20.53	37.58	47.11	26.4	18.2	5.4	49	5.7
	Mean	**23.14**	**34.94**	**56.83**	**24.7**	**19.0**	**5.2**	**51**	**5.6**
Checks									
1	AAH 1	57.47	40.73	98.50	18.9	14.4	7.5	56	6.9
2	GSaV 1056	13.07	29.50	19.53	22.0	16.7	3.6	46	5.3
	SEm+	2.37	1.63	6.37	0.64	0.49	0.22	0.65	0.08
	CD (p=0.05)	4.78	3.28	12.83	1.30	0.99	0.44	1.31	0.16
	CD (p=0.05)	6.39	4.39	17.14	1.73	1.32	0.58	1.74	0.22
	CV (%)	14.47	6.10	18.62	3.22	3.24	5.08	1.59	1.83

and hybrids recorded significantly higher fibre length over the hybrid check AAH 1. Seven crosses and all parents exhibited higher fibre length over varietal check GSaV 1056. The range of heterosis for span length over mid parent was from -13.97 (MSD 7 nkd × Jayadhar) to 18.94 per cent (MSD 7 nor × RAhS 14) and four hybrids showed significant mid parent heterosis in desirable direction. Only one cross, MSD 7 nor × RAhS-14 showed heterobeltiosis in desirable direction. The heterosis over AAH 1 was from 14.02 (MSD 7 nkd × Jayadhar) to 48.68 per cent (MSD 7 nor × RAhS 14) and all the crosses exhibited significant positive heterosis in desirable direction. Except three crosses (MSD 7 nkd × DLSa 102, MSD 7 nkd × Jayadhar and MSD 11 × DLSa 102) all the crosses had significant positive heterosis over the varietal check GSaV 1056. These findings are in agreement with those of Modi *et al.,* (1999), Tuteja *et al.,* (2005), and Maisuria *et al.,* (2007).

Fibre strength (g/tex) : The overall mean fibre strength observed was 18.3 g/tex in females and males. In hybrid it ranged from 14.90 (MSD 7 nkd × Jayadhar) to 22.50 g/tex (MSD 7 nor × DDhc 11) with overall mean of 19.00 g/tex and all the entries showed higher fibre strength over the hybrid check AAH 1. The range of heterosis over mid parent was from -21.84 (MSD 7 nkd × Jayadhar) to 37.20 per cent (MSD 7 nor × DDhc 11), four hybrids showed significant positive mid parent heterosis. Three hybrids had highly significant heterobeltiosis. Except one (MSD 7 nkd × Jayadhar) all other crosses revealed significant positive heterosis over the check AAH 1 with a range from 3.48 (MSD 7 nkd × Jayadhar) to 56.79 per cent (MSD 7 nor × DDhc 11). All crosses except two (MSD 7 nkd × Jayadhar and MSD 11 × DLSa 102) have exhibited significant heterosis over GSaV 1056. Two crosses MSD 7 nor × ARBH 35 and MSD 7 nor × DDhc 11 exhibited significant heterosis in desirable direction over mid parent, better parent and both the checks. So these crosses can be used for exploiting the heterosis for this trait. The results are in conformity with those of Karande *et al.,* (2004), Tuteja *et al.*, (2007) and Maisuria *et al.,* (2007).

Micronaire (10^{-6} g/inch) : The average micronaire ranged between 4.20 (MSD 7 nor × ARBH-35) and 6.60 g/inch (MSD 7 nkd × Jayadhar) in hybrids. The overall mean for micronaire recorded by female, male and hybrids were 5.70, 4.50 and 5.20, respectively. All the hybrids recorded significantly lower micronaire values than the check AAH 1. The range of heterosis over mid parent was from -16.96 (MSD 7 nor × DDhc 11) to 38.95 per cent (MSD 7 nkd × Jayadhar), a total of four hybrids displayed significant mid parent heterosis in desirable (negative) direction. Only one cross (MSD 7 nor × DDhc 11) exhibited significant heterobeltiosis in desirable direction. All the hybrids manifested highly significant heterosis in negative direction over the hybrid check AAH 1 with a range from -44.30 (MSD 7 nor × ARBH 35) to -11.41 per cent (MSD 7 nkd × Jayadhar). None of the crosses showed useful heterosis in desirable direction over the varietal check GSaV 1056 for this trait. The finest fibre was noticed in the cross MSD 7 nor × ARBH 35. Similar results have been noticed by Maisuria *et al.,* (2007) and Jyotiba (2007).

Uniformity ratio (%) : The overall mean for uniformity ratio was 49, 50 and 51 per cent recorded by the female, males and hybrids, respectively. The range of heterosis over mid and better parent was from -2.51 (MSD 11 × ARBH 35) to 8.25 per cent (MSD 11 × DLSa 102) and from -6.73 (MSD 11 × ARBH 35) to 5.00 per cent (MSD 11 × DLSa 102) respectively. A total of five crosses showed significant positive heterosis over both the mid parent and better parent. None of the crosses had significant positive heterosis over check AAH 1 for this trait. All the crosses over GSaV 1056 exhibited significant heterosis ranging from 5.43 (MSD 11 × ARBH 35 and MSD 7 nor × RAhS 14) to 16.30 (MSD 7 nkd × Jayadhar). The findings are in accordance with the reports of Tuteja *et al.,* (2005) and Jyotiba (2007)

Fibre elongation (%) : The hybrids (5.60%) showed higher mean fibre elongation (%) than the males (5.30%) and females (5.50%). The mid parent heterosis ranged from -5.02 (MSD 7 nkd × Jayadhar) to 21.00 per cent (MSD 7 nor × DDhc 11) and three crosses showed significant mid parent heterosis. Only two crosses (MSD 7 nor × ARBH 35, and MSD 7 nor × DDhc 11) had

Table 2. Percentage heterosis for important yield component characters and fibre quality traits over mid parent (MPH), better parent (BPH) and checks (AAH-1 and GSav-1056)

Sl. No,	Crosses	Number of bolls/plant				Ginning outturn				Seed cotton yield (g/plant)			
		MPH	BPH	AAH 1	GSaV 1056	MPH	BPH	AAH 1	GSaV 1056	MPH	BPH	AAH 1	GSaV 1056
1	MSD 7 nor × ARBH 35 (a x a)	29.73*	3.08	-61.02**	71.43**	29.66**	25.79**	-11.99**	21.53**	112.77**	82.07**	-40.80**	198.55**
2	MSD 7 nor × DDhc 11 (a x h)	95.69**	89.06**	-57.89**	85.20**	10.72*	2.65	-20.95**	9.15	214.06**	190.81**	-32.71**	239.30**
3	MSD 7 nor × Jayadhar (a x h)	106.42**	101.04**	-55.22**	96.94**	21.48**	13.29*	-13.86**	18.94**	256.44**	195.60**	-31.61**	244.88**
4	MSD 7 nor × RAhS 14 (a x h)	130.27**	102.08**	-54.99**	97.96**	33.70**	25.71**	-6.06	29.72**	294.92**	220.61**	-25.82**	274.06**
5	MSD 7 nkd × DLSa 102 (a x a)	98.40**	96.30**	-56.96**	89.29**	8.51	6.55	-23.49**	5.65	144.49**	132.87**	-45.96**	172.53**
6	MSD 7 nkd × Jayadhar (a x h)	92.64**	91.13**	-58.99**	80.36**	24.74**	19.15**	-9.41*	25.08**	202.05**	150.19**	-41.94**	192.80**
7	MSD 10 × RAhS 14 (a x h)	78.00**	72.31**	-69.03**	36.22	12.30*	9.31	-18.31**	12.79*	150.33**	141.93**	-62.57**	88.75**
8	MSD 11 × DLSa 102 (a x a)	87.73**	86.24**	-59.16**	79.59**	16.29**	15.94**	-16.26**	15.63**	170.62**	151.33**	-47.21**	166.21**
9	MSD 11 × ARBH 35 (a x a)	20.31	-5.51	-64.27**	57.14**	29.76**	27.72**	-7.75	27.38**	89.32**	47.09*	-52.17**	141.19**
	SEm+	2.06	2.37	2.37	2.37	1.41	1.63	1.63	1.63	5.51	6.37	6.37	6.37
	CD (p=0.05)	4.14	4.78	4.78	4.78	2.84	3.28	3.28	3.28	11.11	12.83	12.83	12.83
	CD (p=0.05)	5.53	6.39	6.39	6.39	3.80	4.39	4.39	4.39	14.85	17.14	17.14	17.14

Sl. No,	Crosses	25 per cent span length (mm)				Ginning outturn				Micronaire (µg/inch)			
		MPH	BPH	AAH-1	GSaV 1056	MPH	BPH	AAH-1	GSaV 1056	MPH	BPH	AAH-1	GSaV 1056
1	MSD 7 nor × ARBH 35 (a x a)	2.64	0.40	33.86**	15.26**	19.83**	10.20**	50.52**	29.73**	-11.23**	18.57**	-44.30**	16.90**
2	MSD 7 nor × DDhc 11 (a x h)	5.25*	1.87	29.89**	11.85**	37.20**	36.78**	56.79**	35.14**	-16.96**	-13.08**	-37.58**	30.99**
3	MSD 7 nor × Jayadhar (a x h)	3.08	2.03	32.80**	14.35**	0.70	-6.74*	25.44**	8.11**	10.16*	47.14**	-30.87**	45.07**
4	MSD 7 nor × RAhS 14 (a x h)	18.94**	16.60**	48.68**	28.02**	16.37**	12.11**	38.68**	19.52**	-9.43*	1.05	-35.57**	35.21**
5	MSD 7 nkd × DLSa 102 (a x a)	-8.82**	-8.82**	23.02**	5.92	-3.49	-4.01	25.09**	7.81*	-9.57**	-5.45	-30.20**	46.48**
6	MSD 7 nkd × Jayadhar (a x h)	-13.97**	-15.49**	14.02**	-1.82	-21.84**	-23.06**	3.48	-10.81**	38.95**	88.57**	-11.41**	85.92**
7	MSD 10 × RAhS 14 (a x h)	7.96**	2.32	39.95**	20.50**	9.97**	2.95	45.99**	25.83**	5.77	15.79**	-26.17**	54.93**
8	MSD 11 × DLSa 102 (a x a)	-13.13**	-13.73**	16.40**	0.23	-3.99	-5.68*	21.60**	4.80	-3.74	-0.96	-30.87**	45.07**
9	MSD 11 × ARBH 35 (a x a)	4.87*	4.76	39.68**	20.27**	-3.07	-7.40**	26.48**	9.01**	22.99**	52.86**	-28.19**	50.70**
	SEm+	0.56	0.64	0.64	0.64	0.42	0.49	0.49	0.49	0.19	0.22	0.22	0.22
	CD (p=0.05)	1.12	1.30	1.30	1.30	0.86	0.99	0.99	0.99	0.38	0.44	0.44	0.44
	CD (p=0.05)	1.50	1.73	1.73	1.73	1.14	1.32	1.32	1.32	0.50	0.58	0.58	0.58

Sl. No	Crosses	Uniformity ratio (%)				Elogation (%)			
		MPH	BPH	AAH 1	GSaV 1056	MPH	BPH	AAH 1	GSaV 1056
1	MSD 7 nor × ARBH 35 (a x a)	-1.51	-5.77**	-12.50**	6.52**	5.88**	4.46**	-15.22**	10.38**
2	MSD 7 nor × DDhc 11 (a x h)	0.51	-2.94*	-11.61**	7.61**	21.00**	10.00**	-12.32**	14.15**
3	MSD 7 nor × Jayadhar (a x h)	5.21**	3.06*	-9.82**	9.78**	-4.15**	-5.45**	-24.64**	-1.89
4	MSD 7 nor × RAhS 14 (a x h)	1.04	-1.02	-13.39**	5.43**	3.23*	1.82	-18.84**	5.66**
5	MSD 7 nkd × DLSa 102 (a x a)	3.00*	3.00*	-8.04**	11.96**	0.00	-1.79	-20.29**	3.77*
6	MSD 7 nkd × Jayadhar (a x h)	8.08**	4.90**	-4.46**	16.30**	-5.02**	-7.14**	-24.64**	-1.89
7	MSD 10 × RAhS 14 (a x h)	5.53**	2.94*	-6.25**	14.13**	-1.38	-2.73	-22.46**	0.94
8	MSD 11 × DLSa 102 (a x a)	8.25**	5.00**	-6.25**	14.13**	2.26	0.89	-18.12**	6.60**
9	MSD 11 × ARBH 35 (a x a)	-2.51*	-6.73**	-13.39**	5.43**	1.79	1.79	-17.39**	7.55**
	SEm+	0.56	0.65	0.65	0.65	0.07	0.08	0.08	0.08
	CD (p=0.05)	1.13	1.31	1.31	1.31	0.14	0.16	0.16	0.16
	CD (p=0.05)	1.51	1.74	1.74	1.74	0.19	0.22	0.22	0.22

*, ** - Significant at 5% and 1% level of probability.

significant positive heterobeltiosis. None of the crosses manifested significant heterosis in desirable direction over the check AAH-1. Heterosis over GSaV-1056 ranged from -1.89 (MSD 7 nor × Jayadhar and MSD 7 nkd × Jayadhar) to (14.15 MSD 7 nor × DDhc 11) and total of six hybrids exhibited significant positive heterosis. The results were akin to the reports of Valarmathi and Jahangir (1998) and Thangaraj *et al.,* (2002).

From the present study, it is clear that even though the hybrids evaluated were found to be less superior than the commercial hybrid check AAH-1 for yield attributing characters like number of bolls/plant, ginning outturn and seed cotton yield, they were found to be highly superior to AAH 1 for important fibre quality traits like fibre length, fibre strength and micronaire. Hence, these crosses can be utilized for exploiting heterosis. On the whole, the crosses MSD 7 nor × RAhS 14 and MSD 10 × RAhS 14 for fibre length, MSD 7 nor × DDhc 11 and MSD 7 nor × ARBH 35 for fibre strength, fibre fineness and fibre elongation (%), MSD 11 × DLSa 102 and MSD 7 nkd × Jayadhar for uniformity ratio were found superior.

ACKNOWLEDGEMENTS

First author sincerely thanks Indian Council of Agricultural Research (ICAR) for providing Junior Research Fellowship during Master Degree Programme.

REFERENCES

Govindraju, N. S., 2002, Studies on genetic male sterility system in cultivated diploid cotton and its utilization for exploitation of hybrid vigor. *M. Sc. (Agri.) Thesis,* Uni. Agric. Sci. Dharwad.

Jyotiba, S. S., 2007, Heterosis and combining ability studies in cotton. *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad.

Kajjidoni, S. T., Patil, S. J., Khadi, B. M. and Salimath, P. M., 1999, A comparative study of heterosis in GMS based and conventional intra *arboreum* cotton hybrids. *Ind. J. Genet. and Plant Breeding*, **59**(4) : 493-504.

Karande, S. S., Wandhare, M. R., Ladole, M. Y., Waode, M. M. and Meshram, L. D., 2004, Heterosis and combining ability studies in interspecific diploid cotton hybrids for fibre quality parameters. Int. Symp. on *"Strategies for Sustainable Cotton Production – A Global Vision 1. Crop Improvement,* 23-25 November, 2004, Univ. Agric. Sci., Dharwad,

Maisuria, A. T., Patel, J. C., Patel, K. G., Patel, D. H. and Chhimpi, B. G., 2007, Heterosis for yield and its contributing characters in GMS based Asiatic cottons. *J. Indian Soc. Cotton Improv.*, **32**(1) : 30-40.

Modi, N. D., Patel, J. C., Patel, D. H., Maisuria, A. T. and Patel, U. G., 1999, Heterosis and combining ability for yield and fibre quality in desi cottons. *J. Indian Soc. Cotton Improv.*, **24**(3) : 132-34.

Patel, G. S. and Pethani, K. V., 1998, Studies on heterosis for quantitative characters over environments in desi cotton (*Gossypium arboreum* L.). *J. Indian Soc. Cotton Improv.*, **23**(1) : 54-59.

Patel, U. G., Patel, J. C., Patel, D. H., Patel, K. G. and Chhimpi, B. G., 2004, GMS based diploid cotton hybrid G. Cot. MDH-11 – A new hope for rainfed farming. *J. Indian Soc. Cotton Improv.,* **29(1)** : 49.

Singh, D. P. and Kumar, R., 1993, Genetic male sterility in Asiatic cotton. *Indian J. Gene. Pl. Breed.,* **53(1)** : 99-100.

Thangaraj, K., Raveendran, T. S. and Jehangir, K. S., 2002, Heterosis and inbreeding depression in interracial derivatives of *Gossypium hirsutum* L. for fibre quality. *J. Ind. Soc. Cotton Improv.*, **27**(2) : 5-10.

Tuteja, O. P., Singh, D. P., Narula, A. M. and Singh, U. V., 2000, Studies on heterosis for yield and quality characters over environments in desi cotton hybrids based on GMS system. *J. Ind. Soc. Cotton Improv.*, **25**(2) : 23-28.

Tuteja, O. P., Sunil Kumar, Mahendar Singh and Hamid Hasan, 2005, Heterosis in GMS based intra-hirsutum hybrids (*Gossypium hirsutum* L.) for fibre quality characters. *J. Indian Soc. Cotton Improv.*, **30**(1) : 47-52.

Tuteja, O. P., Verma, S. K., Mahendar Singh and Khadi, B. M., 2007, Effect of restorer lines and *Gossypium harknesii* based cytoplasmic male sterility on yield and fibre quality traits in cotton. *J. Indian Soc. Cotton Improv.*, pp. 41-49.

Valarmathi, S. and Jehangir, K. S., 1998, Line × tester analysis for combining ability analysis in *G. hirsutum* L. cotton. *Madras Agric. J.*, **85**(2) : 103-05.

Genetic variance and combining ability estimates in upland cotton for yield and quality characters (*Gossypium hirsutum* L)

O. P. TUTEJA* AND D. MONGA
Central Institute for Cotton Research, Regional Station, Sirsa 125 055
**E-mail : optuteja2001@yahoo.co.in*

Abstract : Cotton is an often cross pollinated crop and possesses a considerable amount of heterosis. 1st conventional hybrid was developed in India but in other countries hybrid seed production by conventional method could not be made possible being labour intensive. Several alternate methods for emasculation are available; however GMS and CMS systems are quite effective, because in rest of the methods there is always a chance of pistil damage and anthers are not completely eliminated. In case of GMS and CMS systems only GMS system may be more effective, because in CMS system there is a deleterious effect of *G. harknessii* cytoplasm, which suppresses the yield. But the success in development of GMS based hybrid largely depends on availability of stable GMS line and the good combiner male parent. The present study was to estimate the *gca* of the parents and *sca* of the hybrids for the development of high yielding and better quality cultivars. Combining ability was studied in a line x tester design involving five GMS lines as female parent and ten germplasm lines as male parent for yield and quality traits. In a line x tester analysis, analysis of variance for combining ability indicated predominance of non-additive variance for all the characters except 2.5 per cent span length. The studies on *gca* of parents revealed that the male parents OK 2885, CSH 2912, CSH 3129, CSH 2907 and female parents GMS 26, GMS 27, GMS 17 for seed cotton yield were found to be good general combiners. Similarly GMS 17 for ginning percentage and CNH 911 for 2.5 per cent span length and 004 NAH, OK 2885, CNH 911, GMS 27 for fiber strength (g/tex) showed significant positive *gca* effects. Among fifty cross combinations, *sca* was significant for fifteen parents in terms of seed cotton yield and GMS 20 x CNH 911, GMS 27 x H-103, GMS 17 x 004 NAH hybrids had the highest *sca*. The crosses showing significant positive *sca* effects were having one of the parents with good general coming ability.

Key words: Combining ability, cotton, genetic male sterility, *Gossypium hirsutum*

Cotton (*Gossypium hirsutum* L.) is an important fibre crop and plays a vital role as a cash crop in commerce of many countries such as USA, China, India, Pakistan, and Africa. Cotton crop is mainly cultivated for fibre. High seed cotton yield is the ultimate objective of any crop breeding programme. Seed cotton yield is the end product of number of yield component such as boll number, boll weight etc. Industrial demand of cotton with superior fibre trait is also source of guide line for cotton breeders. Seed cotton yield and its quality parameters are quantitative traits, which are controlled by several genes thus showing a range of values in segregating generation. Line x tester analysis is one of the most widely used techniques for identification of genetic variation in characters. Combining ability analysis provides an ample opportunity to cotton breeders to understand the basis on which certain parental lines could be exploited in the breeding programme . The main objective of this study was to evaluate general combining ability of parents and specific combining ability of hybrids and also for selecting the superior hybrids that can be used in breeding program of cotton.

MATERIALS AND METHODS

The line x tester design used in the present study comprised of 15 parents (5 lines namely GMS 26, GMS 20, GMS 27, GMS 21,GMS 17 and 10 testers 003 NAH, 004 NAH, OK 2885, CNH 911, CSH 2912, CSH 2832, CSH 3129, H-103, CSH 2907, CSH 2810 was under taken at Central Institute for Cotton Research, Regional Station, Sirsa during 2011-2012. Fifteen parents and fifty crosses were grown in a randomized block design (RBD) with three replications and also with a spacing of 100 x 60 cm between row to row and plant to plant, respectively. Data were recorded on five competitive plants for seed cotton yield (kg/plot), monopodia/plant, sympodia/plant, bolls/plant, boll weight(g), ginning outturn(%), seed index(g), 2.5 per cent span length (mm), micronaire value (ìg/inch), fibre strength (g/tex), The data on seed cotton yield was recorded on per plot basis and converted to kg/ha basis. The data were used for statistical analysis using the method developed by Kempthorne (1957).

RESULTS AND DISCUSSION

The analysis of variance indicated that the mean squares due to genotypes for all the characters were significantly different, revealed presence of genetic diversity among them. The mean squares due to parents and hybrids were significant for seed cotton yield (kg/ha), monopodia, sympodia and bolls/plant, boll weight (g), GOT (%),seed index, 2.5 per cent span length and strength (g/tex) except micronaire value. Similarly the interactions due to parents *v/s* hybrids were also significant for seed cotton yield, monopods, sympods and bolls/plant boll weight, ginning outturn, 2.5 per cent span length and bundle strength except seed index, micronaire value. This indicated that hybrids and parents showed significant genetic variation.

From Table 1, the variance due to *gca* was lower than *sca* for seed cotton yield, ginning percentage, boll weight, bolls, monopods and sympods/plant, micronaire value and fibre strength expressed non-additive gene action which is in accordance with the previous results of Ahuja and Dhayal (2007), Ilyas *et al., (*2007), Preetha and Raveendran (2008) and Cetin Karademir *et al.,* (2009). However, General combining ability variance (ó^2 *gca*) was higher than specific combining ability variance (ó^2 *sca*) for 2.5 per cent span length, which reflects the role of additive type of gene action (Table1). The results are in compromise with the findings of Iqbal *et al.*, (2005), Rauf *et al.,* (2006) and Cetin Karademir *et al.,* (2009). Lukange *et al.,* (2007) revealed additive gene effects for fibre strength and microanire value and non additive gene action for fibre length. These results suggested that heterosis breeding was suitable for all the characters including fibre properties. The non-additive gene actions are also important for varietal adaptability.

The *gca* effects of parents are presented in Table 2. Among the parents, the best general combiner was line GMS 26, GMS 27, GMS 17 and testers OK 2885, CSH 2912, CSH 3129, CSH 2907 recorded positive significant *gca* effects for seed cotton yield. Therefore the line GMS-26, GMS 27, GMS 17 and tester OK 2885, CSH 2912, CSH 3129, CSH 2907 were identified as good source in improving yield characters. Apart from this 003 NAH, 004NAH, OK 2885, CSH 2810,GMS-20, GMS-21 has recorded high *gca* for monopodia/ plant and while only two male parents H 103, CSH 2907 has positibve and significant *gca* effects for sympodia/plant.

Significant and positive *gca* effects were recorded for bolls/plant by the male parents CSH 2832, CSH 3129, H 103 and female parent GMS 17. Similarly, for boll weight, only three male parents OK 2885, CNH 911, CSH 3129 had the significant and positive *gca* effects while only one male parent CSH 2810 showed negative and significant *gca* effect and other parents effects were negative. It was also found that for boll weight, no one female parents showed significant *gca* effect. Among the fifteen parents, only one line GMS17 showed significant and positive *gca* for ginning percentage while other parents effects were non-significant. For seed index five parents 004 NAH, OK 2885, CNH 911, CSH 3129 and GMS 21showed significant and positive *gca* effect and these were considered as good combiners for seed index.

For fibre quality characters only one male parent CNH 911 showed high significant *gca* for 2.5 per cent span length. None of the male and female parents showed significant estimates of *gca* for Micronaire value. Likewise, four parents 004 NAH, OK 2885, CNH 911, GMS 27 displayed positive and significant *gca* effect for fibre strength (g/tex). For this reason these parents were selected as the most promising parents to improve this property.

The *sca* effects of the crosses are presented in Table 3. The specific combining ability value of any cross was helpful in predicting the performance of the better parents. Out of the 50 hybrids, fifteen hybrids GMS 26 x CSH 2912, GMS 20 x 004 NAH , GMS 20 x CNH 911, GMS 20 x CSH 3129, GMS 27 x CSH 2912, GMS 27 x CSH 2832, GMS 27 x H 103, GMS 27 x CSH 2907, GMS 27 x CSH 2810, GMS 21 x 003 NAH , GMS 21 x OK 2885, GMS 21 x CNH 911, GMS 21 x CSH 2832, GMS 17 x 004 NAH , GMS 17 x CSH 3129 showed significantly positive *sca* effects but GMS 20 x

Table 1. Analysis of variance for line x tester and combining ability for yield and quality characters

Source	D.F.	Yield (kg/ha)	Mono-podia/ plant	Sym-podia/ plant	Bolls/ plant	Boll weight (g)	GOT index	Seed length	2.5 per cent span (mm)	Micro-value	Strength (g/tex)
Replication	2	4787.09**	0.061	3.017**	8.025	0.073	10.447**	1.001**	0.191	0.041	0.033
Genotypes	64	310154.00**	2.153**	5.300**	125.424**	0.349**	4.010**	1.175**	0.269**	0.027	0.322**
Parents	14	199974.18**	1.639**	4.359**	218.260**	0.646**	6.785**	1.872**	0.487**	0.035	0.574**
Parents *vs* Hybrids	1	4682320.34**	5.053**	2.437**	84.720**	0.361**	8.650**	0.181	0.674**	0.000	0.233**
Hybrids	49	252406.06**	2.241**	5.627**	99.730**	0.263**	3.123**	0.996**	0.198*	0.025	0.252**
gca (Lines)	4	1109377.67**	2.882**	4.578**	211.919**	0.360**	7.701**	1.215**	0.629**	0.036	0.517**
gca (Tester)	9	313583.06**	1.819**	5.596**	139.411**	0.501**	1.228	2.447**	0.256*	0.028	0.310**
sca (Line x Tester)	36	141892.75**	2.275**	5.751**	77.345**	0.193**	3.088**	0.610**	0.136	0.023	0.208**
Error	98	11331.40	0.086	1.004	6.830	0.067	0.652	0.093	0.102	0.033	0.037
ó^2 *gca*		25,315.01*	0.003	-0.030	4.370	0.011	0.061	0.054	0.014	0.000	0.009
ó^2 *sca*		44,504.72**	0.731**	1.606	23.679**	0.043	0.786	0.170	0.006	-0.003	0.057
ó^2 *gca*/ ó^2 *sca*		0.57	0.004	-0.018	0.184	0.255**	0.077	0.317**	2.33**	0.00	0.157**

*p=0.05, **p=0.01, respectively

Table 2: General combining ability effects of parents for yield and quality characters

Source	Yield (kg/ha)	Mono-podia/ podia	Sym-podia/ plant	Bolls/ plant	Boll weight	GOT Index	Seed length	2.5 per cent span	Micro-value	Strength (g/tex)
003 NAH	-72.453*	0.485**	-0.705*	1.280	-0.033	0.117	-0.723**	-0.169	0.040	-0.242**
004 NAH	-208.454**	0.245**	0.075	-1.947*	-0.042	-0.537	0.377**	0.158	0.073	0.158**
OK 2885	192.947**	0.331**	-0.145	-2.520*	0.220*	0.277	0.383**	0.078	-0.040	0.111*
CNH 911	10.813	-0.449**	-0.759*	-6.293**	0.289**	0.150	0.510**	0.198*	0.007	0.185**
CSH 2912	112.547**	-0.282**	-0.472	-0.673	-0.014	-0.343	-0.497**	-0.129	0.000	-0.175**
CSH 2832	-32.453	0.018*	-0.039	2.987**	-0.160	-0.057	-0.243*	-0.142	-0.060	0.025
CSH 3129	189.680**	-0.222*	0.548	3.393**	0.231*	-0.157	0.250*	0.045	-0.047	0.011
H 103	-44.653	0.058	0.988*	3.213**	-0.139	0.357	-0.150	-0.109	0.040	-0.142*
CSH 2907	66.480*	-0.502**	0.815*	-0.387	-0.123	0.250	0.030	0.065	0.013	0.065
CSH 2810	-214.454**	0.318**	-0.305	0.947	-0.228*	-0.057	0.063	0.005	-0.027	0.005
S.E.	**22.421**	**0.070**	**0.236**	**0.615**	**0.063**	**0.209**	**0.077**	**0.084**	**0.043**	**0.048**
GMS 26	120.347*	-0.199*	0.525	-1.890	-0.055	-0.487	-0.090	-0.229*	0.013	-0.119*
GMS 20	-126.554*	0.248**	0.131	0.433	0.116	-0.337	0.070	-0.055	0.007	-0.135*
GMS 27	115.747*	-0.275**	0.121	-2.893*	-0.124	0.207	-0.227	0.128	-0.023	0.185**
GMS 21	-276.153**	0.415**	-0.369	0.350	0.116	-0.163	0.307*	0.075	0.047	0.028
GMS 17	166.613*	-0.189*	-0.409	4.000*	-0.052	0.780*	-0.060	0.081	-0.043	0.041
S.E.	**14.948**	**0.047**	**0.158**	**0.410**	**0.042**	**0.140**	**0.051**	**0.056**	**0.029**	**0.032**

* p=0.05, ** P=0.01, respectively

Table 3. Estimates of *sca* for yield and quality traits of hybrids

Crosses	Yield (kg/ha)	Monop-odia/ plant	Symp-odia/ plant	Bolls/ plant	Boll weight (g)	GOT (%)	Seed index	2.5 per cent span length (mm)	Mic. value	Bundle strength (g/tex)
GMS 26 x 003 NAH	70.78	0.159	0.43	-0.03	0.09	0.75	-0.00	-0.03	0.01	0.29**
GMS 26 x 004 NAH	21.78	-0.601**	0.32	-6.47**	0.141	-2.42**	0.06	-0.46**	-0.02	-0.27**
GMS 26 x OK 2885	-178.94**	-1.021**	0.97*	0.43	-0.12	0.46	-0.04	-0.01	-0.10	0.10
GMS 26 x CNH 911	-182.14**	1.192**	3.48**	4.77**	-0.02	0.82	-0.10	0.19	-0.02	-0.16
GMS 26 x CSH 2912	240.78**	-1.075**	-0.79	0.05	0.06	-1.52**	-0.03	0.12	0.053	0.12
GMS 26 x CSH 2832	30.78	1.059**	-1.23**	4.26**	0.03	1.59**	-0.38*	-0.16	-0.08	-0.27**
GMS 26 x CSH 3129	39.98	-0.135	0.08	2.19	0.10	0.09	-0.21	-0.11	0.06	-0.19*
GMS 26 x H-103	-3.01	-0.181	0.54	-3.29**	-0.06	-0.02	0.35*	0.26	0.04	0.12
GMS 26 x CSH 2907	86.18	-0.621**	-2.18**	-3.56**	-0.02	-0.34	0.47**	0.06	0.00	0.21*
GMS 26 xCSH 2810	-126.21**	1.225**	-1.63**	1.63	-0.19	0.59	-0.12	0.1	0.04	0.04
GMS 20 x 003 NAH	-21.31	1.145**	-1.07*	5.54**	-0.06	-0.29	-0.0	0.3*	0.05	0.10
GMS 20 x 004 NAH	222.35**	-1.048**	-1.18*	-1.46	0.32**	-0.14	0.47**	0.06	-0.01	-0.29**
GMS 20 x OK 2885	98.62*	-0.368**	-0.73	-2.22	0.02	-0.22	0.46**	-0.19	0.03	-0.31**
GMS 20 x CNH 911	311.75**	-0.588**	-0.01	-0.11	0.25*	-0.19	0.33*	0.08	-0.21*	0.51**
GMS 20 x CSH 2912	-330.31**	0.712**	-0.83	-0.40	0.05	0.06	0.37*	0.08	-0.00	0.14
GMS 20 x CSH 2832	-200.31**	-0.38**	0.26	1.27	-0.13	-0.89*	0.32	-0.00	0.02	0.27**
GMS 20 x CSH 3129	147.88**	1.18**	1.80**	4.43**	0.19	-0.59	-0.07	0.17	0.07	0.08
GMS 20 x H-103	42.88	-0.36*	1.46**	0.61	-0.20	0.29	-0.23	-0.40*	-0.04	-0.091
GMS 20 x CSH 2907	-113.91*	-0.06	1.20*	-6.78**	-0.24*	1.37**	-0.78**	0.08	0.04	-0.13
GMS 20 xCSH 2810	-157.64**	-0.22	-0.90	-0.88	-0.20	0.61	-0.81**	-0.21	0.05	-0.30**
GMS 27 x 003 NAH	-294.61**	0.66**	0.93*	-1.02	0.18	-1.10**	-0.30	-0.19	-0.11	-0.41**
GMS 27 x 004 NAH	-529.28**	0.14	1.05*	0.20	-0.55**	1.54**	-0.70**	0.34*	-0.08	0.58**
GMS 27 x OK 2885	25.98	0.62**	0.17	0.57	0.21	-1.10**	0.02	0.25	0.09	0.20*
GMS 27 x CNH 911	-146.54**	0.60**	-1.40**	6.78**	-0.16	-1.14**	-0.100	-0.02	0.11	-0.10
GMS 27 x CSH 2912	152.72**	0.90**	1.50**	2.72*	-0.00	1.78**	-0.560**	-0.46**	0.02	-0.34**
GMS 27 x CSH 2832	205.05**	-0.53**	-0.39	-3.60**	0.20	-0.86*	0.72**	0.01	-0.01	-0.17
GMS 27 x CSH 3129	-248.41**	-0.39**	-0.08	-4.00**	-0.22	0.20	0.12	-0.20	-0.06	-0.09
GMS 27 x H-103	310.25**	-0.10	-0.55	3.04*	0.38**	-0.54	0.49**	0.24	0.01	0.05
GMS 27 x CSH 2907	291.78**	-0.54**	0.31	0.54	0.13	1.52**	0.01	-0.06	0.01	0.01
GMS 27 xCSH 2810	233.05**	-1.36**	-1.56**	-5.22**	-0.16	-0.30	0.28	0.09	0.01	0.27**
GMS 21 x 003 NAH	189.62**	-1.45**	-0.23	-3.13*	-0.26*	0.33	0.26	-0.00	-0.02	-0.02

Contd...

Table 3 contd...

GMS 21 x 004 NAH	-45.04	0.45**	-0.45	-2.14	0.25*	0.483	0.03	0.06	-0.02	0.04
GMS 21 x OK 2885	140.55**	1.13**	0.43	6.33**	-0.206	0.00	-0.507**	0.04	-0.04	0.39**
GMS 21 x CNH 911	91.02*	-0.28*	-1.05*	1.10	0.10	0.563	0.06	-0.07	0.11	-0.04
GMS 21 x CSH 2912	-57.04	-0.78**	-1.00*	-8.08**	0.09	0.32	0.50**	0.25	0.05	0.11
GMS 21 x CSH 2832	87.95*	-0.42**	1.32**	-3.31**	-0.32**	0.53	-0.71**	0.06	-0.08	0.11
GMS 21 x CSH 3129	-149.51**	-0.18	-2.15**	1.18	0.10	0.43	-0.44**	-0.08	0.03	-0.14
GMS 21 x H-103	-53.84	-0.02	-0.03	2.93*	0.29*	0.09	-0.00	-0.16	-0.05	-0.15
GMS 21 x CSH 2907	-226.98**	0.43**	0.14	0.73	-0.09	-1.97**	0.58**	-0.00	0.04	-0.16
GMS 21 xCSH 2810	23.28	1.14**	3.02**	4.39**	0.03	-0.79	0.21	-0.08	-0.02	-0.13
GMS 17 x 003 NAH	55.52	-0.51**	-0.06	-1.35	0.04	0.32	0.10	-0.08	0.07	0.03
GMS 17 x 004 NAH	330.18**	1.05**	0.25	9.87**	-0.16	0.54	0.13	-0.00	0.13	-0.06
GMS 17 x OK 2885	-86.21	-0.36**	-0.85	-5.12**	0.09	0.86*	0.06	-0.09	0.01	-0.38**
GMS 17 x CNH 911	-74.08	-0.91**	-1.01*	-12.54**	-0.17	-0.04	-0.20	-0.18	0.00	-0.19
GMS 17 x CSH 2912	-6.14	0.24	1.13*	5.70**	-0.21	-0.65	-0.29	0.01	-0.12	-0.03
GMS 17 x CSH 2832	-123.48**	0.28*	0.03	1.37	0.22	-0.37	0.05	0.09	0.17*	0.06
GMS 17 x CSH 3129	210.05**	-0.47**	0.34	-3.80**	-0.18	-0.14	0.59**	0.23	-0.11	0.34**
GMS 17 x H-103	-296.28**	0.67**	-1.42**	-3.28**	-0.40**	0.18	-0.60	0.05	0.03	0.06
GMS 17 x CSH 2907	-37.08	0.80**	0.51	9.08**	0.24	-0.58	-0.28	-0.08	-0.10	0.05
GMS 17 x CSH 2810	27.52	-0.78**	1.06*	0.08	0.53**	-0.10	0.44**	0.04	-0.09	0.11
S.E.	**44.84**	**0.14**	**0.47**	**1.23**	**0.12**	**0.41**	**0.15**	**0.16**	**0.08**	**0.09**

*p=0.05, **p=0.01, respectively

CNH 911, GMS 27 x H-103, GMS 17 x 004 NAH hybrids had the highest *sca*. Therefore, these were selected as the promising hybrids to increase seed cotton yield in the breeding programme.

Among fifty cross combinations, eighteen cross combinations had positive and significant estimates for *sca* effects for monopodial branches but GMS 26 x CNH 911, GMS 20 x CSH 3129 hybrids had the highest *sca*. Similarly GMS 26 x CNH 911, GMS 21 x CSH 2810 hybrids exhibited maximum positive and significant estimates for *sca* effects for sympodial branches .Twelve cross combinations GMS 26 x CNH 911, GMS 26 x CSH 2832, GMS 20 x 003 NAH , GMS 20 x CSH 3129, GMS 27 x CNH 911, GMS 27 x CSH 2912, GMS 21 x OK 2885, GMS 21 x H-103, GMS 21 x CSH2810, GMS 17 x 004 NAH , GMS 17 x CSH 2912, GMS 17 x CSH 2907 exhibited positive and significant *sca* effects for boll/plant but the maximum being in case of GMS 17 x 004 NAH, GMS 17 x CSH 2907.Therefore, these hybrids are important for improvement of boll number.

Among fifty cross combinations, only six cross combinations showed positive and significant *sca* effect for boll weight and ginning percentage but the maximum being in case of GMS 27 x H 103, GMS 17 x CSH 2810 and GMS 26 x CSH 2832, GMS 27 x CSH 2912, respectively. For seed index thirteen cross combinations showed positive and significant *sca* effect but GMS-27 x CSH 2832 and GMS-17 x CSH 3129 hybrids showed highest *sca* effect. Therefore, these hybrids are important for improvement of seed index.

For 2.5 per cent span length only two cross combinations GMS 20 x 003 NAH, GMS 27 x 004 NAH proved to be the best as it shown positive and significant *sca* effect and only two cross combinations GMS 20 x H 103, GMS 27 x CSH 2912 shown negative and significant *sca* effect. Only one cross GMS 17 x CSH 2832 displayed positive and cross GMS 20 x CNH 911 shown negative significant *sca* effect for micronaire value. Out of fifty crosses, nine cross combinations exhibited positive and significant *sca* effect for fibre strength but maximum is being in case of GMS 20 x CNH 911, GMS 27 x 004 NAH. Therefore, these were selected as the promising cross combinations to improve this property.

Improvement of yield and fibre quality is one of the important targets of all cotton breeders. The present study aimed to facilitate the selection and development of cotton with high yielding and better fibre quality in cotton breeding program. In this study, additive variances were significant only for 2.5 per cent span length and non-additive gene effects for seed cotton yield, ginning percentage, boll weight, bolls, monopods and sympods/plant, Micronaire value and fibre strength. *gca* was significant for male parents OK 2885, CSH 2912, CSH 3129, CSH 2907 and female parents GMS 26, GMS 27, GMS 17 for seed cotton yield, Parent GMS 17 for ginning percentage and CNH 911 for 2.5 per cent span length and parents 004 NAH, OK 2885, CNH 911, GMS-27 for fiber strength (g/tex). Similarly, among fifty cross combinations, *sca* was significant for fifteen parents in terms of seed cotton yield and GMS 20 x CNH 911, GMS 27 x H-103, GMS 17 x 004 NAH hybrids had the highest *sca*. These all were seem to be good general combiner for seed cotton yield.

REFERENCES

Kempthorne, O. 1957. *An Introduction to Genetic Statistics.* John Wiley and Sons. Inc., New York, U.S.A.

Iqbal, M., Khan, R.S.A. Hayat, K. and Khan, N.U.I. 2005. Genetic variation and combining ability for yield and fibre traits among cotton F_1 hybrid population. *Jour. Bio. Sci.* **5**: 713-16.

Rauf, S., M., Hassan, M. A. Shahzad, B. and Ergashev, A. 2006. Combining ability analysis in upland cotton (*Gossypium hirsutum*) L. *Inter. Jour. Agri. Bio.* **8** : 341-43.

Ahuja, S. L. and Dhayal L. S. 2007. Combining ability estimates for yield and fibre quality traits in 4 x 13 line x tester crosses of *Gossypium hirsutum. Euphytica* **153**:87-98.

Ilyas, M., T. Naveed, M and Khani, I. A. 2007. Combining ability studies in some quantitative and qualitative traits of *Gossypium hirsutum* L. *Jour. Agri. Soc. Sci.* **3** : 39-42.

Lukange, E.P., Labuschagne, M.T. and Herselman, L. 2007. Combining ability for yield and fibre characteristics in Tanzanian cotton germplasm. *Euphytica,* **161**:383-89.

Preetha, S., and Raveendran, T.S. 2008. Combining ability and heterosis for yield and fibre quality traits in line x tester crosses of Upland cotton (*G. hirsutum.* L). *International Jour. Plant Breed. Gene.,* **2**(2), 64-74.

Karademir, Cetin, Karadmir, Emine, Ekinci, Remzi, Gencer, Oktay 2009. Combining ability estimates and heterosis for yield and fiber quality of cotton in line x tester design. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* **37** (2): 228-33.

Biotech seed genes textural texture taxonomy [BSGT] and biotech research steps, aspect and direction [BRSAD] and methods of extension

PRAVINCHANDRA M. RAKHOLIA
Saga Seeds Company Ahmedbad - 382 210
Email : pravin_rakholia@yahoo.co.in

We all are doing lots of work in conventional breeding and try to mitigate requirement of time. In the late stage of 20th century and early stage of present century we also adopted and shown result of transgenic work. At present there are lots of research works beings carried out in life science laboratory. We will try to identify, modified and develop specific input and output trait related genes to mitigate climate changes. Those all genes or genes family are in the stages of identification, modification and development, some of them are in steps of transgenic transformation on different ladder stages of laboratory and as well as in process of regulatory.

Biotechnological research works have been very costly, time consuming and patience-full. Regulatory process, labs and open field trails as well as promotional and market intelligence has also required to know the acceptance of technology and method of commercialization.

Sometimes various frequently asked questions (FAQs) have been raised in our mind for marketer, end users and consumers during extension and promotional activity of new technology. Some of them are as under:

- How to easily extension work will be carrying out in market or for end users? [Our population are segmented in literate and illiterate, rural and urban, Science educated and non science educated people groups]
- Which methods adopt to create general awareness in lots of diversity in geographical area and languages?
- How much long time will be required to explain agronomical practice and their precaution and products FABs?
- Who will be doing ToT? [Either Private or Public sector or PPP mode]
- We have any sound and common strategy to transfer new technology in desire and popular /local GP and parental line?
- We have any general awareness and strategy to recovering cost of RandD through market intelligence, commercialization of product and sales of technology?

To find solution of above all question; we may need to setup separate one institute or organisation either existing resource full leading organisations or group of organisation or association or PPP format, if they will willingly take responsibility. Which will be standardise source of genes, their modification and others methods of genetically improvement of plant (Only in the definition of Genetic Engineering). In the same way institute will also be standardise identified gene insertion program in various level of available germplasm (Application of biotech work) and action and benefit of gene on particular outputs and inputs traits. Institute may also be certified status of transgenic plant in respect of number of gene insertion/ modification and their effect on trait improvement of plant.

Organisation may be involved in monitoring field level activity by various extension agencies (Public and private) and also themselves he will be promoting and carry out extension activity as a third party services. Imagine organisation may be playing an active role in transgenic parental or varietal line exchange program with various seed institute.

To serve above objective we may need to simply standardise and categorise source of genes, their action and benefit in improvement of particular output and input traits and steps of gene insertion program in various level of available germplasm by way of adopting and accepting following our suggesting things:

Table 1. BSGT (gene Category on the basis of their sources) Chart:

Particulars	Conventional source		Modified	
	Non aquatic	Aquatic	Non aquatic	Aquatic
	Alphabetic Sign (Code)			
Vegetative	VG	AVG	MVG	AMVG
Non vegetative	NG	ANG	MNG	AMNG
Microbes	MG	AMG	MMG	AMMG
Artificial	AG	AAG	MAG	AMAG

Others methods	Deleted genes	Self modification	Conventional replacement [Within same crop line]	Modified replacement [Within same crop line]
Alphabetic sign	DG	SMG	CRG	MRG

We everybody know Dr. J.D.Smith, He have been classified soil by comprehensive system of soil genesis and that is called soil taxonomy and it is popular as relevant approximation for the purpose of many objectives like research, education, extension and geographical indication of soil. Similarly, same kind of taxonomy will be required for serving same objectives and some others objectives for our BIOTECH SEEDS WORK.

Here we are categorised major 4x2 groups of source of gene and if it wills insertion in plant after modification/improvement of their expression or without any modification have also mentioning in chart. Similarly, if we follow others method of genetic engineering for plant trait improvement, it has also mention in chart. Numeric number and back ground colour indicate or standardise for graphical and symbolic representation during extension activities. Clarification regarding source of gene in front of public will be maintaining harmony and trustworthiness among mass.

When more number of gene identification and their genetic modification will be possible for all desirable traits in one plant to get the "Ideal Plant Type" or " Super Crop" Which may require to notice on commercial product pack by symbolic or graphical representation for promotional and extension activities. Here we are categorised major function in six groups and their alphabetic abbreviate sign for mentioning on symbolic representation. Standardise of back ground colour in symbol will be useful during extension activity.

Biotech Research Steps, Aspect and Direction:
Concept: Exploration of various available transgenic germplasm to make newly desirable F1 combination.
Direction: Cross Pollinated Crops
Steps and Aspect:

- **VI1st LSCBVAHV: Set, creates, develop and check :** Breeding combination in between parental lines of own organisation. Choose a genetically genes, inserted successful and existing operative lines of each crop. Assume possible desirable F_1 characteristics through check of combinability of recessive and dominant characteristics of parental lines. (We all are following this steps from last ten years and now we may need to move for next steps)

- **V2nd LSCBVAHV: Set, creates, develop and check** : Breeding combination in between parental lines of divergent origin of nearer geographical (Within state or Country boundary) area. Choose a genetically genes, inserted in successful and existing operative lines of each crops of selected divergent organisation. Assume possible desirable F_1 characteristics through check of combinability of recessive and dominant

Table Action and benefit of genes in improvement of traits

Sr. No.	Function of added genes	Symbolic alphabet	Back ground colour representation	Name of the color	Traits
	Protection	PG			
1	Worms	WP		Red	Input
2	Sap sucking pest	SP			
3	Disease	DP			
4	Stored product pest	SPP			
	Nutritional enhancement	NEG			
5	Carbohydrate	CI		Blue	Output
6	Protein/ amino acids	PI			
7	Fatty acid/oil	FI			
8	Sugar (TSS)	SI			
9	Vitamins	VI			
10	Others nutritional enhancement	OI			
	Stress relief/ tolerance	STG			
11	Temperature/cold	TC-S		Dark green	Input
12	Salinity (acidic/basic)	SA-S			
13	Drought/water logging	DW-S			
14	Physiological disorder +/-	PD-S			
	Quality parameters improvement	QPIG			
15	Keeping quality	KQ		Deep pink	Output
16	Color/ shining	CQ			
17	Size	SQ			
18	Shape	SHQ			
	Key functionality improvement	KFIG			
19	Weed management	WK		Dark violet	Input
20	Duration +/-	DK			
21	By product	BPK			Output
22	Plant growth (root/shoot) habit	PGHK			
23	Yield	YK			
	Inputs use efficiency	IUEG			
24	NPK U	FE		Sky blue	Input
25	Irrigation	IE			
26	Others	OE			

characteristics of parental lines.

- **IV3rd LSCBVAHV: Set, creates, develop and check :** Breeding combination in between parental lines of divergent origin of neighbour countries geographical area. Choose a genetically genes, inserted in successful and existing operative lines of each crops of selected divergent organisation of neighbour countries geographical area. Assume possible desirable F_1 characteristics through check of combinability of recessive and dominant characteristics of parental lines.

- **III4th LSCBVAHV: Set, creates, develop and check :** Breeding combination in between parental lines of divergent origin within continental boundary geographical area. Choose a genetically genes, inserted in successful and existing operative lines of each crops of divergent organisation of within continental geographical area. Assume possible desirable F_1 characteristics through check of combinability of recessive and dominant characteristics of parental lines.

- **II5th LSCBVAHV: Set, creates, develop and check** breeding combination in between parental lines of world. Choose a desirable gene or gene sequence (More than two genes), inserted in successful and existing operative parental lines of each crops of divergent organisation of all over the world. Assume possible desirable F_1 characteristics through check of combinability of recessive and dominant characteristics of parental lines.
- **I6th LSCBVAHV: Set, creates, develop and check :** Breeding combination in between parental lines of world. Choose a desirable gene or gene sequence (More than two genes), inserted or/and an undesirable gene or gene sequence deletion in successful and existing operative lines of each crops of divergent organisation of all over the world. Assume possible desirable F_1 characteristics through check of combinability of recessive and dominant characteristics of parental lines.
- **07th LSCBVAHV: Set, creates, develop and check** Breeding combination in between own prenatal lines by own genetic engineering technology or improved own transgenic parental lines of each crop. Assume possible desirable F_1 characteristics through check of combinability of recessive and dominant characteristics of parental lines.

[Note: LSCBVAHV: Life science crop Conventional breeding value added variety]

Direction: Open Pollinated Crops

Steps and Aspect:

- **1stLSCVAV: Set, creates, develop and check** : Transgenic work up to two gene insertion in own varietal line.
- **2ndLSCVAV: Set, creates, develop and check** : Transgenic work up to two gene insertion in varietal lines of divergent origin of nearer geographical (Within state or country boundary) area.
- **3RDLSCVAV: Set, creates, develop and check** : Transgenic work up to two gene insertion in varietal lines of divergent origin of neighbour countries geographical area.
- **4thLSCVAV: Set, creates, develop and check** : Transgenic work up to two gene insertion in varietal lines of divergent origin within continental boundary geographical area.
- **5thLSCVAV: Set, creates, develop and check** : Transgenic work on more than two gene insertion in varietal lines of world. Choose a desirable gene or gene sequence (More than two genes) inserted successful and currant operative varietal lines of each crops of divergent organisation of all over the world.
- **6thLSCVAV: Set, creates, develop and check** : Transgenic work on more than two gene insertion in varietal lines of world. Choose a desirable gene or gene sequence (More than two genes) inserted or/and an undesirable gene or gene sequence deleted in successful and currant operative lines of each crops of divergent organisation of all over the world.
- **7thLSCVAV: Set, creates, develop and check :** Transgenic work on more than two gene insertion in own varietal lines by own genetically engineering technology.

[Note: LSCVAV: Life science crop value added variety] : Here we are suggesting exploration of vast availability of germpasm at various level and check out their suitability. Uses of divergent origin source of GP may be given out break in existing F_1 combination. Abbreviate form and roman and numeric sign indicating steps and aspect standardise for identified gene insertion program in various level of available germplasm worldwide. Aspect and direction are also useful during ToT process from lab to land in form of knowledge and product FABs. If any desirable costly biotech research not transferring from lab to land within time and with low cost modules then we will be unable to harvest benefit of new technology and it will discourage our researcher, promoters and policy maker. New research also wrapping our earlier research and it will

Table Transgenic Product Status

Sr. No.	Particulars desirable transgenic work to get ideal plant type	Designated status of product	Status mention in Logo
1	Three or more than three genes inserted or deletion or combination of that	Super three star Transgenic Product	3G / 3G+
2	Five or more than five genes inserted or deletion or combination of that	Super five star Transgenic Product	5G / 5G+
3	Seven or more than seven genes inserted or deletion or combination of that	Seven star super crop	7G / 7G+
4	Nine or more than nine genes inserted or deletion or combination of that	Nine star super kingdom	9G / 9G+
5	Eleven or more than eleven genes inserted or deletion or combination of that	Eleven star super life	11G / 11G+
6	Thirteen or more than thirteen genes inserted or deletion or combination of that	Galaxy peace of life science	13G / 13G+

ultimately discourage research institute.

Here we are trying to reflecting or certifying status of Ideal plant type on the basis of number of gene insertion or deletion to get desirable trait improvement through transgenic work.

Methods of Extension and their incorporation with proposed BSGT and BRSAD : We suggest cheaper, new and unique extension tools to promote and transferring precise message of biotech research transformation in desirable popularly local and divergent origin GP and their FABs. **Message is in form of graphic, colour combination, numeric and alphabetic sign and abbreviate format.**

OBJECTIVE

- **Mitigation of cooperation, synchronisation, comprehension of involver :** Sometimes acceptance of new things will be starting discussion in between direct and indirect involver.
- **Facilitating in awareness program in methods of Extension :** BSGTand BRSAD helping us in extension
- **Easy to understand by all diversified and segmented group of people in low cost and time saving module to promote :** Symbolic representation of BSGTand BRSAD easy to understand by end users.
- **Followup of standardise process, accreditation and certificate and relevant third party extension and promotion services :** Make and maintaining trustworthiness in markets and end users as like ISI and ISO certificate but in something different perceptiveness of perspective of seeds and biotech works.
- **Synchromesh of genes:** Systemic manner of movements of Steps among the divergent origin for the movement of exchange and business process of transgenic parental line.
- **Distinguish within 2nd to 7th approach :** Steps, Aspects and Direction distinguish our biotech work with non classified and non transgenic work..
- **Organising Institute of BSGT, BRSAD and Relevant System and Service Provider Agency :** Likely to be help in control of imitation of transgenic work and products.
  -Institute may be helpful in registration process of product under various authorities.
  • BSGT and BRSAD punch-line make punch on impact of ToT of TWOO [Transgenic work oriented organisation].
  • Relevant operating systems open third eye in future to monitor performance of GM crops and relevant vulnerability in the markets.

***Similarly we may need to do it for serving some others objectives are as under* :** R and D process of genetic engineering, transformation and regulatory process of approval is time consuming, patience full and costly process. May not be any one organisation is able to identified, modified and develop all desirable gene and their transformation process within limit of available resources. Therefore, we may need to take cooperation of all leading organisations for the insertion of all available and desirable genes in open and cross pollinated crops (wherever it applicable). Those all organisations have a specific purpose with financial, business and branding interest. In this context commonly accepted design, graphic, logo and relevant methods of representation with commercialized product may be make smoother, fairly and easy understanding in farmers and market.

Highlighting sourcing of insertion genes and their benefit and action in product will be display on pack by common short, abbreviate, artistic and stepping mode mechanism in various available transgenic GP combination will be easily understand by end users and channel people. That’s all things will be in low cost and short time period.

Design and Logo: Here suggesting design and color scheme will same across the user after commonly acceptances will happen, whereas steps, source of genes and their effect on input and output trait will changeable based on transgenic variety development program adopt. Frame work of rules and regulation for uses of design will develop on the bases of consensus of acceptance among industrial and governmental members

ABSTRACT : Mitigate of climate change through adopting fundamental aim of biotech research. The aspect and steps of research along with gene wings taxonomy will be provide direction to biotechnologist team and institute for the existing and huge future transgenic works. These gene works facilitate to transformers and breeder for incorporation of conventional breeding. The overall those works and FABs of final F_1 value added Hybrid variety will be representing to ultimate users through defining, Symbolizing, abbreviating, formatting, research steps aspect indication and artistic manners relevant to literary work with incorporation of scientific language and sense for the purpose of easiness to understand. The acceptance of BSGT will be make harmony among the public governances, technocrats, policy makers, biotechnologist, researcher, breeder, regulatory, marketer, Seller and ultimate users. Whereas; adoption, action and execution on the basis of taxonomy will be facilitating and shifting speed gears of overall works, regulation, permission, extension and adoption by marketer and ultimate users. Cooperation among the institutes will goes on higher level. Extension awareness creation and marketing intelligence will support to policy maker.

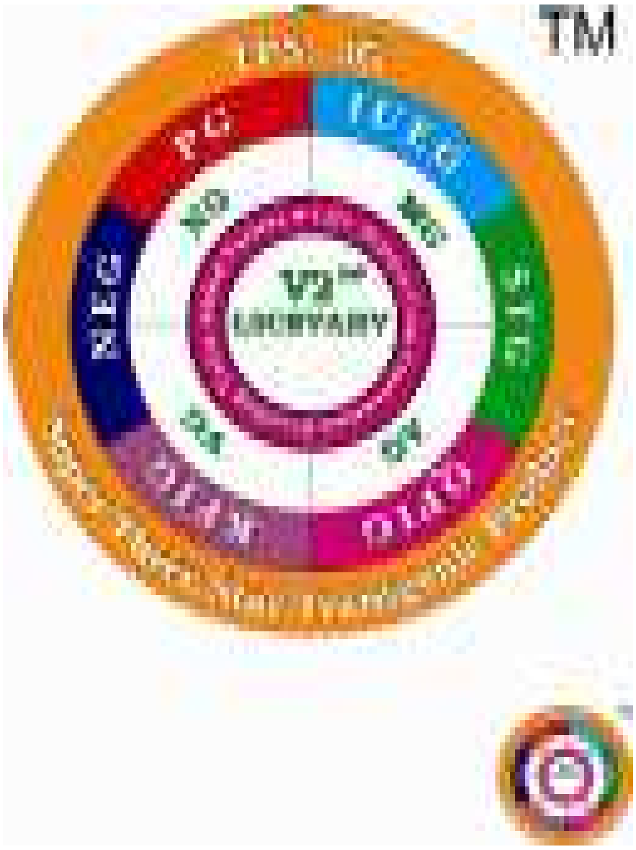
We all have been doing lots of work in conventional breeding and adopting $1^{st\ GM\ crops}$ and try to mitigate requirement of time in the late stage of 20^{th} and early stage of 21^{st} century. Sometimes, we don’t much worried about various FAQs relevant to biotech works. We are trying to summarise answer of those FAQs in our things.

Why BSGT, BRSAD and Extension Methods?

Purposes of serving objectives like research, education, extension and geographical indication of origin and following others objectives:

- Mitigation of involvers.
- Low cost and time saving module in diversified population.
- Improve trust worthiness in markets and ultimate users.
- Synchromesh of genes in systemic manner of movements.
- System may be control the imitation of transgenic work and products.
- systems open third eye in future to monitor performance of GM crops and relevant vulnerability in the markets
- Punch line make punch on impact of ToT.

Overall our tiny works and creation are indicating 2^{nd} to 7^{th} level/Steps/ Aspects/ Concept/Direction of life science crops conventional breeding value added hybrid variety development program and relevant artistic graphics and designing symbols for representing it’s in abbreviate and synchronisation formats. We have been trying to categories sources of genes and their benefit in output and input traits of plant through genetic engineering. Symbolic logo through proposed design and colour scheme will categories product group and reflecting source of gene and transgenic product status. Tiny



creation may be appreciated by the way of utilization of our works, creation and systems.

REFERENCES

Marcel, Bruins (SG-ISF) 2012. Growth In the seed Industry, ISC-2012 Souvenir

Asitava, Sen and Chopra, Vaishali 2012. Global Trends In seeds Industry And Implications for India, ISC Souvenir

Shrawat, Ashok, K. and Good, Allen G. Genetic Engineering Approaches

Performance of introgressed genotypes of *Gossypium arboreum* for fibre quality parameters

V.N.CHINCHANE* AND A.H.MADKEMOHEKAR
Cotton Research Station. Marathwada Krishi Vidyapeeth Parbhani 431401
**E-mail :*

Abstract : Cotton is an inevitable source of natural fibre in the textile industry throughout the world . India is the only country where all the four cultivated species are grown. The two diploid species *G.arboreum* and *G. herbaceum* are characterized by inherent biotic strees tolerance as compared to their trtraploid counterparts *G.hirsutum* and *G.barbadense*, but tetraploids have high yield potential and superior fibre properties .*G.arboreum* genotypes are grown by marginal farmers . *G.arboreum* varieties fetches low returns to farmers due to its inferior fibre properties and low yield potential especially in these times of open end high speed spinning machines. Therefore efforts were done to introgress desirable traits from a tetraploid genotype of *G.hirsutum* to *G.arboreum.* It was seen that improved genotypes with bigger boll size and yield potential were isolated

Among the fourteen genotypes of *G.arboreum* developed through introgession breeding , the genotype PAIG 326 and PAIG 368 were the best introgressed genotypes for seed cotton yield as well as fibre properties like fibre length, fibre strength, uniformity ratio and ginning outturn.

Key words : Diploid, gentoypes, Introgressed, quality parameters, tetraploid

It is well known fact in Indian cotton scenario that the diploid cottons have been replaced drastically by tetraploid varieties and hybrids with superior fibre quality and yield potential. Inspite of this change, the cultivation of diploid cottons by marginal farmers in certain pockets of India, which is mainly due to their inherent abiotic and biotic stress tolerance. With the maximum research efforts being directed for improving tetraploid cottons , improved *arboreum* varieties released also are very meager. Therefore efforts to improve these vatieties with respect to yield and fibre properties would be a boon to these marginal farmers to fetch better returns. The ‘D’ genome contributing to the high yield potential and superior fibre properties could be used for introgession of these into diploid cottons. In this direction efforts were made to transfer the desirable traits from cultivated tetraploid cotton to *arboreum* cotton

MATERIALS AND METHODS

The experimental material comprised of fourteen introgressed genotypes developed from two cotton research centers under the project,Technology Mission on Cotton .Mini Mode 1.1 entitled , “ Development and promotion of medium to long linted diploid cotton *G.arboreum* and *G.herbaceum*” were sown at Cotton Reserch Station, M.K.V.,Parbhani during *kharif,* 2011-2012. Out of which twelve were contributed by M.K.V. Parbhani and two by UAS, Dharwad. These introgressed genotypes were sown in replicated trials with 4 rows each of 60x30 cm spacing. Manures and fertilizers as well as plant protection was applied as per recommendations . Five plants were selected randomly in each genotype for recording observations on yield and yield related characters along with fibre quality.

RESULT AND DISCUSSION

Fourteen genotypes developed through introgressive breeding along with three checks, *viz.,* PA 255, PA 402 and NH 615 were evaluated under rainfed condition . The results revealed that the genotype PAIG 326 recorded highest seed cotton yield (1636 kg/ha) with 38.05 per cent,24.88 per cent and 56.10 per cent increase over the check varieties PA 255 (1185 kg/ha), PA 402 (1310 kg/ha) and NH 615(1048 kg/ha), respectively. It is followed by DIa 08-25 (1605 kg/ ha) and PAIG 368 (1479 kg/ha). As many as, one two and five genotypes each recorded significant superiority over local check PA 402 ,PA 255 and NH 615, respectively. These genotypes also recorded boll weight of 2.90 g/boll as well as more bolls/plant. Therefore these genotypes can be used in breeding programme for the improvement

Table 1. *Per se* performance of genotype developed through introgressive breeding

Sr. No.	Entry	Seed cotton yield (kg/ha)	Increase over (%)			G.O.T. (%)	S.L. (mm)	Lint yield (kg/ha)	Bolls/ plant	Boll weight (g)	Lint index	Seed index
			PA 255	PA 402	NH 615							
1	PAIG 12	1349	13.83	2.97	28.72	37.48	27.60	484	15.33	2.74	3.87	6.49
2	PAIG 39	1287	8.60	-	22.80	35.19	26.26	442	14.66	2.68	3.91	6.49
3	PAIG 62	1460	23.20	11.45	39.31	36.36	26.76	520	16.33	2.86	3.69	6.93
4	PAIG 77	1095	-	-	4.48	35.38	26.00	380	10.66	2.62	3.90	7.12
5	PAIG 308	1316	11.05	0.45	25.57	36.77	25.96	474	15.00	2.90	3.45	6.78
6	PAIG 311	1011	_	_	_	34.15	26.10	340	11.33	2.66	3.95	6.69
7	PAIG 325	1461	23.29	11.52	39.40	35.98	28.43	526	15.66	2.78	4.21	7.38
8	PAIG 326	1636	38.05	24.88	56.10	36.87	29.00	586	17.00	2.90	3.99	7.07
9	PAIG 327	1166	-	-	11.25	36.93	25.23	422	12.00	2.58	3.84	6.39
10	PAIG 332	1240	4.62	-	18.32	37.27	25.46	454	13.66	2.70	4.13	6.67
11	PAIG 346	1098	-	-	4.77	36.65	26.73	394	11.66	2.66	4.44	7.10
12	PAIG 368	1479	24.81	12.90	41.12	34.93	28.23	510	15.33	2.80	3.89	6.11
13	DIA 08-25	1605	35.44	22.51	53.14	35.15	25.80	560	17.66	2.72	3.52	6.17
14	DIA 08-26	1258	6.16	-	20.03	35.11	26.43	434	13.00	2.68	3.74	6.65
Checks												
15	PA 255 (c)	1185				36.54	27.23	426	12.66	2.68	3.57	5.31
16	PA 402 (c)	1310				36.93	26.06	480	14.00	2.62	3.97	6.43
17	NH 615 (c)	1048				38.20	27.06	392	11.33	3.10	3.57	5.40
	S.E ±	115.67										
	CD (p=0.05)	320..15										
	CV(%)	15.20										

Table 2. Quality characters of genotypes developed through introgressive breeding

Sr. No.	Entry	2.5 per cent SL (mm)	U.R. (%)	Micronaire value (MV)	Strength (g/tex) (3.2 mm)
1	PAIG 12	27.3	50	4.8	21.6
2	PAIG 39	25.8	52	4.8	21.0
3	PAIG 62	29.3	50	5.1	22.4
4	PAIG 77	25.2	52	5.2	18.6
5	PAIG 308	25.9	52	5.0	20.4
6	PAIG 311	26.7	52	4.9	20.5
7	PAIG 325	30.0	49	4.9	21.3
8	PAIG 326	27.9	51	5.2	21.1
9	PAIG 327	26.1	51	5.1	19.8
10	PAIG 332	27.5	50	5.5	21.0
11	PAIG 346	27.6	51	4.9	19.1
12	PAIG 368	29.8	50	4.4	21.9
13	DIA-08-25	28.2	52	4.9	21.1
14	DIA-08-26	26.3	51	5.4	19.8
Checks					
15	PA 255 (c)	26.1	50	4.8	19.6
16	PA 402 (c)	24.9	53	5.6	19.8
17	NH 615 (c)	26.9	49	2.5	21.1

of boll size in agronomically superior genotypes.

Introgressed genotypes depicted wide range for fibre quality parameters. The ginning outturn ranged from 34.15 per cent (PAIG 311) to 37.48 per cent (PAIG 12) amongst the genotypes under testing . A range of 25.23 mm (PAIG 327) to 29.00 mm (PAIG 326) was observed amongst the genotype under testing for halo length . The genotype PAIG 326 recorded highest halo length (29.00 mm) followed by PAIG 325 (28.43mm) and PAIG 368 (28.23mm) .The genotype PAIG 326 recorded highest lint yield (586 kg/ha) followed by DIa 08-25 (560 kg/ha) and PAIG 325 (526 kg/ha). 2.5 per cent span length ranged from 25.2 to 30.0 mm . Fibre strength ranged between 18.6 to 22.4 g/tex, whereas , uniformity ratio ranged from 49 to 53 .Micronaire value ranged from 4.4 to 5.5 . Highest 2.5 per cent span length was recorded by genotype PAIG 325 (30.0mm) followed by PAIG 368 (29.8mm) and PAIG 62 (29.3mm). The Genotype PAIG 62 recorded highest fibre strength (22.4 g/tex) followed by PAIG 368 (21.9 g/tex) and PAIG 12 (21.6 g/tex) .

Considering overall fibre quality parameters, introgressed genotypes viz.,PAIG 326 , PAIG 368 and PAIG 12 were found superior to local *arboreum* as well as *hirsutum* checks .The study emphasized the necessity to develop introgressed genotypes with superior fibre qualities to meet requirements of textile industry.

REFERENCES

Modi, N.D, Patel, J.C, Patel, D.H. Maisuria, A.T, and Patel, U.G 1999 Heterosis and combining ability for yield and fibre quality in deshi cottons. *J.Indian Soc.Cotton Improv.* **24(2)** : 132-34.

Deshpande, L.A, Deosarkar, D.B, and Deshmukh, D.C 1991. Combining ability analysis for economic traits in interspecific cross of *desi* cotton. *J. Indian Soc. Cotton Improv.* **16** : 19-26

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

Yadava O.P, Lather, B.P.S and Dhayia, B.N 2000. Studies on variability, correlation and path ananlysis in desi cotton (*Gossypium arboreum L.*). *J.Cotton Res.Dev.* **14 (2)** :143-46.

Evaluation of promising – pre-released genotypes for suitability in High Density Planting Systems for Climate resilient agriculture

VINITA GOTMARE*, MADHAV KATRE, PUNIT MOHAN, V. N. WAGHMARE, M. SARAVANAN, SUMANBALA SINGH, T. R. LOKANATHAN, S. M. PALVE , V. SANTHY , P. R. VIJAYKUMARI, P. K. CHAKRABARTY, K. R. KRANTHI AND M. V. VENUGOPALAN
Central Institute for Cotton Research, Nagpur – 440 010
**E-mail : vinitag22@gmail.com*

Abstract : Cotton in Vidarbha region of Maharashtra is cultivated under rainfed conditions and productivity of cotton is low. Protective and supplemental irrigations are not possible in 97 per cent of the area. Water and nutrient requirement during peak boll formation phase are most critical for high yields. Rainfall starts in June and recedes in September. Boll formation in long duration varieties and hybrids starts in October after and reaches a peak in November. Boll formation and retention get negatively affected due to low soil moisture, especially in shallow soils thus resulting in low yields. Hence, development of High Density Planting System (HDPS) can maximize productivity of rainfed cotton. We have evaluated eighteen (18) *G.hirsutum* and nine (9) *G. arboreum* pre released genotypes along with two checks for each of the two species amenable to high density planting (High input and Low Input) with variable spicing *i.e. G.hirsutum* – 60 x 30 cm and 30 x 20 and *G.arboreum* 60 x 15 cm and 30 x 15 cm at the Central Institute for Cotton Research, Nagpur during 2010-2011. The best performing three genotypes in terms of yield and yield contributing characters for high and low input at variable spacing were identified which could be used in high density planting system with further refinement in spacing and agronomic practices. In ***G. hirsutum*** for High input conditions with 60 x 30 cm spacing; NDLH 1938 (1278 kg/ha) was highest yielder followed by 28I (1168 kg/ ha) and PHULE 688(1167 kg/ha) while at a closer spacing of 30 x 20 cm CNH-2 2167 kg/ha was the highest yielder followed by CNH 1109 (1833 kg/ha) and 28I (1333 kg/ha). Under low input conditions with 60 x 30 cm, NDLH 1938 (833 kg/ha) was highest yielder followed by CNH1109 (612 kg/ha) and NH452 (611 kg/ha) while at a closer spacing of 30 x 20 cm the highest yielder was 28I (1000kg/ha) followed by CNH11 (833) and CNH1108 (667 kg/ha).In *G. arboreum* for High input conditions with 60 x 15 cm spacing JK 5 (1667 kg/ha) was the highest yielder followed by PA 402 (1333 kg/ha) and PA255 (1333 kg/ha) while with 30 x 15 cm spacing; CINA 396(2444 kg/ha) was the highest yielder followed by CNA 1011 (2222 kg/ha), CNA 1012(2222 kg/ha). Under Low input conditions with 60 x 15 cm spacing CNA 1012(2222 kg/ha) was the highest yielder followed by PA 402(2778 kg/ha), PA 255(2111 kg/ha while with 30 x 15cm spacing CNA 1011(2444 kg/ha) was the highest yielder followed by JK 5(1778 kg/ha) and PA 255(1778 kg/ha).

Cotton plays a vital role in the economy of the nation being an important raw material for the textile industry. In the Vidarbha region of Maharashtra, cotton is almost exclusively cultivated in about 16 lakh ha as a rainfed crop. Despite complete saturation with Bt hybrids, the productivity is wuite low. Protective and supplemental irrigations are not possible in 97 per cent of the area in this tract. Optimizing water and nutrient requirement during peak boll formation phase are most critical for high yields. Rainfall starts by mid June and recedes in September. Boll formation in long duration varieties and hybrids starts in October after and reaches a peak in November and water demand is mt by the receding soil moisture. The soil moisture storage is limited in shallow and medium deep black soils often subjecting the hybrids to terminal drought during boll development phase reducing its productivity. Boll formation and retention get negatively affected due to low soil moisture, especially in shallow soils thus resulting in low yields. An alternate system, the High Density Planting System with varieties is as an alternative for such situations (Venugopalan *et al.,* 2011). This system offers an opportunity to maximize productivity of rainfed cotton in Vidarbha region of Maharashtra (CICR, 2011). The optimum plant density will depend upon genotypic characteristics, properties of soils, climatic parameters and management regime (Silvertooth *et al.,* 1999). The earliness associated with high density planting makes this system suitable for rainfed regions of Vidarbha dominated by shallow and medium black soils (Venugopalan *et al*, 2011). The genotypes suitable for such high density planting system should be dwarf and compact type ; and cotton breeding in India needs focus on developing such plant types (Jagannath and Venkatiswamy, 1996; CICR, 2011).The present experiment was therefore designed to evaluate promising pre released genotypes along with released varieties developed at CICR and SAU's amenable to high density planting system at variable spacing under high and low input conditions.

MATERIALS AND METHODS

The field experiments were conducted on separate plots (0.25 ha each) under rainfed conditions at CICR, Nagpur during the *kharif,* (monsoon) season of 2010-2011. The inputs provided to the two plots were of contrasting types-one with low input meaning the light soil was supplied with minimum FYM @ 1 t/ha at the time of field preparation and other chemical fertilizers (40:30:30 NPK) during the growth period. On the other hand, the plot selected for high input [25% more fertilizer than Recommended Dose of Fertilizer (RDF)] condition had heavy soil and was supplied with double the dose of recommended dose of chemical fertilizer during crop growth period and prior to spacing also; a double dose of FYM was spread in the soil. Rainfall spread over 53 days received during the season 2010-11 was 1005 mm as against an average rainfall of 760 mm.

Two sets of experiments were laid out *i.e.* for *G. hirsutum* and *G. arboreum* under high and low input conditions. The pre released and advance cultures developed at CICR, Nagpur and some released varieties of the SAU's were evaluated during 2010-2011. Among the evaluated genotypes; eighteen (18) were *G.hirsutum* and nine (9) were *G. arboreum* pre released genotypes along with two checks (LRA5166, LRK 516, PA255 and AH8401) for each of the two species. They were subjected to high input and low Input conditions with the spacings: *G.hirsutum* – 60 x 30 cm (55,555 pl/ha) & 30 x 20 cm (1,66,666 pl/ha) and *G.arboreum* 60 x 15 cm (1,11,110 pl/ha) & 30 x 15 cm (2,22,000 pl/ha).

A total of 18 *G. hirsutum* (both pre-released genotypes and released varieties) namely CNH 11, CNH 12, CNH 102, CNH 1108, CNH 1109, 28 I, CNHPT 6, CNH 1, CNH 2, CNH 3, CNH 4, PHULE 688, NH 452, NH 545, SIVANANDI, NARASIMHA, NDLH 1938, PKV 081 and 9 *G. arboreum* genotypes namely CINA 396, CNA 1011, CNA 1012, CNA 1013, CNA 1, CNA 2, PA 402, JK 5, AKA7 were evaluated along with two checks under this experiment. Observation recorded were plant height, number of monopodia, no. of sympodia, plant width, height of first sympodia, lowest height of first boll, bolls on sympodia and total number of bolls at three intervals *i.e* at square formation, peak flowering and first picking.

RESULTS AND DISCUSSION

The variation among all the genotypes (*G. hirsutum* and *G. arboreum*) for yield contributing traits *viz.,* plant height, number of monopodia, number of sympodia, plant width, height of first sympodia, lowest height of first boll, number of bolls and bolls on sympodia for high input condition at two different spacings are represented in Tables 1 – 4 while for Low input condition they are represented in Tables 5 – 8. The effect of spacing, genotype and genotype x spacing interaction on seed cotton yield and number of bolls was significant. The yield levels of *G. hirsutum* and *G. arboretum* genotypes are depicted in the Graph 1 and 2.The highest yielding three genotypes under each of the spacing and input condition for *G. hirsutum* and *G. arboreum* is depicted in Table 1 and 2.

The best performing three genotypes in terms of yield and yield contributing characters for high and low input at variable spacing were identified which could be used in high density planting system with further refinement in spacing and agronomic practices. In *G. hirsutum* (Table 9) for high input conditions with 60 x 30 cm spacing; NDLH 1938 (1278 kg/ha) was highest yielder followed by 28I (1168 kg/ha) and PHULE 688(1167 kg/ha) while at a closer spacing of 30 x 20 cm CNH 2 (2167) kg/ha was the highest yielder followed by CNH 1109 (1833 kg/ha) and 28I (1333 kg/ha). Under low input conditions with 60 x 30 cm, NDLH 1938 (833 kg/ha) was highest yielder followed by CNH1109 (612 kg/ha) and NH452 (611 kg/ha) while at a closer spacing of 30 x 20 cm the highest yielder was 28I (1000kg/ha) followed by CNH11 (833) and CNH1108 (667 kg/ha). In *G. arboreum* (Table 10)

Table 1. Mean performance of *G. hrisutum* genotypes for yield and yield contributing traits (60 x 30 cm) (High input)

Genotypes	Observation on square forming			Observation on peak flowering			Observation on first picking					
	PH	MON	SYM	PH	SYM	PH	SYM	PW	HFS	LHFB	NB	BS
CNH 11	79	1.7	13	86	17	97	22	61	32	14	10	5
CNH 12	68	2.8	10	74	14	83	23	61	30	16	15	7
CNH 102	49	2.3	12	67	13	75	19	64	36	14	13	4
CNH 1108	56	2	11	71	17	86	25	57	31	14	13	5
CNH 1109	47	1.5	9	56	12	57	18	58	25	11	10	5
28 I	47	1	10	61	14	67	20	53	26	11	12	5
CNHPT 6	42	0.3	8	44	10	49	16	34	27	17	7	4
CNH 1	47	1.3	8.6	52	12	62	18	37	28	24	9	5
CNH 2	48	1.1	10	55	10	63	18	37	29	12	8	5
CNH 3	35	1.8	9.6	37	13	52	17	34	24	20	4	4
CNH 4	48	1.3	9	57	13	59	18	40	31	13	9	6
PHULE 688	54	1	8.8	65	14	77	17	35	31	13	9	4
NH 452	55	1.6	9	50	11	55	16	36	25	10	9	5
NH 545	61	1.6	10	58	15	74	25	44	33	10	11	6
SIVANANDII	44	1	9	58	14	62	26	39	29	16	11	5
NARASHIMHA	51	2	11	62	14	67	23	49	19	13	11	5
NDLH 1938	53	1.1	8	60	16	78	32	51	18	14	13	7
PKV 081	55	1.5	10	52	13	53	24	38	24	10	5	5
LRA 5166	46	1.8	11	48	11	53	20	39	20	12	7	3
LRK 516	44	2	15	48	11	46	24	34	22	11	7	3

PH= Pant height (cm), MON = Monopodia, SYM = Sympodia, PW = Plant Width (cm), HFS = Height of first sympodia (cm), LHFB = lowest height of first boll (cm), NB = Number of bolls, BS = bolls on sympodia.

Table 2. Mean performance of *G. hrisutum* genotypes for yield and yield contributing traits (30 x 20 cm) (High input)

Genotypes	Observation on square forming			Observation on peak flowering			Observation on first picking					
	PH	MON	SYM	PH	SYM	PH	SYM	PW	HFS	LHFB	NB	BS
CNH 11	62	1.1	12	71	15	75	29	49	36	25	8	5
CNH 12	46	0.8	9	49	12	57	17	44	23	18	6	3
CNH 102	57	1.5	12	61	12	76	21	40	26	27	6	3
CNH 1108	52	1	10	61	14	72	24	45	23	29	5.8	3
CNH 1109	62	0.3	11	57	14	68	23	38	24	24	11	7
28 I	68	0.3	11	69	13	77	23	50	29	20	9	4
CNHPT 6	66	1	12	62	11	76	20	29	32	36	7	3
CNH 1	57	0.8	10	81	15	87	26	55	26	32	8	4
CNH 2	52	1.1	9	66	12	70	18	34	26	16	6	3
CNH 3	67	0.8	12	56	12	68	16	39	28	23	6	4
CNH 4	57	1.3	11	60	13	75	21	43	29	20	9	4
PHULE 688	68	2.8	11	84	17	87	18	39	33	18	10	5
NH 452	50	1.1	10	73	18	74	20	44	26	15	6	3
NH 545	51	1.1	10	54	12	74	20	52	30	14	11	6
SIVANANDII	50	1.1	10	56	13	57	19	39	20	15	7	4
NARASHIMHA	53	1.3	11	61	11	63	20	44	20	15	9	5
NDLH 1938	47	1	11	70	12	68	19	36	25	18	8	4
PKV 081	50	1.1	10	47	10	47	13	38	28	18	8	4
LRA 5166	44	1	10	51	11	53	17	33	26	19	7	4
LRK 516	40	1.1	9	52	12	67	17	31	22	20	5	3

PH= Pant height (cm), MON = Monopodia, SYM = Sympodia, PW = Plant Width (cm), HFS = Height of first sympodia (cm), LHFB = lowest height of first boll (cm), NB = Number of bolls, BS = bolls on sympodia.

Table 3. Mean performance of G. arboreum genotypes for yield and yield contributing traits (60 x 15 cm) (High input)

Genotypes	Observation on square forming			Observation on peak flowering			Observation on first picking					
	PH	MON	SYM	PH	SYM	PH	SYM	PW	HFS	LHFB	NB	BS
CINA 396	122	1.5	15	153	28	154	44	58	53	31	11	5
CNA 1011	111	0.5	16	121	25	154	44	41	45	21	10	4.6
CNA 1012	119	1.1	15	142	29	156	51	3	64	23	13	7
CNA 1013	90	0.2	16	112	25	112	34	49	43	16	10	5
CNA 1	120	1.3	17	145	35	151	41	48	32	31	9	5
CNA 2	99	1	16	102	19	141	36	37	46	20	10	6
PA 402	108	1	17	168	33	203	52	56	30	23	10	4.8
JK 5	82	0.1	14	104	27	119	54	36	57	19	11	5
AK 7	71	1.5	14	79	26	119	39	31	56	16	9	4
PA 255	112	1	19	118	24	138	44	45	24	22	12	7
AKA 8401	110	0.6	18	133	33	166	57	48	24	21	11	6

Table 4. Mean performance of *G. arboreum* genotypes for yield and yield contributing traits (30 x 15 cm) (High input)

Genotypes	Observation on square forming			Observation on peak flowering			Observation on first picking					
	PH	MON	SYM	PH	SYM	PH	SYM	PW	HFS	LHFB	NB	BS
CINA 396	86	1	18	132	30	96	34	37	20	17	12	6
CNA 1011	76	1.5	17	128	32	90	29	30	18	15	9	4.5
CNA 1012	91	1.1	18	121	30	119	49	29	22	12	12	7
CNA 1013	98	3	26	136	45	94	30	41	25	14	9	4.6
CNA 1	127	1.5	32	122	28	139	50	46	26	20	11	6
CNA 2	110	1.8	13	117	24	131	42	36	18	17	10	4.6
PA 402	99	1	14	132	35	163	45	42	29	23	10	4.8
JK 5	99	0.5	15	98	27	92	35	45	33	19	10	5.5
AK 7	74	1.3	14	100	31	99	34	44	25	23	11	6.6
PA 255	92	1.8	14	122	24	129	35	41	28	18	11	5
AKA 8401	115	2.3	21	102	28	116	36	40	26	24	13	7

PH= Pant height (cm), MON = Monopodia, SYM = Sympodia, PW = Plant Width (cm), HFS = Height of first sympodia (cm), LHFB = lowest height of first boll (cm), NB = Number of bolls, BS = bolls on sympodia.

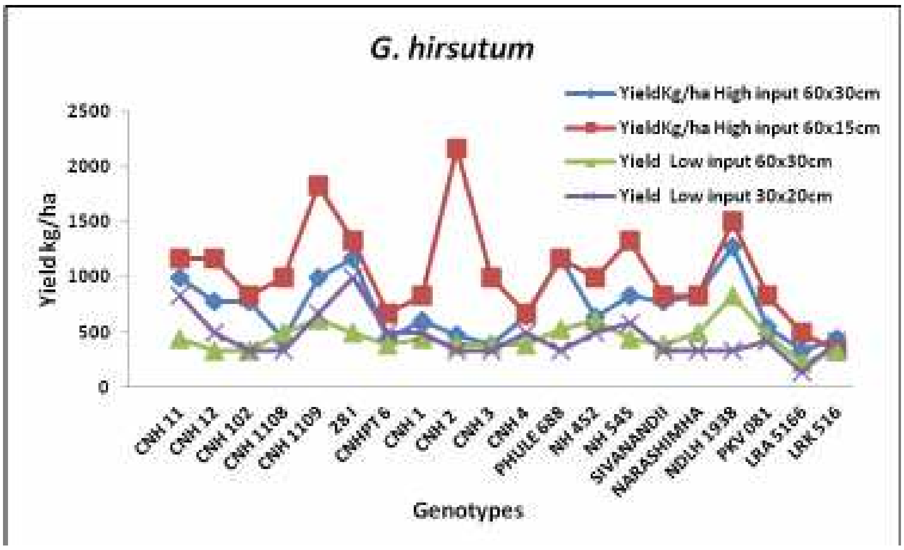


Table 5. Mean performance of *G. hrisutum* genotypes for yield and yield contributing traits (60 x 30 cm) (Low input)

Entries	Observation on square forming			Observation on peak flowering			Observation on first picking					
	PH	MON	SYM	PH	SYM	PH	SYM	PW	HFS	LHFB	NB	BS
CNH 11	58	1	11	85	17	89	24	63	29	32	10	5.5
CNH 12	48	1	8.8	65	15	80	25	59	31	30	14	8
CNH 102	54	1.5	10	70	14	85	25	46	32	36	10	5.5
CNH 1108	53	1.6	10	74	15	94	28	57	33	31	8	2.5
CNH 1109	45	1.3	9	58	14	66	22	44	25	25	10	5
28 I	46	1.1	11	67	16	81	25	62	24	26	10	5
CNHPT 6	42	0.3	10	58	13	62	21	30	23	27	14	7.8
CNH 1	46	1.1	10	60	12	77	25	41	27	28	13	4.5
CNH 2	45	1	10	55	12	68	23	40	22	29	20	8
CNH 3	35	1.1	8	54	12	61	23	34	17	24	12	5
CNH 4	45	1.3	9	56	15	68	22	40	25	31	9	4
PHULE 688	51	0.3	9.5	67	13	77	23	42	28	31	9	5
NH 452	49	1.6	9	67	15	78	24	35	24	25	10	3.6
NH 545	48	1.6	8.8	56	15	77	26	39	31	33	10	4.5
SIVANANDII	46	1	8	64	15	78	29	49	24	29	16	6
NARASHIMHA	42	1.3	9	64	16	70	23	47	21	19	13	5
NDLH 1938	53	2	8	72	17	86	37	52	23	18	14	3.6
PKV 081	45	2	7	52	13	59	25	42	19	24	7	5
LRA 5166	47	1.5	8	61	14	72	20	44	20	14	9	4
LRK 516	35	1.8	6	46	11	50	17	41	22	23	11	4

PH= Pant height (cm), MON = Monopodia, SYM = Sympodia, PW = Plant Width (cm), HFS = Height of first sympodia (cm), LHFB = lowest height of first boll (cm), NB = Number of bolls, BS = bolls on sympodia.

Table 6. Mean performance of *G. hirsutum* genotypes for yield and yield contributing traits (30 x 20 cm) (Low input)

Entries	Observation on square forming			Observation on peak flowering			Observation on first picking					
	PH	MON	SYM	PH	SYM	PH	SYM	PW	HFS	LHFB	NB	BS
CNH 11	55	1.3	9	81	16	98	25	45	36	29	10	4
CNH 12	45	1.3	9.6	62	12	71	20	43	27	22	6	2
CNH 102	48	1.1	8	66	14	77	20	47	24	26	9	2.6
CNH 1108	56	2.6	8	79	14	86	26	46	44	21	7	2
CNH 1109	62	1.6	8.8	80	15	72	23	40	44	21	6	1.8
28 I	60	1.6	9	83	17	91	26	48	43	17	10	7
CNHPT 6	52	1.8	9	75	15	77	30	43	32	26	10	6
CNH 1	57	2	8	78	14	81	22	44	24	23	7	4
CNH 2	50	1.6	7	66	14	75	21	47	24	24	7	4
CNH 3	48	0.8	7	65	15	73	26	48	37	17	10	7
CNH 4	34	1.3	8	80	17	84	22	51	26	31	10	6
PHULE 688	58	0.5	10	81	14	85	25	45	32	23	10	5
NH 452	49	1.3	8	71	16	79	24	45	32	14	8	4
NH 545	50	2	9	69	15	75	23	48	30	16	9	5
SIVANANDII	41	0.5	9	60	13	68	23	41	23	20	11	7
NARASHIMHA	45	1.5	7	63	15	72	26	54	20	18	9	4
NDLH 1938	53	1.1	9	73	15	79	25	46	29	21	10	6
PKV 081	45	0.8	8	58	13	64	21	42	25	18	9	5
LRA 5166	38	1	9	54	13	59	22	36	20	21	9	5
LRK 516	26	2	7	52	13	55	26	40	24	20	5	5

PH= Pant height (cm), MON = Monopodia, SYM = Sympodia, PW = Plant Width (cm), HFS = Height of first sympodia (cm), LHFB = lowest height of first boll (cm), NB = Number of bolls, BS = bolls on sympodia.

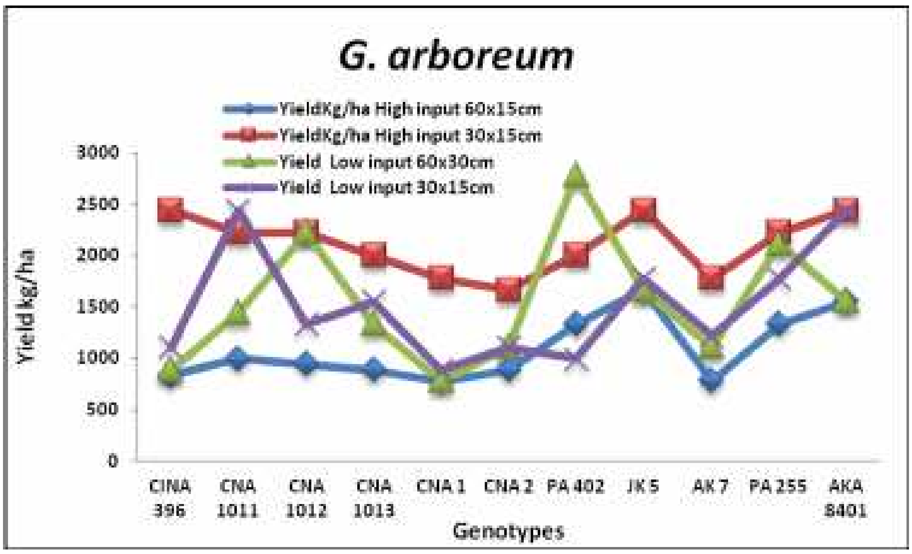
Table 7. Mean performance of *G. arboreum* genotypes for yield and yield contributing traits (60 x 15 cm) (Low input)

Entries	Observation on square forming			Observation on peak flowering		Observation on first picking					
	PH	MON	SYM	PH	SYM	PH	SYM	PW	HFS	LHFB	BS
CINA 396	90	2	12	128	22	140	28	54	36	21	10
CNA 1011	96	1.1	12	120	21	141	32	49	34	27	13
CNA 1012	76	3	10	96	22	122	30	47	33	26	12
CAN 1013	84	2	12	127	22	150	42	47	33	16	11
CNA 1	103	2	14	142	24	154	43	53	27	22	11
CNA 2	99	1.1	14	132	21	147	39	46	36	16	11
PA 402	104	1.6	15	152	22	160	45	57	30	16	10
JK 5	94	1.1	12	119	22	136	35	50	27	16	13
AK 7	83	1.5	13	96	18	100	29	46	33	17	10
PA 255	107	1.5	14	142	22	150	43	50	32	12	9
AKA 8401	113	1.3	15	141	23	160	43	49	35	15	11

Table 8. Mean performance of *G. arboreum* genotypes for yield and yield contributing traits (30 x 15 cm) (Low input)

Entries	Observation on square forming			Observation on peak flowering		Observation on first picking						
	PH	MON	SYM	PH	SYM	PH	SYM	PW	HFS	LHFB	NB	BS
CINA 396	113	1	18	127	30	168	36	47	19	12	10	8
CNA 1011	106	1.5	14	120	24	163	39	45	19	17	9	3
CNA 1012	110	1.1	14	118	29	148	33	45	26	14	10	4
CNA 1013	106	3	14	145	32	166	46	40	27	9	10	4.5
CNA 1	88	1.5	12	123	34	12	38	46	28	18	12	4.5
CNA 2	99	1.8	12	115	27	132	39	43	26	18	12	5
PA 402	96	1	13	146	33	140	41	36	32	16	10	5
JK 5	98	0.5	13	102	28	134	37	44	29	21	11	5
AK 7	94	1.3	14	102	32	129	38	39	26	20	12	4.6
PA 255	89	1.8	14	115	30	148	44	44	27	17	9	3.8
AKA 8401	104	2.3	12	120	26	117	42	43	24	26	10	3

PH= Pant height (cm), MON = Monopodia, SYM = Sympodia, PW = Plant Width (cm), HFS = Height of first sympodia (cm), LHFB = lowest height of first boll (cm), NB = Number of bolls, BS = bolls on sympodia.



for High input conditions with 60 x 15 cm spacing JK 5 (1667 kg/ha) was the highest yielder followed by PA 402 (1333 kg/ha) and PA255 (1333 kg/ha) while with 30 x 15 cm spacing; CINA 396(2444 kg/ha) was the highest yielder followed by CNA 1011 (2222 kg/ha), CNA 1012(2222 kg/ha). Under Low input conditions with 60 x 15 cm spacing CNA 1012(2222 kg/ha) was the highest yielder followed by PA 402(2778 kg/ha), PA 255(2111 kg/ha while with 30 X 15cm spacing CNA 1011(2444 kg/ha) was the highest yielder followed by JK 5(1778 kg/ha) and PA 255(1778 kg/ha). These genotypes need need further evaluation for their suitability to High Density Planting System in Vidarbha.

Table 9. Best Performing *G.hirsutum* genotypes at different spacing and input condition

Name	Spacing (Cm)	Seed cotton yield (kg/ha.)	
1. NDLH 1938		1278	
2. 28 I		1168	**High**
3. PHULE 688	(60 x 30 cm)	1167	**input**
4. LRA 5166 (Check)		334	
5. LRK 516 (Check)		445	
1. CNH 2		2167	
2. CNH 1109		1834	
3. 28 I	(30 x 20 cm)	1333	
4. LRA 5166 (Check)		500	
5. LRK 516 (Check)		333	
1. NDLH 1938		833	
2. CNH 1109		612	
3. NH 452	(60 x 30 cm)	611	
4. LRA 5166 (Check)		223	**Low**
5. LRK 516 (Check)		334	**input**
1. 28 I		1000	
2. CNH 11		833	
3. CNH 1108	(30 x 20 cm)	667	
4. LRA 5166 (Check)		142	
5. LRK 516 (Check)		417	

Table 10. Best Performing *G. arboreum* genotypes at different spacing and input condition

Name	Spacing (Cm)	Seed Cotton Yield (Kg/ha.)	
1. JK 5		1667	
2. PA 402		1333	High
3.CNA 1011	(60 x 15 cm)	1000	input
4.PA 255 (Check)		1333	
5. AKA 8401 (Check)		1556	
1. JK 5		2445	
2. CINA 396		2444	
3. CNA 1014.	(30 x 15 cm)	2222	
4. PA 255(Check)		2223	
5. AKA 8401(Check)		2445	
1.PA 402		2778	
2.CNA 1012		2222	
3.JK 5	(60 x 15 cm)	1667	
4.PA 255(Check)		2111	Low
5. AKA 8401(Check)		1556	input
1.CNA 1011		2444	
2.JK 5		1778	
3.CNA 1013	(30 x 15 cm)	1556	
4.PA 255(Check)		1778	
5.AKA 8401(Check)		2444	

REFERENCES

Belot, J.L. and Salles, A.O. 2010. Second- cycle cotton grown with high plant density in Mato Grosso, Brazil. The *ICAC Recorder* **28(2)** : 9-15

Bonde, W.C. 1992. Achievements in cotton production technology. Edited by A.K.Basu and S.S. Narayanan, 1992.Achievements of AICCIP (1967-92), 176pp

CICR 2011. CICR vision 2030. Central Insitute for Cotton Research, Nagpur

Darawsheh,M.K, Khah, E.M., Avivalakis, G.,Chachalis, D. And Fatbardh Sallaku 2009. Cotton row spacing and plant density cropping systems. Effects of accumulation and partitioning of dry mass and LAI. *Jour. Fd. Agri. Envir.* **7(3&4)** : July –October 2009

Gomez, K. A. and Gomez, A. A. 1984. *Statistical Procedures for Agricultural Research,* 2nd edn.John Wiley, New York, USA.

ICAC 2008. Nitrogen fertilization in cotton. The *ICAC Recorder* **26(1) :** 8-13

Jagannathan, N.T.and Venkitaswamy, R. 1996. Effect of plant density and nutrient levels of new cotton varieties. *Madras agri. J.* **83(3)** : 156-61.

Jost, P.H. and Cothren, J. T. 2000. Growth and yield comparisons of cotton planted in conventional and ultr-narrow row spacings. *Crop Sci.* **40** : 430-35.

Moll, R.H., Kamprath, E.J., and Jackson, W. A. 1982. Analysis and interpretation of factors which contribute to efficiency of N utilization. *Agron. J.* **74 :** 562-64

Oritz-Monasterio, R. J. I., Sayre, K. D., Rajaram, SMcMohan, M. 1997. Genetic progress in wheat yield and N use efficiency under four N rates. *Crop Sci.* **37 :** 88-90.

Reddy, K. N., Burke, I. C., Boykin, J. C. and Williford, R. 2009. Narrow row cotton [production inder irrigated and non-irrigated environment: plant population and lint yield. *Jour. Cotton Sci.* **13** : 48-55.

Rossi, J., Brajos, E. and Basce Vanos, D. 2007. Varietal response to ultranarrow row cotton in Spain. Paper 1772 *Proc. World Cotton Conference-4,* (Sept.10-14, 2007). Lubbock, Texas. wcrc.confese.com/wcrc/2007/tech program/1772-HTM

Silvertooth, J.C., Edmisten, K.L., and McCarty, W.H. 1999. Production practices. In C.W. Smith (eds.) Cotton: Origin, history, technology and production. John Wiley and Sons, New York-pp.463-465.

Venugopalan, M.V., Prakash, A.H., Kranthi, K.R., Deshmukh, R., Yadav, M.S., and Tandulkar, N.R. 2011. Evaluation of cotton genotypes for High Density Planting Systems on Rainfed Vertisols of Central India. *Book of Papers,* wcrc-5, WCRC-5 /2011 pp 341-346.

CROP PRODUCTION AND MECHANIZATION

Studies on drip irrigation, fertigation and spacing in *Bt* cotton

R.P.S. CHAUHAN AND B.S. YADAV*

Swami Keshwanand Rajasthan Agricultural University, Agricultural Research Station, Sriganganagar – 335 001

**E-mail : drbsyadav@gmail.com*

Abstract : Three experiments were conducted to find out suitable crop geometry under drip irrigation, optimum irrigation schedule and optimum fertigation schedule for *Bt* cotton at Agricultural Research Station, Sriganganagar during *kharif*, 2009 to 2011. Paired row spacing of 60 x 120 cm and single row spacing of 90, 108 and 120 cm gave statistically *at par* seed cotton yield. When the row spacing of cotton was further increased to 135 cm, the yield of cotton was significantly reduced as compared to other closer row spacings tested in the study. The minimum drip cost was observed in paired row of 120 x 60 cm. Thus, 120 x 60 cm paired row spacing was found optimum for *Bt* cotton. The maximum seed cotton yield was recorded when drip irrigation was scheduled at 1.2 ETc, however, it was *at par* with seed cotton yield obtained at 1.0 ETc. Seed cotton yield at 0.8 and 0.6 ETc was significantly less than that of 1.0 per cent 1.2 ETc treatments. Thus, drip irrigation to *Bt* cotton at 1.0 ETc was found optimum. This treatment gave 31.0 per cent higher seed cotton yield and saved 32.9 per cent of irrigation water over conventional flood irrigation. The water expense efficiency was higher in the drip irrigated treatments as compared to flood irrigation. The maximum water expense efficiency of 4.21 kg/ha mm was recorded at 1.0 ETc followed by 3.98 kg/ha mm at 0.8 ETc irrigation treatment with drip system. The maximum seed cotton yield was recorded at 120 per cent RD of fertilizers, however, it was *at par* with 100 per cent and 80 per cent RD of fertilizer with 2 per cent KNO_3 spray. Thus, 80 per cent RD of NPK+ foliar spray of 2 per cent KNO_3 at 90 and 105 DAS was found optimum for *Bt* cotton. This treatment gave 15.6 per cent higher seed cotton yield over conventional method of fertilizer application and irrigation. The maximum water expense efficiency of 3.95 kg/ha mm was recorded with120 per cent of RD, followed by 3.87 kg/ha mm with100 per cent of RD +2 per cent KNO_3 as foliar spray at 90 and 105 DAS and 3.78 kg/ha mm with 80 per cent of RD +2 per cent KNO_3 as foliar spray at 90 and 105 DAS.

Key word : *Bt* cotton, drip irrigation, fertigation, crop geometry, yield, water use efficiency

Cotton is the main *kharif* crop in irrigated north-western plain zone of Rajasthan. The water requirement of cotton is the highest in comparison to other *kharif* crops except paddy in this zone. This crop requires 700 to 900 mm water during its growth period. Time of the water application as well as its total requirement both are the important factors influencing crop production. Cotton is deep rooted crop and the time of application of first irrigation is very important from the point of view of its root development and subsequent water requirement. The first irrigation in American cotton is recommended at 30 to 35 days after sowing in this zone. Similarly, the last irrigation is recommended in the second fortnight of October. The application of irrigation at later stage results continuous growth and ultimately undeveloped bolls remains on the plants. The farmers of the zone grow cotton in limited area because of shortage of irrigation water. Land is not the constraint but water availability is the main constraint to increase the area under cotton in this zone. The introduction of *Bt* cotton in the zone further increased the productivity of cotton.

Drip irrigation can help to use water efficiently. Irrigation scheduling through drip can be managed precisely to meet crop water demands, holding the promise of increased yield and quality. A well designed drip irrigation system looses practically no water to runoff, deep percolation or evaporation. Drip irrigation reduces water contact with crop leaves, stems, and fruit. Thus conditions may be less favourable for the onset of diseases. Agricultural chemicals can be applied more efficiently with drip irrigation. Since only the crop root zone is irrigated, nitrogen already in the soil is less subject to leaching losses, and applied fertilizer N can be used more efficiently. Nutrient applications can be better timed to meet plant needs. In the case of insecticides, less quantity is needed. These objectives can be achieved by following optimum irrigation and fertigation schedules for cotton by adopting efficient water application method. An effort has been made in the present investigation to generate information on optimum irrigation schedule, fertigation schedule and optimum crop geometry for drip irrigation in *Bt* cotton in irrigated north western plain zone of Rajasthan.

MATERIALS AND METHODS

The experiments on drip irrigation, drip fertigation and crop geometry in *Bt* cotton were conducted at Agricultural Research Station, Sriganganagar during *kharif* seasons from 2009 to 2011. The soil was sandy loam, low in organic carbon (0.20 %), medium in available phosphorus (34 kg P_2O_5/ha) and high in available potash (350 kg K_2O/ha) with a pH of 8.3. These experiments were laid out in randomized block design. *Bt* cotton (JKCH 1947) was taken as test crop. Drip lines having in line drippers at 30 cm distance with water discharge of 2 LPH were used in the study. In the experiment on crop geometry, five crop geometries (60 x 120 paired, 90, 108, 120 and 135 cm single row) for *Bt* cotton under drip irrigation system were tested to evaluate their performance. In paired planting drip line was placed between two lines and in single row plantings, drip line was placed along the line. In paired planting, drip running time was double than single row planting of 90 cm and in all other geometries water application was as per 100 per cent area to make the water application uniform/unit area in all the crop geometries. Alternate day irrigation schedule was followed. In another experiment on irrigation scheduling four levels of drip irrigation (0.6, 0.8, 1.0, 1.2 ETc) with recommended practice of surface irrigation were tested for *Bt* cotton. Irrigation was applied on alternate day by drip irrigation as per treatment. In third experiment four fertilizer levels (120 % recommended dose of NPK, 100, 80 and 60% recommended dose of NPK + 2% KNO_3) for *Bt* cotton crop under drip irrigation system with control (recommended dose with flood irrigation) were evaluated. In this experiment water soluble fertilizer 0 : 52 : 34 N : P : K and urea were used for nutrient application. In all the drip treatments fertilizers were applied through drip in six equal splits at an interval of 15 days. In flood irrigation treatment nitrogen was applied in three splits (1/3 at sowing as basal, 1/3 at first irrigation and 1/3 at square formation) and full dose of phosphorus as single super phosphate and potash as muriate of potash as basal. Treatment wise yield, yield attributing parameters, water use and water use efficiency in all the experiments were recorded. The data were statistically analyzed and inferences were drawn accordingly.

RESULTS AND DISCUSSION

Effect of planting method : Paired row spacing of 60 x 120 cm and single row spacing of 90, 108 and 120 cm gave statistically *at par* seed cotton yield (Table 1). When the row spacing of cotton was further increased to 135 cm, the yield of cotton was significantly reduced as compared to other closer row spacings tested in the study. Aujla *at al.*, (2005) reported superiority of paired planting in cotton than normal planting under drip irrigation at Bathinda in Punjab, however, Sidhpuria *at al.*, (2005) found planting of hybrid cotton at a spacing of 1 m x 1 m optimum under drip irrigation in loamy sand soil of Bawal, Haryana. The water expense efficiency (WEE) in the present investigation was also lowest at row spacing of 135 cm. The minimum drip cost was also observed in paired row of 120 x 60 cm. Thus, 120 x 60 cm paired row spacing was found

Table 1. Effect of different crop geometry treatments on yield and water expense efficiency (average of three years)

Crop Geometry (cm)	Seed cotton yield (q/ha)	Bolls /plant	Plant population /ha	Total water use (mm)	WEE (kg/ha mm)
60 x 120 x 60	30.85	70.10	17593	759	4.06
90 x 60	31.65	68.33	17562	759	4.17
108 x 60	31.36	73.23	14609	759	4.13
120 x 60	30.71	74.73	13102	759	4.05
135 x 60	26.42	74.75	11605	759	3.48
SEd	1.56	4.63	297	-	-
CD (p=0.05)	3.41	10.08	647	-	-

Table 2. Effect of different irrigation treatments on yield and expense efficiency (average of three years)

Irrigation schedule	Seed cotton yield (q/ha)	Balls/plant	Total water use (mm)	WEE (kg/ha mm)
0.6ETc	23.60	57.05	602	3.92
0.8ETc	26.26	60.20	660	3.98
1.0ETc	30.93	63.98	736	4.21
1.2ETc	30.96	63.51	802	3.86
Flood	23.61	55.17	978*	2.41
CD	1.57	7.93	-	-

* Including 25 per cent conveyance losses

optimum for *Bt* cotton in this zone.

Effect of drip irrigation : The maximum seed cotton yield was recorded when drip irrigation was scheduled at 1.2 ETc, however, it was at par with seed cotton yield obtained at 1.0 ETc (Table 2). Seed cotton yield at 0.8 and 0.6 ETc was significantly lesser than that of 1.0 and 1.2 ETc treatments. Thus, drip irrigation to *Bt* cotton at 1.0 ETc was found optimum. This treatment gave 31.0 per cent higher seed cotton yield and saved 32.9 per cent of irrigation water over conventional flood irrigation. The water expense efficiency was higher in the drip-irrigated treatments as compared to flood irrigation. The maximum water expense efficiency of 4.21 kg/ha mm was recorded at 1.0 ETc followed by 3.98 kg/ha mm at 0.8 ETc irrigation treatment with drip system.

Effect of fertigation : The maximum seed cotton yield was recorded at 120 per cent RD of fertilizers, however, it was *at par* with 100 per cent and 80 per cent RD of fertilizer with KNO_3 (2%) spray (Table 3). Thus, 80% RD of NPK+ foliar spray of KNO_3 (2%) at 90 and 105 DAS was found optimum for *Bt* cotton. This treatment gave 15.6 per cent higher seed cotton yield over conventional method of fertilizer application and irrigation.

The maximum water expense efficiency of 3.95 kg/ha mm was recorded with 120 per cent of RD treatment, followed by 3.87 kg/ha mm with 100 per cent of RD + KNO_3 (2%) as foliar spray and 3.78 kg/ha mm with 80 per cent of RD + KNO_3 (2%) as foliar spray. Reddy and Aruna (2010) reported that fertigation with 125 percent recommended dose of N and K applied 10 per cent as basal and remaining 90 per cent from 30-120 days in nine splits recorded higher *kapas* yield as compared to recommended manual fertilizer application under drip irrigation on *Bt* cotton (BG I) in vertisols at Nandyal, Andhra Pradesh.

Table 3. Effect of different irrigation treatments yield and water expense efficiency (average of three years)

Treatments	Seed cotton yield (q/ha)	Balls/plant	Total water use (mm)	WEE (kg/ha mm)
RD (120 %)	29.96	65.87	759	3.95
RD (100%) + KNO_3 (2%)	29.40	64.08	759	3.87
RD (80%) + KNO_3 (2%)	28.72	64.92	759	3.78
RD (60%) + KNO_3 (2%)	24.44	58.25	759	3.22
Recommended Practice	24.85	55.24	1003*	2.48
SEd	0.67	4.32	-	-
CD (p=0.05)	1.46	9.41	-	-

* Including 25 per cent conveyance losses

REFERENCES

Sidhpuria, M.S., Singh, Jagdev and Yadav, S.S. 2005. Performance of drip irrigation under different crop geometries for cotton crop. *J. Water Management*, **13** : 6-8.

Aujla, M.S., Thind, H.S. and Buttar, G.S. 2005. Effect of drip irrigation, spacing and fertigation in cotton. *Agricultural Water Management,* **71** : 167-79.

Reddy, B. Sahadeva and Aruna, E. 2010. Effect of doses and split application of nutrients through fertigation in *Bt* cotton (*Gossypium hirsutum* L.). *J. Cotton Res. Dev.,* **24** : 59-63.

Proceedings on "Global Cotton Production Technologies *vis-a-vis* Climate Change" 161-164

Agronomic studies on promising *hirsutum* varieties in relation to spacing and fertilizer levels

P.L.NEHRA* AND RAJNI GUMBER
Swami Keshwanand Rajasthan Agricultural University, Agricultural Research Station, Sri ganganagar - 335 001
**E-mail: pl.nehra@yahoo.co.in*

Abstract : A field experiment was carried out during kharif season at Agricultural Research Station, Sriganganagar on sandy loam soil to see the effect of spacing and fertilizer levels on promising *hirsutum* varieties for improvement in productivity of cotton. Significantly higher seed cotton yield was recorded under LH 2107 (2632 kg/ha) over F 2164 (2192 kg/ha) but it was statistically at par with LH 2108 (2521 kg/ha). The increase in yield under this variety might be due to significant increase in bolls/plant and boll weight over F 2164. As regards spacing both were statistically at par. Increasing dose of fertilizer from 100 to 125 per cent RDF could not show its impact on seed cotton yield and application of 100 per cent RDF (80: 40: 20) seems to be optimum dose of fertilizer. Fibre length, uniformity ratio, micronaire value and strength g/tex, have been recorded but the parameters were not influenced by different treatments.

Key words : *hirsutum* varieties, seed cotton yield, spacing, productivity

Cotton (*Gossypium hirsutum l.*) is one of the most important fibre crops of India. The seed cotton yield and yield parameters have been found to vary with fertilizer application under variable plant stand (Singh and Rathore, 2007). Adopting new genotypes at optimal plant population/ha with chemical fertilizers may help to obtain maximum yield of cotton. In view of the escalating prices of chemical fertilizers, there is a strong need of judicious and balanced use of all the three major nutrients to obtain optimum and economically viable net returns/unit area. However, the success of cotton crop depends on the agronomic practices especially fertilization and spacing adopted to exploit the maximum yield potential .Therefore, the present study was undertaken to investigate the effect of different levels of fertilizer and spacing on the growth and yield of *hirsutum* cotton.

MATERIALS AND METHODS

The field experiment was conducted during *kharif,* 2011 on sandy loam soil with a status of low in nitrogen (0.21 % O. C.), medium in phosphorus (18 kg P_2O_5 /ha) and high in available potash (325 kg K_2O /ha) at Agricultural Research Station, Sriganganagar. The experiment was laid out in split plot design with four replications with spacing in main plots and fertilizer in sub plots. The *hirsutum* varieties were sown on 5.4 x 4.05m^2 plot size on 25 May, 2011. The main plot treatments consisting of three varieties V_1=LH 2108, V_2=LH 2107 and V_3=F 2164. The sub plot treatments consisting two spacing S_1 - 67.5 x 30 and S2 - 67.5 x 60 and the sub-sub plot consisting two levels of fertilizer *viz.,* F_1- R.D.F (100%) and F_2- R.D.F (125%). One third dose of N and full dose of P_2O_5 (DAP) and K_2O (MOP) were applied at the time of sowing as basal dose. Remaining nitrogen was top dressed at first irrigation and at square initiation stage as per treatment. The data on plant height, boll weight and bolls/plant were recorded from randomly selected five plants from each plot and seed cotton yield was recorded / plot basis. Adequate plant protection measures were adopted as per recommendations.

RESULTS AND DISCUSSION

Effect of varieties : The data in Table 1 revealed that in *hirsutum* varieties significantly the highest seed cotton yield was recorded under LH 2107(2632 kg/ha) over F 2164 (2192 kg/ha) which was 20.07 per cent higher, but it was statistically *at par* with LH 2108 (2521 kg/ha). The increase in seed cotton yield might be due

Table 1. Performance of different *hirsutum* varieties in relation to spacing and fertilizer on yield and yield attributing characters

Treatments	Seed cotton yield (kg/ha)	Bolls/ plant	Boll weight (g)	Plant height (cm)	Plant stand/ha
Varieties (Main plot)					
V_1 LH 2108	2521	86	3.67	166	35246
V_2 LH 2107	2632	90	3.74	169	35789
V_3 F 2164	2192	81	3.40	165	35589
CD (p=0.05)	228	3.91	0.27	NS	NS
Spacing (Sub plot) (cm)					
S_1 67.5 x 30	2298	84	3.53	166	47300
S_2 67.5 x 60	2599	86	3.67	167	23783
CD (p=0.05)	NS	NS	NS	NS	1401
Fertilizer Levels (Sub sub plot)					
F_1 RDF (100%)	2431	85	3.58	165	35760
F_2 RDF (125%)	2465	86	3.62	168	35322
CD (p=0.05)	NS	NS	NS	NS	NS

Table 2. Performance of different *hirsutum* varieties in relation to spacing and fertilizer on nutrient uptake

Treatments	Nutrients uptake (kg/ha)			Dry matter (kg/ha)
	Nitrogen	Phosphorus	Potassium	
Varieties (Main plot)				
V_1 LH 2108	271	30.88	153	9054
V_2 LH 2107	262	33.97	162	9119
V_3 F 2164	256	30.55	153	9117
CD (p=0.05)	NS	NS	6. 98	NS
Spacing (Sub plot) (cm)				
S_1 67.5 x 30	267	32.52	158	9326
S_2 67.5 x 60	259	31.08	153	8867
CD (p=0.05)	NS	NS	NS	NS
Fertilizer Levels (Sub sub plot)				
F_1 R. D.F (100%)	264	31.89	155	9145
F_2 R.D.F (125%)	263	31.71	156	9048
CD (p=0.05)	NS	NS	NS	NS

to improvement in yield attributing characters *viz.*, bolls/plant and boll weight (g). Sisodia and Khamparia (2007) also recorded significantly higher seed cotton yield due to more number of bolls. The data on ancillary characters showed that the bolls / plant and boll weight were influenced significantly by different *hirsutum* varieties. The highest nutrient uptake (N, P_2O_5 and K_2O) was recorded in variety LH 2107 and lowest was recorded in F-2164 (Table 2). Highest NPK use efficiency was obtained in variety LH-2108(6.32kg/ha) closely followed by LH 2107(6.29kg/ha) and lowest was recorded in F 2164 (5.65kg/ha) (Table 3). The data in Table 5 showed that highest water expense efficiency (3.23kg/ha.mm.) and water productivity (13.59 Rs/kilolitre of water) was observed in LH 2107 whereas lowest values 2.69kg/hamm. and 11.31 Rs/kilolitre of water was recorded with F 2164.

Table 3. Performance of different *hirsutum* varieties in relation to spacing and fertilizer on nutrient use efficiency

Treatments	Nutrient use efficiency (Based on nutrient uptake kg/ha.)			
	N	P_2O_5	K_2O	NPK
Varieties (Main plot)				
$\mathbf{V_1}$ LH 2108	10.82	90.52	18.24	6.32
$\mathbf{V_2}$ LH 2107	10.78	87.01	18.25	6.29
$\mathbf{V_3}$ F - 2164	9.67	81.66	16.27	5.65
CD (p=0.05)	NS	NS	NS	NS
Spacing (Sub plot) (cm)				
$\mathbf{S_1}$ 67.5 x 30	10.24	78.76	16.01	5.55
$\mathbf{S_2}$ 67.5 x 60	10.60	94.04	19.08	6.62
CD (p=0.05)	NS	NS	NS	NS
Fertilizer Levels (Sub sub plot)				
$\mathbf{F_1}$ R. D.F (100 %)	10.37	85.97	17.55	6.06
$\mathbf{F_2}$ R.D.F (125 %)	10.47	86.82	17.62	6.11
CD (p=0.05)	NS	NS	NS	NS

Table 4. Performance of different *hirsutum* varieties in relation to spacing and fertilizer on quality parameters

Treatments	Span length (2.5%)	UR	Micronaire value	Tenacity (g/tex)
Varieties (Main plot)				
$\mathbf{V_1}$ LH 2108	30.4	49.5	4.5	24.0
$\mathbf{V_2}$ LH 2107	29.8	51.2	4.6	23.2
$\mathbf{V_3}$ F 2164	30.3	49.7	4.3	23.1
Spacing (Sub plot) (cm)				
$\mathbf{S_1}$ 67.5 x 30	30.1	50.2	4.5	23.6
$\mathbf{S_2}$ 67.5 x 60	30.2	50.1	4.4	23.2
Fertilizer Levels (Sub sub plot)				
$\mathbf{F_1}$ RDF (100%)	30.1	50.6	4.5	23.9
$\mathbf{F_2}$ RDF (125%)	30.2	49.6	4.4	22.9

Table 5. Performance of different hirsutum varieties in relation to spacing and fertilizer on total water expense, water expanse efficiency and water productivity

Treatments	TWE (ha.mm)	WEE (kg/ha.mm)	Water Productivity (Rs/Kilolitre of water)
Varieties (Main plot)			
$\mathbf{V_1}$ LH 2108	813	3.10	13.01
$\mathbf{V_2}$ LH 2107	813	3.23	13.59
$\mathbf{V_3}$ F 2164	813	2.69	11.31
Spacing (Sub plot) (cm)			
$\mathbf{S_1}$ 67.5 x 30	813	2.82	11.87
$\mathbf{S_2}$ 67.5 x 60	813	3.19	13.42
Fertilizer Levels (Sub sub plot)			
$\mathbf{F_1}$ RDF (100%)	813	2.99	12.55
$\mathbf{F_2}$ RDF (25%)	813	3.03	12.73

Effect of spacing : The results in Table 1 indicated that 67.5 x 60 cm spacing gave highest seed cotton yield (2599 kg/ha) over 67.5 x 30cm spacing (2298kg/ha) but both were statistically *at par*. Similar trend was recorded with regards to bolls/plant and boll weight (g)

Effect of fertilizer levels : The application of different fertilizer levels did not exert any significant effect on growth and yield parameters of *hirsutum* cotton. Application of RDF (125%) gave highest seed cotton yield (2465 kg/ ha) but it was statistically at par with RDF (100%) (Table 1). The results are in closer conformity with the findings of Kaur and Brar (2008) and Singh *et al.,* (2012).

Fibre quality parameters : Fibre lengths, uniformity ratio, micronaire value and strength g/tex, parameters were not influenced by different spacing and fertilization (Table 4). Similar results have been reported by Blaise *et al.,* (2005).

REFERENCES

Blaise, D., Singh, J.V., Bonde A.N., Tekale K.U. and Mayee, C.D. 2005. Effect of farmyard manure and fertilizers on yield, fibre quality and nutrient balance of rainfed cotton (Gossypium hirsutum). *Bioresource Technology* **96** : 345-349.

Kaur, Mandeep and Brar, A.S. 2008. Effect of nitrogen and spacing on desi cotton hybrid (*Gossypium arboreum* L.). *J. Cotton Res. Dev.* **22** : 160-62.

Singh, Kulvir; Singh, Harmandeep; Rathore, Pankaj and Gumber, R. K. 2012. Response of desi cotton (Gossypium arboreum L.) genotypes to plant geometries and nutrient levels under irrigated conditions. *J. Cotton Res. Dev.*, **26** : 58-61.

Singh, Kulvir and Rathore, Pankaj 2007. Effect of different spacing and nitrogen levels on growth and yield attributes of American cotton (*Gossypium hirsutum* L.) genotypes. *J. Cotton Res. Dev.*, **21** : 178-79.

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

Screening of *Gossypium hirsutum* genotypes for drought tolerance by studying genotypic variability for growth and biophysical parameters

B. C. PATIL*, A.G., BABU, K.N. PAWAR AND A.B., SHAHEEN
University of Agricultural Sciences, Agricultural Research Station, Dharwad - 580 007
**E-mail : bc_patil@yahoo.com*

Abstract : Drought stress is a complex phenomenon affecting the physiology of cotton plant in turn reduces crop growth and yield. An experiment was conducted in two years 2010-2011 and 2011-2012 using twenty *Gossypium hirsutum* genotypes grown in RBD design at Agricultural Research Station, University of Agricultural Sciences, Dharwad to evaluated for genotypic variability for growth, biophysical parameters, yield parameters under irrigated as well as in water deficit rainfed condition. The two years pooled analysis showed that, the genotypes ARBH 2004, ARBH 813, Sahana recorded highest bolls/plant while GSHV 96/612 recorded the least. Maximum boll weight was recorded by AKH 0205 followed by RCR 102 and the least by GSHV 96/612 in irrigated condition. In both irrigated as well as rainfed condition BS 279 and ARBH 2004 recorded the highest water potential while GSHV 96/612 and HBB 101 showed the least. The genotypes BS 279 and ARBH 2004 recorded highest photosynthesis rate and chlorophyll content, while CDP 168, CPD 231 recorded least. The genotypes BS 279, ARBH 2004 and HBB 101 showed higher LAI while GJHV 358 and NH 635 recorded by least. The Biplot of seed cotton yield under irrigated condition *v/s* DSI showed that genotypes BS 279, BS 30 and RCR 102 recorded more cotton yield irrigated condition but high drought susceptibility index. Overall the BS 279, ARBH 813, ARBH 2004 and Sahana proved better as they recorded highest seed cotton yield both in irrigated and also in rainfed condition and least to moderate drought susceptibility indices. This increased yield may be due to higher photosynthesis rate, Water use efficiency and other biophysical and genetic factors. These genotypes can be used as desirable genotypes for drought situations.

Key words : Biplot, cotton, growth, photosynthesis rate, yield, water deficit, water potential.

Cotton (*Gossypium* spp.) is the most preferred source of natural fibre and economically important for farmers globally. In India, cotton is an important cash crop and India has the largest cotton area in the world. However, cotton production is limited by biotic and abiotic factors. Among them, drought, or water deficit, is a major abiotic stress, which limits fiber development. Yield is severely affected when drought stress occurs during the reproductive phase (Selote and Chopra, 2004). More than 60 per cent of cotton cultivated in India is rainfed where water stress frequently occurs in any phase of crop development. Growth and yield of a crop plant is drastically affected directly or indirectly by altering metabolism, growth and development (Pettigrew, 2004). The detrimental effect of drought on cotton crop can be minimized by developing drought tolerant cultivars. Drought tolerance is a complex mechanism that is influenced by a wide range of physiological traits which have some relationship with productivity under water deficit conditions. It is known that the quantity and quality of the fiber produced in cotton plants is directly related to water availability during the different phenological phases of development. Genetically equivalent cotton plant populations, when submitted to water deficits, show reduction in yield up to 50 per cent if compared to those that have been irrigated, especially when the stress factor is imposed during the period between flowering and boll developing (Araújo *et al.*, 2003). Reduction of photosynthetic rate in cotton under water limited environment is documented (Ephrath *et al.*, 1993). This reduction may be attributed to stomatal (Flexas *et al.*, 2005) and non stomatal factors (Ennahli *et al.*, 2005). A higher photosynthetic rate under drought is a decisive factor for higher cotton production (Lopez *et al.*, 1995). There is a considerable variation of growth parameters *viz,* plant height, number of leaves, specific leaf area, plant dry weight, leaf dry weight and productivity traits *viz,* bolls/plant, boll diameter, staple length, fibre strength, ginningout percentage in relation to varying moisture deficit periods. The juvenile growth stages were more susceptible to water deficit

(Seema mahmood *et al.*, 2006). Therefore, development of drought resistant cotton cultivars has long been a major cotton breeding objective. Hence present study was made on the genotypic variability among the cotton cultivars for growth, biophysical parameters, yield characters, focusing on identifying a suitable screening index for drought tolerance.

MATERIALS AND METHODS

Twenty *G.hirsutum* cotton genotypes belonging to north, central and south cotton growing zones of India were selected from Breeding trilas (Br 04 (a) (b)) of All India Coordinated Cotton Improvement Project. These genotypes selected were from top performing entries from different centers. The experiment was conducted at Agricultural Research Station, Dharwad. The rainfall received during 2010 and 2011 was 882.4mm (16.0 % more) and 827.6 (8.2% more) than the normal. The experiment was sown in rainfed as well as irrigated condition during 2010-2011 and 2011-2012. The experiment was laid out in RBD with three replications. The sowing was done in June in both years and all the cultural practices for cotton were followed.

Measurement of physiological parameters :

Biophysical parameter such as photosynthesis rate, stomotal conductance, Transipiration rate, photosynthetically active radiation was determined with portable photosynthesis system (LI 6400). Three plants were selected from each plot. The top fully opened leaves (fourth node from the top on main shoot) were selected. The measurements were made between 1000-1200 h, the observations were recorded at 90 days after sowing. Seed cotton was picked from each plot at 170 days and recorded as seed cotton yield. The water potential was determined with the help of a pressure chamber apparatus. The fully expanded leaf (three from each plot) was used for determination of water potential by pressure chamber Mean of three leaves. The leaf area index was determined with help of plant canopy analyser (LAI 2000). The total dry matter production at harvest was determined from five plants from each plot. The biplot was drawn by taking mean yield under irrigated condition on X axis and drought susceptibility index on Y axis.

RESULTS AND DISCUSSION

Seed cotton yield : The pooled analysis of the data for the year 2010-2011 and 2011-2012 is presented in Table 1. In irrigated condition the variety BS 279 has recorded highest mean yield (2015kg/ha) followed by BS 30 (1694 kg/ha) and RCR-102 (1608 kg/ha) whereas GBHV 164 (1059 kg/ha) and GJHV 358 (948 kg/ha) recorded the least yield. In rainfed condition BS 279 (1594 kg/ha) followed by H 1353/10 (1483 kg/ha) recorded the highest yield while, GBHV 164(1035 kg/ha) followed by GJHV 358 (859 kg/ha) recorded the least yield. In present study, the varieties exhibited considerable variation for growth and productivity traits in relation to varying moisture deficit periods.

The per cent yield reduction in rainfed condition compared to irrigated condition was highest in the genotype GISV 218 (53.4%) followed by HBB 101(45.7%) indicating their sensitivity to moisture regimes, whereas the least reduction was observed in ARBH 813 (3.8%) and H 1353/10 (4.6%) (Table 1).

Similar observations on cotton genotypic variability were recorded by Seema Mohmood *et al.*, 2006.

The Biplot of seed cotton yield under irrigated condition *v/s* DSI is given in Figure 1, showed that genotypes BS 279, BS 30 and RCR 102 recorded more cotton yield in irrigated condition but high drought susceptibility index (more than 1.2). These lines can be used in breeding programmes for moisture stress tolerance as well as for yield stability. Whereas Sahana and ARBH 2004 recorded moderate yield with low DSI (less than 0.51) these are the genotypes suitable for stress condition.

The least yield was recorded by GJHV 358 and GBHV 164 and these showed low DSI (<0.8). But AKH 0205 and LRA 5166 recorded low yield as well as high DSI which are undesirable features for drought condition. These conclusions are supported by yield components and physiological characters.

Table 1. Seed cotton yield (kg/ha), bolls/plant and boll weight in cotton genotypes under irrigation and rainfed condition (Pooled data of 2010-2011 and 2011-2012).

Sl. No.	Genotypes	Seed cotton yield				Bolls/ plant			Boll weight (g/boll)		
		(Irr)	(Rf)	Reduction (%)	DSI	(Irr)	(Rf)	Reduction (%)	(Irr)	(Rf)	reduction (%)
1	BS 279	2015	1594	25.8	1.54	15.6	11.7	25.1	4.65	3.86	17.3
2	BS 30	1694	1285	25.6	1.78	16.3	12.9	20.6	4.28	3.99	7.1
3	RCR 102	1608	1352	30.4	1.18	13.0	8.8	34.0	4.63	4.57	1.2
4	SAHANA(ZC)	1538	1428	11.6	0.52	16.7	13.0	22.5	4.39	3.88	13.4
5	ARBH 2004	1516	1410	22.3	0.51	17.1	13.6	20.2	4.87	4.45	8.7
6	MR 786	1509	1174	31.3	1.63	13.7	11.7	14.2	4.73	3.60	24.4
7	H 1353/10	1502	1483	4.6	0.09	16.1	13.2	17.1	4.39	4.13	6.5
8	ARBH 813	1478	1361	3.8	0.54	16.4	13.4	17.6	4.12	3.61	13.3
9	NH 635	1474	1178	36.4	1.48	13.1	10.0	23.2	4.01	3.83	4.4
10	H 1452/10	1469	1294	32.0	0.88	15.8	12.7	19.0	4.81	4.51	6.1
11	GISV 218	1422	1100	53.4	1.67	12.9	10.9	14.5	4.45	3.74	16.4
12	HBB 101	1403	1117	45.7	1.50	12.4	10.0	17.6	4.60	3.57	22.4
13	CPD 231	1383	1344	16.7	0.21	13.8	12.3	11.3	4.56	4.07	11.1
14	AKH 0205	1377	1148	38.5	1.23	14.4	11.7	18.9	5.39	4.12	22.9
15	LRA 5166(NC)	1373	1143	35.2	1.24	14.0	10.3	27.3	3.96	3.77	4.6
16	F 2228	1354	1209	27.7	0.79	12.7	10.2	20.1	4.55	3.83	16.6
17	CPD 168	1303	1147	21.9	0.88	13.8	11.7	16.5	4.52	3.98	12.4
18	GSHV 971612	1215	1092	29.1	0.75	11.2	7.6	27.9	4.43	3.49	19.4
19	GBHV 164	1059	1035	22.5	0.16	14.4	11.2	21.6	4.68	3.74	19.7
20	GJHV 358	948	859	25.6	0.69	13.0	9.5	27.5	4.89	4.24	12.9
	Mean	**1432**	**1238**	**27.0**	**0.96**	**13.6**	**10.8**	**20.3**	**4.56**	**3.95**	**13.81**
	SEm +	90.05	85.9	-	-	1.4	1.1	-	0.40	0.31	-
	CD (p=0.05)	268.9	245.3	-	-	4.0	3.2	-	1.20	0.92	-
	CV (%)	14.1	14.15	-	-	17.4	16.8	-	16.15	14.03	-

Irr=Irrigated condition, Rf =Ranifed condition

Bolls/plant : In irrigated condition highest numbers of bolls were recorded by ARBH 2004 (17.1) followed by Sahana (16.7) and the least in GSHV 97/612 (11.2) followed by HBB 101 (12.4). In rainfed condition highest number of bolls were observed in ARBH 2004 (13.6) followed by ARBH 813 (13.4) while GSHV 97/612 (7.6) followed by RCR 102 (8.8) recorded the least number of bolls/plant (Table 1).

Boll weight (g/boll) : Maximum boll weight was recorded by AKH 0205 (5.39 g/boll) followed by GJHV 358 (4.89g/boll) and the least by LRA 5166 (3.96 g/boll) in irrigated condition. In rainfed condition it was RCR 102 which recorded the highest boll weight (4.57g/boll) and GSHV-97/612 recorded the least (3.49 g/boll). Maximum percent reduction was observed in MR 786 (24.371%) followed by AKH 0205 (22.86%) and minimum in RCR 102 (1.15%) (Table 1).

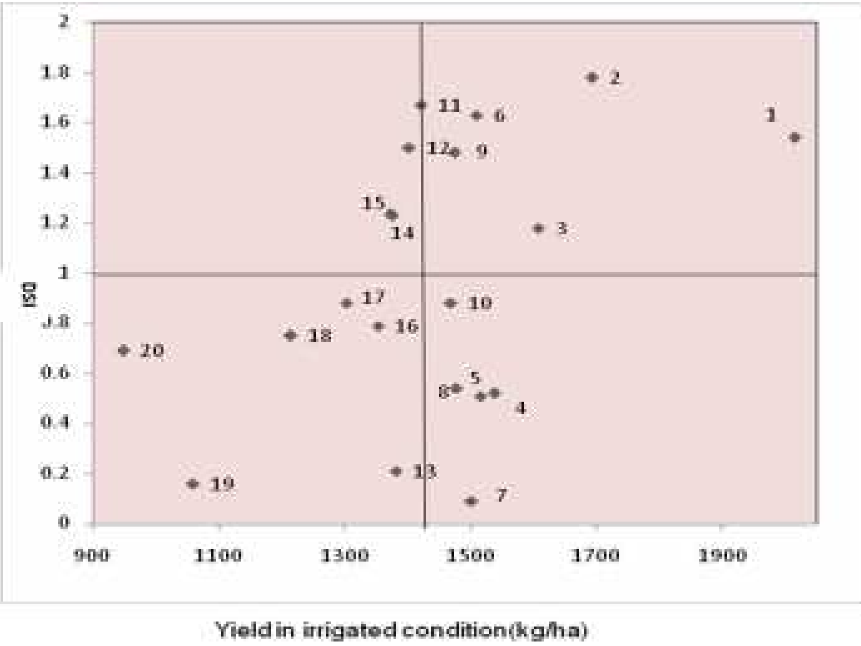
Leaf area index : In general the difference in LAI between irrigated and rainfed condition were less. However, there was significant difference among the genotypes in irrigated condition. The genotype GJHV 358 and BS 279 (4.6) recorded highest LAI followed by HBB101(4.4). While, Sahana (3.5) and F 2228 (3.8) recorded the least LAI in irrigated condition.

In rainfed condition ARBH 2004 and HBB 101 recorded the highest LAI (4.0), while Sahana and RCR 102 recorded the least LAI (3.3). The mean percent reduction in LAI in rainfed condition compared to irrigated condition was maximum in GJHV-358 (26.7%) followed by NH 635 (18.4%). While the least reduction was recorded by CPD 168 (1.4%) followed by H 1353/10 (5.3%) (Table 3).

Total dry matter (g/plant) : The total dry matter at harvest showed significant differences for genotypes in both irrigated and rainfed conditions. The mean TDM in irrigated condition was highest in GBHV 164 (150.4g/plant) followed by GJHV 358 (127.7g/plant) but the lowest recorded by GSHV 97/612 (65.8). In rainfed condition the TDM was highest in ARBH 813 (89.8g/plant) and lowest in AKH 0205 (56.3g/

Table 2. Photosynthetic rate (ì mol/m ²/s) and SPAD readings (chlorophyll content), water potential (- Bars) in irrigated and rainfed condition. (2010-11 to 2011-2012)

Sl. No	Genotypes	Photosynthetic rate (Irr)	Photosynthetic rate (Rf)	Reduction (%)	SPAD readings (Irr)	SPAD readings (Rf)	Reduction (%)	Water potential (- Bars) (Irr)	Water potential (- Bars) (Rf)	Difference
1	BS-279	19.3	15.6	17.0	42.8	40.5	5.3	14.7	18.5	3.8
2	BS-30	15.8	13.9	12.4	40.8	38.9	4.5	15.1	19.4	4.3
3	RCR-102	13.9	12.8	8.4	39.7	36.0	9.2	14.6	21.2	6.6
4	SAHANA(ZC)	16.6	14.7	10.5	39.5	36.4	7.8	15.7	22.5	6.8
5	ARBH-2004	19.0	14.2	26.7	40.2	37.5	6.5	15.7	19.2	3.5
6	MR-786	17.0	13.1	20.0	41.2	38.1	7.5	16.2	20.7	4.5
7	H-1353/10	18.7	15.3	15.0	39.8	37.4	5.9	14.8	22.6	7.8
8	ARBH-813	17.9	14.8	17.5	41.3	37.2	10.0	14.9	20.2	5.3
9	NH-635	17.2	15.6	9.2	40.8	38.7	4.9	14.5	21.9	7.4
10	H-1452/10	16.9	11.9	30.0	41.9	37.1	11.2	14.5	22.4	7.9
11	GISV-218	17.6	12.0	30.1	41.3	35.9	13.1	15.7	22.3	6.6
12	HBB-101	17.8	15.4	12.6	38.8	37.6	3.3	15.9	24.9	9.0
13	CPD-231	14.9	13.9	5.7	40.5	39.8	1.7	15.8	19.2	3.4
14	AKH-0205	17.3	13.8	18.8	39.6	37.4	5.6	16.6	21.6	5.0
15	LRA-5166(NC)	17.2	14.6	12.3	37.4	35.7	4.5	14.7	21.4	6.7
16	F-2228	16.5	14.8	10.3	41.6	39.2	5.9	16.3	21.0	4.7
17	GSHV-971612	17.0	15.0	12.6	44.9	36.5	18.4	16.8	21.6	4.8
18	GBHV-164	17.0	14.9	12.8	39.9	36.0	9.7	15.8	23.5	7.7
19	GJHV-358	18.4	15.1	14.4	41.4	38.5	6.6	16.2	23.1	6.9
20	CPD-168	16.0	15.0	6.7	43.9	40.0	9.0	16.1	22.7	6.6
Mean		**16.6**	**15.0**	**9.9**	**40.9**	**37.9**	**7.0**	**15.5**	**21.5**	**6.0**
SEm +		1.3	1.7	-	1.7	2.3	-	-	-	-
CD @ (p=.05)		3.7	4.7	-	4.9	6.5	-	-	-	-
CV %		12.6	18.0	-	7.3	10.3	-	-	-	-



Sl. No	Genotypes
1	BS-279
2	BS-30
3	RCR-102
4	SAHANA(ZC)
5	ARBH-2004
6	MR-786
7	H-1353/10
8	ARBH-813
9	NH-635
10	H-1452/10
11	GISV-218
12	HBB-101
13	CPD-231
14	AKH-0205
15	LRA-5166(NC)
16	F-2228
17	CPD-168
18	GSHV-971612
19	GBHV-164
20	GJHV-358

Fig.1. Biplot of yield and drought susceptibility index (DSI) in cotton genotypes (mean of 2010-2011 and 2011-2012)

plant). The mean TDM in irrigated condition was 95.2 whereas in rainfed it was 74.2. Thus there was a reduction of only 22.0 per cent. Thus there was a mild stress experienced by the crop under rainfed condition than it would have been.

Among the genotypes H 1353/10 (1.2%) followed LRA 5166 (6.8%) recorded the least reduction in TDM in rainfed condition compared to irrigated. But the per cent reduction was maximum in GBHV 164 (45.4%) and GJHV 358 (44.3%) (Table 3).

Biophysical parameters :

a. Water potential: The mean water potential measured at 120 DAS showed significant differences among the genotypes and moisture regimes (irrigated and rainfed condition) (Table 2). In irrigated condition the mean water potential was -15.5 bars, while in rainfed condition it was -21.5 bars indicating that the cumulative effect of water stress exists which shows a difference of -6.0 bars of difference between irrigated and rainfed conditions (Table 3). In irrigated condition the highest water potential was observed in BS 279 (-14.7) and NH 635 (-14.5) followed H 1452/10 (-14.5). While the least water potential was recorded by CPD 168 (-16.8) followed by AKH 0205(-16.6). In rainfed condition BS 279 (-18.5 bars), followed by ARBH 2004(19.2 bars) recorded high water potential while HBB 101 (-24.9 bars) followed by GSHV 97/612 (-23.5) recorded least water potential. The difference in water potential (the reduction in water potential) in rainfed condition as compared to irrigated was least in CPD 213 (-3.4) following ARBH 2004 (-3.5) and BS 279 (-3.8) while the difference was maximum in HBB 101(-9.0), followed by H 1452/10 (-7.9).

b. Photosynthesis rate: The mean rate of photosynthesis was 16.6 ì mol/m ^{2}/s in irrigated condition while, it was 15.0 in rainfed condition. The highest photosynthesis rate was recorded in BS 279 (19.3) followed ARBH 2004(19.0) while, the least rate was recorded by RCR 102(13.9) and CPD 231(14.8). In rainfed condition the highest photosynthetic rate was recorded by BS 279 (15.6) followed by NH 635 (15.6) while the least rate was recorded by H 1452/10(11.9), GISV 218(12.0) and RCR 102(12.8). The percent reduction in photosynthesis rate in rainfed condition over irrigated condition was least in CPD 231 (5.7) while it was more in GISV

218 (30.1%) and H 1452/10 (30.0%) (Table 2).

c. Total chlorophyll content : The chlorophyll content as measured by SPAD readings at 110 DAS. The mean SPAD readings (chlorophyll content) were decreased from 40.9 in irrigated to 37.9 in rainfed condition. Among the genotypes CPD 168(44.9) followed by GJHV 538 (43.9) recorded the highest SPAD reading while LRA 5166 (37.4) followed by HBB 101(38.8) recorded least chlorophyll content. In rainfed condition BS 279(40.5), GJHV 164(40.0) recorded the highest SPAD values, while least SPAD values was observed in LRA 5166(35.7) and GISV 218 (35.9). The percent reduction in SPAD reading in rainfed as compared to irrigated condition maximum in CDP 168(18.4%) while it least in CPD-231(1.7%) (Table 2).

CONCLUSION

The cotton genotypes BS 279, BS 30 and RCR 102 recorded more cotton yield in irrigated condition but high drought susceptibility indices (more than 1.2). These lines can be used in breeding programmes for moisture stress tolerance as well as for yield stability. Whereas Sahana and ARBH 2004 recorded moderate yield with low DSI (less than 0.51). These are the genotypes suitable for stress condition. The least yield was recorded by GJHV 358 and GBHV 164 and these showed low DSI (<0.8). But AKH 0205 and LRA 5166 recorded low yield as well as high DSI which are undesirable features for drought condition. These conclusions are supported by yield components and physiological characters.

Table 3. Leaf area Index(LAI) and total dry matter accumulation (g/plant) in irrigated and rainfed condition.

Sl. No.	Genotypes	LAI (Irr)	LAI (Rf)	Reduction (%)	Total dry matter accumulation (g/plant) (Irr)	Total dry matter accumulation (g/plant) (Rf)	Reduction (%)
1	BS 279	4.6	3.9	15.2	92.4	67.9	26.1
2	BS 30	4.2	3.5	16.0	96.9	59.9	38.2
3	RCR 102	4.0	3.3	17.4	84.1	72.3	14.1
4	SAHANA(ZC)	3.5	3.2	11.3	97.2	87.5	9.9
5	ARBH 2004	4.3	4.0	6.1	87.5	71.1	17.3
6	MR 786	4.1	3.7	9.0	97.2	84.8	12.8
7	H 1353/10	4.0	3.8	5.3	80.9	79.9	1.2
8	ARBH 813	4.1	3.4	16.8	98.7	89.8	9.0
9	NH 635	4.1	3.4	18.4	88.9	56.6	36.8
10	H 1452/10	4.2	3.9	6.0	124.8	73.7	40.9
11	GISV 218	4.3	3.7	11.6	95.3	79.9	16.4
12	HBB 101	4.4	4.0	9.9	99.4	87.0	12.4
13	CPD 231	4.1	3.6	15.2	73.3	62.5	15.1
14	AKH 0205	3.9	3.5	11.7	69.6	56.3	19.4
15	LRA 5166(NC)	4.0	3.5	11.5	77.7	72.5	6.8
16	F 2228	3.8	3.6	7.1	97.8	83.0	15.4
17	CPD 168	3.9	3.9	1.4	99.1	86.9	11.6
18	GSHV 971612	4.3	3.5	17.5	65.8	58.9	10.8
19	GBHV 164	4.1	3.3	18.0	150.4	82.0	45.4
20	GJHV 358	4.6	3.4	26.7	127.7	71.1	44.3
	Mean	**4.1**	**3.6**	**11.1**	**95.2**	**74.2**	**20.2**

REFERENCES

Selote, D. S. and Chopra, R.K. 2004. Drought-induced spikelet sterility is associated with an inefficient antioxidant defense in rice panicles. *Physiologia Plantarum,* **121** : 462–71.

Pettigrew, W.T., 2004. Physiological consequences of moisture deficit stress in cotton. *Crop Sci.* **44**, 1265– 72.

Ephrath, J.E., Marani, A. and Bravdo, B.A., 1993. Photosynthetic rate, stomatal resistance and leaf water potential in cotton (*Gossypium hirsutum* L.) as affected by soil moisture and irradiance. *Photosynthetica* **29**, 63–71.

Flexas, J., Bota, J., Loreto, F., Cornic, G. and Sharkey, D.T., 2004. Diffusive and metabolic limitations to photosynthesis under drought and salinity in C3 plants. *Plant Biol.* **6**, 269–79

Ennahli, S. and Earl, H.J., 2005. Physiological limitations to photosynthetic carbon assimilation in cotton under water stress. *Crop Sci.* **45**, 2374–82.

Lopez, M., Gutierrez, J.C. and Leidi, E.O., 1995. Selection and characterization of cotton cultivars for dry land production in the south west of Spain. *Eur. J. Agron.* **4**, 119–24.

Mezhar Irfan, Farah Raheel and Asma Hussain, Seema Mahmood, 2006. Characterization of Cotton (*Gossypium hirsutum* L.) Varieties for Growth and Productivity Traits Under Water Deficit Conditions. *Int. J. Agri. Biol.,* **8 (6)** : 796–800.

Variations in soil properties and nutrient status as influenced by organic *vis-a-vis* conventional method of cotton cultivation and climatic factors in black cotton soils of Krishna zone

A.LALITA KUMARI* AND K.VEERAIAH
Acharya N. G. Ranga Agricultural University, Regional Agricultural Research Station, Guntur - 522 034
**E mail : lalithakumari.atmakuri@gmail.com*

Abstract : Cotton is one of the important commercial crops grown in Krishna zone under intensive cultivation. The soil nutrient status is one of the key factors for higher yields. Hence a study was taken up to study the variation due to the effect of organic and conventional method of cultivation on soil properties and nutrient status at monthly intervals in black cotton soils of Regional Agricultural Research Station, Lam during *kharif,* 2011-2012. The initial soil sample analysis indicated that the application of fertilizers in conventional method showed reduction in soil pH whereas under organic cultivation, the soil pH values were high. In case of soil EC, the reverse was true. Organic plots showed higher organic carbon than inorganic plots. The available potassium content was high in the inorganic plots compared to organic plots. The trend was same at 0-15 and 15-30 cm depths.When the initial soil samples were compared with the post harvest soils of previous crop, they indicated that there was an increase in the soil pH from March to July during summer in both organic and inorganic plots. There was a decrease in soil EC from March to July in both the treatments which may be due to heavy rainfall received by the end of July month.. There was a decline in the soil organic carbon during summer in both the treatments. In case of soil available K_2O, there was a decline in the organic plots and there was an increase in fertilizer plots during summer. In case of available N there was an increase in both the treatments. At different stages, soil available N, K_2O and EC values were high in conventional plots where as OC content and soil pH values were higher in organic method. At 90 DAS, there was a further decline in OC content, available N, K_2O and EC values while only pH values recorded increase. When the seasonal variations in soil properties were studied and related to climatic conditions, there was an initial increase in soil pH up to July and decreased in September followed by a continuous increase up to 120 DAS. Heavy rain fall during July and September could reduce the soil pH and EC. Sol nutrient contents like OC, available N, P_2O_5 and K_2O also showed a continuous decline with progress of the season. The study indicated that though the soils under organic farming are rich in organic carbon and Available P contents, the low soil available N in this method was resulting in lower yields

Key words : Conventional method, potassium, organic, inorganic, variation

Cotton is an important commercial crop grown in vertisols of Krishna zone both under irrigation and rainfed conditions. Balanced fertilization plays a major role in improving the water and nutrient use efficiency, yield and quality of the crops. Use of indiscriminate and imbalanced heavy inorganic fertilizers led to soil health problems like salinity, deterioration of soil structure, micro nutrient deficiencies, etc.. It also caused the problem of environmental pollution and loss of applied fertilizers through leaching, volatilization and de nitrification of N and fixation of P. To overcome these problems and to improve the soil health and biological activity in soil, organic cultivation is being popularized in recent days. However the soil nutrient dynamics under organic method *vis-a-vis* conventional method as affected by seasonal climatic variations were studied little even though the very purpose and focus of organic cultivation is improving soil health and sustainability of crop production rather than getting higher yields.

MATERIALS AND METHODS

In majority of the organic farms, the yields were low due to various soil, climatic and management factors. Maintenance of optimum nutrient status in soil is one of the key factors for achieving higher yields under the organic method of cultivation. Supplementation of N and P through organics may be insufficient to meet the crop needs. Further organic cultivated plots are becoming more vulnerable to weather vagaries or any pest out break. With this objective, an experiment was conducted in black cotton soils of Regional Agricultural Research Station, Guntur during *kharif,* 2011-2012.to study the effect of organic farming practices and seasonal climatic conditions on soil properties. The soils of the experimental sight are slightly alkaline with a pH of 8.21, non saline with an EC of 0.26dSm^{-1}. Soils were low in OC (0.43%) and available N (178 kg/ha) contents, medium in available P_2O_5 (45.6 kg/ha) and high in available K_2O (856 kg/ha). The experiment was taken up with two treatments *viz.*, conventional method and organic method of cultivation with cotton crop variety LCA 770 with a s pacing of 105 x 60 cm in non replicated bulk plots. Ten samples were collected in each plot to record the data on different parameters. Under the conventional method, recommended package of practices like recommended dose of fertilizers (120.60.50) and recommended pest management practices were followed. Under organic cultivation method; the following organic practices were followed. i) Basal dose at the time of sowing — FYM 4 tons /ac + *neem* cake @ 200kg/ac + vermin compost 200 @ kg/ac ii) Top dressing Two times at 4 and 8 WAS — *neem* cake 200kg/ ac (well composted, commercial grade) and iii)Foliar nutrition with bio nutritional sprays. Data was recorded on soil nutrient status at basal, 30, 60, 90, 120 DAT and at harvesting. Pest management was taken up with neem cake extract and *neem* oil (local preparations) and Azardictin 1000 ppm (commercial grade)

RESULTS AND DISCUSSION

The initial soil sample analysis before initiation of the experiment indicated that in conventional method of cultivation a little lower values of soil pH ((8.02 to 8.16) whereas under organic cultivation, the soil pH values were slightly higher (8.12 to 8.22).. In case of soil EC, the fertilized plots showed higher EC values (0.468 to 0.470 dS/m) than the organic plots (0.380 to 0.410 dS/m). Organic plots showed higher organic carbon(0.599 to 0.688 %) and available P_2O_5 contents (45.6 to 48.5 kg/ha)) than inorganic plots(0.435 to 0.482 % and 39.2 to 43.8 kg/ha, respectively). The available N and K_2O contenst were higher in the inorganic plots compared to organic plots. This trend was same at 0-15 and 15-30 cm depths

When the initial soil samples were compared with the post harvest soils of previous crop, they indicated that there was an increase in the soil pH from March to July during summer in both organic and inorganic plots. However the pH values were lower in inorganic plots compared to organic plots at both sampling times. There was a decrease in soil EC from March to July in both the treatments which may be due to heavy rainfall received by the end of July month. There was a decline in the soil organic carbon during summer in both the treatments. In case of soil available K_2O, there was a decline in the organic plots and there was an increase in fertilizer plots during summer. In case of available N there was

Table 1. Variations in soil properties of organic farming research in cotton at monthly intervals

	Treatment	March 2011		July 2011 (Initial)		September,2011 (30 DAS)	
		0-15cm	15-30cm	0-15cm	15-30cm	0-15cm	15-30cm
pH	Organic	8.123	8.223	8.32	8.40	8.02	8.13
	fertilizer	8.022	8.163	8.18	8.32	8.02	8.04
EC(dS/m)	Organic	0.470	0.468	0.308	0.306	0.308	0.288
	fertilizer	0.535	0.493	0.410	0.380	0.332	0.312
OC(%)	Organic	0.688	0.599	0.623	0.513	0.644	0.356
	fertilizer	0.482	0.435	0.435	0.418	0.495	0.378
Available N	Organic	168.5	162.0	235.5	214.0	209.2	167.4
(kg/ha)	fertilizer	188.2	188.7	253.0	231.5	249.8	228.8
Available	Organic	48.5	45.6	54.5	49.8	56.5	52.0
P_2O_5 (kg/ha)	fertilizer	43.8	39.2	40.3	45.5	49.8	45.4
Available	Organic	953.7	783.7	840	804	649	728
K_2O (kg/ha)	fertilizer	898	652	951	777	876	786

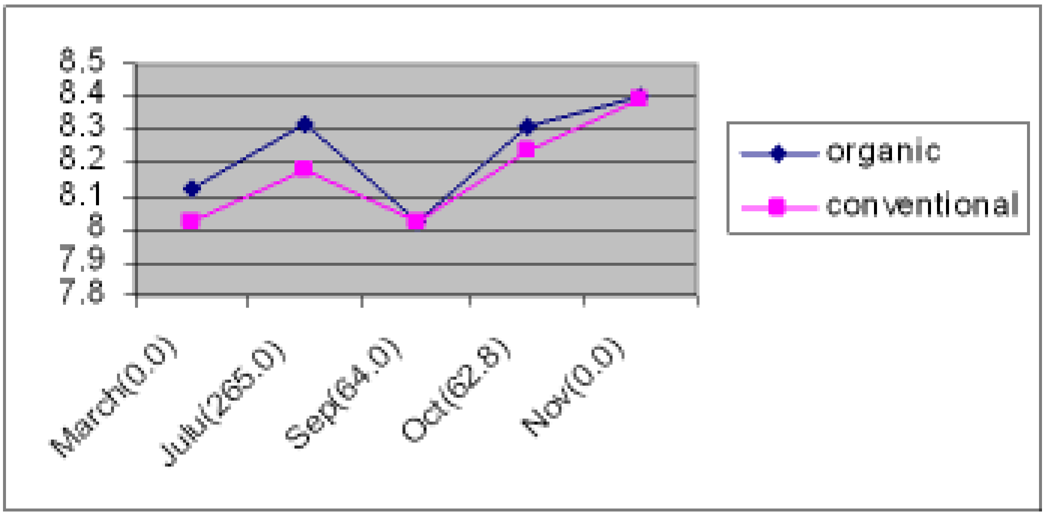


Fig.1. Relationship b/w rainfall and soil pH and variations in soil pH at monthly intervals (upto 90 DAS)

an increase in both the treatments.

At 30 DAS, there was a decline in soil pH which ranged from 8.02 to 8.13 and EC which ranged from 0.288 to0.322 dS/m. The soil organic carbon increased in the 0-15cm depth (0.644 % and 0.495 % in organic and conventional plots respectively) and decrease in 15-30 cm depth (0.available 56% and 0.378% in organic and conventional plots respectively). There was an increase in available P_2O_5 content which ranged from 45.4 to 56.5 kg/ha in both the treatments. This increase may be attributed to solubilisation effect of organics applied organics. However there was a decline in available N (167.4 to 249.8 kg/ha) and available K_2O(649 to 876 kg /ha) contents.

At 60 DAS, soil pH(8.24 to 8.38) and available P_2O_5(49.4 to 58.3 kg/ha)) values showed increase while other properties like soil EC (0.275 to 0.325), %OC (0.425 to 0.565%), available N (162.5 to 196.8 kg/ha), and available K_2O(649 to 876 kg /ha) contents showed decline. The same trend of increasing soil pH and decrease in soil EC, per cent OC, available N, P_2O_5 and K_2O contents was continued at 90 and 120 DAS also.

When the seasonal variations in soil properties were related to climatic conditions, there was an initial increase in soil pH up to July

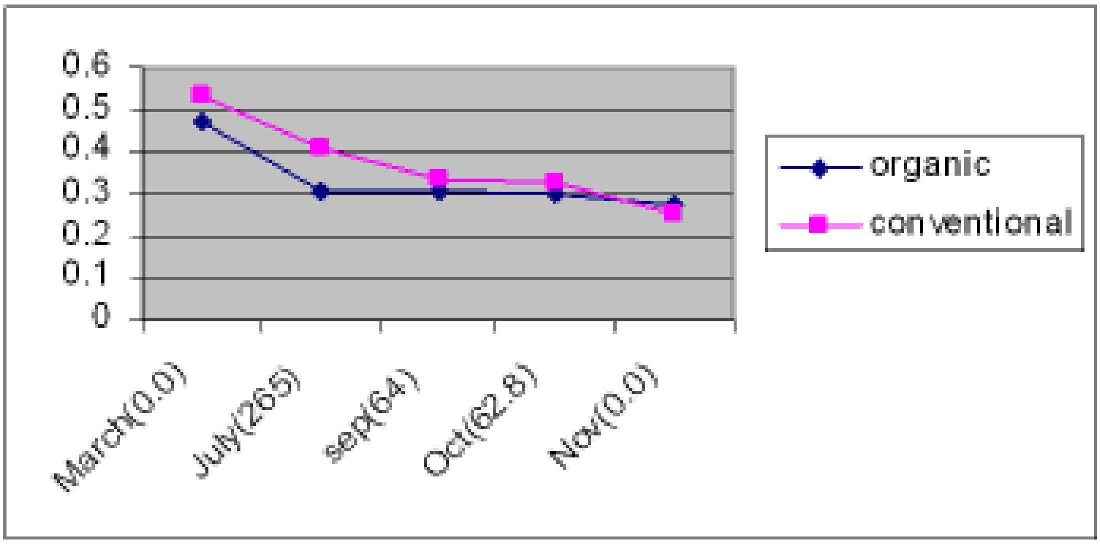


Fig.2. Relationship b/w rainfall and soil EC and variations in soil EC at monthly intervals (upto 90 DAS)

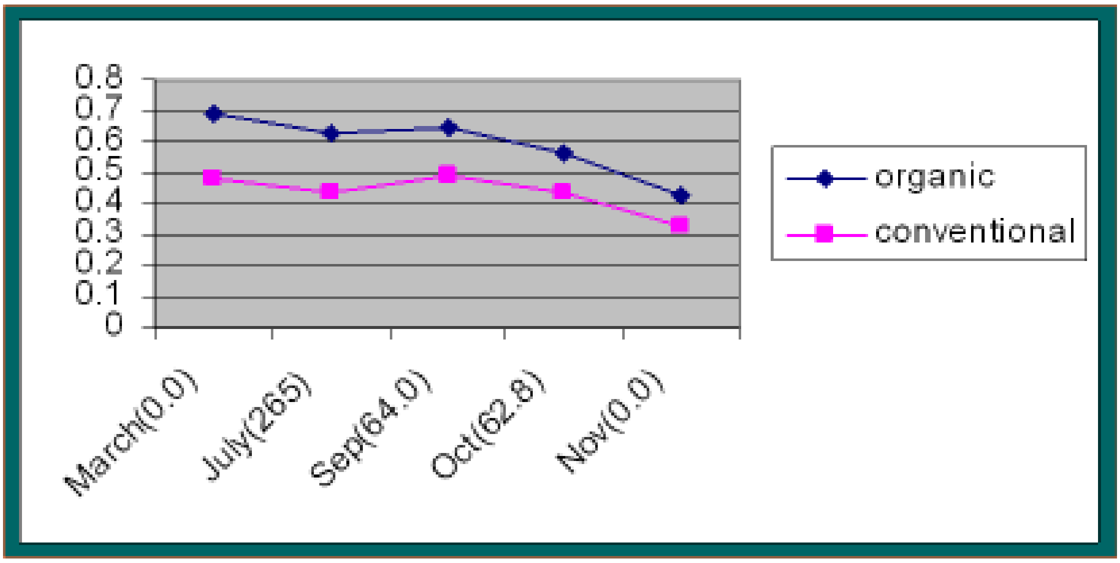


Fig.3. Relationship b/w rainfall and OC in soil and variations in soil OC at monthly intervals (upto 90 DAS)

and decreased in September followed by a continuous increase up to 120 DAS. Heavy rain fall during July and September could reduce the soil pH and EC. Sol nutrient contents like OC, available N, P_2O_5 and K_2O also showed an increase in the initial crop growth period followed by a continuous decline with progress of the season. The non stop rains and continuous water logging in the months of July and August might have showed deleterious effect on soil nutrient status due to heavy leaching losses. The continued dry spell after the cessation of rains also showed adverse effect on soil status. However the organic plots could maintain better organic carbon and available P_2O_5 contents than conventional plots during the different stages of crop growth. This indicates even under the conditions of weather vagaries there is the possibility of retaining more nutrients in organic plots than fertilized plots.

It is reported by many workers that organic carbon and available P status of soils improve under organic method of cultivation. Improvement in overall soil quality with application of organics was also well documented.

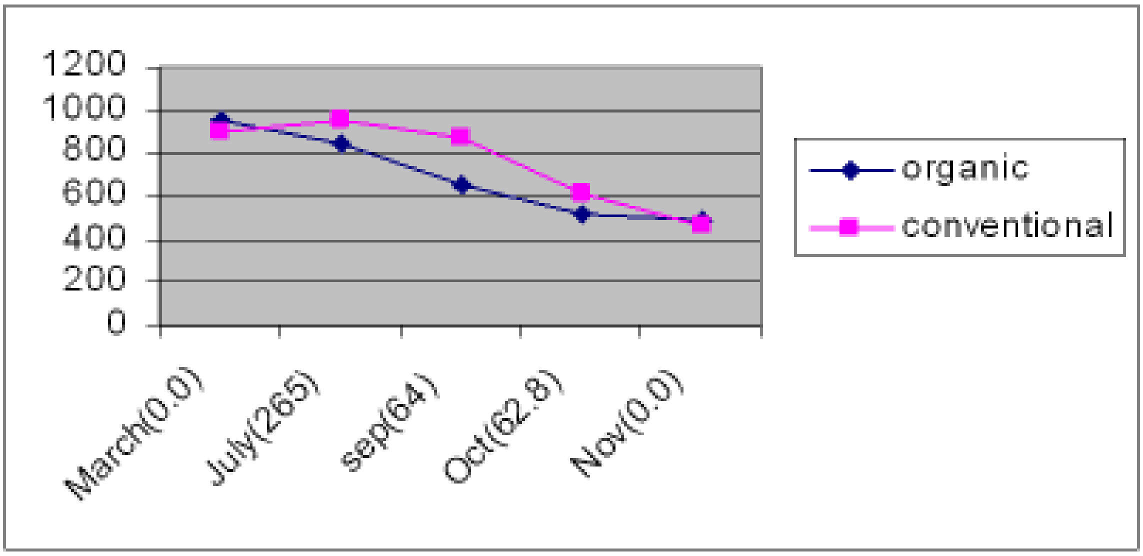


Fig. 4. Relationship b/w rainfall and available K_2O in soil and variations in soil OC at monthly intervals (upto 90 DAS)

A comparison between mean values of soils under organic plots and their controls showed an overall improvement in soil quality with increase in organic carbon content, available P, NO_3, NH_4, CEC and pH (Alexandra Solomou, *et.al.,* 2010). Milosevec and Milosevec, 2009 reported an increase in humus content, a partial increase in total N content and primarily a rise in available P and K values in soil when combined use of organic and inorganic fertilizers was done in apple orchards. Gajera, *et.al.,* 2010 reported an increase in OC content in the 1st year and available N and P_2O_5 contents in 1st and 2nd year of experimentation by applying FYM @ 15t/ha to palmarosa. Significant increase in Fe content was also observed in this treatment during the 2nd year. Sangeetha and Balakrishnan ,2011 reported increase in yield attributed, yield and soil available nutrients in blackgram by applying enriched poultry manure compost and poultry manure compost on N equilant basis to preceding paddy crop. In our study also the benefits of addition of organics was exhibited to some extent. But the seasonal climatic conditions played major role on soil nutrient status at vital growth stages of the crop. Thus, the present study envisaged the continuous monitoring of soil nutrient status during the crop season so that nutritional requirement of the crop in the middle of the crop season can be better understood. Especially, when some seasonal vagaries like excess rainfall and prolonged water logging or continuous dry spell in the peak growing stages of the crop occur, there is every need to monitor the soil status and do the needful.

Table 2. Variations in soil properties of organic farming research in cotton at monthly intervals (60- 120 DAS)

	Treatment	October,2011 (60 DAS)		November,2011 (90 DAS)		December,2011 (120 DAS)	
		0-15cm	15-0cm	0-15cm	15-30cm	0-15cm	15-30cm
pH	Organic	8.31	8.35	8.395	8.495	8.35	8.42
	fertilizer	8.24	8.29	8.387	8.473	8.47	8.51
EC(dS/m)	Organic	0.301	0.275	0.275	0.263	0.253	0.242
	fertilizer	0.325	0.317	0.255	0.262	0.260	0.254
OC(%)	Organic	0.565	0.527	0.425	0.431	0.425	.398
	fertilizer	0.438	0.425	0.328	0.315	0.325	0.310
Available N	Organic	185.0	162.5	151.7	146.5	145	135.6
(kg/ha)	fertilizer	215.0	196.8	192.5	204.0	163	151.3
Available	Organic	58.3	54.2	64.11	59.7	56.5	52.3
P_2O_5 (kg/ha)	fertilizer	50.9	49.4	52.1	51.96	47.4	42.5
Available	Organic	525	508	496.5	443.5	510	485
K_2O (kg/ha)	fertilizer	620	605	468.3	345.3	565	523

REFERENCES

Alexandra Solomou, Athana ssios Sfougaris and Evangelia Vavoulidou. 2010. "The effect of organic and conventional farming systems on selected soil properties of olive grown in Central Greece" 19th World Congress of Soil Science *"Soil Solutions for a changing world"* 1-6th August,2010, Brisbane, Australia

Gareja, A.R., Bafna, A.M., Patil, R.G. and Patil, Z.N. 2010. Soil health as influenced by integrated nutrient management in palmarosa (*Cymbopogon martinii) Green farming* **1 (6)** 568 - 71

Milosevec, T. and Milosevec, N. 2009. The effect of Geolite, organic and inorganic fertilizers soil chemical properties, growth and biomass yield of apple trees. *Plant Soil Environment.* **55 (12)** 528-35

Sangeetha, S. P. and Balakrishnan, A. 2011. Residual effect of organic manures on yield attributes and yield of succeeding blackgram and available nutrients . *Green farming* **2(3)** : 319-21.

Proceedings on "Global Cotton Production Technologies *vis-a-vis* Climate Change" 177-186

Improving the profitability of rainfed *Bt* hybrid cotton based intercropping systems with changing climate

AMBATI RAVINDER RAJU*, SONIYA K. THAKARE AND G. MAJUMDAR
Central Institute for Cotton Research, Nagpur - 440 010
**E-mail : bumaraju@gmail.com*

Abstract : A field experiment was conducted at Central Institute for Cotton Research, Nagpur for four years during 2008-2012 with five *Bt* hybrid cotton based intercropping systems in Vertisols. Two rows of intercrops were accomodated at 45 cm a part by skipping one row of cotton (paired row). Sole *Bt* hybrid cotton (90 x 45 cm) with 2.5 plants/ m^2 was significantly superior only in a year of 30 per cent less than normal in assured rainfall zone over paired row *Bt* hybrid cotton (90 x 135 x 45 cm) with 1.65 plants/ m^2, which was profitable only in ¼ years with change in normal rainfall with lowest yields when 30 per cent excess rains were received in few rainy days. *Bt* hybrid cotton + pigeonpea check row stripcropping (8:2) significantly reduced seed cotton yields followed by intercropped castor, however, they were very efficient in utilizing stored soil moisture below 20-40 cm soil depth when rainfall was received from post September rains. Intercropping with soybean, field bean and marigold did not reduce seed cotton yields in excess rains. The most profitable intercropping systems were *Bt* hybrid cotton with 'African tall' marigold, Fieldbean, followed by soybean variety JS. 93-05 with 11.3, 8.7 and 3.5 thousand/ha respectively over sole *Bt* hybrid cotton in assured rainfall areas. Herbicides Pendimethalin 1.0 kg a.i./ha PPI in 2008 and 2010 years; Oxyflurofen 0.10 kg a.i./ha pre emergence (except fieldbean) in 2009, Pyrthiobac Na 0.070 0 kg a.i./ha early post em. over the top and applications in 2011 were followed as herbicides rotation. *Tridax procumbence, Cyperus rotendus* were found to be tolerant to Pyrithiobac Na herbicide. A multi purpose tool bar was developed which can plant, place fertilizer and conserves soil moisture along with interculture operations for weed control.

Key words : Intercropping, post emergence, pre ergence, proptability

The cotton industry employs an estimated 47 million people in India (Osakawe, 2009). Changing climate is influencing the onset, withdrawal and distribution of monsoon rain challenging their livelihoods. Legumes have been intercropped for improving soil fertility and control of pests in China, Latin America and African countries in diversified farming systems (Zhang, 2007). Intercropping is a well established practice covering over 12 m ha in South Asia. Strip cropping of hybrid cotton with pigeonpea is a farmer's practice in central and south India for protein food supplement (Clouston, 1870) and as insurance against abiotic stress imposed crop losses. Risk and uncertainty imposed by climate change could be managed by adoption of location-specific intercropping systems (Error! Hyperlink reference not valid**.** *et al.,* 2010) due to better interception and infiltration of rainfall and later tapping it from different depth of root zone (Gokhale *et al.,* 2011). The choice of compatible crops for an intercropping system can vary depending on crop canopy, rooting pattern, soil depth, and market demand (Brintha and Seran 2009). Intercropping advantage is due to difference in use of resources by the component crops. The technique of paired row planting in intercropping system is one way of accommodating the whole population of the base crop and creating interspaces wide enough to accommodate one or two rows of intercrop (Sivaraman and Palaniappan, 1996). Yield losses to the extent of 50 per cent and double the cost of cultivation with a crash in market prices to ₹ 38/kg seed cotton resulted in a net financial loss forcing the government of Maharashtra to declare ₹ 4000/ha compensation package to cotton growers in *Bt* hybrid cotton in Vidarbha due to change in rainfall pattern (VJAS 2011). Fertilizer application in proportion to the plant population for better expression of land equivalent ratio (LER) is advocated due to higher nutrient demand in intercropping systems (Giri *et al.,* 2006). Marigold (*Tagetes erecta* L.) is a multipurpose commercial crop grown profitably with a potential refugea for *Bt* hybrid cotton. Vittal *et al.,* (2004) recommended intercropping with cotton + pigeonpea / soybean and maize depending upon the rainfall and type of soil for improving the crop diversification, food security and profitability. Wide spread adoption of commercial soybean and *Bt* hybrid cotton improved their productivity and profitability, but it could not be sustained in recent years due to pest infestation on soybean and reduced crop duration of *Bt* hybrid cotton under changing climate(CAB, 2010). Recommendations for intercropping were made by SAUs' like suitable varieties for intercropping like castor and for stripcropping wilt resistant pigeonpea, alongwith tolerant herbicides pendimethalin and fluchloralin for weed control (Anonymous, 2010 a, c). A field experiment was planned to study the performance of *Bt* hybrid cotton under paired row planting alongwith marigold/ soybean / hybrid maize/ castor / fieldbean + fennel with tolerant herbicides which could improve the profitability by reducing the risk through crop diversification in space and time.

MATERIALS AND METHODS

A field experiment in Vertisols was conducted with eight treatments in RBD design with four replications at Central Institute for Cotton Research, Farm, Nagpur (21°09'N 79° 09'E, altitude 331 MSL) during 2008, 2009 and 2010 monsoon seasons. The treatment details were: sole *Bt* hybrid cotton(90x45), paired row (PR) *Bt* hybrid cotton (PR 90/135x45), PR *Bt* hybrid cotton + soybean(45 x 10), *Bt* hybrid cotton + pigeonpea(90 x 90), PR *Bt* hybrid cotton + marigold (45 x 22.5), PR *Bt* hybrid cotton + maize(45 x 22.5), PR *Bt* hybrid cotton + field bean shrub(45 x 10) and fennel(45 x 10), PR *Bt* hybrid cotton + castor (45 x 22.5). The details of varieties, herbicides used and fertilizers applied are given in Table 2. The experiment was planted when a cumulative rainfall of 150 mm was received *i.e.* 24th June in Vertisol in all the years on the same site with same randomization. Fertilizer was applied in proportion to the intercrop population (Table 2). Need based plant protection measures, with 3-4 intercultural operations and two hand weedings were given to remove herbicide tolerant weeds. In the year 2008, a blanket application of Pendimethalin 1.0 kg/ha a.i. was applied as pre plant incorporation, whereas in 2009 the herbicide was rotated with Oxyflurofen 0.1 kg / ha a.i. as pre emergence spray in 500 L/ha except for sensitive crop like field bean + fennel was applied with only Pendimethalin 1.0 kg/ ha a. i. as PPI. In order to use the existing hoes, only two rows of intercrops were accommodated in between two paired rows(90 x 135). The weed incidence was measured at 3rd interculture and hand weeding in both years and the data was converted into v (x+0.5) before subjecting it to statistical analysis. Economic yield, both fresh and dry weights, biomass, nutrient uptake were estimated and analyzed with ANOVA technique. The marigold flowers were harvested a day before the major festivals and remaining left for seed production after mid-November.

RESULTS AND DISCUSSION

Performance of sole v/s paired row of *Bt* hybrid cotton : Significant difference in mean seed cotton yields @ 1.2 t /ha under higher plant stand of 24, 691 pl /ha than recommended plant stand 18, 555pl/ha as compared to only 0.8 t/ha under lower than recommended plant stand of 16, 296 pl/ha with paired row planting under extreme rainfall situations due to compact nature of hybrid cotton converted to *Bt* was sensitive, and less adjustable to extreme environmental conditions confirms to the observations made by Hebbar *et al.,* 2007 (Table 1, 3). The benefit of higher plant density was conspicuous in a year of relatively deficit rainfall which was absent in years of higher rainfall as cotton was known to be extremely sensitive for higher soil moisture compare to droughts due to its extensive root system. These results were in agreement with vjas (2011) observation of yield losses to the extent of 50 per cent due to abnormal rains. This was possible due to significantly higher production of biomass, recovery of applied fertilizer nutrients, N , P uptake (Table 4, 5) resulting in higher boll number and seed cotton yield in a year of deficit rainfall compared to huge losses in excess rain years. N fertilizer use efficiency (Table 6) and returns from sole cotton

Table 1. Weather parameters during experimentation period 2008- 2010

	Rainfall (mm)						Rainy days					
	June	July	Aug	Sept	Oct	Total	June	July	Aug	Sept	Oct	Total
2008	186	218	132	117	10	663	14	19	9	10		52
2009	104	329	241	83	229	986	6	23	12	10		51
2010	124	406	260	207	0	997	5	18	14	8	0	45.0
Mean	**138**	**318**	**211**	**136**	**80**	**882**	**8**	**20**	**12**	**9**	**34**	**83.7**
Normal	292	302	227	137	97	1055	9.9	17.3	12.2	10.4	49.8	99.6

Table 2. Varieties, herbicides used and fertilizers applied in *Bt* hybrid cotton based intercropping system

Treatments	Method of application, herbicide and dose (kg a.i. /ha)	Fertilizers applied (kg / ha) N	P_2O_5	K_2O
Sole *Bt* hybrid cotton NCS145 Bunny	Three intercultures and 2 hand weedings	90	45	45
PR *Bt* hybrid cotton NCS145 Bunny	PPI Pendimethalin 1.0 —do——-	90	45	45
PR *Bt* hybrid cotton + soybeanJS-93-05	Pre emergence Oxyflurofen 0.1 —do——-	75	30	0
PR *Bt* hybrid cotton + pigeonpeaBSMR 763	Pre emergence Oxyflurofen 0.1 —do——-	50	20	0
PR *Bt* hybrid cotton + marigoldAfrican tall	Pre emergence Oxyflurofen 0.1 —do——-	200	200	200
PR *Bt* hybrid cotton + maizeKomal	Pre emergence Oxyflurofen 0.1 —do——-	120	60	50
PR *Bt* hybrid cotton + field bean Pushpak + fennelLocal	PPI Pendimethalin 1.0 —do——-	75	63	30
PR *Bt* hybrid cotton + castor AKC-1	Pre emergence Oxyflurofen 0.1 —do——-	60	40	0

with higher plant density (Table 7) were 43 per cent significantly higher than paired row. Therefore, a lower density of 16, 296 pl/ ha is not economical for *Bt* hybrid cotton which is neither bushy nor can compensate in adverse climatic conditions. There was no agronomic advantage of higher density or paired row cultivation due to compact, determinate nature of *Bt* hybrid cotton, unless it is grown with a profitable inter/ relay crop. *Bt* hybrid cotton with cry 1 AC gene, retains higher number of early formed bolls, due to competition for nutrients to the developing bolls, the vegetative growth is restricted and becomes more compact and determinate (Hebbar *et al.,* 2007). The concept of paired row planting of cotton was evolved for bushy hybrid cottons for improving the efficiency of natural resources and plant protection measures by the public sector was not fit for converted *Bt* hybrid cottons as confirmed by private companies despite of best extension efforts (Mandava and Alapati, 2007).

Fertilizer recovery, nutrient requirement and input use efficiency : Long duration intercrops pigeon pea and castor reduced significantly the biomass of cotton and reduced N fertilizer recovery due to longer duration and deeper root system (Table 5). Lowest biomass was recorded in year of highest post September rainfall with lowest *Bt* hybrid cotton yields in 2010. PR *Bt* hybrid cotton intercropped with marigold significantly improved the N and P uptake compared to PR cotton alone. PR *Bt* hybrid cotton + maize produced better biomass and N, K fertilizer recovery statistically similar to that of sole *Bt* hybrid cotton (Table 5). PR *Bt*

Table 3. Mean yield of *Bt* hybrid cotton (3 years pooled) and intercrops with seasons interaction IC1, intercrops; IC2, companion crop

Treatments	Mean intercrop yield (t/ ha)		Seed cotton yield (t/ha)				Cotton equivalent yield (t/ha)			
	IC1	IC2	2008	2009	2010	**Mean**	2008	2009	2010	**Mean**
Sole Bt hybrid cotton			2.3	0.7	0.6	**1.2**	2.3	0.7	0.6	**1.2**
PR *Bt* hybrid cotton			1.2	0.8	0.6	**0.8**	1.2	0.8	0.6	**0.8**
PR *Bt* hybrid cotton + soybean	0.4		1.8	0.9	0.6	**1.1**	2	1.1	0.9	**1.3**
PR *Bt* hybrid cotton + pigeon pea	0.4		1	0.9	0.6	**0.8**	1.2	1.3	1.5	**1.3**
PR *Bt* hybrid cotton + marigold	1.2		2.1	0.6	0.6	**1.1**	2.8	1	1.8	**1.8**
PR *Bt* hybrid cotton + maize	4.6		1.9	1	0.5	**1.1**	1.9	1.2	1.1	**1.4**
PR *Bt* hybrid cotton + fieldbean and fennel	1.5	0.04	1.8	0.8	0.6	**1.1**	2	1.2	1.8	**1.7**
PR *Bt* hybrid cotton + castor	0.4		1.1	0.8	0.5	**0.8**	1.2	1	2.3	**1.5**
SEm+			0.8	0.4	0.3	**0.1**	0.9	0.5	0.7	**0.1**
CD (p=0.05)			1.6	0.8	0.6	0.2	1.8	1	1.3	0.3
Interaction SEm+						0.3				0.3
CD (p=0.05)						0.7				0.8

hybrid cotton + soybean in 2008 produced significantly higher P uptake and recovery of applied fertilizer to that of sole *Bt* hybrid cotton even in low rainfall year due to finer root system and higher CEC of soybean. PR *Bt* hybrid cotton intercropped with marigold and field bean improved significantly the N and K nutrient recovery in cotton and higher N fertilizer use efficiency over PR cotton alone. N, P, K recovery was highest with PR *Bt* hybrid cotton + maize followed by PR *Bt* cotton + field bean +fennel compared to marigold. These results were similar to those observed by Giri *et al.,* 2006. It can be concluded that *Bt* hybrid cotton based intercropping systems are more efficient in utilization of applied mineral fertilizer, and requires higher nutrients, therefore needs fertilizer application proportionate to the population of the crop mixture or under PR *Bt* hybrid cotton intercropping the present fertilizer recommendation of 90:45:45 N, P_2O_5, K_2O was sufficient unless high nutrient demand intercrops like maize and marigold were to be planted.

Adoption of *Bt* hybrid cotton based intercropping systems : PR *Bt* hybrid cotton intercropped with tall and longer duration castor or strip cropped with pigeon pea extracted 92 mm soil moisture more than sole cotton reduced the seed cotton yield (Table 4) significantly in low rainfall year(Table 1). These intercrops compensated the loss and returned net profits in 2009 by pigeon pea and 2010 by castor due to their deep root system which exploited the stored soil moisture from post monsoon rain. *Bt* hybrid cotton + marigold was able to give significantly higher yield levels in 2008 than the paired row

Table 4. Mean biomass and nutrient uptake of *Bt* hybrid cotton and intercrops

Treatments	Biomass (t/ ha)			Nutrient uptake (kg /ha) cotton			Intercrop		
	Cotton	Intercrop	**Total**	N	P	K	N	P	K
Sole *Bt* hybrid cotton	2.7		**2.7**	66	17	21			
PR *Bt* hybrid cotton	1.7		**1.7**	46	11	38			
PR *Bt* hybrid cotton + soybean	2.3	3.7	**6.0**	58	17	24	91	23	61
PR *Bt* hybrid cotton + pigeon pea	1.9	0.7	**2.6**	45	11	33	15	5	10
PR *Bt* hybrid cotton + marigold	2.3	1.9	**4.2**	53	14	25	38	16	28
PR *Bt* hybrid cotton + maize	2.5	5.9	**8.4**	61	14	33	114	45	100
PR *Bt* hybrid cotton + fieldbean and fennel	2.1	2.4	**4.5**	51	13	37	46	17	35
PR *Bt* hybrid cotton + castor	1.8	1.3	**3.2**	44	13	28	34	13	21
SEm+	0.2	0.5	**0.4**	3	1	6	9	5	10
CD (p=0.05)	0.3	0.9	**0.8**	7	3	NS	19	10	20
2008	2.4	2.6	**4.3**	57	17	31	57	13	37
2009	2.1	2.7	**4.1**	50	14	32	59	30	55
2010	2.0	2.7	**4.0**	52	12	26	53	17	36
SEm+	0.2			3.3	1.0	2.0	4	3.0	4.0
CD (p=0.05)	0.3			NS	2	4	NS	6	8
Interaction SE m+		0.2	0.2	17	6	10	17	12	18
CD (p=0.05)	0.7	1	1.1	NS	12	20	NS	25	37

seed cotton yield. The year 2009 and 2010 seed cotton yields remained low and unaffected by any intercrop due to reduced growth and biomass accumulation (Table 4). *Bt* hybrid cotton intercropped with field bean + fennel /marigold significantly produced higher cotton equivalent yields over paired row *Bt* hybrid cotton and both were able to show their performance in 2008 and 2010 probably due to failure to have price or yield advantage in 2009 in relatively level fields (Table 3, 7). PR *Bt* hybrid cotton intercropped with field bean+ fennel produced 1.5 t/ha of green pods and 40 kg/ha fennel. Intercropped marigold also produced 1.2 t /ha of fresh flowers which fetches a ₹ 20 / kg whole sale prices during festival time in Indian towns. Both the treatments produced

Table 5. Mean fertilizers recovery (%) by *Bt* hybrid cotton and intercrops

Treatments	Cotton fertilizer recovery			Intercrop fertilizer recovery		
	N	P	K	N	P	K
Sole *Bt* hybrid cotton	73	39	84			
PR *Bt* hybrid cotton	51	25	53			
PR *Bt* hybrid cotton + soybean	64	37	73	121	77	
PR *Bt* hybrid cotton + pigeon pea	50	25	55	30	24	
PR *Bt* hybrid cotton + marigold	59	32	73	20	7	14
PR *Bt* hybrid cotton + maize	68	32	81	94	90	167
PR *Bt* hybrid cotton + field bean and fennel	57	29	63	60	29	119
PR *Bt* hybrid cotton + castor	48	29	62	56	34	
SEm+	4	4	4	8	10	23
CD (p=0.05)	8	8	9	18	21	50
2008	64	37	70	64	64	37
2009	55	30	73	66	55	30
2010	57	26	61	61	57	26
SEm+	4	2	4	19	6	14
CD (p=0.05)	9	5	9	NS	12	31
Interaction SEm+	19	8	9	19	23	46
CD (p=0.05)	NS	25	45	40	50	NS

statistically similar returns and C: B ratios but higher marigold cost of cultivation brought lesser returns from investments as C:B ratio compared to field bean which had in-built risk of catching late rains during flowering being a determinate crop. Clear change in climate was observed in these years with 63 per cent deficit rainfall in June month followed by excess rains in 3 months 50 per cent, 33 per cent in 2009 and 2010, which was clearly reflected in significant decline of not only experimental results but also national average of seed cotton yields, which soared the prices by 50% every year without proper net returns to cotton producers (Anonymous, 2010 b). The price advantage in 2009 and 2010 did not bring changes in C:B ratio and therefore, intercropping did not cover the risk (Table 7).

Weed management cost and control efficiency : Although marigold, soybean, castor showed numerically more weeds in 2008 and only marigold in 2009 but were found to be non significantly influenced by the cropping systems and herbicides rotation. The weed management cost in marigold was significantly highest by 54 per cent in intercropped rows and 42 per cent in cotton rows compared to cotton + pigeon pea strip cropping system (Table 8). This was probably due to weaker stems and shade offered by marigold which resulted in inefficient weed control by hoeing.

Fibre quality of *Bt* hybrid cotton : Composite sample fibre quality of *Bt* hybrid cotton (Table 10) did not significantly influenced by any of the *Bt* hybrid cotton based intercropping system, but higher micronaire in 2008-2009 season was due to the near absence of post September rains resulted in lower bundle strength which was reverse in 2009-2010 season due to 229 mm post September rains resulted in immature bolls contribution reduced micronaire and increased strength, which was not desirable for finished cotton goods.

Scope of adoptability of innovative intercropping systems : *Bt* hybrid cotton paired row intercropped with marigold or field bean + fennel produced significantly superior seed cotton yield similar to that of sole cotton with higher plant stand. This system is more suitable for semi arid climates only in relatively undulated lands. *Bt* hybrid cotton intercropped with field bean produced 1.5 t/ha of fresh green pods, suitable only for rural markets due to prohibitive higher pod picking costs. If adopted, this helps in reducing nutritional deficiency with protein rich diet besides providing rural employment. Additional 25 per cent mixed pole beans maintains supply of vegetable for own

Table 6. Fertilizer and nutrient use efficiency of *Bt* hybrid cotton based cropping systems

Treatments	FUE (kg seed cotton /kg fertilizer)			NUE (kg seed cotton /kg nutrient uptake)			System FUE (kg seed cotton /kg fertilizer)			System NUE (kg seed cotton /kg nutrient uptake)			System NUE P			
	N	P	K	N	P	K	N	P	K	N	P	K	2008	2009	2010	**Mean**
Sole *Bt* hybrid cotton	13	27	27	17	73	31	13	27	27	18	82	34	39	92	113	**82**
PR *Bt* hybrid cotton	9	19	19	18	87	37	9	19	19	18	91	37	60	74	138	**91**
PR *Bt* hybrid cotton + soybean	12	24	24	19	62	32	8	18	30	9	35	15	34	33	37	**35**
PR *Bt* hybrid cotton + pigeonpea	9	19	19	19	74	33	9	20	29	23	88	39	90	71	104	**88**
PR *Bt* hybrid cotton + marigold	12	24	24	20	75	33	6	7	7	18	58	28	76	48	49	**58**
PR *Bt* hybrid cotton + maize	12	25	25	18	78	31	7	15	14	8	27	11	35	16	30	**27**
PR *Bt* hybrid cotton + field bean and fennel	12	24	24	20	78	36	10	16	23	17	62	27	80	39	65	**62**
PR *Bt* hybrid cotton + castor	9	18	18	18	63	27	10	18	34	19	60	31	53	59	67	**60**
SEm+	2	3	3	2	12	4	3	6	8	4	20	8				
CD (p=0.05)	4	NS	NS	NS	NS	NS	NS	NS	15	8	39	16				
2008	15	29	29	23	82	41	9	18	23	16	58	27				
2009	12	25	25	22	82	33	9	18	23	17	54	23				
2010	6	13	13	11	57	23	9	17	22	17	76	34				
SEm+	2	3	3	2	11	3	0.4	1	1	1						
CD (p=0.05)	NS	6	6	3	21	6	NS	NS	NS	NS	14	5				
SEm+	2	16	16	2	28	16	3	4	7	6	38	12				
CD (p=0.05)	NS	NS	NS	NS	55	NS	NS	NS	NS	NS	75	NS				

Table 7. Pooled cost of cultivation and returns interaction with seasons from *Bt* hybrid cotton based cropping systems

Treatments	Cost of cultivation (₹x10³ ha)			Returns (₹x103 ha)			Returns from *Bt* hybrid cotton (₹x103 ha)				Returns from intercrop (₹x103 ha)			
	Bt cotton	ICP	Total	Gross	Net	C: B ratio	8	9	10	**Mean**	8	9	10	**Mean**
Sole *Bt* hybrid cotton	14		13	46	32	2.56	68	33	35	**46**				
PR *Bt* hybrid cotton	13		12	35	23	2.05	35	35	35	**35**				
PR *Bt* hybrid cotton + soybean	13	3	16	55	34	2.44	54	39	47	**47**	7	10	7	**8**
PR *Bt* hybrid cotton + pigeon pea	13	2	14	62	35	2.83	31	39	73	**48**	4	20	18	**11**
PR *Bt* hybrid cotton + marigold	13	6	19	78	44	2.73	62	25	84	**57**	22	19	22	**21**
PR *Bt* hybrid cotton + maize	13	3	16	59	38	2.52	57	43	54	**51**	1	10	11	**8**
PR *Bt* hybrid cotton + field bean and fennel	13	5	18	75	47	2.91	55	35	88	**59**	6	19	22	**16**
PR *Bt* hybrid cotton + castor	12	2	14	73	45	2.81	34	35	102		4	9	37	**17**
SEm+	0.5	0.5	0.5	6.6	5.6	0.2								2.5
CD (p=0.05)	1	1	1	13	11	0.4								5
SEm+	0.2	1	0.5	3.5	3	0.1								1
CD (p=0.05)	0.4	NS	1	7	6	0.2								2
Interaction SEm+	1	2	1.5	18	16	0.6								5.6
CD (p=0.05)	2	4	3	36	32	1.2								11

The former realized cotton prized was 30, 45, 60/- kg seed cotton in 2008, 2009, 2010

Table 8 . Weed incidence (m^2) as influenced by different *Bt hybrid* cotton based cropping systems

Treatments	24th August , 2008				September, 2009			
	135 cm intercropping		90 cm intercropping		135 cm intercropping		90 cm intercropping	
	Broad leaf	Grasses	Broad leaf	Grasses	Broad leaf	Grasses	Broad leaf	Grasses
Sole *Bt* hybrid cotton	5.7(2.5)	12.3(3.6)	6.3(2.5)	18.7(4.3)	0(1.3)	0(1.4)	0(1.6)	0(1.1)
PR *Bt* hybrid cotton	6.0(2.5)	26.7(5.0)	4.3(2.2)	13.3(3.5)	0(3.2)	0(3.3)	0.5(3.8)	0(3.8)
PR *Bt* hybrid cotton + soybean	10.3(2.9)	14.7(3.6)	2.7(1.6)	30.3(5.0)	6.0(2.2)	7.0(2.0)	8.8(2.7)	7.5(2.6)
PR *Bt* hybrid cotton + pigeon pea	1.7(1.4)	15.3(3.9)	9.0(2.5)	21.3(4.1)	7.0(2.8)	7.8(2.6)	10.0(3.3)	10.3(3.2)
PR *Bt* hybrid cotton + marigold	2.7(1.6)	44.7(6.6)	3.0(1.7)	42.3(6.5)	16.0(2.4)	20.5(2.7)	23.0(2.8)	23.8(2.8)
PR *Bt* hybrid cotton + maize	3.3(1.8)	13.0(3.4)	2.3(1.5)	18.7(4.1)	7.0(1.5)	6.0(1.4)	12.0(1.8)	9.3(1.7)
PR *Bt* hybrid cotton + field bean and fennel	6.0(2.5)	15.7(4.0)	4.7(2.1)	18.7(4.3)	9.0(2.9)	8.0(2.6)	14.0(3.5)	13.8(3.4)
PR *Bt* hybrid cotton + castor	10.3(3.1)	27.0(5.0)	4.0(2.1)	23.7(4.9)	8.0(3.1)	5.0(3.4)	9.5(3.7)	9.5(3.7)
SEm+	(0.8)	(1.1)	(0.8)	(1.3)	8.0(2.4)	6.7(2.4)	11.0(2.9)	10.7(2.8)
CD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Note= $\sqrt{(x+0.5)}$ conversions in parenthesis

Table 9. Weed management cost as influence by different *Bt* hybrid cotton based cropping systems under herbicides rotation

Treatments	28, August, 2008		September, 2009	
	Broad row	Narrow row	Broad row	Narrow row
Sole *Bt* hybrid cotton	444	211		
PR *Bt* hybrid cotton	494	151		
PR *Bt* hybrid cotton + soybean	642	759	457	548
PR *Bt* hybrid cotton + pigeon pea	568	444	683	643
PR *Bt* hybrid cotton + marigold	814	685	1001	940
PR *Bt* hybrid cotton + maize	420	204	705	731
PR *Bt* hybrid cotton + field bean and fennel	444	352	619	616
PR *Bt* hybrid cotton + castor	765	481	493	485
Mean of Oxyflurofen	**592**	**368**	**529**	**478**
Mean of intercrops	**602**	**433**	**700**	**683**
SEm+	157	253	160	116
CD(p=0.05)	NS	NS	317	229

consumption up to December as they were late, indeterminate and spreading habit along with more drought resistance compared to 'Puspak' shrub. The next best system was *Bt* hybrid cotton intercropped with marigold for flowers with a production of approximately 1.2 t/ha during different festivals for ornamental /decoration purpose, more suitable for *peri* urban markets only or poultry feed for fancy colored eggs. Marigold flowers can be fed to hens which can lay colored eggs with lutine (â carotene precursor vitamin A) for under nourished children can be sold at premium as neutraceutical (Anonymous, 2009). Both the systems act as trap crop for boll worms and their cultivation could delay the development of *Bt* resistance. They also produced similar net ₹ 47, 000 / ha, but the C:B ratio was higher for field bean (2.91) compared to marigold (2.73) due to the difference in cost of harvesting and demand for flowers (Table 7).

Bt hybrid cotton based innovative intercropping systems in medium deep soils was field bean + fennel or marigold flowers. The agronomical requirements like optimization of spacing, nutrition, flower drop in field bean and weed management need further emphasis for

Table 10. Fibre properties of *Bt* hybrid cotton based cropping systems during 2008-2009, 2009-2010

Treatments	2.5 per cent staple length (mm)	Uniformity ratio	Micronaire value	Bundle strength (g/ tex)
Sole *Bt* hybrid cotton	30.1	47.5	3.66	20.8
PR *Bt* hybrid cotton	30.1	47.6	3.73	21.7
PR *Bt* hybrid cotton + soybean	29.7	48.8	3.61	21.8
PR *Bt* hybrid cotton + pigeonpea	30.6	47.4	3.59	20.9
PR *Bt* hybrid cotton + marigold	31.1	47.3	3.54	21.5
PR *Bt* hybrid cotton + maize	30.6	47.9	3.56	21.5
PR *Bt* hybrid cotton +field bean and fennel	30.7	47.8	3.51	21.4
PR *Bt* hybrid cotton + castor	30.6	48.3	3.66	21.9
SEm+	0.5	0.8	0.14	0.6
CD (p=0.05)	NS	NS	NS	NS
2008	30.0	48.3	3.89	20.0
2009	30.8	47.3	3.32	22.9
SEm+	0.2	0.4	0.06	0.4
CD (p=0.05)	0.5	0.8	0.13	0.7
Interaction				
SEm+	1.2	2.0	0.30	1.8
CD (p=0.05)	NS	NS	NS	NS

popularization of technology among semi arid rain fed cotton farmers.

ACKNOWLEDGEMENT

The project received financial assistance under Technology mission on cotton Mini Mission I from ICAR, Govt. of India is duly acknowledged.

REFERENCES

Anonymous, 2009. Lutein and Eye Health March 3, 2009 Written by JP www.healthyfellow.com/157/lutein-and-eye-health/ -

Anonymous, 2010a. *Recommendations of University of Agricultural Sciences*, University of Agriculture Sciences, Raichur.htm.

Anonymous, 2010b. COTTON FIBRE www.texmin.nic.in/ .../Fibre_ Policy_Sub_ %20 Groups_ Report_ dir_mg_d_20100608_1.pdf

Anonymous, 2010c. Recommendations/Technology developed during last 11 years Junagadh Agricultural University (1999-2010) pp 3.

Bhalerao, P D, Patil B R and Gaikwad, G. S. 2009. Studies on root growth of *Bt* hybrids underrainfed condition. 2.49. *National Seminar on Bt cotton: Opportunities and Prospects.* 17-19th. November pp 65-66.

Brintha, I. and Seran T H. 2009. Effect of paired row planting of radish (*raphanus sativus*l.) intercropped with vegetable *Amaranthus* on yield components of radish in sandy *regosol. Jour. Agri.Sci.* **4(1):**19-28.

CAB, 2010. *Current cotton Scenario*, The Maharashtra state cooperative Marketing Federation.www. Mahacot.html.

Clouston, D. 1870. *Amraoti District Gazeteer* in Central Provinces District Gazeteers. http//:amraoti.nic.in/gazetteer/gazetteer amravati/Agriculture_soils.html#

Giri, A. N., Deshmukh M. N. and Gore, S. B. 2006. Nutrient management in cotton *(Gossypium hirsutum)* - based cropping systems. *Indian Jour. Agro.* **51**(3) **:** 34-36.

Gokhale, D. N., Shinde, V. S., Gadade, G. D., Sawargaonkar, G. L. and Zade, K. K. 2011. Sustaining rainfed *Bt* cotton productivity through moisture conservation and integrated nutrient management technique. *J. Cotton Res. Deve.* **25**(2) **:** 197-201.

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.

Mandava Rao, P. and Alapati, S. 2007. *Bt* cotton offers planting at higher planting densities in India, September 12, 2007, WCRC-4 Lubbock Texas.

Osakwe, Emeka . 2009. Cotton Fact Sheet, India, ICAC reporter, May 19.

Sankaranarayanan, K., Praharaj, C. S., Nalayini, P., Bandyopadhyay, K. and Gopalakrishnan, N. 2010. Climate change and its impact on cotton (*Gossypium sp.) Ind. Jour. Agri. Sci.* **80**(7) **:** 561-75.

Sivaraman, K. and Palaniappan, S. P. 1996. *Cropping systems in the tropics - Principles and management.* New Age International Ltd, India.

Vittal, K. P. R., Rajendran, T. P. G., Ravindra Chary, G. R., Maruthi Sankar, T., Srijaya, Y. S., Ramakrishna Samra, J. S. and Gurbachan, S. 2004. *Districtwise Promising Technologies for Rainfed Cotton based Production System in India.* All India Coordinated Research Project for Dryland Agriculture Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad 500 059.

VJAS. 2011. Indian Agrarian Crisis - Disappointed with farmer's Package 4 more ...

Zhang L L. 2007. Scientists find why some plants are good neighbors. *Proceedings of the National Academy of Science.*

Stale seedbed technique - A novel approach for managing weeds in irrigated cotton based intercropping system

P. NALAYINI* AND M. SUVEETHA
Central Institute for Cotton Research, Regional station, Coimbatore – 641 003
**E-mail : nalayiniganesh@gmail.com*

Abstract : Cotton is sensitive to weed competition due to its slow initial growth and wider spacing. In recent years, *Bt* cotton which is high yielding and responsive to higher levels of inputs like fertilizers, irrigation etc., is grown under intensive cropping system, all these factors promote luxurious growth of weeds which grow more quickly than cotton and compete strongly for soil moisture, nutrients, light and space. Hybrid cotton is normally grown in ridges and furrow methods and sowing is done only on one side of the ridge and the other side is kept vacant. A new method of introducing short duration intercrops which would complete the life cycle within 45-60 DAS was standardized and the short duration intercrop, coriander has been introduced on the other side of the ridge without sacrificing the main crop population of cotton grown under normal recommended spacing. Weed control under intercropping system is very difficult and the removal of weeds by manual method is tedious as it is very difficult to differentiate the young weed seedlings and germinating intercrops. Hence, a novel approach of exhausting weed seed bank before the crop emergence by stale seed bed approach was standardized for *Bt* cotton based intercropping system during 2010-2011 and 2011-2012 cropping season at Regional station of Central Institute for Cotton Research, Coimbatore. Among the treatments, Stale Seed Bed Technique (SSBT) using a mixture of pendimethalin 1.0 kg + glyphosate 1.0 kg one week after irrigation (one week before sowing) recorded the highest weed control efficiency of 85.2% on 35- 45 DAS. Adopting this new method of planting, *Bt* cotton RCH 20 *Bt* with coriander as intercrop under SSBT of managing weeds with pendimethalin 1.0 kg + glyphosate 1.0 kg recorded the highest seed cotton yield (3261 kg/ha), seed cotton equivalent yield (4686 kg/ha ₹ 1,80921/ha).

Key words : Net return, seed cotton equivalent yield, seed cotton yield, stale seed bed technique, weed control efficiency

Cotton being a wide row spaced and relatively slow growing crop in initial stages is subjected to severe weed competition and reduce yield to an extent of 60 per cent (Sadangi and Barik,2007).Present recommendation of pre emergence herbicide (pendimethalin) application followed by two or three inter cultivation is a common practice(Prabhu *et al.,* 2010). However, providing timely weed control may not be possible as inter row cultivation is weather dependent, in case of heavy rains, the soils become sticky and wet and trafficability is poor while in the dry soil, the surface becomes hard making inter-row cultivation difficult and also many times, non availability of human labourers for weeding makes timely weed control as impossible and costly affair. Weed control under intercropping system is all the more difficult because the removal of weeds by manual method is tedious as it is very difficult to differentiate the young weeds seedlings and germinating intercrops and as a result, the required population of intercrops could not be maintained due to manual removal of seedlings of intercrops unknowingly. Hence, a novel approach of exhausting weed seed bank before the crop emergence by stale seed bed (SSBT) approach was standardized for *Bt* cotton based intercropping system. Hybrid cotton is normally grown in ridges and furrow methods and sowing is done only on one side of the ridge and the other side is kept vacant. A new method of introducing short duration intercrop like coriander which would complete the life cycle within 40 - 45 DAS was standardized and the short duration intercrop, coriander has been introduced on the other side of the ridge. A new method of introducing intercrops without sacrificing the recommended cotton plant population and a new approach of weed management before planting of cotton through adoption of stale seed bed approach has been attempted to explore the practical feasibility of stale seed bed technique for exhausting weed seed bank before the crop emergence in *Bt* Cotton based intercropping system and to compare the economics of various weed control methods

MATERIALS AND METHODS

Field experiments were conducted during winter (August – February) of 2010-2011 and 2011-2012 cropping season under irrigated condition in the main farm of Regional station, Central Institute for Cotton research, Coimbatore. Normally cotton crop is grown under ridges and furrow method with sowing of cotton in one side of the ridge and the other side is kept vacant. We have introduced short duration intercrop, coriander cv surabhi on the other side of ridges so that the cotton crop population not sacrificed. The hirsutum based cotton hybrid cv RCH 20 *Bt* has been evaluated at 90x60cm.The seed beds were prepared two weeks in advance of sowing and for stale seed bed technique, irrigation was given two weeks in advance of sowing and after receiving the moisture weed seeds were tempted to germinate and targeted by the weed control treatments. six weed control treatments were evaluated in randomized block design with four replications. The treatments were, W_1-Weed control by stale seed bed technique (SSBT) using glyphosate 1.0 kg (spraying of glyphosate once one week after the first irrigation followed by hand weeding 35- 40 DAS, W_2-Weed control by SSBT using pendimethalin 1.5 kg/ha (herbicide spraying on 3rd day after irrigation) followed by hand weeding 35-40 DAS, W_3 - Weed control by SSBT using glyphosate 1.0 kg + pendimethalin 1.0 kg (spraying of herbicide mixture once 1 week after the first irrigation, a week before sowing) followed by hand weeding 35- 40 DAS, W_4-Pre emergence weed control using pendimethalin 1.5 kg on 3rd day of cotton sowing followed by hand weeding at 35- 40 DAS, W_5- Removal of germinated weeds one week after irrigation (One week before sowing) followed by hand weeding at 15-20 DAS and 35-40 DAS, W_6-Un weeded check. The soil of the experimental fields was low in nitrogen (168.0, 168.0 kg/ha), high in phosphorus (29, 28.5 kg/ha) and potassium (557, 590 kg/ha) in the first and second year of experimentation respectively. 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. The significance of the difference between means of two treatments was tested using least significance (LSD) at 5 per cent probability level. The data on weed count was subjected to square root transformation before statistical analysis to normalize their distribution (Panse and Skhatme,1978)

RESULTS AND DISCUSSION

Weed flora of the experimental field : The experimental field had 29 broad leaved weeds, seven grass weeds, and one sedge weed. The broad leaved weeds were**,** *Abutilon indicum, Acalypha indica, Amaranthus spinosus, Amaranthus viridis,Amaranthus polygamus, Argemone mexicana, Boerhaavia erecta, Boerhaavia diffusa, Coccinia indica, Convolvulus arvensis, Corchorus trilocularis, Celosia argentea,Croton*

Table 1. Weed control treatments on weed count, weed dry matter production and weed control efficiency of *Bt* cotton + coriander system (pooled mean)

Weed control treatments	Weed count 35- 40 DAS*	Weed DMP g/m^2 35- 40 DAS	Weed control efficiency (%) 35- 40 DAS
W_1 SSBT glyphosate 1.0 kg - HW	132.3 (11.50)	54.4	54.1
W_2 SSBT pendimethalin 1.5 kg- HW	40.6 (6.37)	21.5	81.9
W_3 SSBT pendimethalin 1.0 kg + glyphosate 1.0 kg - HW	30.9 (5.56)	17.6	85.2
W_4 Pre emergence weed control with pendimethalin 1.5 kg - HW	53.59 (7.32)	30.5	74.4
W_5 SSBT and manual removal of weeds(thrice)	44.95 (6.71)	29.9	74.8
W_6 Unweeded control	555.25 (15.97)	118.5	-
CD (p=0.05)	0.56	4.67	

*Figures in parenthesis are square root transformed values for statistical analysis *sparsiflorus, Datura fastuosa, Digera arvensis, Euphorbia hirta, Indigofera ennaphylla, Leucas urticaefolia,Malvastrum coromandelianum, Oldenlandia umbellate, Parthenium hysterophorus, Phyllanthus maderaspatensis, Phyllanthus niruri, Portulaca oleracea, Priva leptostachya, Sonchus oleraceus, Trianthema portulacastrum, Tridax procumbens* and *Vicoa indica.* The grassy weeds *viz., Chloris barbata, Cynodon dactylon, Dinebra Arabica, Eleusine aegyptiaca, Panicum colonum, Panicum repens, Pennisetum cenchroides, Sporobolus scabrifolius* and the lone sedge weed *Cyperus rotuntus* were present in the experimental field. Among the weed species, The carpet weed ,*Trianthema portulacastrum* was the most dominant weed flora during initial stage of cotton growth.

Weed control treatments on weeds associated with *Bt* cotton + coriander system : The weed count recorded on 35- 40 DAS (Table 1) has shown significant differences and among the treatments, stale seed bed application of glyphosate 1.0 kg + pendimethalin 1.0 kg one week before sowing recorded the lowest weed count and this might be due to efficient control of germinated weeds by glyphosate and the germinating weeds were controlled by the residual action of pendimethalin. Stale seed bed technique and application of glyphosate alone could not control the weeds efficiently because all the weeds did not germinate in a week time after irrigation and the glyphosate could target only the germinated weeds and could not target the weeds germinating after the glyphosate spraying. The dry matter production of weeds ranged from 17.6 g/m^2 to 118.5 g/m^2. The weed dry matter accumulation followed the same trend as that of weed count. The weed control efficiency ranged from 54.1 to 85.2 per cent and the highest weed control efficiency was being achieved by SSBT and application of a combination of glyphosate 1.0 kg and pendimethalin 1.0 kg/ha.

Weed control treatments on seed cotton yield, intercrop yield and monetary economics of *Bt* cotton + coriander system : The seed cotton yield was significantly influenced by the weed control treatments. The highest seed cotton yield of 3261 kg/ha was achieved by SSBT of pendimethalin 1.0 kg + glyphosate 1.0 kg + one hand weeding (35- 40 DAS) and was on par with SSBT application of pendimethalin 1.5 kg + hand weeding 35- 40 DAS and SSBT and manual removal of weeds (thrice). However SSBT and application of glyphosate alone could not produce the desired result as the weed seed germination is a staggered process and application of glyphosate alone could target only the germinated weeds and the weed which are germinating after the herbicide spray coud not be targeted and hence a lot of weeds were left uncontrolled which might have competed with cotton crop causing significant yield loss. All the treatments under SSBT method except glyphosate with one hand weeding were found significantly superior to normal method of pre emergence application on

Table 2. Weed control treatments on seed cotton yield, intercrop yield, seed cotton equivalent yield and economics of *Bt* cotton + coriander system (pooled mean)

Weed control treatments	Seed cotton yield (kg/ha)	Yield of intercrop (t/ha)	Seed cotton equivalent yield (kg/ha)	Cost of cultivation (₹/ha)	Net return (₹/ha)
W_1 SSBT glyphosate 1.0 kg - HW	1879	2.65	2428	30659	81292
W_2 SSBT pendimethalin 1.5 kg- HW	3080	6.45	4448	31720	1,71,215
W_3 SSBT pendimethalin 1.0 kg + glyphosate 1.0 kg - HW	3261	6.70	4687	32138	1,80,921
W_4 Pre emergence weed control with pendimethalin 1.5 kg – HW	2852	5.39	4004	31720	1,50,986
W_5 SSBT and manual removal of weeds(thrice)	3190	5.35	4325	35750	1,61,410
W_6 Unweeded control	630	0.73	778	26750	9620
CD (p=0.05)	262.1				

third day of cotton sowing. Sanbagavalli *et al.,* 2009 obtained better weed control and highest seed cotton yield with stale seed bed technique and application of glyphosate 2.0 kg/ha before sowing followed by two manual weed control .

Intercrop yield : The yield of intercrop also significantly influenced by the weed control treatments. The unweeded treatments recorded the lowest (0.73 t/ha) of coriander and this was due to smothering of coriander by uncontrolled weeds. Among the treatments, SSBT and application of mixture of pendimethalin 1.0 kg and glyphosate 1.0 kg , SSBT application of pendimethalin 1.5 kg recorded higher inter crop yield. While, the normal method of pre emergence application of pendimethalin 1.5 kg on third day of cotton sowing recorded a reduction of about 1.31 t/ha in intercrop yield and this reduction might be due to sensitivity of intercrop coriander for the dose tested as pre emergence spray since the herbicide spraying was done on third day of sowing of cotton and intercrop. However under stale seed bed technique, as the herbicide spraying has been advanced by7-10 days of sowing, the herbicidal toxicity might be lesser on the intercrop and resulted in higher biomass of coriander. SSBT and manual removal of weeds also recorded a reduction in intercrop yield to the tune of 1.35 t/ha than SSBT and application of pendimethalin + glyphosate. This might be due to removal of coriander seedlings unknowingly while weeding as it was very difficult to differentiate the young intercrop seedlings with other young weeds.

Monetary economics : The seed cotton equivalent yield has been worked out equating the value of intercrop in terms of cotton. The highest seed cotton yield of 4687 kg/ha has been recorded under SSBT application of pendimethalin1.0 kg + glyphosate 1.0 kg with one hand weeding 35- 40 DAS. This was closely followed by SSBT application of pendimethalin 1.5 kg + one hand weeding 35- 40 DAS and SSBT with manual removal of weeds thrice. The same trend was seen towards monetary economics and the highest net return of ₹1,80,921 was being recorded under SSBT with pendimethalin 1.0 kg + glyphosate 1.0 kg with one hand weeding 35- 40 DAS.

From the above studies it is concluded that adoption of stale seed bed technique and application of pendimethalin 1.0 kg + glyphosate 1.0 kg with one manual weeding on 35-40 DAS was the most profitable method of weeding for *Bt* cotton+ coriander system.

REFERENCES

Panse,V.G. and Sukatme,P.V.1978. *Statistical Methods for Agricultural Workers,*ICAR,New Delhi,pp:152

Prabhu, G., Halepyati, A. S. and Pujari, B. T. 2010.Weed Management Studies in *Bt* Cotton (*Gossypium hirsutum*)under irrigated conditions. *Proc.of XIX national Symposium on Resource Management Approach towards livelihood security,* 2-4 December,2010,UAS, Bangalore,pp:263

Sadangi,P.K. and Barik,K.C.2007. Effect of weed management practices on nutrient depletion by weeds,yield and economics of winter irrigated cotton (*Gossypium hirsutum*). *Indian J. Agron.,* **52** (2) :172-75

Sanbagavalli,S.,Kandasamy,O.S.,Selvi,R.V and Ganeshraja, V. 2009. Effect of stale seed bed technique of weed management on weeds and yield of cotton.In; *Proc. National Symposium on weed Threat to Environment,Biodiversity and Agricultural productivity.* August 2-3,2009, Tamil Nadu Agricultural University, Coimbatore,pp : 160

Effect of weather variables on productivity of American cotton (*Gossypium histurum* L) under field conditions

DEVRAJ*, PARVENDER SHEORAN, V. S. MOR, R. S. ANTIL AND S. S. SIWACH
Department of Soil Science, CCS Haryana Agricultural University, Hisar-125 004
**E-mail: devraj_chauhan @rediffmail.com*

Abstract: Climatic conditions in the coming years are expected to be different from that of today. Boll maturation period, which determines the productivity, is a critical stage in the life cycle of cotton. During this period the boll grows, fibre develops and seed matures. Great attention is being paid to the factors affecting this period. In the field, weather conditions are different and complicated. Thus only the field studies can provide realistic assessment of what will happen to the crop growing under field conditions due to change in weather. Keeping this in mind, the seed cotton yield of a long term permanent experiment which were concluded earlier were examined to find out the relationship of weather varieties of boll maturation period to seed cotton yield. From the correlation study it was found that night temperature and vapor pressure of morning during the boll maturation period significantly influenced the seed cotton yield and higher seed cotton yields were obtained when night temperature was lower than normal value of location. The night temperature and vapor pressure of morning were identified as most critical weather variable influencing seed cotton yield and some management practices such as sowing date; irrigation etc. must be taken care of to mitigate the adverse effect of weather variables to improve the production and productivity of cotton on sustainable basis. The other weather variables not much influenced the seed cotton yield.

Key words: American cotton, boll maturation, weather variables, seed cotton yield

Climate change is one of the most important global environmental challenges with implications for food production. The Intergovernmental Panel on Climate Change (IPCC, 2007) has pointed out that the earth's surface temperature has increased by 0.74°C between 1906-2005 due to increase in anthropogenic emissions of greenhouse gases and is likely to rise by 1.8-4.5°C by the end of this century causing 10-40 per cent yield losses despite the beneficial effect of higher CO_2 concentration in the atmosphere. Presently, the vulnerability of agriculture to climatic variability and change is an issue of major importance to International scientific community. Considering all the anticipated or expected changes, global researchers are deeply engaged in analyzing the effect of climate change on different agriculture crops of their interest.

Cotton (*Gossypium hirsutum* L.) is one of the most extensively cultivated commercial cash/fibre crop of global importance. Growth and development of cotton is greatly influenced by complex uncontrolled environmental factors. How environment alters the plant growth and the related processes by influencing the phenological, physiological, morphological, quantitative and qualitative expressions during the crop growing season is of utmost importance for critical analysis (Wall *et al*, 1994). Numerous studies have variously hypothesized the association of weather variables especially temperature (soil and air), evaporation, sunshine duration, humidity, with component characters that affect the flower and boll production of cotton (Sawan *et al.*, 2002). The impact of climatic variables could be assessed by developing a quantitative relationship between climatic variables and seed cotton yield. It has been concluded that temperature is the major environmental factor that influences the plant growth and developmental processes in most crops to a greater extent (Reddy *et al.,* 1991a and b; Lond and Woodward, 1988) and ultimately yield (Roussopoulos *et al.,* 1998, Reddy *et al.,* 1992; Pettigrew, 2008). The development of each phonological phase in cotton has an optimum temperature requirement (Hebbar *et al.*, 2007), above and below which the growth may depress.

Boll maturation period in cotton, a major yield determinant factor, is crucial in deciding the targetted seed cotton yield. During this period the boll grows, fiber develops and seed matures. Matching the boll maturation period of the cotton crop to the duration of most appropriate temperature regime is crucial for attaining potential harvestable yield. Cumulative degree days, the most common temperature index used to estimate plant development and crop display during boll maturation period (Viater *et al.,* 2005) can provide more constructive informations pertaining to the temperature effect on yield and quality of cotton. Daily temperature also plays an important role in the boll maturation period.

Most of the earlier studies had been confined to controlled laboratory or glasshouses conditions by simply taking one or two weather variates of interest. But scanty work has been done towards confounded effect of different weather elements particularly under field conditions to provide more realistic assessment with respect to changing weather variables. In this paper, we attempted to analyze the effect of changing climatic variables on the productivity of american cotton under irrigated semiarid environmental conditions considering all the anticipated or expected changes.

MATERIALS AND METHODS

Field experiments were conducted for six consecutive years (*Kharif* 1997 to 2002) at the Research Farm of CCS Haryana Agricultural University Hisar (29°16' N latitude and 75°75' E longitude) under semiarid irrigated conditions. The soil of experimental field was sandy loam in texture (Typic Ustochrept) having alkaline pH (8.3), 0.22 dS/m electrical conductivity, 0.4 per cent organic carbon, tested low in available nitrogen (120 kg N/ha) , medium in available P (11 kg P/ha) and high in available K (320 kg K/ ha). The american cotton genotype H-1117 was taken as a test genotype. The crop was sown in the month of May in the same field and picking was completed before the end of November in all the cropping season. The recommended dose of nitrogen (80 kg/ha) was applied in two equal splits; first at 45 days after sowing and second dose at the time of flowering 75 DAS. Entire dose of Phosphorus (30 kg P_2O_5/ha) was applied at the time of sowing as band placement. Other cultural and plant protection measures were taken into consideration as per the standard package of practices related to the crop following state recommendations. The crop was irrigated 3-5 times in different cropping seasons as and when required depending up on the seasonal precipitation.

The daily weather data was recorded from metrological observatory of the CCS Haryana Agricultural University located at half kilometer away from experimental site. The cropping season of cotton in Haryana state geenrally confined to May to November and final picking

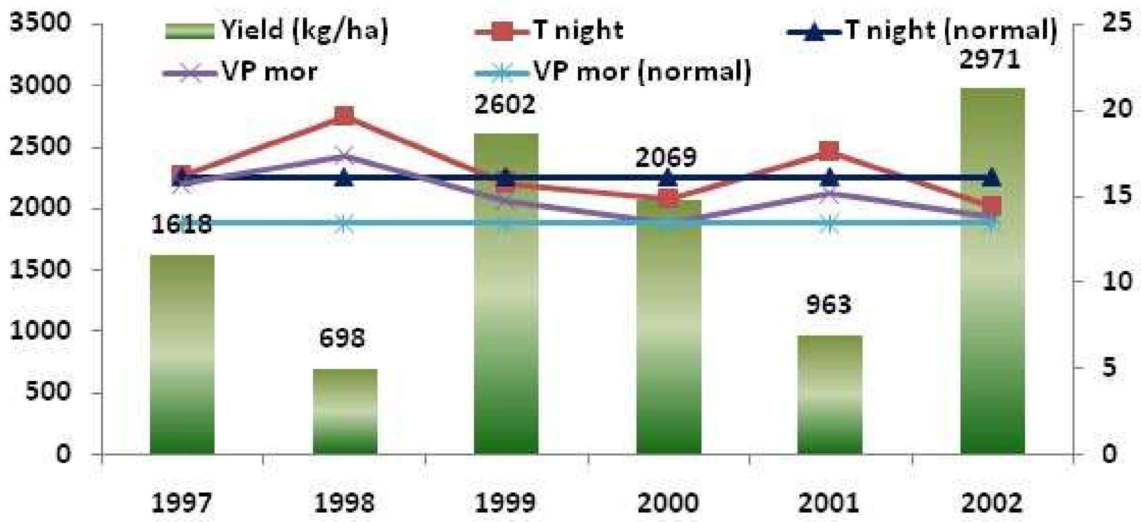


Fig 1. Seed cotton yield (kg/ha) vis-à-vis normal and observed night temperature and vapor pressure morning during experimentation period (1997-2002)

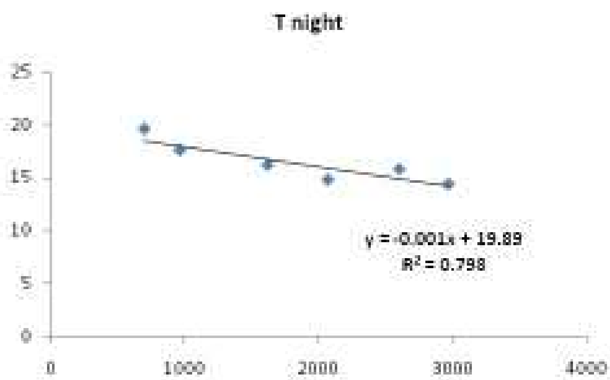
is completed by the end of November. The boll maturation period generally remains in the month of October, therefore, weather data for corresponding month was taken consideration each year for finding correlation studies. The normal values of each weather variable based on the average of 36 years data are also presented in Table 1.

RESULTS AND DISCUSSION

The seed cotton yield varied from 698 kg/ha (1998) to 2971 kg/ha (2002) during different years of experimentation. The relationship of seed cotton yield with different weather variables was determined and yield was found to be highly negatively correlated with night temperature (r=-0.89) and vapour pressure morning (r=-0.76). The other weather variables were not showing much correlation with seed cotton yield (Table 2). The seed cotton yield was higher in order of the years 2002, 1999, and 2000 because sunshine hours and vapour pressure of morning were relatively close to normal values of location and night temperature was lower than the normal value (Fig. 1). These conditions consistently favoured more photosynthesis during day time and less respiration during night leading to more translocation of photosynthates and nutrients from source to sink. However, reverse was the trend during the years 1998, 2001 and 1997, where the sunshine hours was recorded to be lower than normal value and vapor pressure of morning and night temperature were more than normal values ultimately resulting in lower seed cotton yield. This can ascribed by the fact that if the night temperature is remains high, the rate of respiration will be high and more carbohydrates and photosynthates will be utilized for respiration and thus there will be a shortage of photosynthates, as a result more non photosynthetic biomass (stem, leaf and burr) was formed at the expanse of reproductive development (Boote *et al.,* 1985; Roussopoules *et*

Tabble 1. Weather variables during the boll maturation period (1997-2002)

Cropping season	Temp(^{0}C)		VP (mm)		Sunshine (hr)	RH (%)		EVP) (mm)	Rainfall (mm)
	Night	Day	Mor	Eve		Mor	Eve		
1997	16.2	28.0	15.7	17.0	6.0	92	65	3.2	3.4
1998	19.6	31.4	17.3	16.7	6.9	87	53	3.2	0
1999	15.8	34.6	14.7	11.9	8.3	78	30	5.4	0
2000	14.8	36.5	13.4	10.7	9.3	71	24	5.4	0
2001	17.6	34.6	15.1	12.1	8.7	83	31	4.3	0
2002	14.4	32.5	13.8	13.0	8.6	88	36	6.1	0
Normal value of location	16.1	33.4	13.4	12.8	8.9	76	39	5.0	10.5



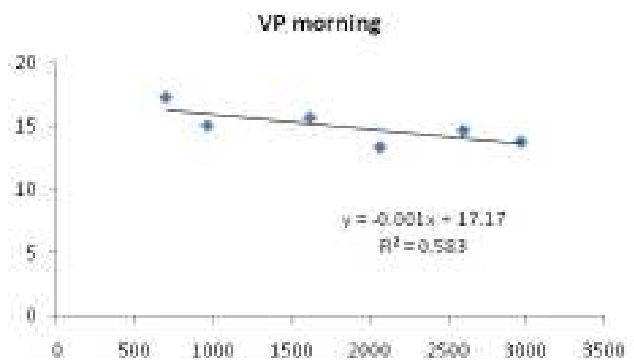


Fig 2. Relationship betweev seed cotton yield (kg/ha) with night temperature and vapor pressure of morning

Table 2. Correlation and regression coefficient between seed cotton yield and weather variables

Variables	Correlation coefficient (r)	Regression coefficient (R^2)
Night temperature.	-0.89	0.80
Day temperature.	0.22	0.05
Vapor pressure morning	-0.76	0.58
Vapor pressure evening	-0.47	0.22
Sunshine hr	0.41	0.16
Relative humidity morning	-0.22	0.05
Relative humidity evening	-0.40	0.16
Evaporation	0.48	0.43

al., 1978 and 1998). The present study revealed that the night temperature was the main weather variable which influenced the seed cotton yield during different years (Fig. 2). Numerous studies with different hypothesis have also shown the importance of night temperature of boll maturation period for seed cotton yield (Gipson and Joham 1968; Reddy *et al.,* 1991, 1992).

Based on the study, it can be concluded that night temperature and vapor pressure of morning during the boll maturation period were the most critical weather variable influencing seed cotton yield and some management practices such as sowing date; irrigation etc. must be taken care of to mitigate the adverse effect of weather variables to improve the production and productivity of cotton on sustainable basis.

REFRENCES

Boote, K.J., Jones, J.W. and Bennett, J.M., 1985. Factors influencing crop canopy CO_2 assimilation of soybean. In Proceedings of the *"Third World Soybean Research Conference"* (ed. R. Shibles), Boulder, CO: Westview Press, 780-788.

Gipson, J.R. and Joham, H.E., 1968. Influence of night temperature on growth and development of cotton (*Gossypium hirsutum* L.). I. Fruiting and Boll Development. *Agron. J.* **60**: 292-98.

Hebbar, K.B., Venugopalan, M.V., Khadi, B.M. and Aggarwal, P.K., 2007. Impact from climate change on cotton production. National Conference on *"Impact of Climate Change with particular reference to Agriculture"*, organized by Agro-climate Research Centre, TNAU, Coimbatore from August 22-24, 2007.

IPCC, 2007. Contribution of Working Group 1 to the Fourth Assessment Report of the Inter Governmental Panel on Climate Change, Solomom S. Qin D. Manning M., Chen Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.C. (eds). Cambridge University Press, Cambridge, UK and Newyork, USA, pp 996.

Lond, S.P. and Woodward, F.I. (eds), 1988. *Plants and Temperature. Symposia of the Society for Experimental Biology, No. 42*. Cambridge, Company of Biologists for the Society for Experimental Biology.

Pettigrew, W.T., 2008. The effect of higher temperatures on cotton lint yield production and fiber quality. *Crop Sci.* **48**: 278-85.

Reddy, K.R., Reddy, V.R. and Hodges, H.F., 1992. Temperature effects on early season cotton growth and development. *Agron. J.* **84**: 229-37.

Reddy, V.R., Baker, D.N. and Hodges, H.F., 1991a. The effects of temperature on cotton canopy growth, photosynthesis and respiration. *Agron. J.* **83**: 699-704.

Reddy, V.R., Reddy, K.R. and Baker, D.N., 1991b. Temperature effect on growth and development of cotton during the fruiting period. *Agron. J.* **83**: 211-17.

Roussopoulos, D. K., Gerakis, P.A., Gagianas, A.A. and Sficas, A.G., 1978). Autoecology of *Gossypium hirsutum* L. II. Relationship of solar radiation to fruiting, boll maturation and yield. Scientific *Annals, Thessalonoki University* **21** : 49-51.

Roussopoulos, D., Liakatas, A. and Whittington, W.J., 1998. Controlled-temperature effects on cotton growth and development. *J. Agril. Sci,* Cambridge, **130**: 451-62.

Sawan, Z.M., Hanna, L.I., Gad El Karim Gh. A. and Mccuistion W.L., 2002. Relationships between climatic factors and flower and boll production in egyption cotton (*Gossypium barbadense*). *J. Arid Envt.* **52**: 499-516.

Viator, R. P., Nuti. R. C., Edmisten, K. L. and Well, R., 2005. Predicting Cotton Boll Maturation Period Using Degree Days and Other Climatic Factors. *Agron. J.* **97**: 494-99.

Wall, G.W., Amthor, J.S. and Kimball, B.A., 1994. COTCO2: A cotton growth simulation model for global change. *Agril. and Forest Meteorology* **70**: 289-342.

CROP PROTECTION AND BIO SAFETY

Pollinators diversity and their role in pollination in cotton

SUNITA YADAV* AND H. D. KAUSHIK
Project Coordinating Unit, AICRP on Honey Bees and Pollinators, CCS Haryana Agricultural University, Hisar - 125 004
**E-mail : sunitayadav10@rediffmail.com*

Pollination of agricultural crops is an important ecosystem service that enables plants to produce fruits and seeds. Two thirds of the world's 3000 species of agricultural crops require animals for pollination. Animals provide pollination services for more than 75 per cent of all staple crops and for 90 per cent of all the flowering plants of the world. Of the total pollination activities, over 80 per cent is performed by insects and bees contribute nearly 80 per cent of the total insect pollination, and therefore, they are considered the best pollinators (Robinson and Morse, 1989). In India, of the 160 million hectares of the cropped area, more than 55 million is under bee dependent crops. India is endowed with the greatest biodiversity as far as honey bee species are concerned. Out of the eight *Apis* species, six (*A. cerana*, *A. florea*, *A. dorsata*, *A. andreniformis*, *A. laboriosa*, *A. koschevnikovi*) are indigenous India and *A. melllifera* has been introduced into India. A plethora of other bee species including carpenter bees, bumble bees, megachilids, halictids, sphecids, andrenids, syrphids, etc. are also known to occur in the country. But out of all pollinator spp. honey bees are considered as dependent and ideal pollinator due to the following reasons:

Honeybees develop populations, which become capable of generating a large pollinating potential; can be reared easily, managed and immediately made available for pollination; can be shifted to places wherever and whenever needed; their abundance on the crop can easily be manipulated; can pollinate large number of plants and a wide variety of crops; their body is equipped to carry the pollen efficiently; they work constantly on a crop and in a locality where they once start foraging on; they collect pollen/nectar for rearing their brood ; they also produce honey and bee wax for the farmers as an additional source of income; they have wel defined communication system for food searching and gathering.

Most of the pollination studies and managed bee pollination work in India are done on hive bees *i.e.* Indian honey bee (*A. cerana indica*) and Italian honey bee *(A. mellifera)* because they are manageable in any number, season and at any place and show behaviour of floral fidelity/ constancy.

Cotton is an important commercial crop in India and plays a key role in our economy. India is the only country in the world where all four cultivated species of cotton along with their hybrid combinations are grown. Cotton is a primarily self-pollinating as its pollen is relatively large, heavy, sticky and watery and thus dispersion by wind is almost zero (Niles and Feaster, 1984). But it is an opportunistic out-crosser when insect pollinators are present (McGregor, 1976). Natural crossing rates in cotton generally varies between practically zero to 10 per cent (Umbeck *et al.*,, 1991) but higher values(up to 50 per cent or more) were also reported by many authors (Anonymous, 2002; Oosterhuis and Jernstedt, 1999) and these wide differences have generally been ascribed to difference in the effective population of bees which act as pollen vectors (Stephens and Finkner, 1953).The cross pollination rates can also be altered by genotype, preference to own pollen, flower colour, nectar content of the flower, planting systems in the area, population of natural pollinators nectaries and type of sugar within nectar during flowering period. Natural crossing or cross pollination in cotton has received increased attention recently because of possible use of this phenomenon in increasing genetic variability or hybrid vigor and also in commercial production of hybrid cotton seed, using cytoplasmic male sterile genotypes of *Gossypium hirsutum*. Honey bees have long been known to be involved in pollination of cotton and help increasing boll retention, higher boll size, higher number of seeds/boll, lint/boll and other yield parameters. In India, cotton is serving as good honey plant during dearth period because of its longer flowering duration when almost all other crops complete flowering. As a result of reduced insecticide use in *Bt* cotton, beekeepers from Haryana, Punjab, Rajasthan, U.P., M.P. etc have again started keeping their bee hives (*A. mellifera*) in *Bt* cotton. These beekeepers are producing good volume of honey, fetching good market price of their honey, and have not reported any negative impact of *Bt* cotton on the population buildup of the bee colonies.

Pollination mechanism in cotton : The cotton flower is available for cross pollination only on the day the flower opens, with the corolla and staminal column falling off on the second day (Rhodes, 2002). Nectar is secreted by floral nectaries inside the flower and by extra floral nectaries. Cotton plant has four extrafloral nectaries: (a) three nectaries just below the sepals at the union of the three bracts (inner or circumbracteal); (b) three nectaries on the pedicel of each flower just below each epicalyx bract (outer or subbracteal); (c) one nectary on the primary vein near the blade and petiole juncture on leaf. Occasionally, there are two additional nectaries, one on a vein on either side of the primary vein (foliar/leaf nectaries) (d) minute unipapillate nectaries on the flower peduncles and young leaf petioles. These unipapillate nectaries are rarely visited by pollinating insects and, contribute nothing to pollination. The bracteal nectaries are main source of nectar for honey bees and begin to secrete 5-6 days before anthesis and continue to secrete for 2 to 3 weeks after flowering. During good honey flow period the bees are collecting nectar from the bracteal nectaries of cotton only. Some upland cotton plants may not have all of these nectaries. The floral nectary consists of a ring of closely aggregated secretory hairs on the inner side of the calyx. They secrete only on the day of anthesis. The nectar reaches its maximum accumulation by mid afternoon, the amount depending upon climatic factors, soil fertility, water, and cultivar involved and ceases when the petal color begins to change, an indication, according to that pollination has occurred. Honey bees prefer to visit extrafloral nectaries therefore to ensure visit to floral nectaries increase hive densities in order to saturate the target area with pollinators (McGregor, 1959).

Pollen dispersal studies in cotton have consistently demonstrated that when outcrossing occurs, it is localized around the pollen source and decreases significantly with the distance (Chauhan *et al.,*, 1983). Therefore uniform distribution of bee hives is required. There are approximately 10,000 pollen grains in a flower. Under normal conditions, the pollen grains are viable upto 24 h and thereafter lose potency and fail to affect fertilization. About 50 ovules must be fertilized if a full complement of seeds is to be produced; therefore, at least 50 viable pollen grains must contact the stigma (McGregor, 1976). Insect pollination, in particular honey bee pollination, can aid in this process and result in higher yields and better quality lint (Rhodes, 2002).

Pollinator diversity and their relative abundance in cotton : Cotton plant is pollinated by an array of pollinating insects. The main pollinating insects differ from region to region due to distribution of insects and ecological conditions. It was reported that cotton is a good source of nectar for bees. Many bee species have been reported visiting cotton flowers *e.g.* honey bees (*A. mellifera*, *A. dorsata*, *A. florea*, *A. cerana*), bumble bees (*Bombus* spp.), carpenter bees (*Xylocopa* spp.) and melissodes bees *(Melissodes* spp.) (Moffett *et al.,*, 1975, McGregor, 1976; Naik *et al.,*, 2011). Other Hymenopteran insects that sometimes visit cotton blossoms include *Anthophora* spp., *Elis thoracica*, *Halictus* spp., *Megachile* spp., *Melitoma euglossoides* and *Nomia* spp. Numerous insects from orders Diptera, Coleoptera, Hemiptera and Lepidoptera also accidently or purposely visit cotton flowers but they are not effective as pollinator.

Many authors have reported bumble bees, melissodes bees and other wild bees as more efficient or primary pollinator of cotton blooms as compared to honey bees as they prefer floral nectaries and touch both stamen and stigma during foraging. Whereas all honey bees forage cotton flowers for nectar, prefer extra floral nectaries and generally do not carry pollens and when bees collect pollen do not carry them to long distances because they clean pollen from their bodies that are getting heavy (Waller *et al.,* 1985). Some studies have shown that hand pollination was better than insect or bee pollination for boll setting and seed quality. The reasons attributed to this are shift in visit of honey bees from cotton to other more rewarding crops in the area, higher gossypol content in cotton which may affect the foraging behaviour and the heavy pesticidal schedule used for the control of pests. Among various sugar components of the cotton nectar especially in CMS flowers, only sucrose showed highly positive and significant correlation with visiting honey bee frequency (Mofett *et al.,* 1975). Thus breeding lines with higher sucrose content are needed for increasing bee visits which in turn can increase the boll setting/plant and decrease the number of aborted seed, resulting in higher yield of hybrid seed. Pairing of seed parents based on measured compatibility of pollinator foraging cues *viz.*, nectar, aroma, colour, flower morphometrics etc. has also been suggested. Although not an ideal pollinator of cotton but due to its abundance the honey bees (*A. mellifera* and *A. cerana*) have been documented as the most effective pollinator of cotton plants by several authors (Moffett *et al.,*, 1975; Rhodes, 2002; Naik *et al.,,* 2011) and has been most studied. In addition to this, honey bees are the only pollinator that can be manipulated on cotton. These work on cotton from 0700 to 2000 h daily but are most abundant near mid day when the amount and concentration of nectar are greatest, and perform little pollination in the afternoon. The behaviour of honey bees on this crop is such that they seldom touch the stigmas on leaving the flower so it favours cross pollination (Tanda and Goyal, 1979).

Sidhu and Singh (1962) observed 41 species of 23 families of seven orders visiting cotton. However, many of the insect visitors did not visit the floral nectaries and many of those that did so failed to touch the flowers' sexual parts. It was reported that an average of 47 insects visited each cotton flower per day. The honey bees, *A. dorsata, A. cerana* and *A. florea* were important pollinators and visited more flowers per minute and per trip than the wasps, *Scolia avreipennis* and *E. thoracica,* but they are more abundant and have greater tendency to visit the flowers in inclement weather.

Moffet *et al.,* (1976) reported that out of total Hymenopteran visits upto 62 per cent were by wild bees as compared to 38 per cent by honey bees. Most common wild bees visited were *Mellissodes* sp. *Agapostemon* sp. *Halictus* sp., *Diadasia* sp. *Bombus* sp. and *Xylocopa* sp.

Tanda (1983) reported that on an average 45.45 honey bees (*A. mellifera, A. cerana*, *A. dorsata* and. *A. florea*), 31.16 wild bees, 17.33 scolids and 55.00 butterflies visited cotton flowers at Ludhiana. Whereas, 43.25 honey bees, 20.66 scolids and 17.00 butterflies visited the cotton flowers at Nakodar/20 observations over 100 flowers.

Loper and Davis (1985) reported non-honeybee floral visitors of cotton as *Trigona nigerima* (Melliponidae), *Xylocopa* spp., *Melaitoma euglossoides*, *Megachile* sp. (Megachilidae), *Agapostemon* sp., *Neocoryanura* sp. (Halictidae), *Scolia* spp. (Scolidae) and an unidentified wasp belonging to family Eumenidae.

Berger *et al.,* (1988) found that among bumble bees visiting cotton blooms, *Bumbus pennsylvanicus* constituted 90 per cent and other species like *B. freternus*, *B. morrisoni,* collectively constituted rest of 10 per cent.

El-Sarrag *et al.,* (1993) reported that among different Hymenopteran pollinators visited on cotton , the most dominant species was *A. mellifera* (67.80 %) followed by *Bombus* sp. (14.70 %). Hymenopteran visitors constituted 56 per cent of the total insect visitors on cotton flowers. Rao *et al.,* (1996) reported that *Apis* spp. and solitary bees were major visitor of the cotton flowers. Pollinating insects that visited A and B line flowers of cotton were *A. dorsata*, *A cerana*, *A. florea* and solitary bees. *Trigona irridipennis* visited only for floral nectar.

Nachappa (2004) reported that *Bt* cotton flowers were visited by *A. mellifera*, *A. cerana*, *A. dorsata* and these collectively constituted about 75 per cent of total pollinators visited. The other pollinators visited were *Xylocopa* sp., *Megachile* sp., *Megachile lanata*, *Papilio demoleus*, *Hemimeris* sp., *Telicota* sp., *Catopsilo pyranthae*. This pollinator fauna did not vary much in *Bt* cotton and non *Bt* cotton.

Ganapathi (2005) reported that *Bt* cotton flowers were visited by as many as 12 pollinator species at Karnataka and eight belongs to Hymenoptera order. The pollinators visited were *A. dorsata, A. cerana, A. florae, Megachile lanata, Megachile* sp., *Xylocopa* sp., *Pithitis* sp., *Papilio* sp., *Catapsila pyranthae, Telicota* sp. and *Dannus chrysiphus.* Among these *Apis* spp. were the dominant visitors.

A total of 14 insect visitors belonging to order Hymenoptera were found visiting the cotton blossoms at Bangalore (Anonymous, 2008). The species were *A. cerana, A. florae, A. dorsata, Megachile lanata, M. disjuncta, M. carbonaria, M. anthracina, M. hera, Trigona iridipenis, Xylocopa latipes, X. aestuans, X. amethystine, Certaina binghami* and *Lessioglossum sp.* Eight species of pollinators were observed foraging on *Bt* cotton during ful, bloom at Hisar *viz.*, *A. dorsata, A. mellifera, A. cerana, Polistes hebareus, Vespa orientalis., Myllocerus undecimpustulatus*, *Mylabris phalerata* , *Pieris brassicae* Out of these, *A. dorsata, A. mellifera* and *A. cerana* were recorded foraging on both nectar and pollen. All the three *Apis* spp. were top workers. *Polistes* sp visited both flower and extra floral nectaries on leaf for nectar collection. (Gulati *et al.,*, 2009).

Naik *et al.,*, (2011) found eight species of pollinators foraging on *Bt* cotton blossoms at Belgum, Karnataka. Of these, seven species belonging to the order Hymenoptera (*A. dorsata, A. cerana, A. florea, Xylocopa* sp., *Pithitis* sp., *Sceliphron* sp. , *Polistes* sp.) formed the dominant group followed by Diptera *(Eristalins obliquus*). Among honey bees, *A. cerana* was the most dominant pollinator (35.21%) followed by *A. florea* (31.22%) and by *A. dorsata* (24.53%).

Effect of bee visitation on yield parameters of cotton : It is reported by many authors that bee pollination in cotton often increases boll set, seeds/boll, seed weight/boll, boll weight, total cotton yield, uniformity of boll ripening and decreases shedding of bolls. Increases in yield as a result of cross pollination may be due to falling of increased numbers of pollen over the entire surface of the stigma (within a flower, *pollen* laden anthers contact only the base of the stigma) and increased rate of pollen tube formation when pollen grains from other flowers fall on stigma. These factors may result in higher fertilization of ovules, resulting in higher levels of fruit setting and seed production. The factors that influence the cross pollination in cotton and subsequently affect the yield are a) the number of insect pollinators present in relation to the number of cotton flowers and b) the flowering habits of the varieties grown c) the abundance of unlike –pollen d) location of the fields in relation to insect habitats e) flowering periods of other plants attractive to insect pollinators f) distance between unlike varieties g) topography and barrier crops and h) by other environmental, climatic and biotic factors.

In India, Mahadevan and Chandey (1959) obtained 23 to 24 per cent and 40 to 53 per cent more yield in MU 1 and MCV 2 cultivars, respectively in open plots than in plots caged to exclude. Sidhu and Singh (1962), also in India, compared production in cages with *A. cerana indica* and *A. florea* and in cages without pollinators and obtained an increase of 17.45 to 18.98 percent in favour of the pollinating insects. The increase was attributed to more and larger bolls. Similar results were also reported on Asiatic cotton by Tanda (1983, 1984).

McGregor (1976) discussed several studies that demonstrated the number of viable seed per cotton boll could be consistently increased with the introduction of higher populations of bees suitable as pollinators of cotton. Later studies where hybrids were produced verified that insect pollinators have significant potential for improving pollination frequencies and increasing pollen transfer across short distances (Waller *et al.,*, 1985).

Tanda and Goyal (1979) obtained 31 to 33 per cent more matured bolls in cotton plants caged with *A. mellifera* and *A. cerana* compared to control and noticed increased boll retention (56%-60%) in bee pollinated crop than self pollinated flowers (28% - 32%). Further, they reported higher seed cotton yield per boll (7.9%-8.2%), higher yield of cotton per plant (349.5-354.2 g) in the crop caged with bees as compared to crop caged without bees (control).

Waller *et al.,* (1985) reported that male sterile produced significantly more seeds per boll, more lint per boll (1.5 g), average number of seeds

Table 1. Systematic position of various pollinators visiting cotton blooms in India

S. No.	Order	Family	Pollinator species	
			Scientific name	Common name
1	Hymenoptera	Apidae	*Apis mellifera* Linnaeus	Italian honey bee
			Apis cerana Fabricius	Indian honeybee
			Apis florea Fabricius	Little honeybee
			Apis dorsata Fabricius	Rock bee
			Trigona iridipenis Smith	Stingless bee
			Ceratina binghami Cockerell	Small carpenter bee
			Xylocopa latipes (Drury)	
			*Xylocopa aestuans (*Linnaeus)	
			Xylocopa amethystine Fabricius	
			Xylocopa pubescens Spinola	Large carpenter bee
		Megachilidae	*Megachile lanata* (Fabricius)	
			Megachile disjuncta (Fabricius)	
			Megachile carbonaria Smith	
			Megachile anthracina Smith	
			Megachile hera Bingham	Leaf cutter bee
		Halictidae	*Lessioglossum* sp	
			Halictus sp.	
			Nomia sp.	Sweat bees
		Anthophoridae	*Pithitis* sp.	Digger bee
		Sphecidae	*Sceliphron* sp.	Thread waisted wasp
		Andrenidae	*Andrena* spp.	Mining bees
		Scoliidae	*Scolia* spp	Scoliid wasp
			Campsomeris sp.	
			Elis spp.	
		Vespidae	*Polistes hebraeus* Fabricius	Yellow wasp
			Vespa orientalis Linnaeus	Wasp
2	Diptera	Syrphidae	*Eristalis* spp.	Hover flies
		Muscidae	*Musca* spp.	House flies
		Trypetidae	*Dacus* sp.	Fruit flies
3	Coleoptera	Curculionidae	*Myllocerus undecimpustulatus* Faust	Ash weevil
		Meloidae	*Mylabris phalerata* Pallas	Blister beetle
		Coccinellidae	*Cocccinella septempunctata* Linnaeus	
			Menochilus sp.	
			Brumus sp.	Lady bird beetles
4	Lepidoptera	Pieridae	*Pieris brassicae* Linnaeus	Cabbage Butterfly
		Papilionidae	*Papilio* sp.	Lemon Butterfly
		Hesperidae	*Telicota* sp	skipper Butterfly
		Nymphalidae	*Dannus chrysiphus* Linnaeus	Monarch butterfly

per boll (23.6) in plots with bee colonies, but this trend was not seen in the plots without bees.

Berger *et al.,* (1988) noticed that seeds/ boll on male sterile and male fertile were much closer in the crop caged with bumble bees (13.7 and 18.7, respectively) than in the crop caged with honey bees (8.2 Vs 29.6).

Significant increase in the total number of bolls harvested (11.1%), total mass of boll (16.5%), total lint mass (15.8%), total seed mass (19.7%) and total number of seeds per sample were obtained from plots receiving the highest number of bee visits compared with plots receiving lowest number of bee visits. Non-significant increase was observed for mass of 100-seeds (3.8%), average seed weight (3.9%), average number of seeds per boll (4.7%) and average weight of lint per boll (Rhodes, 2002).

Mohapatra *et al.,* (2010) reported 18 per cent increased seed yield by installation of 3-5 bee colonies of *A. cerana* per acre.

Saeed *et.al.*, (2012) evaluated the

potential of bumble bees (*Bombus terrestris*) as cotton pollinator and reported that the maximum number of seeds per boll was produced as a result of bumble bee pollination in green house on cotton varieties MNH 552 and MNH 633 followed by hand pollination and open pollination.

Pollination Recommendations : Little is known about recommendations of managed honey bee pollination in cotton. As honey bees prefer to work the extrafloral rather than the floral nectaries, it is sometimes recommended to saturate the area with honey bee colonies to ensure visit to floral nectaries. Rhodes (2002) and Moffet *et al.,* (1975) both recommend the use of honey bees on cotton crops but gave no indication as to the density of hives required for adequate pollination. Rhodes (2002) used an apiary of 30 hives on 47 ha plot of irrigated cotton (0.6 hives/ha) which showed significant improvements in quality and quantity of cotton lint and seeds and he recommended 0.6 hives/ha. As honey bees prefer to visit the extrafloral nectaries, therefore, it is essential to increase the hive densities to saturate the area with honey bees to ensure their visit to floral nectaries. But the colonies/ac ratio is doubtlessly influenced by the acreage involved, competing crops, and colony strength. McGregor (1959) suggested the bee: flower ratio and on an average 10 bees per 100 cotton flowers are sufficient to practically coat all stigma with pollen.

CONCLUSION

Bee pollinators play a key role in enhancing the cotton yield qualitatively as well as quantitatively. In spite of vallinations such studies there has been relatively little interest in enhancing cotton yield further by exploring bee pollinators except in hybrid seed production programmes. As cotton is heavily attacked by pests and during the flowering period of two months insecticides are regularly applied for the control of many pests. Foraging bees are killed by these sprays and ultimately the colonies die. The application of insecticides should be coordinated in such a way so that bee mortality can be minimized by adopting the important points such as i) use of insecticides during flowering period should be reduced so that bees can frequently visit to this crop ii) insecticides should be applied during afternoon h to reduce hazards to bees as nectar in flowers and extrafloral nectaries is exhausted by mid day and very few bees are foraging in the afternoon iii) during aerial spraying of insecticides, colonies should be located away from the flight path of the plane iv) farmers/stakeholders and policy-makers should be educated and motivated about the contribution of pollinators and their role in pollination of cotton crop in order to protect and conserve these pollinators. With the introduction of transgenic *Bt* cotton there is drastic reduction in insecticide use on cotton. It may now be possible to establish and maintain populations of pollinators, especially honey bees, in many cotton producing areas that are large enough to significantly improve cotton production. This could benefit cotton producers as well as beekeepers because it is an excellent source of nectar for honey production and in some areas, cotton crop is an important late-season nectar source when other sources are scarce.

REFERENCES

Anonymous, 2002. The biology and ecology of cotton (*Gossypium hirsutum*) in Australia.' (Office of the Gene Technology Regulator, Canberra, Australia)

Anonymous, 2008. Annual report of All India Coordinated Research Project on Honey Bees and Pollinators.

Berger, L. A., Vaissiere, B. E., Moffett, J. O. and Merritt, S. J. 1988. *Bombus* spp. (Hymenoptera: Apidae) as pollinators of male-sterile upland cotton on the Texas High Plains. *Environ. Entomol.*, **17** : 789-94.

Chauhan, D. S., Singh, P., Singh, P. 1983. Isolation distance in upland cotton under Nagpur conditions. *Cotton Dev.*, **13**: 23.

El-Sarrag, M. S. A., Ahmed, H. M. and Siddig, M. A. 1993. Insect of certain crops in the Sudan and the effect of pollination on seed yield and quality. *J. King Saud Univ. Agric. Sci.*, **5** : 253-62.

Free, J. B. 1970. *Insect Pollination of Crops*. Academic Press, London, 544 p.

Ganapathi, K. 2005. Impact of bee attractants on bee activity and yield parameters of *Bt* cotton. *M. Sc. (Agri.) Thesis,* Univ. Agric. Sci., Dharwad.

Grout, R. A. 1955. Honey bees make hybrid cotton possible. *Am. Bee J.*, **95**: 10-11.

Gulati, R., Sharma, S. K. and Asha. 2009. Insect visitors and nectar sugar concentration of *Bt* cotton flowers at Hisar, India. In: *National Symposium on Bt-Cotton: Opportunities and Prospects* held on November 17-19, 2009 at CICR, Nagpur and organized by CRDA, Hisar, Paper No. 3.78, p. 110.

Loper, G. M. and Davis, D. D. 1985. Disparity of cotton pollen dispersal by honey bees visiting upland and Pima pollen parents. *Crop Sci.*, **25**: 585-89.

Mahadevan, V. and Chandy, K. C. 1959. Preliminary studies on the increase in cotton yield due to honey bee pollination. *Madras Agri. J.*, **46**: 23-26.

Mcgregor, S. E. 1959. Cotton-flower visitation and po1len distribution by honey bees. *Science* **129**: 97-98.

McGregor, S. E. 1976. Cotton. In: *Insect pollination of cultivated crop plants*, Ed. Agricultural hand book No. 496. USDA, Agricultural Research Service, Washington, D. C., pp 171-90.

Moffett, J. O., Stith, L. S., Burkhart, C. C. and Shipman, C.W. 1975. Honey bee visits to cotton flowers. *Environ. Entomol.*, **4**: 203-06.

Mohapatra, L. N., Sontakke, B. K. and Ranasingh, N. 2010. Enhancement of crop production through bee pollination. *Orissa rev.,* pp 44-47

Nachappa, M. S. 2004. Effect of *Bt* cotton on the performance of *Apis mellifera* L. and *Apis cerana* F. colonies. *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad (India).

Naik, A., Viraktamath, S., Vastrad, A. S., Udikeri, S. S. and Megeri, S. N. 2011. Pollinator fauna and foraging activity of honey bees in two genotypes of *Bt* cotton. *Karnataka J. Agric. Sci.* **24**(3): 400-03

Niles, G. A. and Feaster, C. V. 1984. Breeding. In: *Cotton* (Eds, R. J. Kohel and C. F. Lewis). American Society of Agronomy, Madison, Wis. Pp. 201–31

Oosterhuis, D. M. and Jernstedt, J. 1999. Morphology and anatomy of the cotton plant. In: *Cotton: Origin, History, Technology and Production* (Eds. W. C. Smith, J. T. Cothren). John Wiley and Sons, Inc., New York, pp 175-206.

Rao, G. M., Nadre, K. R. and Suryanarayana, M. C. 1996. Studies on the utility of honey bees on production of foundation seed of cotton cv . NCMHH 20. *Indian Bee J.*, **58**:13-15.

Rhodes, J. 2002. Cotton pollination by honey bees. *Aust. J. Exp. Agr.*, **42**: 513-18

Robinson, W. E. and Morse, R. A. 1989. The value of honeybees as pollinators of US crops. *Am. Bee J.*, **129** (1): 477-87.

Saeed, S., Sajjad, A. and Kwon, Y. J. 2012. Bumble bees (*Bombus terrestris*) can be the efficient pollinators of cotton crop. *Pak. Entomologist,* **34** (1): 17-20

Sidhu, A. S. and Singh, S. 1962. Role of honey bees in cotton production. *Indian Cotton Grow. Rev.*, **16**: 18-23.

Simpson, D. M. and Duncan, E. N. 1956. Cotton pollen dispersal by insects. *Agron. J.*, **48**: 305 - 08.

Stephens, S. G. and Finkner, M. D. 1953. Natural crossing in cotton. *Econ. Bot.*, **7**(3): 257 - 69.

Tanda, A. S. 1983. Assessing the role of honey bees in a field of Asiatic cotton (*Gossypium arboreum* L.). *Am. Bee J.*, **123**: 593-94

Tanda, A. S. 1984. Bee pollination increases yield of 2 interplanted varieties of Asiatic cotton (*Gossypium arboreum* L.). *Am. Bee J.*, **124**: 539-40.

Tanda, A. S. and Goyal, N. P. 1979. Insect pollination in Asiatic cotton (*Gossypium arboreum*). *J. Apic. Res.*, **18**(1): 64-72.

Umbeck, P. F., Barton, K. A., Nordheim, E. V., McCarty, J. C., Parrott,W. L. and J. N. Jenkins. 1991. Degree of pollen dispersal by insects from a field test of genetically transformed cotton. *J. Econ. Entomo.,***84**:1943–50

Waller, G. D., Moffet, J. O., Loper, G. M., Martin, J. H. 1985. Evaluation of honey bees foraging activity and pollination efficacy for male-sterile cotton. *Crop Sci.*, **215**:211-14

Proceedings on "Global Cotton Production Technologies *vis-a-vis* Climate Change" 204-208

Evaluation of popular *Bt* and non *Bt* transgenic cotton hybrids against major pests

A.V. KOLHE*, U.P. BARKHADE, P.N. ZADE AND B.R. PATIL
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola - 444 104
**E-mail : avkolhe@gmail.com*

Abstract : Popular *Bt* transgenic hybrids (RCH 2 BGI , Bunny BGI and KDCH 9632 BG I) along with their non *Bt* counterpart, conventional hybrid (PKV Hy-2) and variety (PKV Rajat), as a local check were evaluated against major pests under unprotected and rainfed condition for 3 consecutive years (2008-2009 to 2010-2011) at All India Coordinated Cotton Improvement Project, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The results revealed that there were no significant differences amongst *Bt* transgenic hybrids and its non *Bt* counterpart as regards major sucking pests and predators (Leady bird beetle adult and grubs, chrysopa larvae, spiders and syrphid fly larvae). Lowest leaf hoppers population was recorded in PKV Hy 2 and PKV Rajat as compared to rest of the hybrids tested indicating tolerant reaction to leaf hopperss. Highest population of leaf hopperss and lowest count of thrips and white flies was recorded in RCH 2 *Bt* and non *Bt*. Loculi damage due to bollworm complex at harvest in *Bt* cotton hybrids was significantly lower (1.46 to 2.32 %) than non *Bt* hybrids tested (5.68 to 12.66 %).

As regards yield parameters, plant stand was uniform. Sympodial branches and height of plants was statistically equal in all the hybrids tested, except, RCH 2 *Bt* and non *Bt*. Highest bolls/plant was noticed in PKV Hy 2 followed by PKV Rajat , Bunny *Bt* and non *Bt*. Highest seed cotton yield was obtained from PKV Hy 2 and being equal to Bunny *Bt* and its non *Bt*. Under unprotected condition, there is increase of 33.85, 11.47 and 7.04 per cent seed cotton yield in *Bt* transgenic hybrids *viz*., RCH 2, KDCH 9632 and Bunny over their non *Bt* counterpart, respectively

Key words : Bollworms, *Bt* cotton, sucking pests

Cotton is important cash crop of India often succumb to the various pests menaces. It includes broadly sucking pests like, leaf hoppers, *Amrasca biguttulla biguttulla* (Ishida), thrips (*Thrips tabaci*), and white fly (*Bemisia tabaci*) and bollworms like american bollworm, Helicoverpa armigera Hubner, spotted bollworm, *Earias vitella* Fabricius and pink bollworm, *Pectinophora gossypiella* Saunders. Unprotected crop lead to 20 to 80 % yield loss due to various pests. In conventional cotton, bollworms alone can cause yield losses from 30 to 80 per cent, however, in *Bt* cotton hybrids losses reduced to negligible. The sucking pests can cause yield losses of 20 to 40 per cent.

With the introduction of *Bt* cotton hybrids since 2002, the pest scenario changed, bollworms attained secondary pest status and sucking pests remains as such. Moreover, sucking pests may aggravated due to large scale use of high yielding *Bt* hybrids including HXB hybrids, replacement of conventional varieties and hybrids having high adaptability, intensive cultivation, lack of crop rotation and intercropping, changes in planting and pesticides use pattern etc.

Bt cotton hybrids as such are highly input intensive and relatively more susceptible to the pests. Now a day's introduction of several new *Bt* cotton hybrids which are highly susceptible to pests resulted in increase of damage of sucking pests like leaf hoppers, thrips, white fly, mealy bug and mirid bugs. Similarly, due to large scale use of neonicotinoids as seed dressers against sucking pests, the issue of resistance development in the target pests has emerged. The indiscriminate use of chemical insecticides through foliar sprays is also a major concern. Due to effectiveness of neonicotinoids (imidacloprid 17.8 SL, acetamiprid 20 SP, thiamethoxam 25 WG), they are largely used against sucking pests followed by organophosphates (dimethoate 30 EC and monocrotophos 36 SL). Recent field study showed that repeated use of these chemicals caused resurgence in major sucking insect pests (Gawande, 2012)

Bt cotton offered full protection against bollworms, however, variability in Cry 1 Ac toxin in plant parts, with the age of crop and agronomic condition of plant, when it decreases below a level of protection, often leads to bollworm damage. Due to rampant and continuous use of single gene *Bt* hybrids by ignoring planting of refuge may also leads to development of resistance in bollworms. There are reports of 2 to 15 per cent damage of bollworms on *Bt* cotton from different parts of the cotton growing areas of India (Sharma and Pampapathy, 2006 and Kolhe *et al.*, 2009 and Gujar *et al.*, 2011). Dhara Jyoti, 2009 reported overall corresponding increasing trend in the mean population of sucking and pink bollworm incidence on *Bt* and non*Bt* hybrids.

Therefore, this study was conducted to evaluate the popular *Bt* cotton hybrids, their non *Bt* counterparts and local conventional check hybrids against major pests.

MATERIALS AND METHODS

The field experiment was conducted at All India Coordinated Cotton Improvement Project, Dr Panjabrao Deshmukh Krishi Vidyapeeth , Akola for three consecutive years (*kharif,* 2008, 2009 and 2010) under rainfed situation in randomozed block design with eight treatments and three replications. All the crop production practices were followed as per university recommendations, except, plant protection. The experimental treatments were completely unprotected throught the crop season. Every year the crop was sown in 1st week of July at a spacing of 90 cm x 60 cm with gross plot size of 6.30/ 6.00 cm x 4.80/ 5.40 cm.

Observations on major sucking pests were recorded at weekly interval by randomly selecting 5 plants from each treatment plot. Population of sucking pests (aphids, leaf hopperss, thrips and white flies on 3 leaves per plant selected from top, middle and lower portion of the plant. Population of predators (*Chrysopa* eggs and larvae, Lady bird beetle larvae and adults and spiders) on whole plant was also recorded. Three years data was averaged and subjected to pooled analysis.

RESULTS AND DISCUSSION

Sucking pests : As regards aphids there were no significant differences noticed amongst various cotton hybrids evaluated. These findings are in support with the study conducted by Dhara Jyothi *et al.*, (2009) who reported equal population of aphids on *Bt* cotton and non*Bt* counterparts.

Minimum leaf hoppers population was recorded in PKV Hy 2 (1.41/leaf) and being equal with PKV Rajat. Bunny *Bt*, KDCH 9632 *Bt* and their non *Bt* counterpart were next to record leaf hopper population. RCH 2 *Bt* and its non *Bt* being *on par* and recorded highest leaf hoppers population. The leaf hoppers contribute highest share of yield loss amongst the sucking pests. Their incidence is relative to the pubescence of genotype (Parnell *et al.,* 1949). PKV Hy 2 and PKV Rajat having medium to high hairs leaf density proved to be tolerant registering lowest leaf hopper population. The leaf hopper population increases with the decrease of hairiness of the genotypes indicating high susceptibility of RCH 2 *Bt* and non *Bt* counterpart, which registered highest leaf hopper population. Surulivelu *et al.,* (2009) reported higher population of Leaf hoper population on RCH 2 *Bt* than Bunny *Bt*.

Minimum thrips population was noticed in RCH-2 *Bt* (1.51/leaf) and being *on par* with non *Bt* counterpart. KDCH 9632 *Bt*, Bunny *Bt* and their non *Bt* counterparts, PKV Hy 2 and PKV Rajat being *on par* and ranked second. Thrips population was lowest in RCH 2 *Bt* and non *Bt* counterpart, it seems to be the phenomenon of competitive displacement, since, the RCH 2 *Bt* and non *Bt* counterpart reported highest leaf hoppers, the thrips may not multiply at the same time. Similar findings as regards thrips numbers were reported by Anonymous (2010). Dhara Jyothi *et al.*, (2009) reported equal population of whiteflies on *Bt* cotton and non *Bt* counterparts.

RCH 2 *Bt*, Bunny *Bt* and their non *Bt* counterpart were lowest to record whitefly adult population followed by KDCH 9632 *Bt* and being *on par* with its non *Bt*. Highest population of whiteflies was recorded in PKV Hy 2 and PKV Rajat being *on par*. The whiteflies incidence again associated with the leaf hair density of the genotypes. Low leaf hair density impart resistance against white flies (Surulivelu,2005). These results are in the agreement of study

Table 1. Evaluation of cotton hybrids under unprotected condition – Average population of sucking pests, predators, bollworm damage at harvest, yield parameters and seed cotton yield

Sr.	Treatments	Sucking pests/leaf				Predator/ plant	Bollworm damage by bollworm complex at harvest (%)			Plant stand/ plot	Yield parameters Number/plant			Height/ plant (cm)	Seed cotton yield (kg/ ha)
		Aphids	Leaf hoppers	Thrips	White fly		Open boll damage due to BWC	Loculi damage due to BWC	Loculi damage due to PBW		Mono-podia	Simp-odia	Bolls		
1	RCH 2 *Bt*	13.66	2.89	1.51	0.71	0.94	3.4	1.46	0.24	30.67	2.37	17.4	10.73	50.27	452.42
		-3.69	-1.7	-1.23	-0.84	-0.97	-10.54	-6.9	-0.85						
2	Bunny *Bt*	15.81	2.08	2.06	0.82	1.06	7.8	2.32	0.76	29.83	3.03	22.73	17.83	67.07	851.64
		-3.97	-1.44	-1.44	-0.9	-1.03	-16.15	-8.63	-1.1						
3	KDCH 9632 non *Bt*	14.05	2.07	2.04	0.9	1.08	34.39	12.66	5.44	30.83	3.47	20.3	13.37	68.83	655.88
		-3.75	-1.44	-1.43	-0.95	-1.04	-35.89	-20.83	-2.44						
4	PKV Rajat	11.73	1.49	2	1.08	0.96	28.81	11.12	3.72	27.83	2.97	21.2	19.63	70.53	672.87
		-3.42	-1.22	-1.41	-1.04	-0.98	-32.45	-19.47	-2.05						
5	RCH 2 non *Bt*	15.5	2.89	1.51	0.69	0.97	22.53	10.89	4.87	26.5	2.9	18.27	10.12	53.83	299.3
		-3.94	-1.7	-1.23	-0.83	-0.98	-28.29	-19.19	-2.31						
6	KDCH 9632 *Bt*	13.74	2.04	1.85	0.93	1.04	4.16	1.72	0.24	29.5	3.07	20.83	16.23	66.73	740.55
		-3.71	-1.43	-1.36	-0.96	-1.02	-11.71	-7.47	-0.86						
7	PKV Hy 2	15.49	1.41	1.95	1.23	0.96	20.66	7.54	2.34	28.67	3.37	21.63	22.2	71.83	910.84
		-3.93	-1.19	-1.39	-1.11	-0.98	-26.94	-15.86	-1.68						
8	Bunny non *Bt*	14.61	1.94	1.97	0.84	1.06	15.8	5.68	2.37	30.5	2.6	20.33	18.57	66.43	791.82
		-3.78	-1.39	-1.4	-0.91	-1.03	-23.4	-13.74	-1.68						
	C.D. at (p=0.05)	-	0.089	0.09	0.084	-	3.795	2.758	0.304	-	0.522	2.953	2.737	7.759	118.848
	C.V. at (p=0.05)	7.03	3.53	3.77	5.06	6.18	9.35	11.24	10.72	7.26	10.03	8.29	9.72	6.88	10.1

* square root values, ** Arc sine transformation

conducted by Anonymous (2010).

Predators : There were no significant differences among the various *Bt* and non *Bt* hybrids tested as regards the predator population. The population was in the range of 0.94 to 1.08 per plant indicating no deleterious effects of *Bt* hybrids which confirm safety to the predatory fauna. Similarly, Biradar and Vennila (2008) reported the abundance of predatory fauna of target pests on *Bt* and non *Bt* cotton hybrids.

Bollworm damage at harvest (2009-2010 to 2010-2011) : Open boll and loculi damage (3.40 to 7.80 and 1.46 to 2.32 %) due to bollworm complex in all *Bt* hybrids tested was significantly lower than non *Bt* hybrids (15.80 to 34.39 and 5.68 to 12.66 %). Similarly, loculi damage (0.24 to 0.76 %) due to pink bollworm was also significantly lower in all *Bt* hybrids than non *Bt* hybrids evaluated (2.34 to 5.44 %). These results are in line with studies conducted by Sharma and Pampapathy (2006) and Kolhe *et al.*, (2009) and Gujar *et al.*, (2011).

Yield parameters (2009-2010 to 2010-2011) : The plant stand was uniform in experimentation in various cotton hybrids. Highest monopodia (No/PL) was recorded in KDCH- 9632 *Bt* and non *Bt*, Bunny *Bt*, PKV Hy 2 and PKV Rajat. Height and sympodial branches were on par in all genotypes evaluated, except, RCH-2 *Bt* and non *Bt* counterpart. Numbers of bolls were highest in PKV Hy 2 but *on par* with PKV Rajat. Bunny *Bt*, non *Bt* and KDCH 9632 *Bt* were on par and ranked second in respect of boll retention followed by statistically equal hybrids, KDCH 9632 non *Bt* and RCH 2 *Bt*. Lowest monopodia, sympodia/Plant and height was recorded in RCH 2 *Bt* and its non *Bt*. Bunny non *Bt* also equal and recorded least monopodial branches. Lowest bolls were recorded in RCH-2 non *Bt*. Though, Bunny *Bt* and non *Bt* counterpart *on par* with PKV Rajat as regards retention of bolls, but because of big bolls, both the genotypes surpass PKV Rajat and stood second after PKV Hy 2 as regards yield of seed cotton.

In present study, *Bt* hybrids (KDCH 9632 and RCH 2) having higher bolls as compared to non *Bt* counterparts. Similar findings of 16.7 per cent higher bolls and 10 per cent higher boll weight was recorded in *Bt* hybrids as compared to non *Bt* was reported by Patil *et al.,* (2009)

Seed cotton yield: Highest seed cotton yield (910.84 kg/ha) was obtained in PKV Hy-2 and it was *on par* with Bunny *Bt* (851.64 kg/ha) and Bunny non *Bt* (791.82 kg/ha). KDCH 9632 *Bt* ranked 2nd and being *on par* with PKV Rajat and KDCH 9632 non *Bt*. Lowest yield was obtained from RCH 2 non *Bt* followed by RCH 2 *Bt*. Under unprotected condition, there is increase of 33.85, 11.47 and 7.04 per cent seed cotton yield in *Bt* transgenic hybrids *viz.*, RCH 2, KDCH 9632 and Bunny over their non *Bt* counterpart, respectively.

These genotypes were grown with recommended agronomic practices, except, plant protection. Hence, in absence of plant protection which genotype performs better in respect of yield will have higher sustainability against major pests. During the period of study (*kharif*, 2009 and 2010) the average loculi damage due to bollworm complex at harvest in all genotypes, except, KDCH 9632 non *Bt*, PKV Rajat and RCH 2 non *Bt* were below 10 per cent. As per the standard protocol by AICCIP for screening of genotypes against bollworms, these genotypes (> 10 % damage) belongs to the category of “Bollworm tolerant”. The remaining genotypes KDCH 9632 non *Bt*, PKV Rajat and RCH 2 non *Bt* which recorded marginally higher Loculi damage (*i.e.* 12.66, 11.12, 10.89 per cent, respectively) belongs to “Bollworm tolerant” catagory. The bollworm damage during these years was at medium to low level, therefore, which may not have much impact on yield loss. Similarly, the genotypes which are unprotected for sucking pests do not have luxuriant growth and greenness, preferred less for egg laying by bollworms.

Secondly amongst sucking pests, leaf hoppers caused highest damage to crops, moreover, in central zone , AICCIP , Dr PDKV., Akola considered as hot spot for leaf hoppers. Hence, leaf hoppers have major contribution towards the sustainability of genotype in this region. Therefore, leaf hopper tolerant genotypes perform better and having high sustainability, which reflect in the yield.

In LRA 5166 (Local check) higher yield of 10 per cent over RCH 2 *Bt* has been reported by Sankarnarayanan *et al.,* (2009). Gitte *et al.*,

(2009) reported the higher yield of Bunny *Bt* and N*Bt* than RCH 2*Bt* and N*Bt*. Under rainfed situation Bhalerao *et al.*, (2012) reported higher yield of PKV Hy-2 as compared to Bunny *Bt*. Hence, these investigation are in agreement with present study. However, Gujar *et al.,* (2011) reported significantly higher seed cotton yield in *Bt* hybrids over non *Bt* counterparts. Which did not match with present study because of bollworms damage in non *Bt* was at low level which may not cause considerable yield loss over *Bt* hybrids.

REFERENCES

Anonymous, 2010. *Annual Report.* Cotton Entomology, Cotton Research Unit., Dr PDKV., Akola, M.S. pp.81-99.

Bhalerao, P.D., Deshmuk, P.W. and Patil, B.R. 2012. Comparative performance of cotton varieties and hybrids for yield potential under rainfed conditions. In Souvenir and Abstract of State level Seminar on *Breaking Yield Barriers in Major Field Crops,* January 5-7,2012. Department of Entomology, Dr PDKV., Akola. pp.93-94.

Biradar, V.K. and Vennila, S. 2008. Pest Management for *Bt* Cotton : Need for conservation of biological control, *Curr. Sci.* **95(3)** : 317-18.

Dhara Jyothi, Gopalkrishnan, N., Natrajanan K. and Manjula, T. R. 2009. Relative incidence of pests complex on different *Bt* and non *Bt* hybrids. In National symposium on "*Bt Cotton : Opportunities and Prospects",* November 17-19,2009 at Central Institute for Cotton Research, Nagpur-440010.pp 99.

Gawande, V.P., 2012. Evaluation of insecticides on sucking pests on Cotton. *M.Sc. Thesis*, Dr Panjabrao Deshmukh Krishi Vidyapeeth, Akola. pp. 1-68.

Gitte, A.N., Deosarkar, D.B., Patil, D.V. and Gaikwad, A.R. 2009. Physiological efficiency of *Bt* cotton hybrids. in rlation to growth and yield contributing characters. In National symposium on *"Bt Cotton : Opportunities and Prospects",* November 17-19,2009 at Central Institute for Cotton Research, Nagpur-440010.pp 67.

Gujar, G.T., Bunkar, G.K., Singh and B.P., Kalia, V. 2011. Field performance of F_1-F_2 and non *Bt* of BG II (MRC 7017 *Bt*) and JKCH-1947 *Bt* Against Bollworms of Cotton. *In books of papers of World Cotton Research Conference,* November 7-11,2011 at The Renaissance Hotel and Convention Centre, Mumbai, India. Pp.165-173.

Kolhe, A.V., Sonalkar, V.U., Patil, B.R. and Bhongale, S.A. 2009. Performance of *Bt* Cotton hybrids under rainfed situation. In National symposium on "*Bt Cotton : Opportunities and Prospects",* November 17-19,2009 at Central Institute for Cotton Research, Nagpur-440010.pp 74.

Parnell, F.R., King, H.E. and Ruston, D.F. 1949. Jassid resistance and hairiness of the cotton plant, *Bull. Ent. Res.* **39** : 539-75.

Patil, B.C., Pawar K.N. and Koler, Prakash 2009. Morpho-physiological basis of yield difference in *Bt* and non *Bt* hybrids at two dates of sowing. In National symposium on "*Bt Cotton : Opportunities and Prospects*", November 17-19,2009 at Central Institute for Cotton Research, Nagpur-440010.pp 65.

Sankarnarayanan, K., Nalayini, P., Praharaj,C.S., Bandyopadhyay, K. K and Gopalkrishnan N., 2009. Assessment of suitability of *Bt* cotton hybrids under rainfed ecosystem. In National symposium on "*Bt* Cotton : Opportunities and Prospects", November 17-19,2009 at Central Institute for Cotton Research, Nagpur-440010.pp. 49.

Sharma, H.C. and Pampapathy, G. 2006. Influence of transgenic cotton on the relative abundance and damage by target and non-target insect pests under different protection regimes in India. *Crop Protection,* **25** : 800-13.

Surulivelu, T. 2005. Mechanism of resistance in cotton cultivars against major pests. In proceedings of National training on Recent Advances in Host Plant Resistance, February 9-March 1,2005.Centre of advance studies in Entomology, TNAU, Coimbatore, pp. 111-15.

Surulivelu, T., Dhara Jyothi, B. and Manjula, T. R. 2009. Relative occurrence of leaf hopper and assessment of yield loss due to sucking pest in the popular hybrids of *Bt* cotton grown in south India. In National symposium on "*Bt Cotton : Opportunities and Prospects",* November 17-19,2009 at Central Institute for Cotton Research, Nagpur-440010. pp 99.

Insecticidal toxin genes from bacteria *Paenibacillus* sp potent against insect pests potential under climate change

NANDINI GOKTE-NARKHEDKAR*, KANCHAN BHANARE, PRACHI NAWKARKAR, S.KRANTHI AND K.R.KRANTHI
Division of Crop Protection, Central Institute for Cotton Research, Nagpur - 444 104
**E-mail : nnarkhedkar@rediffmail.com*

Abstract : With the threat of global warming looming large, altered climate conditions have the potential to intensify pest and disease problems in agricultural crops. It is speculated that under climate change hitherto minor pests and diseases are likely to become dominant in pest spectrum while present day dominant pests may be relegated to minor status. The possible enhanced pest and disease infestations may bring about need for greater use of chemical pesticides to control them necessitating further development and refinement of biological control based management techniques. With the advent of Bt cotton developed for protection against cotton bollworms, sucking insect pests now account for major chunk of insecticides used in cotton. Entomopathogenic nematodes (EPN) and their bacterial symbiont have been recognized as a potent management tool against insects pests of cotton. At central Institute for Cotton Research, Nagpur an heat tolerant isolate of EPN *Heterorhabditis indica* has been selected and developed which was capable of infecting insect larvae at temperatures as high as 40^0C. An bacterial isolate associated with this EPN isolate was found to be effective against sucking pests as mealybug and white flies. Therefore, this bacteria was characterized based on biochemical and molecular parameters and work was initiated to clone insecticidal toxin genes from this bacteria as it has potential for use against sucking pests which are fast emerging as major insect pests of crops under climate change.

Key words : Catalase, gelatinase, heterorhabditis, insecticidal toxin

MATERIALS AND METHODS

The bacterial symbiont associated with heat tolerant isolate of Entomopathogenic nematode *Heterorhabditis indica* was isolated on standard bacteriological media and characterized for biochemical and molecular parameters . The biochemical parameters taken up were colony morphology on nutrient agar, gram stain, pigmentation, levan production, methyl red, voges-proskauer test, starch hydrolysis, oxygen requirement, H_2S production, indole production, nitrate reduction, Urease test, ADH test, citrate, catalase, gelatinase, motility, tyrosinase and Galactosidase tests. Carbohydrates fermentation studies for the bacterial isolate were carried out for 21 carbohydrates.

For molecular characterization standard methods were used to extract bacterial genomic DNA .

16s ribosomal RNA sequence of bacterial symbiont was amplified using oligonuceotide primers (5'GGA GAG TTA GAT CTT GGC TC3' sense and 5'AAG GAG GTG ATC CAG CCG CA3'. Samples amplified using 25µl of reaction with 10mM of each primer, 0.1 µg of DNA template , 12.5 µl 2X PCR- master mix and distilled Water. PCR conditions were same as Brunel *et al.*, 1997 with amplification at 57^0C. The sequence amplified was around 1550 bp and it was cloned in pEMT vector for sequencing. Plasmid DNA was isolated using Qiagen miniprep kit and sequenced.

Amplification of toxin genes : Primers designed for amplification of *Photorhabdus* toxin genes by aligning known toxin sequences from data bases were used in PCR reactions.

F-5'ACCGCCGAGTCCCTTGGCTA3' ,R-CGCTGCTGTCTGTGGAGCGTT
F-5'CTTCGGCGCCATTCCCCGTT 3', R-GCGCTACTCTCGGCAGCAGG
F-5'GCGGAGGATGGCCGCAAACT 3', R-CGTGCTGTGCTACCGCGTCA

F-5’CTTCGGCGCCATTCCCCGTT 3’,R-GCGCTACTCTCGGCAGCAGG
F-5’CGGTGACGCCGCACAGTTCT3’,R-TCTGTGCGACCGGAAACGGC
F -5’ TACC AATA TGTTAATTG TGGAC 3’ , R R - 5’ CCA TCA TTTCAC ATA ACCG 3’
F-5’ TTCG AATA CCAA TATG TTAA TTGTGGAC 3’ , R-5’ CCA TCA TTTCAC ATA ACCG 3’
F-5’ ATTACCAATATGT TAATTGTGG 3’ ,R - 5’ TCATCATATATTTTATAATG
F -5’ GGTCTAGAATGTAAAGGCAACAC-3'), R- 5'-GGAAGGACGGAAAGTGGAGA-3‘
F-(5'-ACCATACGCATCGGACAAAC-3') , R-5'-CGTAGCGGTTATTCACTCTTCT-3‘
F -TCAGACTGATGCCAAAGG , R - CCATCAATAGTTCCTGCC,
F -TCAGACTGATGCCAAAGG , R -CCATCAATAGTTCCTGCC
F-5’ TACTTAGTTGAGCGGTCAGG , R - 5’ GCCATGCTCAGTTACTGC
F-5’ TACTTGCTCA GACATTTCTCTATGG 3’,R – TTATTTAATGGTGTAGCG 3’
F 5’ACCATACGCATCGGACAAAC-3’, R 5”CGTAGCGGTTATTCACTCTTCT-3’
F- 5’GGTCTAGAATGTAAAGGC-3’, R -5’GGAAGGACGGAAAGT 3’
F- 5’TACCACTGACAATACGTTTAT 3’, R- 5’CGGTTACTGACGATTGCTG3’
F- 5’ TCATGAAATACGTCCTAAGTGG 3’ , R- 5’ AAA TATGT AAAACTATGGG GTTC3’
F- 5’ ACCTTAACTAATACAGACTTAG 3’, R- 5’ AA AGAAAAGAAATTTACGCGTG 3’
F - 5’ TGTAGTTACAAGAAAGAACC 3’, R- 5’ ATGTCTAAATACAAATTAAACC 3’
F-5’ CTTATACTATACTCAGGCAG 3’, R- 5’ ATTGCAAGATATTAATTACAAAG 3’

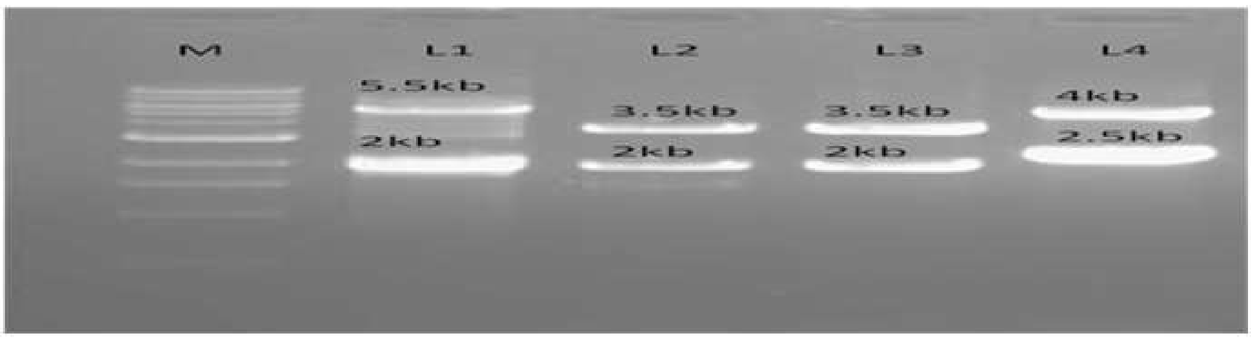
RESULTS AND DISCUSSION

Cells of bacterial symbiont were rod-shaped and motile. Oval shaped endospores were produced in swollen, spindle-shaped sporangia. The bacterial symbiont was rather slow growing on nutrient agar and growth was optimum at 37^{0}C, growth was recorded at pH 6-11. Analysis of the 16S rRNA gene placed the isolates within the genus *Paenibacillus*. On blasting, 16s ribosomal RNA sequence was found to have 96 per cent similarity with *Paenibacillus*. Biochemical characterization of this bacterial isolate was carried out and based on the results identity of bacteria as *Paenibacillus sp* was confirmed (Table 1).

Paenibacillus nematophilus has been recorded associated with *H.indica* and clumping of nematode juveniles in cultures is reported to be attributed to this bacteria (Enright *et al.,* 2003).

Amplification of insecticidal toxin gene : Two insecticidal toxin genes could be amplified. The amplicons <3kb were cloned in pGEMT vector and sequenced by primer walking.

Initial results with primer walking indicate that these amplicons show 96-97 per cent similarity with TccC and TcaC insecticidal toxin genes. The sequences had 96 per cent similarity with *Photorhabdus* TccC toxins having oral and intrahaemocoleic toxicity. Further work on cloning full length gene and expression of protein using prokaryotic expression vector system is underway.



M: Molecular weight marker, L1 : PaeTccC, L2 : PaeTcc, L3 : Pae TcA, L4 : Pae TccC

Table 1. Biochemical characterization of bacterial isolate associated with *H. indica*

Test	Result	Test	Result
Gram stain	Gram negative (Gram variable in older cultures)	Methyl red test	Negative.
Pigmentation	No pigmentation	Voges proskauer test	Positive
Levan production	No levan production	Gelatin test	Weakly positive
Urease test	Negative	Oxygen requirement	Facultatively anaerobic
Tyrosinase test	Positive	Production of H_2S gas	No H_2S production was observed
Citrate test	Negative	Production of indole	No Indole production was seen
Catalase test	Positive	Nitrate reduction	Negative
Amino acid decarboxylase	Negative	growth on Mc Conkey agar	Growth observed
Starch hydrolysis test	Positive.	Esculin hydrolase test	Positive
Casein hydrolysis	Positive	Arginine hydrolase test	Negative
Motility Test	Negative	Oxidase test	Negative

Carbohydrate fermentation test

The test strongly positive for glucose, fructose, galactose, maltose, raffinose, sucrose, salicin , trehalose and weakly positive for adonitol.

The test is negative for—arabinose, cellobiose, inositol, inulin, lactose, mannose, mannitol, melibiose, rhamnose, sorbitol, xylose and dulcitol. no gas production was observed.

REFERENCES

Brunel B., Givaudan A., Lanois A., Akhurst R.J. and Boemare N.E. 1997. Fast and accurate identification of *Xenorhabdus* and *Photorhabdus* by restriction analysis of PCR amplification. *Appl. Environ. Microbiol.*, **63**, 574-80.

Enright, M.R., McInerney J.O. and Griffin, C.T. 2003. Characterization of endospore-forming bacteria associated with entomopathogenic nematodes, *Heterorhabditis spp.,* and description of *Paenibacillus nematophilus* sp. nov. *Inter. Jour. Sys. and Volutionary Microbiology* **53** : 435–41.

POST HARVEST TECHNOLOGY AND SOCIO ECONOMIC DEVELOPMENT

Trends and instability in area, production and yield of cotton in northern India

SUKHPAL SINGH*, MANJEET KAUR AND H. S. KINGRA
Department of Economics and Sociology, Punjab Agricultural University, Ludhiana-141 004
**E-mail : sukhpalpau@yahoo.com*

Cotton is one of the principal crops of India and plays a vital role in the country’s economic growth by providing substantial employment and making significant contribution to export earnings. The cotton cultivation sector not only engaged around 6 million farmers but also involved another about 40 to 50 million people relating to cotton cultivation, cotton trade and its processing. Despite having the largest area under cotton in the world, India ranked third in the world output of cotton due to its abysmally low average yield of 300-400 kg against the world average of 580 kg/ha during 2004-2005 (Singh *et al.*, 2011)

The pest problem on cotton crop became serious in 1990s causing fast deceleration in average yield at compound growth rate (CGR) of minus 0.41 per cent. This was a period of serious economic turmoil for cotton growers pushing a number of them in heavy debt and even in suicide trap. In Punjab state the productivity of cotton suffered most serious setback where it dipped from 582 kg/ha in terms of lint in 1991-1992 to just 180 kg/ha in 1998-1999 (Singh, 2010). However, revival of cotton crop due to introduction of *Bt* strain since 2002 has given a new lease of life to them. As a result, there has been spectacular increase in production and productivity of cotton. The area under cotton was about 9 million hectares with annual production of 19 to 21 million bales of 170 kg each in 2004-2005 which increased to 11.14 million hectares and production to 33.43 million bales during 2010-2011. The average productivity of cotton has reached to 510 kg/ha and India being net-cotton- importing nation, has become the world’s second producer and exporter of cotton. But still the productivity of cotton in India is lower than the world average. Even the yield of cotton in China is two and half times more than that of India.

Although cotton is cultivated in large number of states in the country, the nine states of Punjab, Haryana, Rajasthan, Gujarat, Maharashtra, Madhya Pradesh, Andhra Pradesh, Tamil Nadu and Karnataka accounts for more than 95 per cent of area and output. The northern cotton region of India includes states of Punjab, Haryana and Rajasthan which occupies only 16 per cent of the total cultivated area but contributes about 21 per cent of the production. Further in these states the cotton crop is cultivated in specific pockets of the states. In Haryana state, the districts of Sirsa, Fatehabad, Hisar, Jind and Bhiwani constituted more than 90 per cent of the area in the state. In Punjab, the cotton is grown in south western region (popularly known as cotton belt) of the state. In this region, the districts include Bathinda, Muktsar, Faridkot, Ferozepur, Mansa and Moga which accounts for 95 per cent of area under cotton in the state. In Rajasthan, the districts of Sriganganagar and Hanumangarh are included; about 80 per cent of total cotton area of the entire state falls under these areas. A significant change was observed in the area, production and productivity of cotton in these states since 1980s. Thus, the present study has planned to analyze the trend/growth in area, production and productivity of cotton among different states of northern region (Punjab, Haryana and Rajasthan) of India. An attempt has also been made to analyze the instability in area, production and productivity of cotton in these states.

MATERIALS AND METHODS

The study is based on secondary data relating to area, production and productivity of cotton for the three important cotton growing states namely Punjab, Haryana and Rajasthan. The data has been collected from various sources such as Centre for Monitoring Indian Economy, Statistical Abstract of Punjab, Agricultural Statistics at a Glance and other published documents and reports.

Analytical techniques : To study the growth in area, production and productivity of cotton in northern states of India, the compound growth rates were estimated by using following formula:

$Y = ab^{t}$

Where;

Y = area/ production/yield of cotton

t = corresponding year

b = regression coefficient

r = compound growth rate (%) = (b-1) x 100

To estimate the variability in area, production and yield of cotton, the coefficient of variation (CV) was estimated using the formula:

$$CV = \frac{\text{Standard deviation}}{\text{Arithmetic mean}} x100$$

The instability index (II) is used to de trend the change in any series over time. The instability index given by Cuddy and Della Valle (1978) was used to measure instability in area, production and yield of cotton for different time periods.

Instability Index (II) = CV 1-? $?^2$

Where;

CV = Coefficient of variation

$?^2$ = Adjusted Coefficient of multiple determination

For the purpose of analysis the whole period of 31 years (1980-81 to 2010-11) was divided into :

Period I: 1980-1981 to 1989-1990
Period II: 1990-1991 to 1999-2000
Period III: 2000-2001 to 2010-2011
Overall : 1980-1981 to 2010-2011

RESULTS AND DISCUSSION

Growth pattern of cotton : The area, production and productivity of cotton among cotton producing states of north zone of India have been incorporated in Table 1 and their decade-wise growth rates have been presented in Table 2 for the period 1980-1981 to 2010-2011. The area under cotton in northern region was 15.02 lakh ha during triennium ending (TE) 1989-1990 increased to 18.01 lakh ha during TE 1999-2000 and declined to 13.68 lakh ha during TE 2010-2011. In Punjab state, the area under cotton declined in successive decades from 7.04 lakh ha to 5.07 lakh ha from TE 1989-90 to TE 2010-2011. In Rajasthan and Haryana, the area under cotton was maximum during TE 1999-2000 at 5.89 lakh ha and 6.24 lakh ha, respectively.

Decadal growth rate showed different picture, the CGR of area under cotton in northern region remained non significant in all the decades under study but coefficient was negative for eighties (1980-1981 to 1989-1990) and for 2000-2001 to 2010-2011 but positive during nineties. The area under cotton in Punjab state decelerated significantly at about one per cent during the study period. Decade wise scenario reveals that CGR of area under cotton was non-significant in Punjab state in all the decades indicating no significant decrease/increase in area in these decades. Overall the area and production of cotton registered a significant growth in Haryana with the annual rate of 1.59 and 2.59 per cent respectively. The area under cotton increased significantly in Haryana at 3.47

Table 1: Area, production and yield for cotton among different states of northern India

Triennium ending (TE)

Period	Punjab			Haryana			Rajasthan			Northern region		
TE	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield
1989-1990	7.04	21.44	518	4.39	8.12	347	3.59	6.01	278	15.02	35.57	381
1999-2000	5.89	8.27	245	5.89	8.90	258	6.24	12.00	324	18.01	27.42	262
2010-2011	5.07	20.38	681	4.86	14.42	505	3.60	9.50	445	13.68	39.42	491

Area in lakh ha; production in lakh bales and yield in kgs/ha per cent growth rate per annum during eighties and even during nineties at 2.28 per cent whereas the production and yield decelerated at 4.08 and 6.25 per cent during this decade, a period of failure of cotton crop. The rate of growth of area was negative at 1.83 per cent per annum during 2000-2001 to 2010-2011, a period of *Bt* cotton cultivation. In case of Rajasthan, the area under cotton increased significantly at the rate of 4.53 per cent/annum during nineties which was a complete failure of cotton crop period for Punjab state. Production of cotton was the lowest during nineties at 27.42 lakh tones in northern region. Moreover, during this period the production of cotton decelerated with 5.14 per cent/annum in northern region as a whole mainly because of significant decline in the yield with rate of 6.09 per cent/annum. The compound growth rate of production and yield was positive and significant in northern zone during 2000-2001 to 2010-2011 being 5.96 and 6.84 per cent/ annum, respectively. In case of Punjab and Haryana states similar trend was observed; the growth rate of production was significant during 2000-2001 to 2010-2011 and were as high as 6.79 per cent for Punjab and 7.28 per cent for Haryana. This happened mainly because of high growth rate of yield of cotton at 6.16 per cent and 9.39 per cent per annum due to *Bt* cotton crop cultivation during this period, the CGR of area was positive but non significant in Punjab whereas negative and significant for Haryana during this period. In Rajasthan the yield of cotton also increased significantly with 4.10 per cent/annum but the coefficient of CGR of production though positive but non-significant during this decade. Overall the period of 1990s was a failure of cotton crop in northern zone. The production increased significantly with high growth rate of yield during 2000-2001 to 2010-2011 but there no significant increase in area with the introduction of *Bt* cotton in the region.

Variability : To examine the variability in area, production and yield of cotton in northern cotton producing states of India the coefficient of variation (CV), a commonly used measures of dispersion and Cuddy and Della Valle (1978) Index of Instability (II) which de- trend the time series observations were used. The CV and II of area, production and yield of cotton in Punjab, Haryana, Rajasthan and for overall northern region has been depicted in Tables 3 and 4, respectively. Lower the value of this coefficient lower will be the variability and better it will be and *vice versa*. For the northern region as a whole, the CV of area ranged from 7.24 to 10.48 per cent in different decades being the highest during eighties and the lowest during 2000-2001 to 2010-2011. The CV of production and yield of cotton remained above 20 per cent and less than 25 five per cent. In Punjab state, the CV of area of cotton declined in successive decades being 13.22 per cent during eighties and declined to 10.45 per cent during 2000-2001 to 2010-2011. The CV of production of cotton was the highest during nineties at 36.04 per cent mainly because of high variation in yield (CV being 32.69%), CV of area, production and yield was the lowest during the period of *Bt* cotton production (2000-2001 to 2010-2011). In Haryana, CV of cotton production was the highest during the 2000-2001 to 2010-2011 because of higher variability in yield than area. The difference in CV of yield and production in these two states during 2000-2001 to 2010-2011 might due to variation in the adoption level of *Bt* cotton.

In case of Rajasthan, the CV of area increased in successive decades *i.e.* from 10.74 per cent in eighties to 15.60 per cent in 2000-2001 to 2010-2011. In contract to Punjab and Haryana, CV of production and yield in Rajasthan was the lowest during nineties at 12.97 per cent and 9.93 per cent, respectively. The instability index (II) which shows the instability in area, production and yield of cotton among different states of north India (Table 4) also give similar results as that of CV. The II for area decelerated in successive decades and remained lower than the II of production and yield in northern region of India. The II of production and yield was almost same in all the decades indicating the variation in productivity to be the sole factor of production not area. In other words, whatever the instability occurred in cotton production, it happened due to variability in its yield alone. Among different states, the II of area, production and yield did not follow the same pattern. Similarly, in a study of Punjab state, (Kaur *et al.*, 2011) reported that CV and II of area, production and productivity for pulses were higher than that of food grain indicating less production risk in food grain and

Table 2. Compound growth rate of area, production and yield of cotton in northern India

Period	Punjab			Haryana			Rajasthan			Northern region		
	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield
Period I	0.5	9.54***	9.00***	3.47***	2.2	1.09	-0.64	4.18	4.85	1.02	6.74***	5.27***
(1980-1981 to 1989-1990)	-0.29	-3.33	-3.05	-2.62	-1.31	-0.56	(-0.49)	-0.91	-1.18	(-0.79)	(-3.86)	-2.87
Period II	-2.41	-10.52***	-8.34***	2.28**	-4.08**	-6.25***	4.53***	3.07***	-1.53	1.24	-5.14***	-6.09***
(1990-1991 to 2000-2001)	(-1.68)	(-3.77)	(-2.92)	-2.24	(-2.07)	(-3.39))	-4.04	-2.59	(-1.33)	-1.15	(-2.80)	(-3.35)
Period III	1.05	6.79**	6.16***	-1.83**	7.28***	9.39***	-1.74	1.94	4.10**	-0.81	5.96***	6.84 ***
(2000-2001 to 2010-2011)	(0.99)	-2.86	-3.41	(-2.46)	-2.95	-3.73	(-1.19)	(0.77)	-2.53	(-1.14)	-2.78	-3.59
Overall	-0.84***	1.26	2.188***	1.59***	2.59***	0.73	0.21	2.69***	2.39***	0.22	1.42***	1.31***
(1980-1981 to 2010-2011)	(-2.94)	-1.71	-3.12	-4.84	-5.06	-1.29	-0.47	-3.48	-4.67	(0.75)	-2.8	-2.67

Figure in parentheses are t values. ***, ** indicate significant at 1% and 5% level respectively.

Table 3. Coefficient of variation of cotton among different states of northern India

Period	Punjab			Haryana			Rajasthan			Northern region		
	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield
Period I (1980-1981 to 1989-1990)	13.22	32.34	28.85	14.07	15.06	15.02	10.74	36.49	31.69	10.48	24.26	20.37
Period II (1990-1991 to 1999-2000)	12.68	36.04	32.69	10.43	19.04	22.74	15.43	12.97	9.93	9.58	20.60	22.13
Period III (2000-1901 to 2010-2011)	10.45	27.48	22.28	9.33	25.13	28.71	15.60	21.99	16.38	7.24	23.438	23.38
Overall (1980-1981 to 2010-2011)	15.77	33.34	34.63	19.63	31.72	25.11	23.47	35.72	25.94	14.21	25.39	24.98

Table 4. Instability Index for cotton among different states of northern India

Period	Punjab			Haryana			Rajasthan			Northern region		
	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield	Area	Prod.	Yield
Period I (1980-1981 to 1989-1990)	13.15	20.38	19.17	10.24	13.65	14.73	10.58	34.68	29.15	10.09	14.05	14.12
Period II (1990-1991 to 1999-1900)	10.09	14.05	14.12	10.92	22.51	23.22	8.14	15.46	14.85	8.87	14.83	14.55
Period III (2000-2001 to 2010-2011)	9.92	19.60	14.46	7.24	17.61	17.52	14.52	21.29	12.41	6.77	16.97	14.70
Overall (1980-1981 to 2010-2011)	13.85	31.76	29.88	14.55	22.98	24.41	23.38	29.88	19.49	14.07	22.49	22.35

high production risk in pulses cultivation in the state. Thus cotton crop remained a risky crop due to high variability in productivity.

Overall it is concluded that the cotton cultivation remained a risky crop in northern region of India. The CV and instability index were high for production, which is mainly because of high variability in yield rather than area. In spite of the high growth rate of yield and production after the introduction of *Bt* cotton, the area under cotton cultivation remained stagnant in northern states of India.

REFERENCES

Cuddy, J. and Della Valle P. 1978. Measuring the Instability of Time Series Data, Oxford *Bull, Econ. Statist.*, **40 (1)**, 79-85.

Mahal, Amrit Kaur, Sekhon, MK, Kaur, Manjeet 2011. Pulses and Food grains in Punjab: Growth and instability, *Jour. Res.*, Punjab Agricultural University, **48(172)** : 58-62.

Singh, Sukhpal, Kaur Manjit and Kingra, H. S. 2011. Total Factor Productivity of Cotton in India, Department of Economics and Sociology, Punjab Agricultural University, Ludhiana.

Singh, Joginder 2011. Impact Assessment of IPM Cotton for Boosting Diversification Process in Punjab, Final Report, Bombay House Homi Modi Street, Mumbai.

Structural changes in cost of cultivation of cotton in Gujarat after the introduction of *Bt* cotton

A. R. REDDY*, SACHITA M YELEKAR, ISABELLA AGARWAL

Central Institute for Cotton Research, Nagpur - 444 104
**E-mail : ar.reddy@gmail.com*

Abstract : This study examines the changes in costs and returns in cotton cultivation during pre *Bt* period and post *Bt* period in Gujarat. The cost of cultivation data obtained from Commission for Agricultural Costs and Prices was analyzed using simple tabular analysis. The analysis revealed that total cost of cultivation increased by 134 per cent during post *Bt* period when compared with pre *Bt* period. Major contribution to this increase was made by the increase in human labour and rental value of owned land. Cost of all items showed an increase during post *Bt* period. Quantities of human labour and fertilizers used in cotton cultivation showed an increase while quantities of bullock labour, seed, insecticides and manures recorded a decrease. Seed cotton yield/ha recorded a threefold increase making the cotton cultivation more profitable during post *Bt* period.

Cotton is one of the important commercial crops of India providing employment to lakh of population. Cotton production had experienced tremendous change during this decade. *Bt* cotton was introduced in India in the year 2002-2003. Simultaneously many improved method of crop production and protection were adopted by the cotton farmers. All these have tremendous impact on cost structure and quantity of various input used. These changes are associated with the quantity, quantity of inputs and their prices. These in turn will affect the income from cotton production. Gujarat is one of the states which got maximum advantage of the technological advancements in cotton production. Cotton productivity increased from 304 kg lint /ha during 1999-2000 to 650 kg lint /ha during 2008-2009 (Table 1). Similarly cotton production increased from 27.5 lakh bales to 90 lakh bales during the same period. Hence this study was done to analyze the temporal changes in the cost structure of cotton production in Gujarat.

MATERIALS AND METHODS

This study is based on the estimate of cost of cultivation of cotton. The data have been obtained from the reports of cost of cultivation of principal crops in India and the reports of Commission for Agricultural costs and prices. The data pertain to the period 1998 to 2008-2009. Simple tabular analysis has been used to analyze the changes in cost structure. Average of triennium 1999-2000 to 2001-2002 was considered as of Pre *Bt* period and triennium 2006-2007 to 2008-2009 as of post *Bt* period for the purpose of comparison. The change between two periods was measured in absolute terms as well as per centage terms.

RESULTS AND DISCUSSION

Chang in cost of cultivation : Table 2 depicts the cost structure in cotton production in Gujarat during two periods as well as difference during two periods. Total cost of cultivation of cotton during pre *Bt* period was Rs. 14024/ha out of which the operational cost was 77.28 per cent and fixed costs was to 22.72 per cent. Among the operational costs cost of human labour ranked first accounting for 31.42 per cent of total cost followed by bullock labour and machine labour. Bullock labour accounted for 7.24 per cent of total cost while machine labour accounted for 7.34 per cent of total cost. Cost incurred on insecticides was Rs. 986/ha. Cost of seed accounted for 5.70 per cent of total cost while cost of fertilizers and manures accounted for 6.34 and 4.81 per cent of total cost. Cost of irrigation during this period was Rs. 780/ha. Among the fixed costs rental value of owned land was the only major cost item accounting for 15.25 per cent of total cost.

Table 1. Area production and productivity of cotton in Gujarat

Year	Area (lakh ha)	Production (lakh bales*)	Productivity (kg lint/ha)
1999-2000	15.39	27.5	304
2000-2001	16.15	23.8	251
2001-2002	16.9	32.5	327
2002-2003	16.34	30.5	317
2003-2004	16.5	50.00	515
2004-2005	19.06	73.00	651
2005-2006	19.06	89.00	794
2006-2007	23.9	103.00	733
2007-2008	24.22	110.00	772
2008-2009	23.54	90.00	650

Source: Cotton Corporation of India
* : 1 bale = 170 kg cotton lint

During post *Bt* period cost of cultivation of cotton was Rs. 32787/ha of which 69.84 per cent was operational cost and 30.16 per cent was fixed cost. In post *Bt* period also human ranked first accounting for 30.50 per cent of total cost. Bullock labour and machine labour accounted for 5.05 and 5.64 per cent of total cost respectively. Cost incurred on seed during this period was Rs. 2060 per ha which accounted for 6.28 per cent of total cost. Fertilizers and manure contributed 6.27 and 3.32 per cent to total cost. Cost incurred on insecticides and irrigation was Rs. 1759 and Rs. 1883/ha, respectively. Among the fixed costs rental value of owned land was the major cost item accounting for 22.85 per cent of total cost.

If we observe the change in cost structure from pre *Bt* period to post *Bt* period, it is clear that there was an increase in value of all cost items. Total cost of cultivation increased from Rs. 14024 during pre *Bt* period to Rs. 32787 during post *Bt* period, a 133 per cent increase, respectively. Highest increase was observed in case of human labour. Cost of human labour increased by Rs. 5594/ha. Similarly cost of bullock labour and machine labour increased by Rs. 639 and Rs. 821/ha, respectively. Cost of seed increased from Rs. 799 to Rs. 2060/ha registering an increase of 157.86 per cent. Increase in the cost of fertilizers and manures was Rs. 1162 and Rs. 414/ha respectively. Cost of insecticides and irrigation charged increase by Rs. 773 and Rs. 1103/ha. There was a steep hike in rental value of owned land during post *Bt* period when compared with pre *Bt* period. Rental value of owned land increased form Rs. 2139/ha during pre *Bt* period to Rs. 7492/ha during post *Bt* period registering an increase of 250 per cent.

If we observe the share of each item in the total change, it is clear that cost of human labour and rental value of owned land contributed maximum to the total change. Cost of human labour contributed 29.81 per cent to increase in total cost while Rental value of owned land contributed to 28.53 per cent. Share of bullock labour and machine labour in increase in total cost wasf 3.41 and 4.37 per cent, respectively. Similarly fertilizers and manures added 6.19 and 2.21 per cent to increase in total cost. Cost of seed contributed to 6.72 per cent to increase in total cost while insecticides and irrigation contributed to 4.12 and 5.88 per cent, respectively.

If we examine the share of each item in total cost during both periods, we can observe only a marginal change. The share of human labour remained almost same at 31 per cent. Share of bullock labour, machine labour, insecticides and manures marginally decreased while share of seed increased marginally. The share of fertilizers and irrigation charges remained same during both the periods.

Change in quantities of inputs used : The extent of changes in physical inputs and their prices along with changes in physical output and its price are given in table 3. Quantity of human labour and fertilizers recorded an increase during post *Bt* period when compared with pre *Bt* period while the quantity of animal labour, seed and manures decreased. Human labour utilization in cotton cultivation during pre *Bt* period was 87.92 man days/ha and it increased to 134.42 man days per ha during post *Bt* period. Thus there was an increase of 52.89 per cent in the use of human labour during the two periods. The price of human labour also increased from Rs. 49.98/ man day to Rs. 73.41/man day. Hence the increase in the human labour cost was the combined effect of increase in the quantity of human labour used as well as increase in the labour charges.

Similarly use fertilizers doubled from 73.86 kg nutrients/ha in pre *Bt* period to 150.62 kg nutrients/ha during post *Bt* period. The price of the fertilizers also showed a marginal

Table 2. Cost structure and changes in cost of cultivation in Gujarat

Particulars	Cost of cultivation				Change		
	Pre *Bt* (1999-2003)		Post *Bt* (2006 - 2009)				
	Rs/ha	Per cent	Rs/ha	Per cent	Rs/ha	Per cent	**Total change**
Operational costs							
Hired human labour	2207	15.74	5309	16.19	3102	140.55	**16.53**
Family labour	2200	15.68	4691	14.31	2491	113.27	**13.28**
Total human labour	4407	31.42	10000	30.50	5594	126.93	**29.81**
Bullock labour	1016	7.24	1655	5.05	639	62.95	**3.41**
Machine labour	1029	7.34	1850	5.64	821	79.79	**4.37**
Seed	799	5.70	2060	6.28	1261	157.86	**6.72**
Fertilizers	886	6.32	2048	6.24	1162	131.17	**6.19**
Manure	674	4.81	1088	3.32	414	61.43	**2.21**
Insecticides	986	7.03	1759	5.37	773	78.45	**4.12**
Irrigation charges	780	5.56	1883	5.74	1103	141.32	**5.88**
Interest on working capital	262	1.87	555	1.69	294	112.20	**1.57**
Sub total	**10838**	**77.28**	**22899**	**69.84**	**12061**	**111.28**	**64.28**
Fixed costs							
Rental value of owned land	2139	15.25	7492	22.85	5353	250.24	**28.53**
Rent paid for leased land	8	0.05	63	0.19	56	734.65	**0.30**
Land revenue	21	0.15	18	0.05	-4	-17.61	**-0.02**
Depreciation on implements buildings	184	1.31	288	0.88	105	56.97	**0.56**
Interest on fixed costs	834	5.95	2028	6.18	1194	143.08	**6.36**
Sub total	**3186**	**22.72**	**9889**	**30.16**	**6703**	**210.39**	**35.72**
Total cost	**14024**	**100.00**	**32787**	**100.00**	**18764**	**133.80**	**100.00**

increase. The cost of fertilizers increased from 12.04/kg of nutrients to 13.60/kg of nutrients during the same period. Here the increase in the value of fertilizers used per ha was mainly due to the increase in the quantity used than that of prices.

The quantity of animal labour marginally reduced from 6.16 pair days/ha during pre *Bt* period to 5.30 pair days/ha during post *Bt* period. Probably the increase in the use of machines may have led to this change. The cost of animal pair day increased from 162.49 in pre *Bt* period to 311.20 in post *Bt* period which led to the increase in the value of bullock labour used between these two periods.

The quantity of seed used per ha reduced from 5.52 kg/ha during pre *Bt* period to 2.71 kg during post *Bt* period while the cost of seed per kg increased from 146.10 to 879.59 during the same period. Similarly quantity of manures used per ha also reduced from 40.79 q/ha during pre *Bt* period to 37.16 q/ha during post *Bt* period but the prices of manures increased from 16.49 to 29.06/quintal during the same period.

Yield and income : Cotton yield recorded an increase of 205 per cent during post *Bt* period when compared with pre *Bt* period. Cotton yield increased from 5.41 q/ha during pre *Bt* period to 16.53 q/ha during post *Bt* period. The price of the seed cotton also increased from 2317/q during pre *Bt* period to 2712 during post *Bt* period. This led to increase the gross income from 12844 to 45566/ha during the same period. Net income was negative during pre *Bt* period. Increase in yield as well as prices make the net income positive during the post *Bt* period. During this period the net income obtained was 12779/ha.

Table 3. Extent of change in inputs and output after the introduction of Bt cotton in Gujarat

Particulars	Pre *Bt*	Pre Bt	Change	Change (%)
Quantity of inputs				
Human labour (Man days)	87.92	134.42	46.50	52.89
Animal labour (Pair days)	6.16	5.30	-0.86	-13.98
Seed (kg.)	5.52	2.71	-2.82	-51.00
Fertilizer (kg nutrients)	73.86	150.62	76.76	103.93
Manure (q)	40.79	37.16	-3.63	-8.90
Prices of inputs				
Human labour (Rs/Man day)	49.98	73.41	23.43	46.89
Animal labour (Rs/Pair day)	162.49	311.20	148.71	91.52
Seed (Rs/kg.)	146.10	879.59	733.49	502.05
Fertilizer (Rs./kg nutrients)	12.04	13.60	1.56	12.96
Manure (Rs/q)	16.49	29.06	12.56	76.17
Yield and income				
Yield/ha	5.41	16.53	11.12	205.36
Price Rs/q	2317	2712	394.10	257.29
Value of main product (Rs)	12544.98	44821.51	32276.52	149.21
Value of by product (Rs)	299.13	745.46	446.33	254.77
Gross Income (Rs)	12844.11	45566.97	32722.85	
Net income (Rs)	**-1179.62**	**12779.54**	**13959.16**	**17.01**

CONCLUSIONS

From the above analysis it is clear that though there was increase in all the cost items as well as total of cultivation there was no major change in the structure of cost of cultivation of cotton during post *Bt* period in Gujarat. Physical quantities of human labour and fertilizers used in cotton cultivation showed an increase during post *Bt* period over that of post *Bt* period. Whereas the quantity of insecticides, seeds and manure used recorded a decrease during the same period. However the increase in yield and prices of seed cotton during post *Bt* period led to the increase in gross incoming making cotton cultivation profitable.

Proceedings on "Global Cotton Production Technologies *vis-a-vis* Climate Change" 221-224

Socio economic assessment of cotton growers' awareness about climatic change and adaptation strategies – An empirical analysis

S. USHA RANI*, M. V. VENUGOPALAN, A.H. PRAKASH AND S.M. WASNIK
Central Institute for Cotton Research Regional Station, Coimbatore - 641 003
**E-mail : ushajoshua@rediffmail.com*

Abstract : One among the many challenges faced by cotton, the most important commercial crop of India is aftermath of climate change. Cotton production is both a contributor and victim to climate change. As a contributor, it contributes between 0.3 and 1.0 per cent to total global gas emissions (ITC, 2011) As a victim, the consequences of climate change *viz.*, higher temperature and higher climate variability may severely affect the cotton production in near future. Anticipating the vulnerability of the crop to climate change, the researchers and policy makers propose many adaptation strategies to cope up with the problem. But the reach of this knowledge to the end users at bottom level is always not measured. Simultaneously the perspectives of cotton growers with regard to climate change and the coping strategies adopted by them are not properly documented for researchable proposals. Viewing this, a survey with a well structured interview schedules was conducted among 200 randomly selected cotton growers in Tamil Nadu for assessing their awareness about climate change and adaptation strategies. The average age of the cotton growers interviewed was 49 years and more than 50 per cent of them had high school level education. The study revealed that more than 60 per cent of them felt that the onset of monsoon was delayed and distribution of rain was more erratic, which delayed the sowing of monsoon crop. More than three fourth of them felt that the frequency and duration of dry spells were increased and *vice versa*. More than of half of them perceived that there were changes in the duration and severity of winter and summer seasons. Around sixty percent of them perceived that there were crop failures due to climatic change. Deposit of salts, formation of crusts and water logging were the major physical signature of climate change on soil as perceived by the respondents. Coping strategies viz., changing the crops, varieties, season, date of sowing and quantity of inputs were adopted by majority of the respondents to mitigate the impact of climate change. Thus, documenting cotton growers' experiences and perspectives about climate change will be useful to recommend appropriate policy initiatives to sustain cotton production in near future in midst of disasters.

Key words : Adaptation, awareness, climate change, empirical, variability, vulnerability

One among the many challenges faced by cotton, the most important commercial crop of India is aftermath of climate change. Cotton production is both a contributor and victim to climate change. As a contributor, it contributes between 0.3 and 1.0 per cent to total global gas emissions. As a victim, the consequences of climate change *viz.*, higher temperature and higher climate variability may severely affect the cotton production in near future (ITC, 2011). Anticipating the vulnerability of the crop to climate change, the researchers and policy makers propose many adaptation strategies to cope up with the problem. But the reach of this knowledge to the end users at bottom level is always not measured. Simultaneously the perspectives of cotton growers with regard to climate change and the coping strategies adopted by them are not properly documented for researchable proposals. Viewing this, a study was conducted among 200 randomly selected cotton growers in Tamil Nadu for assessing their awareness about climate change and adaptation strategies.

MATERIALS AND METHODS

For this study, expost facto research design was used. A random sampling was followed to select the districts, blocks, villages and farmers under both irrigated and rain fed conditions of cotton. To select the districts, secondary data pertaining to the cotton cultivated districts both in irrigated and rain fed conditions were perused. Among the 16 cotton growing districts in Tamil Nadu, Coimbatore, Salem and Erode districts were selected at random for irrigated and rain fed cotton growing conditions.

A total of 200 cotton growers from both the conditions were selected as respondents for the study. Taking into consideration, the scope and objectives of the study, a well-structured interview schedule was prepared after perusal of literature and in consultation with cotton scientists. A pre testing in the form of pilot survey was done in the non-sampling area to probe into the relevancy of the schedule. Suitable modifications were made based on the pre-testing and the final interview schedule was prepared. The respondents were personally contacted for collection of data by undertaking tours to the selected districts.

RESULTS AND DISCUSSION

Socio economic background of cotton growers interviewed : Of the farmers interviewed for the study, the average age was 49 years, with most of the farmers (68.00%) were above 45 years old. More than half of them (62.00 %) had some formal education: either to high school level or below. Among them 38.00 per cent were illiterates. Majority of them (85.00%) had farming as their sole occupation. The average farm holding size was 1.7 ha. In their total land, 25.00 to 50.00 per cent was allotted to cultivation of cotton. Almost all of them (95.00%) had more than 10 years of farming experience, 5 – 10 years of experience in cotton cultivation. They had good contact with extension agency and had high economic motivation. They had good exposure to mass media and had participated in less number of training programmes. Some of them were risk takers, progressive farmers and innovators.

Farmers' awareness regarding climate change : The distribution of respondents under irrigated and rain fed conditions according to their awareness knowledge regarding climate change is furnished in Table 1. Sixteen questions were included in the interview schedule to assess their awareness about climate change. The questions were focused on the changes observed by the farmers in onset of monsoon, distribution of rains, shift in sowing time of monsoon crop, frequency and duration of dry spells and wet spells, changes in duration and severity of winter and summer, crop failures, physical impact of climate change on soil, new pests and diseases emerged and other signs of climate change. More than sixty per cent of the respondents (63. 50%) felt that the onset of monsoon was delayed and nearly forty per cent (36.50%) of them felt that the onset of monsoon was advanced. Similarly, almost sixty per cent of the farmers opined that the rainfall started very early and the distribution of rain was more erratic. Almost three fourth of them (72.00 %) had delayed and 25.00 per cent of them had advanced the sowing date of monsoon crop from their traditional fixed time. Nearly three fourth of them had felt that the frequency of dry spells (76.00%) and duration of dry spells (69.50%) were

Table 1. Frequency of the respondents according to their awareness regarding climate change (n=200)

S. No	Particulars	BE/MET/E/I		D/ME/L/D		No change	
		Number	Per-centage	Number	Per-centage	Number	Per-centage
1	Onset of monsoon	73	36.50	127	63.50	-	-
2	Distribution of rains	120	60.00	80	40.00	-	-
3	Shift in sowing time of monsoon crop	49	24.5	144	72.00	7	3.50
4	Frequency of dry spells	152	76.00	48	24.00	-	-
5	Duration of dry spells	139	69.50	61	30.50	-	-
6	Frequency of wet spells	66	33.00	119	59.50	15	7.50
7	Duration of wet spells	50	25.00	144	72.00	6	3.00
8	Change in duration of winter	112	56.00	65	32.50	23	11.50
9	Change in severity of winter	72	36.00	109	54.50	19	9.50
10	Change in duration of summer	120	60.00	68	34.00	12	6.00
11	Change in severity of summer	187	93.50	7	3.50	6	3.00
12	Crop failures due to climatic change	116	58.00	83	41.50	1	0.50

(BE- Become Early, MET – More Erratic, E-Early, I- Increased; D-Delayed, ME- More Even, L- Late, D- Delayed) increased and nearly one third of them felt the other way. Similarly more than 60.00 per cent of the respondents felt the frequency (59.50%) and duration (72.00%) of wet spells were decreased than the normal. Regarding the changes felt in duration and severity of winter, more than half of them felt an increase in the duration and decrease in the severity. But, with regard to the changes in duration and severity of summer, majority of them felt the duration of summer (60.00%) and the severity (93.50%) had increased than normal. More than half of them felt that crop failures due to climatic change were increased (58.00%) and 42.00 per cent of them felt not so.

Regarding the physical signature of climate change on soil, majority of them observed crust formation (44.50%), frequent water logging (38.50%) and salt deposits (17.00%) in their fields. With regard to occurrence of new pests and diseases in cotton, majority of them stated that they could observe an increase in the occurrence of mealybugs, miredbugs, stem weevil and para wilt in cotton fields for the past one decade. Decrease in the yield, severe drought and inadequate rainfall were some of the other symptoms observed by the majority of cotton farmers with regard to climate change.

Farmers' indigenous strategies to cope up with climatic change : The farmers were interviewed about the indigenous strategies they adopted to cope up with the climatic change in terms of changes in the variety / hybrid, crop, inputs, agronomic practices and other management strategies. For the question, if monsoon is delayed for two weeks, nearly three fourth of them (74.00%) had answered that they would not make any changes in their crop plan and nearly one forth of them (20.50%) said that they would change the variety of the same crop planned to cultivate and only 5.50 per cent of them opined that they would change the crop itself. If the monsoon is delayed for four weeks, almost one third of them (33.50%) stated that they would change the variety / hybrid of the crop and 37.50 per cent of them opined that they would change the crop. A meager per cent of the respondents stated that they would change the agronomic practices to cope up the delay in the monsoon. To cope up with the situation of monsoon failure after sowing left with poor germination, nearly one third of the respondents expressed that they would gap fill the same seed (33.00%) and resow the same crop (30.00%) and the others said that they would opt for other crop.

Table 2. Frequency of the respondents according to level of application of inputs under various situations in percentage (n=200)

S. No	Situation / Input application	Fertilizers application			Pesticides application			Seed rate		
		More	Less	Same	More	Less	Same	More	Less	Same
1	Early monsoon	83.50	13.50	3.00	7.00	88.00	5.00	11.50	63.50	25.00
2	Delayed monsoon	21.50	72.50	6.00	79.00	17.50	3.50	56.00	29.00	15.00
3	Dry spell	59.00	39.00	2.00	19.00	78.00	3.00	17.50	68.50	14.00

The respondents' behavior of input application at the time various situations *viz.*, early monsoon, delayed monsoon and dry spell was also studied (Table 2). Majority of them (83.5 %) expressed that the application of fertilizers during early monsoon will be more and it would be very less (72.50%) during delayed monsoon. Similarly 88.00 per cent of the respondents informed that the application of pesticides would be less during early monsoon and more (79.00%) during delayed monsoon. During dry spell, majority of them stated that the application of fertilizers (59.00 %) and application of pesticides (78.00%) would be more and the seed rate would be less (68.50%) due to withdrawal of sowing.

Majority of them (>80.00 %) of them adopted the sowing time for cotton as new moon day in the Aadi Pattam (*kharif* season). This was the indigenous practice adopted by majority of the respondents for deciding optimum planting time in cotton. Majority of them (>90.00%) them had cultivated pulses and other short duration crops to cope up with break in monsoon and left the land without cultivation as the coping strategy for terminal drought.

CONCLUSION

A better understanding of farmers' perceptions regarding long term climatic changes, current adaptation measures and their determinants will be important to inform policy for future successful adaptation of the agricultural sector. This paper provides insights on cotton farmers' awareness regarding climate change and the indigenous strategies adopted by them to cope up with climatic change. Validating the indigenous strategies adopted by cotton growers to cope up with climatic change will facilitate the researchers and policy makers to come out with new innovations and policies concerning adaptation to climate change.

REFERENCES

Iglesias, A. Erda, L. and Rosenzweig, C. 1996. Climate Change in Asia: A review of the vulnerability and adaptation of crop production. *Water, Air Soil Pollution.* **92** :13-27

ITC Technical paper. 2011. Cotton and Climate Change: Impacts and Options to mitigate and adapt. ITC, Geneva. Doc. No.MAR-11-200.E

World Bank Report 2006. India Inclusive and Service Delivery: Building on India's success. Development Policy Review May 29. **No.34580-1N.**

Evaluation of energy consumption and interventions to improve energy efficiency of cotton bale presses in ginneries

V. G. ARUDE*, S. K. SHUKLA, JYOTI M. NATH
Central Institute for Research on Cotton Technology, Mumbai - 400 019
**E-mail : arudevg@gmail.com*

Abstract : Bale packaging is the final step in processing cotton at cotton ginneries. The fully automatic down and up packing presses that are commonly used in modernized ginneries were evaluated for power requirement, energy consumption, and capacity utilization and to suggest the interventions to improve energy efficiency. The energy consumption for different unit operation such and pressing, tramping, tying, cooling etc. were measured. The actual pressing capacity was found to be 14 bales/hr. The total power requirement was found to be 78 and 71 hp for down packing and up packing presses respectively. The energy consumption for hydraulic ram for pressing operation was found to be 1.10 and 0.62 units /bale, for tramping operation 0.450 and 0.255 units/bale for down packing and up packing presses respectively. The total energy consumption per bale was found to be 1.750 and 1.025 units/bale for down and up packing presses respectively. The power requirement and energy consumption was found to be comparatively less for up packing than down packing press. The energy consumption was found to be influenced by time required and mode of operation of the electric motors employed for each unit operations. The idle and tying time was found to vary between 23 to 30 per cent of the total time/bale. The operational interventions were for improving the energy efficiency and would be useful to cotton ginners.

Key words : Efficiency, energy consumption, ginneries, interventions

Ginning industry in India has over 4000 ginneries that produced about 347 lakh bales of 170 kg each last year. It is a primary processing industry and its functions are to clean and gin the seed cotton, clean the lint and form a bale. Last one decade has brought out sea changes in the ginning industry by adopting new technological developments through modernisation. With the continued development in press manufacturing in India, the focus is shifted from the double stage conventional presses to fully automatic either down or up packing, oil hydraulic presses. In India presently more than 1000 automatic baling presses are in use. Increased usage of these presses has resulted in reducing the contamination and improving the quality of lint. The safety of the workers is ensured by eliminating the drudgery involved in the operation of bale press.

Bale packaging is the final step in processing cotton at ginneries. Bale packaging is done to assist in handling the lint in trade channels and to protect the lint and improve the quality. Bale press machines can be categorized into different types. A majority of the bale presses in India are conventional double stage type. Due to advent of modernization automatic single stage presses are becoming more popular in India. These presses are either single box or double box, up packing or down packing type, revolving and fixed, door less and door type, mechanical and hydraulic tramper, oil and water hydraulic presses etc. These presses have many advantages over the existing conventional presses. These presses also have an auto-trampling facility, which reduces the requirement of labourers and avoids contamination too.

Gin manufacturers market bale presses that meet the needs of gin plants. The pressing capacity of bale presses found between 8 - 35 bales/h. The selection of the appropriate bale press has become a difficult task for the ginners due to variation in design, make, model, capacity and techno economic feasibility. The techno-economic feasibility is governed by many factors such as functional suitability of the bale press, design features, initial and operating cost and after sale service by the manufacture. Ginners don't have the necessary information with regard to technical as well as economic aspects of the bale presses. Different makes and models of presses have their own techno economic constraints as well as advantages.

Operating cost is largely affected by the total power requirement and energy consumption/bale. The bale press comprises the battery condenser, tramper, hydraulic ram, press box and power pack. Each component of a bale press performs a specific function. Different types of mechanism are used to operate it. The major unit operations in bale packing are pressing, tramping, tying, cooling, lint feeding and conveying. All modern gins plants are powered electrically. Individual motors for each machine or machine group. The selection of sizes of electric motors is rather limited, so it is often difficult to match connected horse power to actual load requirements. To be on safer side many ginners have installed larger motors than actually needed throughout the gin plant. Excess connected horsepower can result in unnecessary high seasonal energy costs. Power requirement of a machine vary considerably as a result of changes in the condition of cotton and nature of unit operation.

Energy consumption is an essential element in development of a nation. Higher energy consumption correlates with higher GDP growth. While increased energy use clearly has many benefits but it there are many negative impacts of energy use. We experience these negative impacts globally and locally in the form of climate change However more efficient use of energy in all stages of supply/demand chain could reduce the negative impacts of energy consumption, while allowing the same economic development. Inefficient use of energy generally implies higher than necessary operating costs. Energy efficiency means the utilisation of energy in the most cost effective manner to carry out a manufacturing process or to provide a service, whereby energy waste is minimized and the overall consumption if primary energy resource is reduced. Energy efficient practices or systems use less energy while conducting any energy-dependent activity.

The energy consumptions vary as per tramping mechanism either mechanical or hydraulic. Also the press has hydraulic rams whose number and size varies with the type of bale press. It has a direct impact on the energy requirement and efficiency of the bale press. Hydraulic power packs are being used with different types of pumps and motors. Variation in energy consumption for different types of presses has a direct bearing on the operating cost.

The fully automatic down and up packing presses are commonly used in modernized ginneries. Hence a need was felt to evaluate automatic down and up packing type baling presses to determine the energy consumption and to suggest the measures for improving the energy efficiency and reducing the cost of operation. The findings and recommendations would prove useful to cotton ginners for appropriate selection of a baling press and for conservation of energy and to make the ginning business more profitable.

MATERIALS AND METHODS

The fully automatic down and up packing type bale presses were selected for the experimentation. Constructional features of these presses are described below.

Down and up packing type automatic presses consist of a battery condenser, lint slide, lint feeder, tramper, bale press box, ram and cylinder, bale tying mechanism, bale handling system, hydraulic power pack, hydraulic fittings and an electrical and control panel. In down packing type presses the hydraulic ram and press box are located above the ground level and pressing is carried out by the downward movement of the rams inside the box. While in up packing type of presses, the hydraulic ram and press box are located below the ground level and pressing is carried out by upward movement of the ram inside the box. The components are same for both down and up packing type of presses.

Condenser : Lint conveyed from lint cleaner is passed through a condenser before pressing. The main purpose of the condenser is to feed the lint to the bale press uniformly and in an orderly manner. Condensers have a slow turning, screened or perforated metal covered drum on which the ginned lint forms a batt. This batt is discharged between doffing rollers to the lint slide.

Lint slide : Lint slide is a sheet metal that connects the battery condenser to the lint feeder on the tramper. It is installed at an angle

Fig. 1. Down packing bale press

Fig. 2. Up packing baler press

of 33-45° to ensure movement of lint without rolling of batt. The length of the lint slide is based on the capacity of the ginning system and time required to turn the press.

Lint feeder : The lint feeder is a device for moving the lint from lint slide into the charging box of the press. The lint feeders could be of revolving paddle kicker type, belt feed in conjunction with kicker and lint pusher. Lint feeder deposits the lint into the charging box with a fast but gentle action, without breaking up the batt as it is received from the condenser.

Tramper : The purpose of the tramper is to pack the lint into the press box under the restraining dogs near the top end of the press box. Trampers are either mechanical or hydraulic. Tramper stroke length and speed decide the capacity of the bale press.

Bale press frame : The bale press frame consists of a metallic support framework with bale boxes, centre column, revolving tray, one or two rams and cylinders, hydraulic ducting, sensors, limit switches etc.

Hydraulic power pack : Power pack generates hydraulic power to drive both the ram and the tramper. The hydraulic power pack consists of the basic components such as radial or vane pump driven by electric motor, directional control valves, pressure relief valve, flow control valve, solenoid valves, hydraulic ducting, oil tank, heat exchanger, etc.

Electric controls and panel : The bale press operation is controlled by the PLC in automatic or in manual mode. The operations are done through a control panel. The sensors and limit switches are installed at the desired locations in the bale press frame to initiate and stop the required operation of any component of the bale press. The control panel is properly labeled to assist in easy operation of the bale press.

Principle of operation : Lint is fed into the charging box from the lint condenser with the help of a lint slide and feeder. The lint is trampled with the help of a hydraulic tramper. The purpose of the tramper is to pack the lint into the press box under the restraining dogs near the top end of the press box. Tramper stroke length and speed decide the capacity of the bale press. The required quantity of lint is fed into the press box. Once the feeding is over the press boxes rotates round the centre column. The box with lint comes below the hydraulic rams and the other box comes under the feeder for next charging. In down packing type presses, pressing is carried out by the downward movement of the rams inside the box while in up packing type of presses, pressing is carried out by upward movement of the ram inside the box. Simultaneously the feeding is carried out in the other box. The pressed bale is then tied and released. The bale so produced is weighed on the weighing scale and moved forward with the help of bale handling system.

Experimental trials were carried out in ginneries that are modernised as per Technology Mission on Cotton Mini Mission IV (TMC MM-IV) of Government of India. The characteristic features of fully automatic down and up packing type bale presses were noted. The different unit operations involved in cotton bale pressing were studied. The power requirement and energy consumption for different unit operations was measured. The time motion study of each unit operation was carried out. The clamp on power meter (CW240) manufactured by Yokogawa, Japan was used for measurement of energy consumption (Fig. 3). Fig.4 showed the system configuration block diagram of clamp on power meter. The data was collected on power required, energy consumption, current, voltage, and power factor for each unit operation. Data analysis was carried out to find out the energy consumption per bale. The comparative analysis of down and up packing bale presses was carried out and recommendations were suggested to improve the energy efficiency.

Fig. 3. Clamp on Power Meter (CW240)

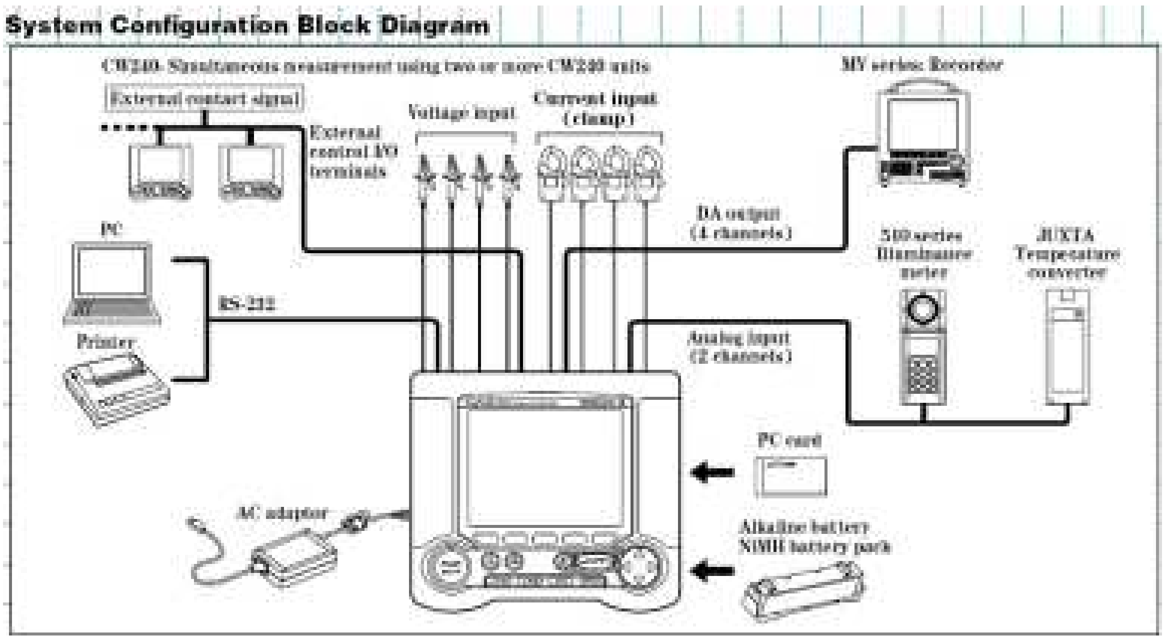


Fig. 4. System configuration block diagram of clamp on power meter

RESULTS AND DISCUSSION

Power requirement : The power requirement for fully automatic down and up packing type bale presses for electric motor for carrying out different unit operations was assessed (Table 1). Separate electric motors were used for hydraulic ram pressing, tramping, oil circulation, cooling, box tuning and tying operations. The maximum power required was found for pressing and tramping operations. The total power required was found to be 78 and 71 Hp, respectively for down and up packing type bale presses.

Table 1. Power requirement of down and up packing type press

Motor	Power requirement (Hp)	
	Down packing	Up packing
Hydraulic ram	50	50
Tramper	20	15
Oil circuit	2	—
Cooling	1	—
Turning	2	3
Compressor	3	3
Total	**78**	**71**

Time motion study : The time required to press a bale was measured. During pressing operation different unit operations were performed. It includes downward and upward movement of hydraulic ram, downward and upward movement of press box, tying of bale, tramping and turning of the box. The time required for each unit operation significantly affects the energy consumption and the actual capacity of bale press. The actual capacity of these presses was found to be 14 bales/h.

The movement of hydraulic ram is controlled automatically. In auto-mode the time required for each unit operation was preset with PLC based control system. Table 2 depicts the time required for individual operations. Idle time is the time lag between turnings of press box till start of pressing of next bale excluding turning time. Tying time is the actual time required for strapping the bale. Time required for these operations affects the pressing capacity and energy consumption.

Table 2. Time motion measurement of different unit operations

Down packing		Up packing	
Operation	Time (sec)	Operation	Time (sec)
Ram down	60	Ram up	58
Box up	10	Tying	75
Tying	80	Ram down	22
Box down	5	Punch down	12
Ram up	30	Punch up	12
Turning	15	Turning	8
Idle	60	Idle	71
Total time	**260**	**Total time**	**258**

The total time required to press a bale was found to be 260 and 258 sec, respectively for down and up packing type bale press. The time required for pressing the bale was found to 60 and 58 sec, respectively for down and up packing press. The idle time was measured to be 60 and 71 sec, respectively for down and up packing type press, respectively. Tying time was observed to be 80 and 75 seconds for down and up packing type bale press, respectively. The idle and tying time was found to vary between 23 to 30 per cent of the total time/bale.

Down packing type presses employs door-less press box. Downward and upward movement of press box is necessary during pressing operation. Down packing type presses found to require time of 15 sec for down ward and upward movement of boxes. Up packing type presses employs punch at the top of press box, their upward and downward movement is needed for holding and releasing the bale. Time required for this operation was found to be 24 sec. Tramper operates throughout the operating cycle of pressing operation except during the turning of press box.

Energy consumption : During the process of compressing the lint to form a bale, large variations in the load was observed. Initially the load was accounted for the frictional force and for operation of the mechanical transmission system. During the pressing operation the load was found to increase non linearly. For the initial half of the travel of the ram the load is approximately 25 per cent of the maximum load. During the last phase of compression, the load rises very steeply. The energy consumption/bale for pressing was determined by measuring the energy for one complete cycle of pressing operation right form the starting of the downward movement of hydraulic ram till the start of next pressing cycle. The parameter *viz.,* power, power factor, current and voltage were measured during the complete cycle. Table 3 shows the variation in energy parameters for hydraulic ram and tramper motor in down and up packing bale presses with a capacity of 14 bales/h.

Table 3. Variation in energy parameter in down and up packing type presses

Parameter	Down packing		Up packing	
	Hydraulic ram motor	Tramper motor	Hydraulic ram motor	Tramper motor
Power (Kwh)	7.39-38.90	3.02-16.20	9.0-62.70	3.70-7.13
Power factor	0.387-0.851	0.325-0.851	0-0.863	0.421-0.611
Current (A)	23.00-61.00	12.19-27.97	0-80.3	12.8-15.9
Voltage (V)	426.0-432.1	426.8-431.7	425.0-427.0	424.0-430.0

The maximum power required for hydraulic ram operation was found to be 38.90 and 62.70 kwh for down and up packing presses, respectively. Power factor was found better for up packing press than down packing press. The current requirement found to range between 23-61A and 0-80.3A for down and up packing bale press respectively. It was noticed that the hydraulic ram motor of up packing type press was ran during pressing operation only and it was stopped during the rest period of baling cycle. In down packing type bale press the hydraulic ram motor ran throughout the baling cycle. It was found to be under loaded for about 50 per cent time of baling cycle. Energy consumption for forward and reverse stroke was found to be less for up packing than the down packing type bale press. Energy consumption was found to be less for pressing operation in up packing than down packing type bale press.

Energy consumption/bale for both the presses for hydraulic ram, tramper and other motors were measured. The cumulative energy consumption for 5 bales was also recorded at the end of each bale. Table 4 and Table 5 depict the energy consumption/bale for down and up

Table 4. Energy consumption/bale for pressing operation of hydraulic ram in down and up packing type bale presses

No. of bales	Energy/ bale (Kwh)	Cumulative energy (Kwh)	Energy/ bale (Kwh)	Cumulative energy (Kwh)
1st	1.007	1.007	0.642	0.642
2nd	1.108	2.115	0.627	1.269
3rd	1.005	3.120	0.605	1.874
4th	1.098	4.218	0.615	2.489
5th	1.117	5.335	0.612	3.101
	Average: 1.10		**Average: 0.620**	

Table 5. Energy consumption/bale for tramping operation in down and up packing type bale presses

No. of bales	Down packing		Up packing	
	Energy/ bale (Kwh)	Cumulative energy (Kwh)	Energy/ bale (Kwh)	Cumulative energy (Kwh)
1st	0.446	0.446	0.216	0.216
2nd	0.462	0.908	0.295	0.511
3rd	0.455	1.363	0.276	0.787
4th	0.441	1.804	0.239	1.026
5th	0.443	2.247	0.252	1.278
	Average: 0.450		**Average: 0.255**	

packing presses for pressing and tramping operation. The average energy consumption/ bale for pressing operation of hydraulic ram for down and up packing press was found to be 1.10 and 0.62 kwh/bale, respectively. The energy consumption/bale for tramping operation was measured over a period of one complete cycle to press a bale including the idle period.

The energy consumption for tramping operation for down and up packing type bale press was found to be 0.450 and 0.255 kwh/bale, respectively. The number of tramper strokes required for tramping the lint to from a bale was measured and found to be 6 and 8, respectively for down and up packing type press.

Table 6. Unit operationwise comparative energy consumption/down and up packing type bale presses

Unit operation	Energy consumption (Kwh/bale)	
	Down packing	Up packing
Pressing	1.100	0.620
Tramping	0.450	0.255
Others	0.200	0.150
Total	**1.750**	**1.025**

The total energy consumption/bale down and up packing type press is depicted in Table 6. It was found to be 1.750 and 1.025 Kwh/bale, respectively for down and up packing type bale press for pressing capacity of 14 bales/hr. Energy consumption was found to be less for up packing than down packing type bale press.

Table 7. Comparative analysis of down and up packing type bale presses

Particulars	Down packing	Up packing
Capacity (bale/h)	14	14
Time required/bale (Sec)	260	258
Power required (Hp)	78	71
Energy consumption (Kwh/bale)	1.750	1.025

Measures for improving energy efficiency : Energy efficiency means the utilisation of energy in the most cost effective manner to carry out a process or to provide a service, whereby energy waste is minimized and the overall consumption is reduced. Energy efficient practices or systems use less energy while conducting any energy dependent activity.

Horsepower requirement can be minimized when the bale press is designed by careful selection of component, sizes and combinations of unit operations. After the installation of baling presses in ginneries nothing much could be done to change or modify the design of press to improve the energy efficiency. After a plant is constructed, however efficiencies in the utilisation of energy will be determined largely by management.

Mismatching between the ginning and pressing capacity was seen in a most of the gin plant. Bale presses installed are over capacity with respect to the actual ginning capacity. Now a days trend is towards the on line ginning and pressing activities *i.e.* ginned lint is directly transferred to the press through conveying systems. Even if the ginning and pressing capacity matches, non uniform feeding of lint to the press is a cause of concern. This prevents the press to operate to its designed capacity. It results in decreased production and increased operating cost due to increased energy consumption. Hence uniform feeding of lint as per the recommendation of manufacturer needs to be ensured.

Energy consumption for up packing type bale press was found to be less than down packing type bale. Hydraulic ram motor of up packing type of press stops after its upward movement while downward movement of the ram is governed by the self weight and gravitational force on the ram. But in case of down packing type of press the hydraulic ram motor runs through out the baling cycle. Motor found to be under-loaded for about 50 per cent of its operating time resulting in poor power.

Energy consumption for forward and reverse stroke was found to be less for up packing than the down packing type bale press. Energy consumption was found to be less for pressing operation in up packing than down packing type bale press. Energy efficiency of down packing press can be improved by improving the power factor of the motor employed for this operation and by minimizing time of operating cycle during which ram motor remains under loaded. It could also be achieved by providing the suitable mechanism for stopping the motor at no load condition during the operating cycle. High power factor has direct benefit of energy saving. Power factor reading below a certain range increases the cost/kwh used. It is advisable to keep the total connected load as near actual load requirement as practicable for efficient operation.

Tramper operates throughout the baling cycle except during the turning of press box. To have minimum energy consumption, tramping operation should be finished before the pressed bale is ejected out *i.e.* idle time should be avoided or minimized. Reduction in idle time will increase the pressing capacity and will reduce the energy consumption/bale. Number of tramping strokes should be kept minimum as possible and needs to be optimized. During idle time ram motor remains in operation hence affecting the energy consumption. Idle time has direct impact on the pressing capacity.

For improving energy efficiency tying time needs to be reduced. Double trigger gun can be used for strapping operation. Use of automatic tying machines can reduce the tying time. Reduction in tying time will increase the capacity of bale press. The time required/bale for entire operating cycle should be as low as possible which will ensure the reduction in tramping time.

CONCLUSIONS

The fully automatic down and up packing type presses were evaluated for power requirement and energy consumption. The total power requirement was found to be 78 and 71Hp for down and up packing presses with pressing capacity of 14 bales/h. The energy consumption per bale was found to be 1.750 and 1.025 bales/hr down and up packing presses. The power requirement and energy consumption was found to be comparatively less for up packing press than down packing press. The energy consumption was found to be influenced by time required and mode of operation of the motors employed for different unit operations. The measures for improving the energy efficiency of both types of bale presses were suggested. These findings and recommendations would be useful to cotton ginners for improving energy efficiency of bale presses.

REFERENCES

Anonymous, 2002. *Ginning and the Technology Mission on Cotton.* Book published by Technology Mission on Cotton (TMC). India.

Anonymous, 2003. "Census of Ginning and Pressing Factories in India". A survey report by CIRCOT, ATIRA and Textile Committee sponsored by Technology Mission on Cotton, Mumbai.

Antony, W.S., Van Doorn, D.W. and Herber D. 1994. *Packaging of lint cotton. Cotton Ginners Handbook.* United States Department of Agriculture (USDA). Agricultural Handbook **503**: 119-23.

Arude, V. G., Shukla S. K, and. Manojkumar T. S., 2008. *Book on Cotton Ginning Technology: Trouble shooting and Maintenance,* Published by CIRCOT, Mumbai.

Gerald, Esterand and Nicolas, Gergely, 2009. The economics of roller ginning technology and implications for African cotton sectors. A report on comparative analysis of organization and performance of African cotton sectors.

Gino, J. Mangialardi and Anotony, W. S., 2004. *Cotton bale presses at gins, 1960-2004.* Published by, National Cotton Ginners Association, Memphis, T.N.

Sharma, M. K., 2005. The benefits of standardized bale sizes and packaging. Paper presented at the 64th plenary meeting of the ICAC in Liverpool. USA.

YOUNG SCIENTIST AWARD PAPERS

Proceedings on "Global Cotton Production Technologies *vis-a-vis* Climate Change" 235-243

Genetic, biochemical, histological and molecular analysis of thermosensitive genetic male sterility (TGMS) in cotton (*Gossypium arboreum* L)

L. SEKHAR* AND B. M. KHADI
Department of Plant Breeding, University of Agricultural Sciences, Dharwad - 580 005
**E-mail : sekhargpb@gmail.com*

Abstract : The thermo sensitive genetic male sterility is innovative male sterility system, in cotton it is a first kind of report. TGMS 3 x ARBHA 35 F_2 population was scored for male sterility and fertility and subjected to chi-square test. The observed frequencies of the two categories do not significantly differ from the expected frequencies. The observed frequencies have a good fit with the expected 3:1 indicating that the TGMS trait is controlled by single recessive gene. Timing of callase activity plays role in the formation and degradation of cell walls during microsporogenesis. High callase activity is required for the normal release of microspores from tetrads at late tetrad stage, in fertile anthers, the enzyme activity was strong as compared to TGMS line. Hence the release of microspores was not affected in fertile anthers as compared to TGMS lines.

Comparative observations made in fertile anthers revealed that the the process of microsporogenesis in male sterile anther paralleled that in the fertile anther until shortly after meiosis of the same TGMS line. Later the microspores were released from the tetrad by dissolution of callose walls in sterile and fertile anthers. The first indication of abnormal pollen development in the sterile anther was early disintegration of tapetum in sterile as compared to fertile anthers. The abnormal pollen development in the sterile anther was the vacoulation of microspore, associated with crushing of chromatin material coupled with shrinkage of microspore cytoplasm. The abnormality associated with the further development of released microspores was most likely due to nutrient deficiencies. Finally,from this investigation NAU 2176 and NAU 2096 markers can be used as linked markers for the TGMS trait in cotton as evident from their differential expression in fertile and sterile anthers of same plant during differential temperature regimes.

Key words : Gentic male sterility, micropores, microsporogenesis, pollen disintegration, thermosenitive

Cotton is a major crop of global importance and has high commercial value. It is popularly known as the 'King of Fibre' and often called as the 'White Gold'. It is the prime raw material (85%) of textile industry which provides employment to millions of people in the world over for various activities such as cultivation, seed production, marketing, industrial utilization and research. In India, cotton industry provides the means of livelihood for an estimated population of 60 million through its cultivation (Basu, 1995). It is grown commercially in the subtropical and tropical regions of more than 70 countries including India.

India is the only major country in the world cultivating all four cultivated species of cotton *Gossypium arboreum, G. herbaceum, G. hirsutum* and *G. barbadense.* The area under cotton during 2011-2012 in India was 121.91 lakh ha with production and productivity of 356 lakh bales and 496 kg lint/ha, respectively. In the year 2011-2012, in Karnataka, cotton was grown over an area of 5.49 lakh ha with 14 lakh bales production and 434 kg/ha productivity (Anonnoymous, 2012).

During pre independence era about 97 per cent of the area was under Asiatic (diploid) cottons and only 3 per cent of the area was under American cotton (*G. hirsutum*). Now, upland cotton and its hybrids (both intra and interspecific) cover about 85 per cent of the area in the country and remaining 15 per cent of the area is under Asiatic cottons (Khadi *et al.*, 2010). Among the breeding procedures, heterosis breeding is mainly responsible for increased production of cotton. In India, hybrid cotton covers about 80 per cent of the total cotton area and contributes about 90 per cent of the country's cotton production. In this only about less than 1 per cent is covered by diploid hybrids. Cotton being an often cross pollinated crop, is amenable for heterosis breeding. The system of male sterility in cotton is of great significance, as it avoids the laborious process of emasculation and can aid in production of hybrid seed. Apart from easy hybrid seed production, the hybrid seed produced through male sterility is going to have high genetic purity.

This is mainly because of uneconomical hybrid seed production due to low boll setting through conventional method of hybrid seed production. The low boll setting may be attributed to small size of flowers and close adherence of the brittle staminal column in flowers, which easily breaks during emasculation. Therefore, TGMS was thought to be the best, economical and alternative method for hybrid seed production technique in cotton and especially in diploid cotton over GMS to realize higher yields.

However, inherent limitations of this approach are non availability of quality hybrid seed in adequate quantity at affordable price and relatively cumbersome and expensive hybrid seed production on account of the need for maintainer (B) line to produce the seed of male sterile (A) line. Time consuming process of conversion of maintainer sources into stable A-line, excessive dependence on a single cytoplasmic male sterile (CMS) source, limited scope to use diverse R lines and problem of pollen shedding in less stable CMS lines are other weaknesses of the three line based hybrid technology. Unlike the CMS system, the TGMS system does not require a maintainer line for seed multiplication of a male sterile line; only a TGMS line and a pollen parent are required to produce a hybrid. Hence, this system of developing hybrids is also known as two line system. Hybrid seed production via two line system is relatively simple as compared with three-line system, as the maintenance step is avoided involving a cross between CMS and maintainer.

TGMS line can produce its own seed through selfing by growing them in locations with low-temperature (<18^{0}C) conditions. The same TGMS line when it is raised in a location with high temperatures (>26^{0}C minimum) would produce selectively sterile pollen and thus will be used as female (seed) parent and allowing any other fertile pollen parent to be used for producing hybrid seeds. The extent of heterosis in two line hybrids can be higher than those of three line hybrids, as there is a wide range of choice for pollen parents unlike in the three line system where we need only a restorer class. There is no negative effect of a sterility inducing cytoplasm in TGMS line as encountered in CMS lines. Thus, the two-line system reduces the risk of genetic vulnerability among the hybrids. However, in the development and use of TGMS lines, influence of modifier gene complex affecting full expression of the TGMS trait is often encountered as a serious problem (Oard and Hu, 1995). Molecular markers linked to TGMS trait may accelerate the breeding procedures. Role of *callase* enzyme to induce male sterility and histological aspects have greater significance in understanding the cause of male sterility and its further use.

MATERIALS AND METHODS

Genetics : The Ga TGMS 3 x ARBHA-35 F_2 population containing 185 plants was studied and the observations were subjected to the chi-square test. The chi-square test is a valuable tool that aids the investigator in determining the goodness of fit of genetic ratios. The expected values corresponding to the observed values were calculated based on the presumed ratios. The deviations were put to χ^2 test.

Callase enzyme assay : The anthers from male sterile and fertile flowers of Ga TGMS 3 line were powdered in liquid nitrogen, crushed in cold acetate NaCl buffer (0.08M acetate+0.02 M NaCl, pH 4.8) was used for â-1, 3-glucanase extract. Extract was centrifuged at 10,000 rpm at 4°C for 30 min. Supernatant was used as enzyme source. The substrate consisting of young tetrads from fertile anthers (Pronounced callose in their walls and bindings), was put in a well slide, and the enzyme preparation was added and, the reaction mixture was incubated for about 18 h at 38^{0}C. After incubation, lacmoid (0.1% resorcin blue in absolute ethanol) was added to stop the reaction and to stain the undigested callose. The colour intensity of tetrad walls and bindings (indicating the extent of callose digestion) was determined under a microscope. This determination was based on a five degree scale ranging from dark blue (degree 0) to colourless (degree 4) in Table1. Strong callase activity was often accompanied by the release of young microspores from the tetrad, indicating a total digestion of the callose envelop (Rafael Frankel *et al.,* 1969).

Table 1. Semi quantitative assay of callase enzyme activity given below.

Degree	Enzyme activity
0	No
1	Poor
2	Moderate
3	High
4	Absolutely high

Histology : Anther samples of TGMS line Ga TGMS-3 from the two situations *i.e.* at higher temperature(sterile) and lower temperature (fertile) of the plant of Ga TGMS 3 were collected and fixed in 2 per cent glutaraldehyde in 0.05 M phosphate buffer, pH 7.0 and were post-fixed in 2 per cent osmium in the same buffer. An ethanol dehydration series were performed and the samples were embedded in spurr resin. Transverse sections were cut using an ultra thin (50-70 nm)sections with a glass knife on ultra microtome(Leica ultra cut UCT-GA-D/E-1/00) and stained with 0.5 per cent toludine blue to stain the callose and related walls. The sections were observed under LAB MADE microscope, photos were taken.

Molecular markers (EST-SSR) : The sterile and fertile anthers were collected in liquid nitrogen used to extract m-RNA and was followed by c-DNA synthesis to know the expression of the pollen during different stages of the plant subjected to varying temperature regimes.

Total RNA from anther samples was isolated using the spectrum total RNA isolation Kit (Sigma Aldrich) according to the manufacturer's instructions. RNA extracted from anthers at sterile and fertile stages of the same plant were used for qRT-PCR. cDNA was synthesized using DyNAmo™ cDNA Synthesis Kit according to the manufacturer's instructions. qRT-PCR reactions were carried out using Corbett Q-PCR, according to the manufacturer's instructions. PCR reactions (final volume of 10 ul) were performed containing gene-specific primers originally tagged for genetic male sterility (Chen *et al.*,2009) and the passive reference dye cyber green in order to normalize fluorescence across the plate. The primers are NAU2176, NAU2096, NAU3156, BNL1227 and BNL1227b. Reaction conditions were as follows: 50^0C for 2 min, 94^0C for 10 min, followed by 40 cycles of 94^0C for 15 sec, and 60^0C for 1 min.

RESULTS AND DISCUSSION

Genetics of temperature sensitive genetic male sterility (TGMS) trait, the observed phenotypic segregation for sterility and fertility in F_2 generation of the cross Ga TGMS 3 and ARBHA 35 are given in Table 2.

Ga TGMS 3 × ARBHA 35 F_2 population was scored for male sterility and fertility at Agricultural Research Station, Dharwad Farm during *kharif* of 2011-2012. The above data were obtained from the F_2 population of Ga TGMS 3 × ARBHA-35. Chi-square value was 1.126,which was less than the critical value, hence it was not significant. The observed frequencies of the two categories do not significantly differ from the expected frequencies. The observed frequencies have a good fit with the expected 3:1 indicating that the TGMS trait is controlled by a single recessive gene. Similar results were observed by Borkakati and Virmani, 1996; Reddy (1997),Reddy *et al.,* (2000) and Lee *et al.,* (2005) in rice.

Callase enzyme activity : Meiotic products are enclosed in beta-1-3 glucans wall, also called callose wall. The callose wall is providing protection from external environment in anther as well as avoids cohesion and fusion between

Table . 2. Observed number of fertile and sterile plants in $F_{2.}$

Sl. No.	Cross	F_2 generation		Ratio	$\chi 2$ value
		Fertile plants	Sterile plants		
1.	Ga TGMS 3 × ARBHA 35	145	40	3:1	1.12

microspores within the tetrad. The enzyme responsible for degradation of callose walls and to release microspores into anther locule is called callase enzyme or glucanase.

A study on the role of callose enzyme in TGMS cotton is important as it is responsible for pollen development. The results of the test for callase activity at different developmental stages in fertile and sterile anthers of TGMS line are presented in Table 3. A semi quantitative assay for callase activity was developed and used to measure the enzyme activity by lacmoid staining. The results indicated that the callase enzyme activity at premeiotic stage in fertile anther was low (degree 1) as compared with sterile anther (degree 2).

At tetrad stage, fertile anther had no callose activity (degree 0) indicating profound callose walls. In sterile anthers of all TGMS line, high callase enzyme activity (degree 3) was seen. During tetrad releasing microspore stage, the fertile anther showed higher callase enzyme activity (degree 4), whereas in all the TGMS line recorded poor callase enzyme activity (degree 1), which indicated that the release of microspores was affected in sterile anthers as compared to in fertile anthers.

Table 3. Callase enzyme activity in TGMS line

Anther type	Stages				
	Premeiosis	Tetrad stage	Tetrad releasing microspore	Old microspores	Pollen grains
Ga TGMS-3(fertile anthers)	1	0	4	0	0
Ga TGMS-3(sterile anthers)	2	3	1	0	0

At old microspore stage the fertile anthers as well as sterile anthers showed no callase activity (degree 0).At pollen grain stage, irrespective of sterile and fertile stages the callase enzyme activity is zero (degree 0). It may be due to, at that time there is no callose walls hence no callase.

Overall the TGMS line had moderate callase enzyme activity during premeiosis and tetrad stage. At tetrad releasing microspore stage enzyme activity was minimum. In fertile anthers, the enzyme activity was maximum at tetrad releasing microspore stage indicating proper release of microspore, minimum at tetrad stage, which indicated callose wall was not disturbed and proper growth of microspores. The results indicated that callase is active in both male fertile and sterile anthers of TGMS lines, but the timing of its activity was different. Relatively poor activity was indicated at the premeiotic stages in both the male sterile and fertile anthers of TGMS line.

At tetrad stage higher callase activity was seen in sterile anthers of TGMS lines, whereas the fertile anthers had 0 or no callase activity. During tetrad releasing microspore stage the fertile anthers had strong callase enzyme activity (Degree 4) as compared to sterile TGMS line anthers. When TGMS anthers had low callase enzyme activity (Degree 1). at old microspore and pollen grain stage irrespective of sterile and fertile anthers, all lines had zero callase activity because at that time there is no role of callose walls and hence callase too.

Timing of callase activity plays a role in the formation and degradation of cell walls during microsporogenesis. High callase activity is required for the normal release of microspores from tetrads at tetrad releasing microspore stage. In fertile anthers, the enzyme activity was strong as compared to TGMS lines. Hence the release of microspores was not affected in fertile anthers as compared to TGMS lines. The delayed release of microspores and their further growth is abnormal in TGMS lines. That resulting in male sterility (Govinda Raju *et al,* 2004). The shrunken microspores were eventually released at the late microspore stage, but with loss of fertility. Our results demonstrate that the timing of callose degradation is important, and a delay in release of microspores affects the subsequent development of pollen, resulting in male sterility. Similar results were obtained by Frankel *et al.,* (1969) and Shamay and Frankel, (1971).

Histology : The comparative developmental pattern of microsporogenesis and male gametophyte development during sterile and fertile stages of the same TGMS line (Ga TGMS 3) were presented in Plate 1, 2 and 3.

The process of microsporogenesis in both fertile and sterile anthers until the release of microspores was normal. The tetrads were intact in fertile (Plate 1a). In sterile stage also the microspore release is normal until release of microspores from tetrad callose wall (Plate 1c). It indicated that the sterility was post-meiotic event. In fertile stage, the tapetum was intact till the microspores were released (Plate 1b), whereas in sterile stage, the tapetum started to disintegrate at the tetrad stage itself (Plate 1d).

In the fertile stage, the microspores were completely developed and well stained by toludine blue. Traces of the tapetum were present as dark grey bodies, indicating proper nourishment from tapetum (Plate 2a). In sterile stage, the miscropores had good intine but were poorly stained by toludine blue. Little or no traces of tapetum were found indicating poor nourishment of the microspores by tapetum (Plate 2d).

In fertile stage, pollen grains were well formed, well stained and filled with cytoplasm (Plate 2b). In case of sterile stage, the locules were filled with sterile pollen grains with well stained intine and broken pollen, with even some locules completely devoid of pollen grains (Plate 2c).

In the fertile stage of TGMS line the pollen grains were regular shaped and had thin intine with full of cytoplasm and were well stained (Plate 2c). In the sterile counterpart stage,the pollen grains were with thicker intine and were poorly stained and misshapen (Plate 2f).

Comparative observations made in fertile anthers revealed that the process of microsporogenesis in male sterile anther paralleled that in the fertile anther until shortly after meiosis of the same thermo sensitive genetic male sterile (TGMS) line. Later the microspores were released from the tetrad mother cell wall by dissolution of callose walls in sterile and fertile anthers. The first indication of abnormal pollen development in the sterile anther was early disintegration of tapetum in sterile as compared to fertile anthers (Khadi *et al.*,1994).

The abnormal pollen development in the sterile anther was the vacaulation of microspore, associated with crushing of chromatin material coupled with shrinkage of microspore cytoplasm (Soddi, 1995 and Kajjidoni,1997).

As the development proceeded the pollen wall did not appear in the same way as in the fertile anthers. The sterile pollen grains had thicker intine as compared to the fertile anthers; later the sterile pollen grains either collapsed or retained abnormal morphological changes, such as further deterioration of nucleus, persistence of vacuoles like structures and ultimately, break down of deformed developing microspores. These results are in conformity with the findings of Soddi,(1995), Khadi *et al.*, (1994), Kajjidoni,(1997) and Bowman *et al.,* (1978).

The abnormality associated with the further development of released microspores was most likely due to nutrient deficiencies. The developing microspores require large amount of nutrients for their growth and differentiation (Cooper,1952).Either the supply or inability of developing microspores to absorb the nutrients might be the reason for the pollen abortion in this particular type of male sterile line because of early disintegration of tapetum(Khadi *et al.*, 1994). However the reasons quoted does not reveal the functional basis for the abnormal behaviour of microspore in its further course of development in sterile anther. To explain the functional basis of male sterility, there might be complete absence or scarce activity of some biochemical substrate/precursor/ enzyme like, choline synthase an enzyme known to play a key role in pollen maturation and determining the pollen wall pattern (Van der Meer, *et al.*, 1992) in petunia. The tapetum plays a vital role in normal development of pollen grains (Maheshwari.,1950). However the vacuolation of tapetal cells bringing about enlargement of the cells may be reasonably attributed to the inefficiency of tapetum to absorb incoming nutrients, since vacuolation of tapetum was seen in some anther locules of TGMS sterile anthers. Tapetum undergoes early programmed cell death. These findings were in hormony with, Kaul and Singh,(1966) and Sujin Ku *et al.,* (2003).

Molecular markers (EST-SSRs) : The TGMS trait was due to post transcriptional changes, because the same plant behaved as sterile during higher (>18^{0}C) temperatures and as fertile during lower temperatures (<18^{0}C). The genome being the same the differences arose during the post transcriptional level. So, it was considered better to study expression using markers at cDNA level rather than at the genomic level which had clear-cut meaning for this situation. The mRNA isolated from two stages on the same TGMS line was converted into cDNA. The EST based SSR markers (primer) obtained from cotton marker database (CMD) originally tagged for genetic male sterility trait were synthesized from sigma Aldrich. Those five primers were studied with RT-PCR for expression levels. The results are furnished in Table 3.

Three primers out of the five showed higher expression, during the sterile and fertile stages of the same TGMS line.

The histone primer expression did not change irrespective of fertile and sterile anthers, hence indicating its constitutive expression across the situations, because it is a housekeeping gene. In the fertile cDNA the primer NAU 2176 had 2.08 folds more expression as compared to sterile cDNA. In fertile cDNA the primer NAU 2096 had 0.079 folds reduced expression. These two markers are highly linked to ms15 and ms5 GMS genes on chromosome 12 (linkage group V) as evident from were at Chen *et al.*, (2009). Similar results were obtained by Guo xiaoqin *et al.,* (2006) and Xiaoding Ma *et al.,* (2007).

Table 3. Expression studies in the TGMS line of cotton

Sl. No.	Primer	cDNA from sterile anthers	cDNA from fertile anthers	Expression
1.	Histone	1.00	1.0	No / constitute
2.	NAU2176	1.00	2.08	High
3.	NAU2096	1.00	0.079	Low

Finally, from this investigation NAU 2176 and NAU 2096 markers can be used as tightly linked markers for the TGMS trait in cotton as evident from their differential expression in fertile and sterile anthers of the same plant during differential temperature regimes.

REFERENCES

Anonymous, 2012, *National Cotton Scenario* by Cotton Corporation Of India Ltd. Mumbai

Basu, A. K., 1995, Current status of cotton research in India. *J. Ind. Soc. Cotton Improv.*, **20** : 14-17.

Borkakati and Virmani, S. S., 1996. Inheritance of a thermosensitive genic male-sterile mutant of Indica rice, 1996.*Rice Genet. Newslett.,* **10** : 45-49.

Bowman, D. T., Weaver, J. B. Jr. and Walker, D. B., 1978. Analysis of dominant male sterile character in upland cotton II.Cytological studies.*Crop.Sci.*,**18** : 730-36.

Chauhan, S. V. S. and Singh, S. P., 1966, Pollen abortion in male sterile hexaploid wheat (Norin) having *Aegilaps ovota* L. cytoplasm. *Crop Sci.,* **6** : 532-35.

Chauhan, S. V. S., Chaudhary Meenu and Chauhan, Seema 2009, Premature Dissolution of Microsporocyte Callose Wall Causes Male Sterility in Ethephon Treated Cotton (*Gossypium arboreum* L.) *The .J. Plant Repro.Biol.,* **1 (1)** : 49-52,

Chen, D., Ding,Y., Guo, W. and Zhang, T., 2009, Molecular mapping of genic male sterile genes ms15, ms5 and ms6 in tetraploid cotton. *Plant Breeding,* **128** : 193-98.

Cooper, D. C., 1952, The transfer of deoxyribose nucleic acid from the tapetum to the microsporocytes at the onset of meiosis. *Amer. Nat.,* **86** : 219-29.

Dong, X, Hong, Z., Sivaramakrishnan, M, Mahfouz, M., Verma, D. P. 2005. Callose synthase (CalS5) is required for exine formation during microgametogenesis and for pollen viability in Arabidopsis. *Plant J* **42** : 315–28.

Eschrich, W. and Currier, H. B. 1964. Identifcation of callose by its diachrome and flouorochrome reactions. *Biotech Histochem* **39** : 303–07.

Frankel, Shamay Izhar and Joseph Nitsan, 1969, Timing of callase activity and Cytoplasmic male sterility in petunia. *Biochem. Genet.,* 3 : 451-55.

Govinda Raju, N. S., Khadi, B. M., Nalini, A. S. and Katageri, I. S., 2004, Histological studies in thermo sensitive genetic male sterile genotypes of cotton. *"International Symposium* on *Strategies for Sustainable Cotton Production" - A Global Vision* Crop Improvement, 23-25 November, 2004, Univ. Agric. Sci., Dharwad.

Guo Xiaoqin, Dong Haitao, Zheng Kangle, Luo Hongmei, Tan Xuelin, Fang Yongqi, Wang Yanqin, Deng Ye, Dai Chengen, Lou Yichun, Shao Jing, Shi Wenqin, Zhao Dong and Li Debao, 2006, Gene expression profiling under different photoperiod/temperature conditions in a photoperiod thermo sensitive genic male sterile line of rice (*Oryza sativa. L*) *Chinese Sci. Bull.,* **51 (2)** : 175-81.

Hird, D.L., Worrall D., Hodge, R., Smartt S., Paul W., Scott, R. 1993. The anther specific protein encoded by the *Brassica napus* and *Arabidopsis thaliana* A6 gene displays similarity to beta-1,3-glucanases. *Plant J* **4** : 1023–33.

Kajjidoni, S. J.,1997, Histological basis of genetic male sterility and its utilization in hybrid development in diploid cotton. *Ph. D. Thesis,* Univ. Agri. Sci., Dharwad,

Kaul, C. L. and Singh, S. P. 1966. Studies in male sterile barley II. Pollen abortion. *Crop Sci.,* **6** : 539-41.

Khadi, B. M., Badigannavar, A. M. Kulkarni, V. N. and Katageri, I. S. 2003. Development of TGMS system in diploid cotton *(Gossypium arboreum* L.) *Indian J. Genet.,* **63(3)** : 269-70.

Khadi, B. M., Katageri, I. S and Nalini, A. S. 1994, Histological basis of CMS in Reba 50A cotton genotypes. *J. Indian Soc. Cotton Improv.,* **19** : 25-28.

Lee, D. S., Chen, L. J. and S. Suh, 2005,Genetic characterization and fine mapping of a novel thermo-sensitive genic male – sterile gene tms6 in rice (*Oryza sativa* L.). *Theor. Appl. Genet.,* **111** : 1271-77.

Maheshwari, P. 1950. *An Introduction to the Embryology of Angiosperms.* Mcgraw Hill Book Company, New York.

Pham Cuong Van, Murayama, Ishimine, Y. M., Kawamistu, Y., Motomura, K. and Tsuzuki, E., 2004, Sterility of thermo sensitive genic male sterile line, heterosis for grain yield related characters in F_1 Hybrid rice (*Oryza sativa*). *Plant Prod. Sci.,*. **7 (1)** : 22-29.

Reddy, O. U. K., 1997, Physiological and molecular characterization and genetics of temperature sensitive genic male sterile sources for heterosis breeding in rice; *Ph.D Thesis*, Osmania University, Hyderabad.

Reddy, O. U. K., Siddiq, E. A., Sarma, N. P., Ali, J., Hussain, A. J., Nimmakayala, P., Ramasamy, P. Pammi, S., Reddy, A. S. 2000. Genetic analysis of temperature-sensitive male sterilty in rice. *Theor Appl Genet.,* **100** : 794–801

Scott RJ, Spielman M, Dickinson, H.G. 2004 Stamen structure and function. *Plant Cell* **16**(Suppl):546–60.

Shamay I. and Rafael F. 1971. Mechanism of male sterility in petunia: the relationship between pH, callase activity in the anthers, and the breakdown of the microsporogenesis. *Theor Appl Genet* **41** : 104–08.

Soddi, R. R. 1995. Histological and biochemical basis of male sterility in cotton (*Gossypium hirsutum* L.).*M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad.

Steiglitz, H. and Stern, H. 1973. Regulation of beta-1, 3 glucanase activity in developing anthers of Lilium. *Dev Biol* **34** : 169–73.

Stone, B.A. and Clarke A.E. 1992. Chemistry and physiology of higher plant 1,3-_-glucans (callose). In: Stone BA, Clarke AE (eds) *Chemistry and biology of (1–3) beta glucans*. La Trobe University Press, Bundoora, pp 365–429.

Sujin Ku, Hyejin Yoon, Hak Soo Suh And Yong–Yoon Chung, 2003, Male sterility of thermosensitive genic male sterile rice is associated with premature programmed cell death of tapetum.. *Planta,* **213** : 559-65.

Van Der Meer,I.M,Stam,ME.,Van Tuen, A.J., Mol, J.N.M. AND Stuitie, A.R., 1992, Antisense inhibition of flavanoid biosynthesis in petunia anthers results in male sterility.*Plant Cell.* 4 : 253-62.

Wang, B., Wang, J. Z., Wu, W., Zheng, H. G., Yang, Z. Y., Xu, W. E., Ray, J. P. and Nguyen, H. T. 1995. Tagging and mapping the thermosensitive genic male sterile gene in rice (*Oryza sativa* L.) with molecular markers. *Theor. Appl. Genet.,* **91** : 1111-14.

Warmke, H.E., and Overman, M.A. 1972. Cytoplasmic male sterility in sorghum: I. Callose behavior in fertile and sterile anthers. *J Hered* **63** : 103–08.

Waterkeyn, L. 1962. Les parois microsporocytaires de nature callosique chez Helleborus et Fadescantia. *Cellule* **62** : 225–55.

Worrall, D., Hird, D.L., Hodge, R., Paul, W., Draper, J. and Scott, R. 1992. Premature dissolution of the microsporocyte callose wall causes male sterility in transgenic tobacco. *Plant Cell* **4** : 759–71.

Xiaoding, Ma, Chaozhu Xing, Liping Guo, Yangcang Gong, Hailin Wang, Yunlei Zhao and Jianyong Wu, 2007, Analysis of differentially expressed genes in genic male Sterility cotton (*Gossypium hirsutum* L.) using cDNA-AFLP. *J. Genet. Genom.,* **34 (6)** : 536-43.

Molecular characterization of genetic male sterile genotypes in diploid cotton (*Gossypium arboreum* L) and development of male sterility specific scar marker

SEKHAR BABU GEDDAM* AND B. M. KHADI
Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad - 580 005
**E-mail : sekharbabug.iari@gmail.com*

ABSTRACT : Genetic male sterility in the *Gossypium arboreum* was found to be under the control of recessive gene. This GMS system has been used for diploid cotton hybrid breeding in India. In the present study RAPD marker system to characterize the Hisar GMS and SRT 1GMS lines which were derived from the repeated back crosses and the male sterility in these genotypes is governed by the single recessive gene ams_1 was used. From the survey of 60 random decamer primers 34 were found to be polymorphic generating 60.73 per cent polymorphism between male sterile and male fertile plant. Out of the polymorphic primers OPAB3, OPAB4, OPAB5, OPAB19, OPH20, OPI2, OPI3 and OPI7 showed a notable differences in the amplicon profile of male sterile and their fertile counterparts. Dendrogram revealed two distinct clusters in which all the male sterile plants made independent cluster and similarly the fertile plants indicating genetic differences between them for sterility. The primer OPI3 was found to be male sterile specific in repeated PCR by consistently producing a specific fragment of 486 bp only in the sterile plants which has been later converted into a locus specific sequence Characterized amplified regions (SCAR) marker. The RAPD markers associated with male sterility and putative SCAR marker specific to male sterility may facilitate the utilization of the GMS system in hybrid breeding in the Asiatic cotton.

Key words : Asiatic cotton, genetic male sterility, random amplified polymorphic DNA, sequence characterized amplified regions marker

Male sterility is the most important approach to exploit the heterosis in various crops. Male sterility found in cotton can be divided into Cytoplasmic male sterility (CMS) and genetic or genic male sterility (GMS) as in the other crop plants. Although the CMS system has been considered more attractive than the GMS system it has its own limitations like instability of the sterility or partial restorability of the male sterility, limited availability of the restorers and possible undesirable cytoplasmic effects. On the contrary GMS system can be more stable for sterility since it is governed by the nuclear genes. It is easier to use in diverse cytoplasmic sources and restorers and has a shorter breeding time than the CMS system. However the major drawback of GMS system is that it should remove 50 per cent of the male fertile plants in a commercial seed production plots.

In cotton perhaps the first case of genetic male sterility was reported by Justus and Leinweber in upland cotton (*Gossypium hirsutum*) later on several cases of genetic male sterility were reported by several of the workers. In cotton 18 loci have been identified in upland cotton , three in Egyptian cotton (*G. barbadense*) and two in Asiatic cotton (*G.arboreum*) respectively for genetic male sterility. Male sterility in cotton was found to be governed by both recessive and dominant genes. However the cases of recessive male sterility are higher than the dominant male sterility. In the Asiatic cotton the two loci reported for genic male sterility so far are under the control of single recessive gene designated as "ams_1"(Singh and Kumar,1993) and "arms" (Meshram *et al.*, 1994 and 1998, respectively). Several genic male sterile genotypes of diploid cotton were developed in India by transferring the ams_1 and $arms_1$ genes and the genotypes were classified into two major groups *viz.*, Hisar Source GMS lines and Akola Source GMS lines. These lines have been successfully used in the heterosis breeding and it led to the release of the world first GMS based diploid cotton hybrid AAH 1(Hisar Source) in 1999 and several other hybrids *viz.*, AKDH 7 (Akola source) , G.cot MDH 11(Hisar source) and CICR 2 (Hisar source) for commercial cultivation in different cotton zones of India.

But the commercial hybrid seed

production using GMS system in Asiatic cotton did not become popular and economically viable because of the sole drawback of the GMS system, the need of rouging out 50 per cent of fertile plants in each generation from seed production plots. Moreover the male sterile and male fertile plants can be distinguished only after the anthesis. Some possible solutions to this problem were proposed in the previous reports (Rao *et al.*, 1990) *viz.,* pyramiding several male sterile genes , introducing a recessive conditional lethal gene, use of seed characters or seedling phenotype and using DNA markers (Ke *et al.*, 2005) linked to the male sterility. However the molecular marker linked to the male sterility in diploid cotton GMS lines has not yet been reported.

In the present study considering its rapidity and non requirement of sequence information specific to the trait the Random Amplified Polymorphic DNA (RAPD) system was adopted to characterize the diploid cotton GMS lines. This paper describes the identification of RAPD markers associated with the genic male sterility in Asiatic cotton and conversion of RAPD marker specific to the male sterility into Putative SCAR (Sequence Characterized Amplified Regions) marker which is first of its kind in diploid cotton.

MATERIALS AND METHODS

Two pairs of near isogenic lines (Hisar GMS and SRT-1 GMS) of Hisar source derived by the repeated back crossing were used in the present investigation. These lines (NILs) were grown in the field at Main Agricultural Resarch Station, Dharwad during *kharif*, 2009. Male sterility was examined by visual observation based on the dichotonomous criteria (Fig.1). Male fertile plants had normal pollen grains and long staminal column whereas the sterile plants had no pollen grains in mature anthers and produced short staminal column.

DNA ISOLATION AND RAPD ANALYSIS : Genomic DNA was isolated from the fresh leaves by following the modified Cetyltrimethyl Ammonium Bromide (CTAB) extraction method. The concentration of DNA was quantified spectrophotometrically and also by gel electrophoresis using 0.8 per cent agarose with known concentrations of DNA. For the spectrophotometric analysis, 5 ml of DNA sample was diluted to 300 l of TE buffer. The spectrophotometer readings were recorded at 260/280 nm. A good DNA preparation generally exhibits the A260 / A_{280} > 1.80. DNA concentration was calculated using OD values at 260 nm using the formula, concentration of DNA (ml/ml) = OD at 260 nm ´ 50 ´ dilution factor. To test the quality of DNA, samples were run on 0.8 per cent agarose gel in 1X TAE buffer and stained with ethidium bromide. DNA was evaluated by comparing it with a standard undigested DNA sample. The sample was treated with RNase enzyme, to remove RNA.

The RAPD analysis was performed with DNA of individual male sterile and fertile plants from two pairs of NILs. Commercial kits of random decamer primers obtained from Operon Technologies Inc. Alamedas, USA were used. Polymerase Chain Reaction (PCR) was performed in 25 µl volume containing primer, DNTPs mix, Kcl, Tris-Hcl (P^H 3.0), $Mgcl_2$ and Taq DNA polymerase. The amplification profile included a pre-incubation at 95 ^{0} C for 4 minutes leading to 37 cycles of melting at 94 ^{0}C for 1 minute , annealing at 37 ^{0}C for 1.3 minutes and synthesis at 72 ^{0}C for 2 min followed by a final extension at 72 ^{0}C for 10 minutes. The amplified products along with 2 l of loading dye (bromophenol blue) were separated on 1.2 per cent agarose gel at 80 volts (45 volts/cm of gel) using 1X TAE buffer of pH 8.0 containing ethidium bromide (0.5 ml/10 ml of gel). Lambda DNA-EcoRI/Hind III double digest was used as DNA molecular weight marker. The amplified fragments were scored as "1" for the presence and "0" for absence of band generating "0" and "1" matrix and per cent polymorphism was calculated. Pair-wise genetic similarities (Sij) between genotypes were estimated by DICE similarity coefficient. Clustering was done using the symmetric matrix of similarity coefficient and cluster obtained based on unweighted pair group arithmetic mean (UPGMA) using SAHN module of NTSYS-PC version 2.02.

SCAR CONVERSION : The RAPD marker which was found to be specific to genic male sterility after repeated PCR has been chosen for the conversion into a locus specific and reliable

SCAR (Sequence Characterized Amplified Regions) marker. The sterile specific DNA fragment generated by the RAPD marker was excised from the 1 per cent agarose gel with a scalpel and blade and purified using DNA gel extraction kit. The re amplified DNA products were cloned to pTZ57R/T vector and used for transformation of *Escherichia coli* DH5á. The recombinant plasmids were screened using colony PCR method and the cloned DNA fragments were sequenced (Genie, Benguluru). Based on the sequence information pair of primers (Forward and Reverse) of SCAR marker were developed using PRIMER 3.0 software.

RESULTS AND DISCUSSION

Although, the GMS system is preferred to the CGMS, but the main drawback of this system is that the offspring of GMS based hybrid F_2 will segregate for male sterility and produce the male sterile and male fertile plants. In order to maintain the pure-breeding male sterile lines, the male fertile segregants are required to be rouged out from the seed production plots. Though, many researchers made an attempt to differentiate the male sterile and fertile plants at the early stages (seedling stage) through the morphological differences, it has not been successful because of lack of suitable morphological markers. Since, male sterile and fertile plants could be differentiated only at the flowering stage through the flower morphological trait differences maintenance of breeding true male sterile plants (lines) in the seed production plots is difficult.

But, after the discovery of the PCR (polymerase chain reaction) several DNA markers have been developed and conveniently used in the marker assisted selection for different traits in different crops. A number of markers systems such as RAPD, AFLP, SSR, ISSR, CAPS, SCAR and STMS are available now to use in the MAS. Among the several molecular techniques, Random Amplified Polymorphic DNA (RAPD) markers (Williams *et al*, 1990) based on PCR (Polymerase Chain Reaction) is simple, widely used, efficient and relatively inexpensive. The technical simplicity and speed of RAPD methodology is a principal advantage (Gepts, 1993) . These markers have been successfully used to discriminate intra and interspecific genotypes in cotton (Pawankumar *et al*, 2003)

However, studies on cultivated Indian cotton genotypes are limited. Similarly, studies on genetic male sterile genotypes of cotton are very rare. Thus, RAPD markers are the best to start to get an insight into molecular diversity and marker development. These genetic markers which are heritable entries associated with economically important traits can be used by plant breeders as selection tools (Darvasi and Soller, 1994). This present study focused on identification of the male sterile and fertile plants of GMS genotypes in diploid cotton through RAPD markers.

Hisar GMS and SRT 1 GMS genotypes are the genic male sterile lines in which the sterility is found to be governed by a recessive gene ams_1. In a sibling population derived from consecutive back crosses between male sterile and male fertile are theoretically isogenic. RAPD analysis was carried out to identify an molecular marker that can distinguish between the male sterile and male fertile plants in GMS in genotypes.

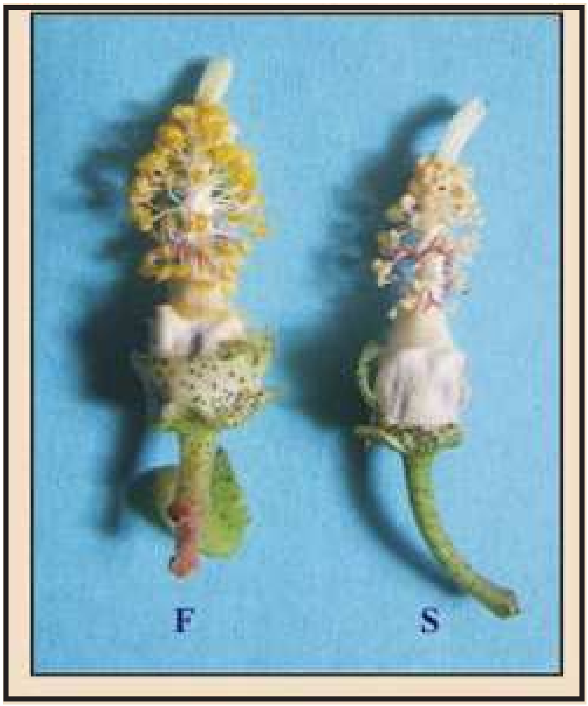


Fig 1. Dihiscent and Indehiscent anthers in the male fertilele (F) and male sterile(S) plants of diploid GMS lines

Total of sixty random decamer primers belonging to AB, H, I, L, M series of Operon Technologies Inc. were used to screen the diploid near isogenic lines, in which seven primers did not show amplification even after repeated PCR, nineteen primers produced monomorphic bands. The remaining 34 primers generated a total of 159 fragments of which 93 (60.73%) were polymorphic. Out of 4.68 fragments per primer, 2.74 fragments per primer were found to be polymorphic. The polymorphism per primer ranged from 14.29 with OPAB3 to 100 per cent with OPI3 and OPL7. The band profile obtained with the 34 primers is summarized in Table 1.

The number of amplified fragments varied with different primers, which ranged from two (OPH9, OPH19, OPI12 and OPL7) to ten fragments (OPAB5). Highest numbers of amplified fragments were obtained with the OPH series primers compared to others. The average fragment per primer was found out to be 4.68. Ying *et al.,* 2003 identified four RAPD markers linked to genic male sterility in chinese cabbage found to be inherited in a Mendelian manner. Since the lines used in the present study are near isogenic lines, any polymorphic fragment present in either of the male sterile and fertile line is a putative marker useful to screen the

Table 1. Summary of RAPD amplicons and polymorphism in diploid GMS lines

Sl. No.	Primer	Sequence	Total bands	Polymorphic bands	Polymorphism (%)
1	OPAB1	CCGTCGCTAG	4	3	75.00
2	OPAB2	GGAAACCCCT	6	4	66.67
3	OPAB3	TGGCGCACAC	7	1	14.29
4	OPAB4	GGCACGCGTT	7	4	57.14
5	OPAB5	CCCGAAGCGA	10	3	30.00
6	OPAB17	TCGCATCCAG	6	4	66.67
7	OPAB18	CTGGCGTGTC	4	3	75.00
8	OPAB19	ACACCGATGG	5	2	40.00
9	OPAB20	CTTCTCGGAC	5	3	60.00
10	OPH1	GGTCGGAGAA	5	4	80.00
11	OPH2	TCGGACGTGA	4	3	75.00
12	OPH3	AGACGTCCAC	3	2	66.67
13	OPH4	GGAAGTCGGC	3	1	33.33
14	OPH5	AGTCCTCCCC	7	3	42.86
15	OPH6	ACGCATCGCA	3	2	66.67
16	OPH7	CTGCATCGTG	5	4	80.00
17	OPH9	TGTAGCTGGG	2	1	50.00
18	OPH12	ACGCGCATGT	5	4	80.00
19	OPH13	GACGCCACAC	5	2	40.00
20	OPH14	ACCAGGTTGG	4	3	75.00
21	OPH16	TCTCAGCTGG	3	2	66.67
22	OPH17	CACTCTCCTC	7	4	57.14
23	OPH18	GAATCGGCCA	4	2	50.00
24	OPH19	CTGACCAGCC	2	1	50.00
25	OPH20	GGGAGACATC	5	4	80.00
26	OPI2	GGAGGAGAGG	5	3	60.00
27	OPI3	CAGAAGCCCA	4	4	100.00
28	OPI4	TCCGCCTAGT	5	4	80.00
29	OPI7	CAGCGACAAG	6	2	33.33
30	OPI11	ACATGCCGTG	6	3	50.00
31	OPI12	AGAGGGCACA	2	1	50.00
32	OPI13	CTGGGGCTGA	3	1	33.33
33	OPI14	TGACGGCGGT	5	4	80.00
34	OPL7	AGGCGGGAAC	2	2	100.00
	Total		**159**	**93**	
	No. of bands/primer		4.68	2.74	60.73

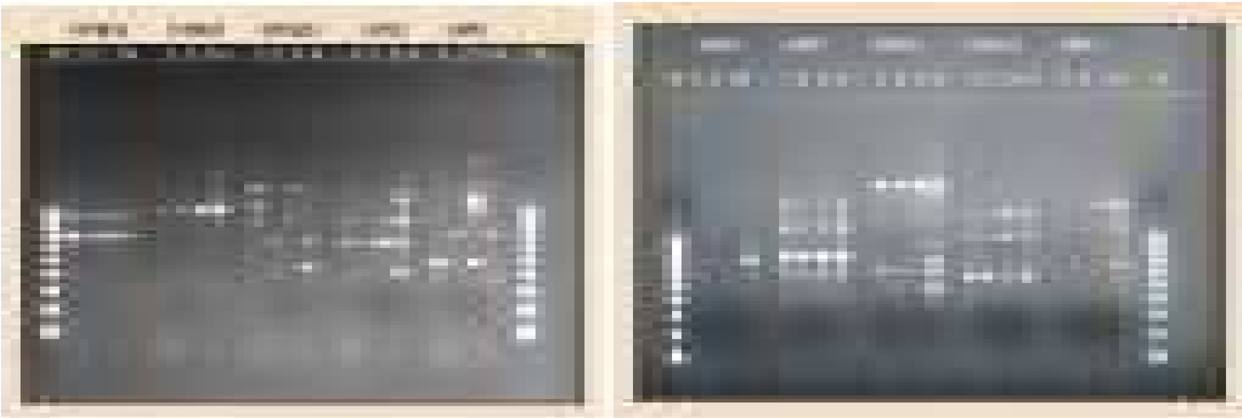


Fig 2. RAPD banding pattern of diploid cotton GMS lines. (M: 1000 bp ladder, 1: SRT- 1 sterile, 2: SRT-1 fertile, 3: Hisar sterile, 4: Hisar fertile)

mapping population for distinguishing between the male sterile and fertile plants.

Pairwise similarity coefficient value for four near isogenic lines was calculated. Overall similarity indices ranged from 0.77 to 0.85. Least similarity (0.77) was observed between fertile and sterile plant of genotype SRT 1 and between sterile plants of genotype Hisar and fertile plant of SRT 1 genotype. Whereas, highest similarity (0.85) was observed between fertile plants of genotypes Hisar and fertile plant of genotype SRT 1 (Table 2). The dendrogram (Fig. 3) revealed two distinct clusters. All fertile plants made independent cluster (II), similarly, all sterile plants made another independent cluster (I). Together, they formed a single cluster at similarity coefficient of 0.78 [20].

To differentiate between fertile and sterile plants of each GMS genotype, out of the 60 RAPD primers used, the primers OPAB3, OPAB4, OPAB5, OPAB19, OPH20, OPI2, OPI3 and OPI7 showed polymorphism in both the pairs of near isogenic diploid GMS lines. The RAPD banding pattern in diploid GMS lines using different primers is depicted in Figure 2. When the diploid NILs were repeatedly screened with primers identifying polymorphic bands for confirmation and further studies, only primers like OPAB19, OPH20, OPI2, OPI3 and OPI7 could show consistent polymorphic bands in the plants. This kind of observation is common in RAPD based analysis of polymorphism. Similarly, Mane (2001) failed to reproduce the polymorphism in 46 of 47 random decamer primer pairs in rice. The observations in other plant species are similar (Murayama *et al.*, 1999). Bharati (2010) identified RAPD primers OPY15 showing consistency in polymorphism in cotton GMS genotypes.

Table 2. Similarity matrix based on RAPD profile analysis in near isogenic diploid GMS lines

		SRT 1		Hisar	
		Sterile	Fertile	Sterile	Fertile
SRT 1	Sterile	1.00	0.77		
	Fertile	0.77	1.00		
Hisar	Sterile	0.82	0.77	1.00	0.78
	Fertile	0.78	0.85	0.78	1.00

In the present investigation primers *viz.*, OPAB19, OPH20, OPI2 and OPI3 showed genetic differences between fertile and sterile plants of both the diploid GMS genotypes. So, they can be considered as putative markers to use them for linkage studies

Conversion of RAPD marker into SCAR marker: Lack of reproducibility is inherent in the RAPD technique itself. Non specific primer binding for various reasons is a main concern. RAPD markers, therefore, are used for analysis of variability in the absence of better markers. Once identified, consistent RAPD markers are converted to sequence defined specific markers such as Alleles Specific Associated Primers (ASAPs) developed in chickpea (Mayer *et al.*,1997) as well as sequence characterized amplified regions (SCARs) in rice, (Naweed *et al.,* 1996) in

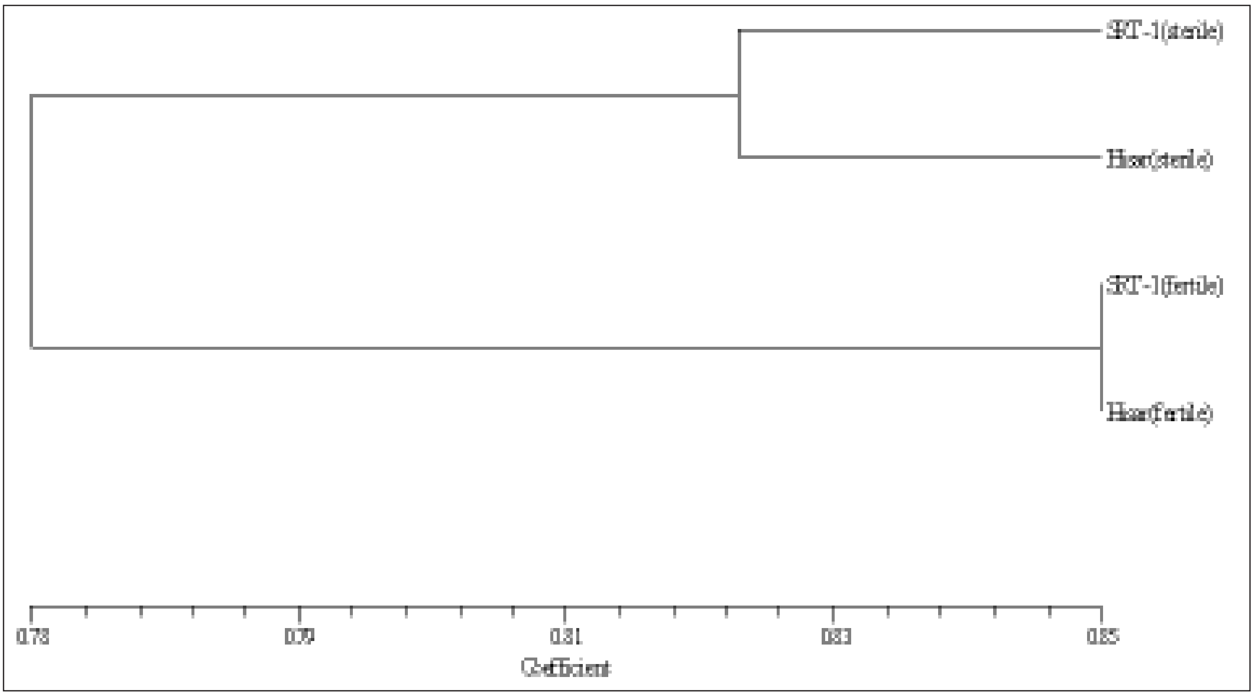


Fig. 3: Dendrogram generated from pooled data of RAPD profile using UPGMA analysis in the diploid near isogenic GMS lines.

tomato (Kawchuk *et al.,* 1998) and in chickpea. The AFLP markers ware used for conversion into SCAR marker for genetic male sterility in *Brassica napus* (Hong *et al.,*2008 and Xie *et al.,* 2008) and *Capsicum annum* [Lee *et al.*, 2010].

Out of the 34 polymorphic RAPD primers, one primer OPI3 was found sterile specific by producing a reproducible specific fragment at 486 bp only in the male sterile plants of the Hisar GMS and SRT 1 GMS lines (Fig 4). The male sterile specific fragment was eluted, gel purified, re-amplified, cloned and sequenced. Based on the sequence information SCAR marker was developed using the PRIMER 3.0 software. The male sterile specific Putative SCAR marker was then designated as DMS1 (Dharwad male sterile 1). The sequence information of the putative SCAR marker is given in Table 3. This putative SCAR marker may be useful in future as a male sterile specific marker in marker assisted selection for commercial exploitation of heterosis using the Genetic male sterility system in diploid cottons.

Fig. 4: Reproducible banding pattern in diploid cotton GMS lines using RAPD marker OPI-3 (M: 1000 bp ladder, S- male sterile, F- male fertile)

Table 3. Sequence and PCR parameters of SCAR marker.

Marker	Designation	Direction	Primer sequence Annealing temperature (^{0}C)
DMS1	Forward	5' AAAGAAATCTTGTAAAGAAATACTCCA 3'	57
	Reverse	5' CCTCATGATAAAATGATGTTGC 3'	57

Acknowledgement

First author acknowledges the receipt of Junior Research Fellowship from the Indian Council of Agricultural Research (ICAR), New Delhi during the Master Degree Programme.

REFERENCES

Bharati, M., Khadi, B. M., Katageri, I. S., Vamadevaiah, H. M. and Fakrudin, B. 2010 Molecular characterization of genetic male sterile genotypes in cotton (*Gossypium spp.*). *Indian J. Gene. Pl. Breed.,* **70** : 94-96.

Darvasi, A. and Soller, M. 1994. Optimum spacing of genetic markers for determining linkage between marker loci and quantitative trait loci. *Theor. Appl. Genet.*, **89** : 351-57.

Gepts, P. 1993. The use of molecular and biochemical markers in crop evaluation studies. In : Hecht MK (Ed.) *Evolutionaty Biology, Vol. 27*, Plenum Press, New York, pp. 51-94.

Hong, D. F., Liu, J., Yang, G. S. and He, Q. B., 2008, Development and characterization of SCAR markers associated with a dominant genic male sterility in rapeseed. *Plant Breeding.*, **127** : 69-73.

Justus, N. and Leinweber, C. L., 1960, A heritable partially male sterile character in cotton. *J. Hered.,* **51:** 1991-92.

Kawchuk, T. M., Hachey, J. and Lynch, D. R., 1998. Development of sequence characterized DNA markers linked to a Verticillium wilt resistance gene in tomato. *Genome,* **41:** 91-95.

Ke, L. P., Y. Q. Sun, D. F. Hong, P. W. Liu, and G. S. Yang, 2005. Identification of AFLP markers linked to one recessive genic male sterility gene in oilseed rape *Brassica napus. Plant Breeding* **124** : 367-370.

Lee, J., Yoon, J. B., Han, J. H., Lee, W. P., Do, J. W., Ryu, H., Kim, S. H. and Park, H. G. 2010, A codominant SCAR marker linked to the genic male sterility gene (ms_1) in chili pepper (*Capsicum annuum*). *Plant Breeding* **129**: 35-38.

Mane, S. P., 2001. Molecular marker analysis on root length in rice (*Oryza sativa* L.). *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Bangalore.

Mayer, M. S., Abebe Tullu, C. J., Simson, J., Kumar, W. J., Kaiser, J. M., Kraft, J. M. and Muchlbauer, F. J., 1997. Development of DNA marker for Fusarium wilt resistance in chickpea. *Crop Sci.*, **37** : 1625-29.

Meshram, L. D., Ghongde, R. A. and Marawar, M. W., 1994. Development of male sterility systems from various sources in cotton (*Gossypium* spp.). *Punjabrao Deshmukh Krishi Vidyapeeth Res. J.,* **18** : 83-86.

Meshram, L. D., Waldodkar, M. B., Marawar, M. W. and Baginwar, A. D., 1998. Development of male sterility in Asiatic cotton (*Gossypium arboreum*). *Agric. Sci. Dig.,* **18** : 175-77.

Murayama, S., Hiroshi Yamagishi and Toru Terachi, 1999. Identification of RAPD and SCAR markers linked to a restorer gene for Ogura cytoplasmic male sterility in radish (*Raphanus sativus* L.) by bulk degregating analysis. *Breeding Sci.,* **49 :** 115-21.

Naweed, I., Naqvi and Chattoo, B. B., 1996. Development of a sequence characterized amplified region (SCAR) based indirect selection method for a dominant blast resistance gene in rice. *Genome,* **39 :** 26-30.

Pawankumar, Singh, K., Vikal, Y., Randhawa, L. S. and Chahal, G. S., 2003. Genetic diversity studies of elite cotton germplasm lines using RAPD markers and morphological characteristics. *Indian J. Genet.*, **63** (1) : 5-10.

Rao, M. K., Devi, K. U. and Arundhati, A. 1990. Applications of genic male sterility in plant breeding. *Plant Breeding* **105** : 1-25.

Singh, D. P. and Kumar, R., 1993. Genetic male sterility in Asiatic cotton. *Indian J. Gene. Pl. Breed.,* **53** (1) : 99-100.

Williams, J. G. K., Kubelik, A. R., Livak, K. J., Rafalski, J. A. and Tingey, S. V., 1990. DNA polymorphism amplified by arbitrary primers are useful as genetic markers. *Nucleic Acids Res.*, **18 :** 6531-35.

Xie, Y. Z., D. F. Hong, Z. H. Xu, P. W. Liu, and G. S. Yang, 2008. Identification of AFLP markers linked to the epistatic suppressor gene of recessive genic male sterility in rapeseed and conversion to SCAR markers. *Plant Breeding* **127** : 145-49.

Ying, M., Dreyer, F., Cai, D. and Jung, C., 2003, Molecular markers for genic male sterility in Chinese cabbage. *Euphytica*, **132** : 227-34.

Study on the epidemiological aspect of Alternaria leaf spot on *Bt* cotton

G. N. HOSAGOUDAR* AND S. N. CHATTANNAVAR
Department of Plant Pathology, University of Agricultural Sciences, Dharwad, 580 007
**E-mail : gnhosagoudar@rediffmail.com*

Abstract: Cotton is one of the most ancient and important commercial crops next to food grains and is the principal raw material for a flourishing textile industry. The present investigations were under taken to study the epidemiological aspect of Alternaria leaf spot on *Bt* cotton caused by *Alternaria* spp during 2010 and 2011 through the aerobiological studies. The spore load in the open air was found maximum during August to October months. Maximum temperature had positive correlation, while remaining weather parameters like minimum temperature, relative humidity (morning and evening), rainfall and rainy day had negative correlation with spore load. Through pooled analysis of *kharif* 2010 and 2011 the multiple linear regression model was obtained as $Y = -28.31 + 1.01X_1 - 1.11X_2 + 0.17X_3 + 0.13X_4 + 0.01X_5 - 0.33X_6$ with R^2 of 0.43. The step down regression equation was fitted as $Y = -9.30 + 0.4\ X_1$ with R^2 value of 0.18 including the factor maximum temperature. The aerobiological studies also revealed that, per cent disease index (PDI) was progressing at linear rate throughout the plant growth and it was negatively correlated with minimum temperature and relative humidity (morning and evening). The multiple regression model developed for PDI is $Y = -250.10 + 10.26X_1 - 12.23X_2 + 2.00X_3 + 0.67X_4 + 0.04X_5 - 0.79X_6$ with R^2 value of 0.78. Stepdown regression had modified the equation as $Y = -235.94 + 9.89X_1 - 11.84X_2 + 1.89X_3 + 0.64X_4 - 1.23X_6$ with R^2 value of 0.78 including variables, temperature (maximum and minimum), relative humidity (morning and evening) and rainy day.

Key words : Aerobiological, Alternaria leaf spot, *Bt* cotton, epidemiological, model

Cotton is one of the most ancient and important commercial crops next only to food grains and is the principal raw material for a flourishing textile industry. Currently, *Gossypium* includes 50 species, four of which are cultivated, fourty four are wild diploids, and two are wild tetraploids (Percival and Kohel, 1990). Out of the four cultivated species, *Gossypium hirsutum* L. and *Gossypium barbadense* L. commonly called as new world cottons are tetraploids (2n = 4x = 52). Whereas, *G. herbaceum* L. and *G. arboreum* are diploids (2n = 2x = 26) and are commonly called as old world cottons.

There has also been a manifold improvement in production, productivity and quality with virtual increase in area. India now produces around 371.20 lakh bales of cotton ranging from short staple to extra long staple from an area of 121.91 lakh ha with productivity of 481.23 kg/ha (Anonoymous, 2012). In Karnataka, the area under cotton cultivation is 5.49 lakh ha with a production of 13.10 lakh bales and an average productivity of 405.65 kg/ha (Anonomyous, 2012).

The low productivity of cotton in Karnataka attributed to many factors, one of which is the loss due to diseases although insect pests continue to be a major production constraint. A large number of fungal, bacterial, viral and nematode diseases have been reported on cotton crop right from early stage to maturity. Among them, the economically most important one are bacterial blight, Alternaria leaf spot, grey mildew, rust and vascular wilts which occur throughout the world (Kotasthane and Agrawal, 1970). However, the production potential of the crop has not been fully exploited due to several biotic and abiotic factors of many fungal diseases, foliar diseases take a heavy toll and these, Alternaria leaf spot causes yield losses up to 26 per cent (Chattannavar *et al.*, 2006). Even before the cultivation of *Bt* cotton, Alternaria leaf spot of cotton was one of the most important diseases noticed throughout the world.

The present investigations were under taken to study the epidemiological aspect of Alternaria leaf spot on *Bt* cotton caused by *Alternaria* spp. during 2010 and 2011 through the aerobiological studies.

MATERIALS AND METHODS

The sowings were taken on the first day of 26th and 25th standard weeks during 2010 and 2011 years and crop was harvested on 50th and 49th standard week (SW) respectively.

Aerobiological studies were carried out to trap the conidia of *Alternaria* spp. present in the air current during *kharif,* 2010 and 2011. For this, aeroscope exposure of stationary slide was done by mounting it on a wind vane and placed inside cotton field at ARS, Dharwad. The observations were made till the harvest of the crop. A slide, which was thinly smeared with vaseline was used for trapping spores, by keeping smeared slide in the slot inside the box. The slide was removed every day at 08.30 h. Average number of conidia per microscopic field (10 X) was recorded under low power taking count of ten microscopic fields on a slide. The information obtained from these observations was studied in relation to weather factors *viz.,* minimum and maximum temperature, rainfall, rainy day and relative humidity (morning and evening) prevailed during the crop period by following standard statistical methods. The multiple regression equation was developed for estimation of spore load and PDI by taking weather parameters as input variables. Further, the equation is modified through step down regression method by taking only significant variables.

Weekly means was calculated from the data on daily spore load, weekly means worked out and used correlation analysis with weather parameters according to the standard procedure (Mehta, 1952 and Kulkarni, 1976).

RESULTS AND DISCUSSION

Aerobiology : Data in Table 1 revealed that during *kharif,* 2010, the spore load was observed in the 3rd week of sowing (0.13) *i.e.,* 28th SW. This spore load increased gradually and recorded peak spore load (5.57) during 34th SW. After that, up to harvest of the crop (50th SW) the spore load recorded in the range of 2.57 to 5.43. Similarly PDI was also lowest during 28th SW (1.68) and increased through out the cropping period. It was peak during last stage *i.e.,* 50th SW (39.94). During the cropping period maximum temperature ranged from 26.40 °C (34th SW) to 30.17 °C (38th SW), minimum temperature from 13.91°C (49th SW) to 21.11°C (31st SW), relative humidity (morning) from 82.43 per cent (49th SW) to 95.57 per cent (29thSW) and relative humidity (evening) from 50.71 per cent (49th SW) to 85.86 (28th SW). However, rainfall was very erratic. It ranged from 0.00 mm (47th, 48th and49th SW) to 117.80 mm (37th SW) and rainy day from 0 days (36th, 47th, 48th and49th SW) to 6 days (29th SW), respectively.

Data in Table 2 revealed that during *kharif,* 2011, the spore load was 0.29 in 25th SW. It increased to 2.71 during 34th SW. However, during further stages, the decreased but during 41th SW suddenly spore load increased to 2.57 and there after again decreased. The PDI trend followed similar to that of previous year. It was least (0.00 PDI) in the beginning and increased continuously every week and reached the peak during the last stage *i.e.,* 48th SW (38.79). The maximum temperature ranged from 25.34 °C (35th SW) to 30.94 °C (48th SW), minimum temperature from 13.11 °C (46th SW) to 21.33 °C (25th SW), relative humidity morning from 62.29 per cent (46th SW) to 96.14 per cent (35th SW) and relative humidity evening from 31.57 per cent (45th SW) to 85.86 per cent (35th SW). Rainfall was highly erratic like previous year, which ranged from 0.00 mm (38th, 44th, 45th and46th SW) to 123.40 mm (41th SW) and rainy day from 0 days (38th, 44th, 45th and46th SW) to 5 days (28th and 35th SW) respectively.

Shtienberg (1996) reported that the intensity of Alternaria leaf spot (*A. macrospora*) in Pima cotton (*G. barbadense*) was investigated over three years in two growing regions in Israel. *Alternaria* leaf spot intensity was recorded at the initiation of flowering and at advanced stage of boll development. However, Amaresh (2000) developed autoregressive model for the estimation of spore load of *A. helianthi*.

Correlation of spore load and PDI with weather parameters : The spore load obtained at different stages of crop growth and PDI were correlated with weather parameters prevailed during the respective stage. The correlation coefficients for both the years (2010 and 2011) are presented in Table 3. The data in Table 3 revealed that during 2010 and 2011, all the

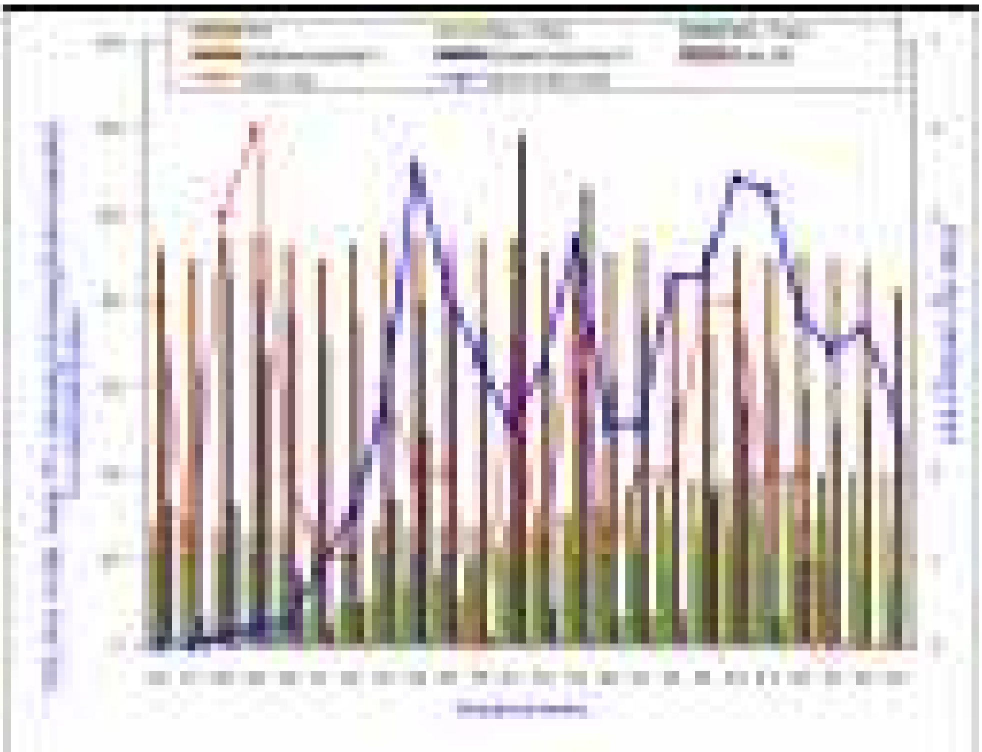


Fig. 1. Effect of weather parameters on spore load and per cent disease index of Alternaria leaf spot of *Bt* cotton (*kharif,* 2010)

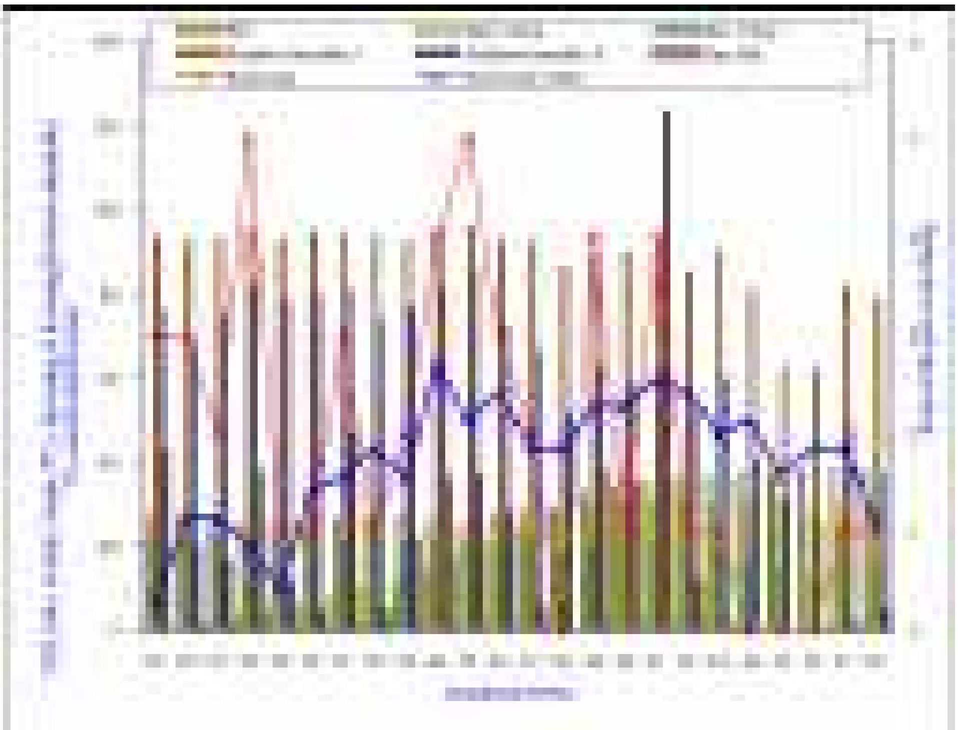


Fig. 2. Effect of weather parameters on spore load and per cent disease index of Alternaria leaf spot of *Bt* cotton (*kharif,* 2011)

Table 1. Effect of weather parameters on spore load and per cent disease index of *Alternaria* leaf spot of *Bt* cotton (*kharif,* 2010)

Std. Met. Week	Calendar period	Stage of crop (days)	Spore load (10X)	PDI	Temperature		Relative Humidity		Rain fall (mm)	Rainy day
					Maxi-mum	Mini-mum	Mor-ning	Eve-ning		
26	4-7-10 to 10-7-10	1 - 7	0.00	0.00	28.21	21.09	91.71	68.71	32.00	4
27	11-7-10 to 17-7-10	8 - 14	0.00	0.00	30.01	20.94	89.29	64.29	5.80	1
28	18-7-10 to 24-7-10	15 - 21	0.13	1.68	26.50	20.73	94.00	85.86	32.40	5
29	25-7-10 to 31-7-10	22 - 28	0.21	3.40	25.77	20.73	95.57	83.71	67.40	6
30	1-8-10 to 7-8-10	29 - 35	0.29	5.70	26.76	20.73	92.57	76.71	16.80	2
31	8-8-10 to 14-8-10	36 -42	0.86	7.50	28.56	21.11	89.43	70.71	4.00	1
32	15-8+10 to 21-8-10	43 - 49	1.57	9.38	28.40	20.80	92.86	75.71	9.20	1
33	22-8-10 to 28-8-10	50 - 56	2.71	10.87	27.29	20.64	95.14	75.14	33.60	3
34	29-8-10 to 4-9-10	57-63	5.57	13.38	26.40	20.44	94.71	80.14	49.80	2
35	5-9-10 to 11-9-10	64-70	4.14	15.87	27.01	20.63	92.29	78.86	10.20	2
36	12-9-10 to 18-9-10	71-77	3.29	18.04	27.43	20.29	93.86	74.00	1.80	0
37	19-9-10 to 25-9-10	78-85	2.57	22.87	28.60	19.27	94.00	71.57	117.80	3
38	26-9-10 to 2-10-10	85-91	3.29	26.33	30.17	20.30	91.00	64.29	8.40	1
39	3-10-10 to 9-10-10	92-98	4.71	30.39	29.83	20.59	95.00	63.86	105.80	4
40	10-10-10 to 16-10-10	99-105	2.57	32.35	27.83	19.77	91.00	61.43	6.00	1
41	17-10-10 to 23-10-10	106-113	2.57	36.15	27.41	20.63	93.14	76.00	6.80	2
42	24-10-10 to 30-10-10	114-120	4.29	37.55	28.94	17.16	84.57	56.71	7.20	2
43	31-10-10 to 6-11-10	121-127	4.29	37.98	27.26	19.49	92.43	71.57	35.60	4
44	7-11-10 to 13-11-10	128-134	5.43	38.12	27.97	19.70	91.71	73.57	56.00	4
45	14-11-10 to 20-11-10	135-141	5.29	38.85	29.16	19.33	89.71	66.00	6.20	2
46	21-11-10 to 27-11-10	142-148	3.86	39.25	28.83	18.49	90.57	58.57	19.40	2
47	28-11-10 to 4-12-10	149-155	3.43	39.63	28.35	17.06	89.43	51.57	0.00	0
48	5-12-10 to 11-12-10	156-162	3.71	39.79	26.90	16.03	87.71	56.57	0.00	0
49	12-12-10 to 18-12-10	163-169	2.71	39.94	26.84	13.91	82.43	50.71	0.00	0

weather parameters were non significantly correlated with spore load. Pooled analysis of both the years revealed that maximum temperature (0.4220) was significantly positively correlated while remaining weather parameters were non significantly correlated with weekly spore load. During 2010, PDI was significantly negatively correlated with minimum temperature (- 0.6828), relative humidity morning (-0.4642) and relative humidity evening (-0.6474), respectively. However during 2011, there was significant positive correlation between PDI and maximum temperature (0.8371), whereas significant negative correlation between PDI and minimum temperature (-0.7151), relative humidity morning (-0.6504), relative humidity evening (-0.8146), rainy day (-0.4662), respectively. The pooled analysis gave significantly positive correlation between maximum temperature (0.6999) and PDI, while significantly negative correlation with minimum temperature (-0.7598), relative humidity morning (-0.6883), relative humidity evening (-0.7985) and rainy day (-0.5290) respectively.

The data was again subjected to multiple linear regression analysis. The regression equations for spore load are given in Table 4. The regression equation for *kharif* 2010 is as :

$Y = -44.83 + 0.97X_1 - 1.30X_2 + 0.44X_3 + 0.09X_4 - 0.01X_5 - 0.06X_6$

with $R^2 = 0.31$

For *kharif* 2011

$Y = -5.27 + 0.25X_1 - 0.43X_2 + 0.08X_3 + 0.02X_4 + 0.00X_5 - 0.03X_6$

with $R^2 = 0.26$

The pooled analysis for both the years gave the equation as :

$Y = -28.31 + 1.01X_1 - 1.11X_2 + 0.17X_3 + 0.13X_4 + 0.01X_5 - 0.33X_6$

with $R^2 = 0.43$

Where;

Y = Spore load

X_1 = Maximum temperature (°C)

X_2 = Minimum temperature (°C)

X_3 = Relative humidity (morning) (%)

X_4 = Relative humidity (evening) (%)

X_5 = Rainfall (mm)

X_6 = Rainy day

Table 2. Effect of weather parameters on spore load and per cent disease index of *Alternaria* leaf spot of *Bt* cotton (*kharif,* 2011)

Std. Met. Week	Calendar period	Stage of crop (days)	Spore load (10X)	PDI	Temperature		Relative humidity		Rain fall (mm)	Rainy day
					Maxi-mum	Mini-mum	Mor-ning	Eve-ning		
25	22-6-11 to 28-6-11	1 - 7	0.29	0.00	27.51	21.33	93.29	76.43	43.00	3
26	29-6-11 to 5-7-11	8 - 14	1.14	0.00	27.91	20.69	92.71	69.14	20.40	3
27	6-7-11 to 12-7-11	15 - 21	1.14	1.28	27.34	20.46	93.57	75.14	16.60	2
28	13-7-11 to 19-7-11	22 - 28	0.86	2.87	25.83	20.44	95.71	82.43	38.20	5
29	20-7-11 to 26-7-11	29 - 35	0.43	4.59	26.86	21.26	93.14	78.43	11.40	1
30	27-7-11 to 2-8-11	36 -42	1.43	6.02	26.49	20.24	94.86	79.86	4.60	1
31	3-8-11 to 9-8-11	43 - 49	1.57	8.21	26.13	21.00	94.14	80.86	47.20	3
32	10-8-11 to 16-8-11	50 - 56	1.86	9.83	26.99	20.93	94.00	73.43	5.40	1
33	17-8-11 to 23-8-11	57-63	1.57	11.79	27.47	20.56	92.86	76.86	21.60	2
34	24-8-11 to 30-8-11	64-70	2.71	14.52	26.46	20.41	95.43	81.79	36.00	4
35	31-8-11 to 6-9-11	71-77	2.14	17.85	25.34	20.77	96.14	85.86	36.80	5
36	7-9-11 to 13-9-11	78-85	2.43	20.02	27.63	20.49	92.86	72.29	28.20	3
37	14-9-11 to 20-9-11	85-91	1.86	24.19	28.60	20.34	92.29	66.43	6.00	2
38	21-9-11 to 27-9-11	92-98	1.86	28.22	29.16	18.04	86.43	50.86	0.00	0
39	28-9-11 to 4-10-11	99-105	2.29	32.81	30.06	19.61	89.57	62.86	38.00	4
40	5-10-11 to 11-10-11	106-113	2.29	34.51	30.40	19.99	89.57	58.86	35.00	1
41	12-10-11 to 18-10-11	114-120	2.57	35.23	29.90	19.63	92.14	60.29	123.40	4
42	19-10-11 to 25-10-11	121-127	2.43	36.10	29.89	19.04	85.29	52.29	11.80	1
43	26-11-10 to 1-11-11	128-134	2.00	36.98	29.74	19.32	90.43	60.43	1.20	1
44	2-11-11 to 8-11-11	135-141	2.14	37.24	30.51	17.40	81.29	40.57	0.00	0
45	9-11-11 to 15-11-11	142-148	1.57	37.64	30.60	14.84	62.43	31.57	0.00	0
46	16-11-11 to 22-11-11	149-155	1.86	37.96	29.74	13.11	62.29	26.29	0.00	0
47	23-11-11 to 29-11-11	156-162	1.86	38.32	28.64	17.20	82.00	49.14	1.40	1
48	30-11-11 to 6-12-11	163-169	1.14	38.79	30.94	16.49	79.00	37.14	5.00	1

Table 3. Correlation studies of spore load of *Alternaria* spp. and PDI with weather parameters during *kharif,* 2010 and 2011

Sl. No.	Weather parameters	Spore load			PDI		
		2010	2011	**Pooled**	2010	2011	Pooled
1.	Maximum temperature (°C)	0.1430	0.3036	**0.4220***	0.1891	0.8371*	**0.6999***
2.	Minimum temperature (°C)	-0.3287	-0.1548	**-0.3652**	-0.6828*	-0.7151*	**-0.7598***
3.	Relative humidity (morning) (%)	-0.0994	-0.0669	**-0.2639**	-0.4642*	-0.6504*	**-0.6883***
4.	Relative humidity (evening) (%)	-0.2692	-0.2001	**-0.3778**	-0.6474*	-0.8146*	**-0.7985***
5.	Rainfall (mm)	0.1018	0.1999	**0.0526**	-0.1154	-0.1183	**-0.1804**
6.	Rainy day	-0.1518	0.0351	**-0.2975**	-0.3039	-0.4662*	**-0.5290***

* Significant at p=0.05 probability

The data was again subjected to step down regression by eliminating the non significant variables and including only significant variables but in our study none of the weather parameters showed significant relation with spore load in both the years, while pooled data maximum temperature significantly positive correlation with spore load. The final equation fitted is for pooled :

$Y = -9.30 + 0.4 X_1$ including only maximum temperature with $R^2 = 0.18$.

In the similar way, the data on PDI were further subjected to multiple linear regression analysis. The coefficients are given in Table 5. The data revealed that for *kharif* 2010 the regression equation when all the parameters are included was :

$Y = -271.21 + 6.49X_1 - 10.97X_2 + 3.60X_3 + 0.03X_4 - 0.17X_5 + 2.09X_6$

with $R^2 = 0.62$.

For *kharif,* 2011, the regression equation is

$Y = -128.48 + 6.69X_1 - 7.97X_2 + 1.13X_3 + 0.22X_4 + 0.04X_5 - 0.17X_6$

Table 4. Multiple linear regressions co-efficient for spore load of *Alternaria* spp in relation to weather parameters

Year	Parameters	Constant (A)	X_1	X_2	X_3	X_4	X_5	X_6	R^2
2010	All weather parameters	-44.83	0.97	-1.30	0.44	0.09	-0.01	-0.06	0.31
	Significant weather parameters	—-	—-	—-	—-	—-	—-	—-	—-
2011	All weather parameters	-5.27	0.25	-0.43	0.08	0.02	0.00	0.03	0.26
	Significant weather parameters	—-	—-	—-	—-	—-	—-	—-	—-
Pooled	**All weather parameters**	**-28.31**	**1.01**	**-1.11**	**0.17**	**0.13**	**0.01**	**-0.33**	**0.43**
	Significant weather parameters	**-9.30**	**0.41**	**—-**	**—-**	**—-**	**—-**	**—-**	**0.18**

X_1 = Maximum temperature (°C) X_2 = Minimum temperature (°C) X_3 = Relative humidity (morning) (%)
X_4= Relative humidity (evening) (%), X_5 = Rainfall (mm), X_6 =Rainy day

with $R^2 = 0.79$.
Pooled analysis of both the years gave regression equation as :
$Y = -250.10 + 10.26X_1 - 12.23X_2 + 2.00X_3 + 0.67X_4 - 0.04X_5 - 0.79X_6$
with $R^2 = 0.78$
Where;
Y = PDI
X_1 = Maximum temperature (°C)
X_2 = Minimum temperature (°C)
X_3 = Relative humidity (morning) (%)
X_4 = Relative humidity (evening) (%)
X_5 = Rainfall (mm)
X_6 = Rainy day

The data were again subjected to step down regression by eliminating the nonsignificant factors and including only significant factors. The final equation is,

For *kharif,* 2010, $Y = 2.18 - 5.29X_2 + 1.93X_3 - 0.76X_4$ including variables minimum temperature, relative humidity morning and relative humidity evening with $R^2 = 0.56$. For *kharif* 2011, $Y = -138.31 + 6.98X_1 - 7.95X_2 + 1.14X_3 + 0.23X_4 - 0.32X_6$ including variables maximum temperature, minimum temperature, relative humidity (morning), relative humidity (evening) and rainy day with $R^2 = 0.79$. and pooled, $Y = -235.94 + 9.89X_1 - 11.84X_2 + 1.89X_3 + 0.64X_4 - 1.23X_6$ including variables maximum temperature, minimum temperature, relative humidity (morning), relative humidity (evening) and rainy day with $R^2 = 0.78$.

Bhaskaran and Kandaswamy (1980) have reported that prolonged minimum temperature of 20°C was very much congenial for the development of the disease. The relative humidity (morning) also had positive correlation with PDI. Higher relative humidity is very much conginial for the excessive spore production and disease development (Kolte, 1984). Higher relative humidity and rainfall were found to be very important factor in the development of *Alternaria* leaf blight by many workers (Borkar and Patil, 1995 and Chattannavar *et al.,* 2002).

Table 5. Multiple linear regressions co efficient for PDI in relation to weather parameters

Year	Parameters	Constant (A)	X_1	X_2	X_3	X_4	X_5	X_6	R^2
2010	All weather parameters	-271.21	6.49	-10.97	3.60	0.03	-0.17	2.09	0.62
	Significant weather parameters	2.18	—-	-5.29	1.93	-0.76	—-	—-	0.56
2011	All weather parameters	-128.48	6.69	-7.97	1.13	0.22	0.04	-0.17	0.79
	Significant weather parameters	-138.31	6.98	-7.95	1.14	0.23	—-	-0.32	0.79
Pooled	**All weather parameters**	**-250.10**	**10.26**	**-12.23**	**2.00**	**0.67**	**-0.04**	**-0.79**	**0.78**
	Significant weather parameters	**-235.94**	**9.89**	**-11.84**	**1.89**	**0.64**	**—-**	**-1.23**	**0.78**

X_1 = Maximum temperature (°C) X_2 = Minimum temperature (°C) X_3 = Relative humidity (morning) (%)
X_4= Relative humidity (evening) (%), X_5 = Rainfall (mm), X_6 =Rainy day

REFERENCES

Amaresh, Y. S., 2000. Epidemiology and management of *Alternaria* leaf blight and rust of sunflower (*Helianthus annus* L.). *Ph. D. Thesis*, Univ. Agric. Sci., Dharwad.

Anonymous, 2012. *Annual Report.* All India Co-ordinated Cotton Improvement Project *(2011-2012)* Central Institute for Cotton Research Regional Station, Coimbatore.

Bhaskaran, R. and Kandaswamy, T. K., 1980. Epidemiology of leaf spot disease of sunflower. *East African Agric. and Forestry J.,* **43**: 5-8.

Borkar, S. G. and Patil, B. S., 1995. Epidemiology of *Alternaria* leaf spot disease of sunflower. *Indian Phytopath.*, **48** : 84-85.

Chattannavar, S. N., Prakash Hegde, Hiremath, S. V., Khadi, B. M. and Narula, A. M. 2002. Study on the relationship between climatic factors, incidence, development and progress of foliar diseases of cotton. *J. Cotton Res. Dev.,* **16 :** 233-34.

Chattannavar, S. N., Srikant Kulkarni and Khadi, B. M., 2006. Chemical control of *Alternaria* blight of cotton. *J. Cotton Res. Dev.,* **20** : 125-26.

Kolte, S. J., 1984. *Diseases of Annual Edible Oilseed Crops.* Vol. -III, CRC Press, Florida, pp. 9-96.

Kotasthane, S. R. and Agrawal, S. C., 1970. Efficacy of four seed protectants for the control of bacterial blight of cotton. *Pest Articles and News Summaries.* **16**: 334-35.

Kulkarni, S., 1976. Epidemiology and control of brown leaf spot of rice caused by *Drechlera oryzae* (Breda de Haan.). Subram and Jain in Karnataka. *Ph. D. Thesis,* University of Agricultural Science, Bangalore.

Mehta, K. C., 1952. *Further studies on cereal rusts in India, Part II, Monograph,* Indian Council Agricultural Research, New Delhi, **18** : 368.

Percival, E. and Kohel, R. J., 1990. Distribution, collection and evaluation of *Gossypium. Adv. Agron.,* **44**: 225-28.

Shtienberg, D., 1996. Variables associated with intensity of *Alternaria* leaf spot in pima cotton. *Phytopath.* **86** : 123-28.

Utilization of *Sesbania aculeata (Dhaincha)* non woven fabric as mulch material

NEETA SINGH* AND ANITA RANI

Department of Clothing and Textiles, G. B Pant, University of Agriculture and Technology, Pantnagar - 263 145

**E-mail : neetasingh.345neeta@gmail.com*

Abstract : The needle punched non woven fabric prepared from processed/treated *Sesbania aculeata (Dhaincha)* fibres was tested for physical properties namely, fabric weight, fabric thickness, abrasion resistance, fabric stiffness, tensile strength and elongation, tearing strength, bursting strength and air permeability. The prepared non woven fabric of *S. aculeata* (*Dhaincha*) fibres had medium weight, compact structure and high air permeability. It was judged suitable for different purposes in agriculture sector like in mulching, air layering/ propagation of plant, packaging, filtering, etc. Finally *S. aculeata* (*Dhaincha*) non woven fabric was found suitable as mulch material comparised to control and other conventional mulch materials *i.e.*, wheat straw and poly mulch. Therefore *S. aculeata (Dhaincha)* non woven fabric can be used as mulch material for increasing the production of cotton according to climate change.

Keywords : Mulch, Needle punching, non woven fabric, Retting, *Sesbania aculeata*

The unconventional bast and leaf resources offer an opportunity to be exploited for producing textile fibres through their processing.

Non woven has emerged as one such structure offering wide applications in different sectors. Non woven is a textile structure produced by interlocking of fibres accomplished by mechanical, chemical, thermal or solvent means, and combinations there of. This technique of fabric construction utilizes fibre for product development omitting the need of yarn production and its use for fabric production.

The needle punched non woven are formed by this technique and it can utilize natural as well as synthetic fibres. The product has lower cost of production, low bulk density, porous, better absorbency, less stiffness and better thermal insulation and is biodegradable. This non woven fabric has found use in both domestic (home furnishing) as well as industrial sphere (automobiles, geotextiles and agro textiles).

One such potential sources of fibre in Uttarakhand state is *Sesbania aculeata,* locally known as *Dhaincha.* The *Dhaincha* plant belongs to *leguminacea* family, so it has nodules in its roots and these provide nitrogen content to the soil. It is grown for green manuring of the fields prior to cultivation of sugarcane and paddy crop in the fields. The stem and leaves serve as a source of organic matter for the soil by crushing entire plant in young stage in the fields. So the stem of this plant could be exploited to extract fibres and prepare eco friendly and biodegradable products to be used in agriculture sector in different practices.

The fibres obtained from *Dhaincha* are harsh, coarse and shiny in appearance but lack elasticity. In some states, the fibre is extracted and utilized for making fish net and rope, sackcloth, sailcloth and cordages. Thus this fibre, owing to its characteristics, is not utilized for regular apparel fabrics but is used only for coarse structures. To diversify the end uses of this fibre, it can be used as a potential fibre for preparing non woven structure and has to be tested for its physical properties.

MATERIALS AND METHODS

Collection and retting of Dhaincha stem : Stems of *Dhaincha* plant were collected from Crop Research Centre (C R C), G. B. P. U. A. and T., Pantnagar for its retting. Small bundles of stem of Dhaincha were carried out in plastic tubs for retting of different time intervals *viz.*, 15, 22 and 30 days in the Department. The retting period was selected for extraction of fibre from its stem, on the basis of scores of visual evaluation and physical properties such as fibre fineness (denier), fiber strength and elongation were determined by Fafegraph-M in joint operation with Vibromat M. Moisture regain of the samples was measured with methods derived by Angappan, and Gopalkrishna (1993).

Fig. 1. *S. aculeata* plants

Processing of fibres and preparation of non woven : Extracted fibres were processed for combing, scouring and bleaching process. These were scoured and bleached with different chemical agents. After that, selected processed fibres were used for making needle punched non woven with mechanical orientation and interlocking of the fibres of a spun bonded or carded web and this mechanical interlocking was achieved with housands of barbed felting needles repeatedly passing into and out of the web for non woven[6] by needle punching method at Obeetee Textiles Ltd., Sidcul, Pantnagar and its physical properties such as fabric thickness, fabric weight, tensile strength and elongation, tearing strength, bursting strength, fabric stiffness, abrasion resistance and air permeability were tested.

Use of non woven fabric in agriculture : A study to explore the use of prepared non woven fabric with *Dhaincha* fibres in agriculture had been conducted through survey among the respective scientists. The opinion and suggestions were compiled for exploring the application in agriculture sector and tested accordingly for mulching to retain the moisture in the soil.

Fig. 2. Processed fibres *(S. aculeata)* and non woven fabric

RESULTS AND DISCUSSION

The prepared non woven fabric was tested for physical properties namely; fabric weight, fabric thickness, abrasion resistance, fabric stiffness, tensile strength and elongation, tearing strength, bursting strength, air permeability and water absorption and the results are presented in Tables 1 and 2.

It is evident from data in Table 1 that the fabric weight of non woven *S. aculeata (Dhaincha)* fabric was between 613 g/m^2 and 630 g/m^2 with an average of 616 g/m^2. Also the fabric thickness of non woven *S. aculeata (Dhaincha)* fabric ranged between 4.6 to 7.97 mm with an average of

Table 1. Physical properties of non woven *S. aculeata (Dhaincha)* fabric

Sl. No.	Property	Min.	Max.	Average
1.	Fabric weight (g/m^2)	613	630	616
2.	Fabric thickness (mm)	4.6	7.97	6.28
3.	Abrasion loss (per cent)	9.4	11.18	10.3
4.	Air permeability (m^3/m^2/m)	241	250	245
5.	Bursting strength (kg/cm^2)	5.0	8.0	6.5

Table 2. Physical properties of non woven *S. aculeata (Dhaincha)* fabric

S. No.	Properties	Fabric direction	Minimum	Maximum	**Average**
1.	Tensile Strength (kg)	Machine direction	4	7	**5.6**
		Cross direction	23	25	**24**
2.	Elongation (%)	Machine direction	45	49	**47.2**
		Cross direction	19	22	**20.6**
3.	Tearing strength	Machine direction	2560	2880	**2713.6**
		Cross direction	2880	3520	**3161.6**
4.	Stiffness (cm)	Machine direction	2.65	3.15	**2.95**
		Cross direction	3.15	3.45	**3.25**

6.28mm. The result are in accordance with the finding of who reported that the jute non woven prepared by needle punching machine had fabric thickness of 4.70 mm. That had also reported that non woven prepared by needle punching method had less weight with more bulk.

It can be envisaged from data in Table 1 that the non woven *S. aculeata (Dhaincha)* fabric made with needle punching method had an average abrasion loss of 10.3 per cent. Abrasion loss was more in non woven *S. aculeata (Dhaincha)* fabric because it was made merely by the entanglement of the fibres without any subsequent finish like resin coating which could make it more abrasion resistant.

It is evident from Table 1 the average value for air permeability and bursting strength of non woven *S. aculeata (Dhaincha)* fabric were 245 $m^3/m^2/m$ and 6.5 kg/cm^2, respectively. Thus the non woven *S. aculeata (Dhaincha)* fabric had high air permeability and good bursting strength.

The fabric stiffness, tensile strength and elongation, tearing strength and bursting strength of non woven *S. aculeata (Dhaincha)* fabric were assessed in both machine as well as cross direction and are presented in Table 2.

It is evident from Table 2 that the tensile strength, tearing strength and stiffness of non woven *S. aculeata (Dhaincha)* fabric was more in cross direction as compared to the machine direction. The average tensile strength was 5.6 kg in machine direction and 24 kg in cross direction; average tearing strength of non woven was 2713.6 g in machine direction whereas in cross direction it was 3161.6 g. The higher tensile strength and tearing strength in cross direction than machine was because the fabric structure was more consolidated in cross direction than in machine direction resulting in less slippage of fibres in cross direction than machine direction of non woven. The structure of non woven fabric was the most important factor affecting the tensile behaviour of the fabric. Besides it the slippage of the fibres was considered the dominating factor in determining strength in non woven fabric prepared by needle punching method.

It is also clear from data in Table 2 that the average elongation of the non woven *S. aculeata (Dhaincha)* fabric was 47.2 per cent in machine direction whereas in cross direction it was 20.6 per cent. Thus the elongation in non woven fabric was found to be more in machine direction than in cross direction. It may be because of the fact that the strength of non woven fabric in cross direction was more than the strength in machine direction which is inversely

Table 3. Moisture per cent of soil for different period interval of time after covering with different mulch material

Treatment	Days of moisture recording(DAS)		Moisture per cent (DAS)	
	3	6	9	12
Control (no covering)	3.34	2.25	1.43	1.17
Polymulch	6.70	5.68	4.59	4.06
Wheat straw mulch	9.21	8.16	7.16	6.10
S. aculeata (dhaincha) non woven mulch	12.5	10.29	9.34	8.14

related to elongation. The above explanation is in validation with other worker. They also reported that as the strength of non woven increased elongation decreased and *vice versa.* The data in Table 2 depicts that the stiffness of non woven *S. aculeata (Dhaincha)* fabric made by needle punching method ranged between 3.15 to 3.45 cm with an average of 3.25 cm in cross direction whereas in machine direction it was found between 2.65 and 3.15 cm with an average of 2.95 cm, respectively. The higher value of stiffness in cross direction than in machine direction may be due to the higher density of fibres in that direction resulting in more compact and stiff fabric in the cross direction.

The results of the survey revealed that non woven fabric was used as mulch materials and found that moisture per cent was more in the soil, which was covered with *S. aculeata* non woven mulch material, as compared to uncovered soil (control), poly mulch and wheat straw mulch material (Table 3).

CONCLUSION

It was concluded that the *S. aculeata* (*Dhaincha*) fibres could be utilized for production of the non woven fabric suitable for end uses in agriculture sector. The retting period for extraction of *Dhaincha* fibres is 15 days. Fibers scoured with one per cent potassium hydroxide and bleached with hydrogen peroxide could be used for production of non woven fabric using needle punching method. The processed fibres exhibited better moisture regain, fibre elongation, fibre fineness and whiteness index while tenacity and fibre bundle strength was low as compared to untreated fibres. The prepared *S. aculeata* (*Dhaincha*) non woven fabric could be used suitable as mulch material as it was found with comparison to control and other conventional mulch materials straw and poly mulch. It provides a viable option to cottage industry for product development and diversification.

REFERENCE

Anonymous, 1982. *ISI Handbook of Textile Testing*. Indian Standard Institution. New Delhi, 596p.

Angappan, P. and Gopalkrishna, R. 1993. *Textile Testing*. Kamarapalayan, S.S.M. Institute of Textile Technology. 266p.

Booth, J. E. 1983. *Principle of Textile Testing.* 3rd ed. London, Newness Butterworth. 576p.

Annual Book of ASTM Standards. 2006. Section seven Textiles. Vol (07.0) West Conshohocken, PA, ASTM International.

Debnath, C. R and Roy, A. N. 1999. Needle punched non woven. *The Indian Textile Journal.* **108(8)** : 34-37.

Smith, S. 2006. *Felt to Stitch creative felting for Textile Artists*. London, Anova Book Company Ltd. 114p

Patel, P. C and Kothari, V. K. 2001. Effect of specimen size and strain rate on the tensile properties of heat-sealed and needle punched non woven fabrics. *Indian Jour. Fibre Textile Research.* **26(14)**: 409-13.

Proceedings on “Global Cotton Production Technologies *vis-a-vis* Climate Change” 263-267

Response of *Bt* cotton to different methods of fertilizer application under irrigated situation in north eastern dry zone of Karnataka

G. Y. VIDYAVATHI*, M.V. RAVI , G.S. YADAHALLI, S. N. UPPERI AND H. S. LATHA
University of Agricultural Sciences, College of Agriculture, Bheemarayanagudi - 585 287
**E-mail : vidyasac@rediffmail.com*

Abstract : The suitable method of fertilizer application for *Bt* cotton was studied in deep black soils of Shahapur and Shorapur taluks of Yadagir District in north eastern dry zone of Karnataka under Upper Krishna Command Project area during 2010 – 2011 and 2011 – 2012. The results (pooled over two years) indicated that cotton seed and dry matter yield were recorded significantly higher in the STCR approach (29.8 q/ha and 48.8 q/ha, respectively) as compared to all other treatments and was followed by NK + 50 % & P + 25 % (27.9 and 44.8 q/ha respectively). The increase in seed yield was 49 per cent with application of fertilizer by STCR approach followed by NK + 50 per cent and P + 25 per cent (40 %) over other treatments. The discounted net returns and B: C ratio were significantly higher in treatment receiving fertilizer by STCR approach (Rs.166788 and 4.55/ha, respectively). This was followed by soil test based NK ± 50 per cent and P ± 25 per cent (Rs. 155896 and 4.43/ha, respectively). Soil available nutrients were also found significantly higher with STCR approach fertilizer recommendation.

Key words : B:C., discounted net returns, soil test, STCR

Upper Krishna Project command area has largest irrigation project in India and also State of Karnataka, ultimate irrigation potential area of about 6.22 lakh ha for which suggested cropping patterns are bajra, maize, groundnut, greengram and sunflower during *kharif* season, sorghum, wheat, chickpea, and sunflower during *rabi* season and long duration crops like redgram, cotton and chilli and horticultural crops. Farmers are practicing cotton, chilli and paddy crops in command area.

Due to adaption of high yielding varieties of principal crops and multiple cropping, soils are depleted in nutrients at a much faster rate than in the case of old cropping system. As a result, crop production has become highly fertilizer oriented. Judicious use of fertilizers is required as cost of fertilizer is very high in our country. Soil test based fertilizer recommendation result in efficient fertilizer use and maintenance of soil fertility. Among the various methods of fertilizer recommendations, the one based on yield targeting is unique as it not only indicates soil test based fertilizer dose but also the level of yield that can be obtained if appropriate practices are allowed in raising the crops.

The existing state blanket recommendation for *Bt* cotton in Karnataka does not ensure efficient and economic use of fertilizers, as it does not take into account the fertility variations resulting in imbalanced use of fertilizer nutrients. The present study was undertaken to develop balanced fertilizer schedule to increase the productivity and fertilizer use efficiency in *Bt* cotton crop and to investigate the changes in soil available N, P and K and yield of *Bt* cotton under different fertilizer application practices.

MATERIALS AND METHODS

The suitable method of fertilizer application for *Bt* cotton was studied in deep black soils of Shahapur and Shorapur *taluks* of Yadagir District in north eastern dry zone of Karnataka under irrigated situations. The experiment was laid out in randomized block design with six treatments (Table 1) with four replications. The fertilizer dosage varied with respect to treatments (Table 1). For all the treatments, recommended FYM and deficient nutrients application were common. The initial soil fertility status of all the locations was low in nitrogen, medium in phosphorus and high in potassium. Soil samples were collected from each plot and analyzed for alkaline $KMnO_4$ –N (Subbaiah and Asija, 1956), Olsen’s –P by Ascorbic acid method (Jackson, 1967) and NH_4OAC-K (Jackson, 1967). The experiment was conducted for two years 2010-11 and 2011-2012. The data collected from the experimental field and laboratory analysis were subjected to statistical analysis by adopting Fischer's method of analysis of variance as outlined by Gomez and Gomez (1984). The level of significance used in 'F' and't' test was p=0.05. Critical differenced were calculated wherever 'F' test was significant.

RESULTS AND DISCUSSION

The results (pooled over two years) indicated that (Table 2) cotton seed and dry matter yield were recorded significantly higher in the STCR approach (T_2) *i.e* 29.8 and 48.8 q/ha, respectively (increase in seed yield was 49 %) followed by (NK ± 50 %) and (P ± 25 %) (T_5) *i.e.* 27.9 and 44.8 q/ha, respectively (increase in seed yield was 40 %). The lowest seed and dry matter yield was recorded in the treatment receiving recommended NPK + FYM (As/POP) (T_1) *i.e.* 20.0 and 29.7 q/ha, respectively. This can be attributed to nature of crop which is exhaustive and grow well with higher dose of fertilizer based on soil test value. The findings are in accordance with that resulted of Gayathri *et al.,* (2009) where they suggested that STCR - IPNS recommendations for potato are better for the efficient and economic use of fertilizer. Stalin and Thiyagirajan (2000) reported that STCR-N methods produced high grain yield with low NUE values. Similarly Srinivasan and Angayarkanni (2008), Subba Rao and Srivastava (1998) also highlighted the STCR approach of fertilizer recommendation in increasing grain yields of the crops.

Table 1. Details of fertilizer application treatmentwise

Treatments	$N:P_2O_5:K_2O$ applied (kg/ha)
T_1 : Recommended NPK (As/POP)	150:75:75
T_2: STCR Approach (Yield target : 45 q/ha)	204-289:51-113:38-67 (2010-11) 251:93:58 204-251:113:66-74 (2011-12) 228:113:69
T_3 : Soil test based NPK (LMH Approach or STL method)	175:75:50
T_4: Soil test based NPK + 25 per cent	188:75:56
T_5: Soil test based NK + 50 per cent & P + 25 per cent	225:75:38
T_6: T3 + 75 per cent RDP + PSB	175:56:50

Soil available nutrients also varied with the method of fertilizer application. The pooled results showed that (Table 3) the available N was significantly higher in the treatment receiving fertilizer dosage as/STCR approach (193 kg/ha) and was found to be superior to all other treatments. In the treatment receiving fertilizer as/package of practice (T_1) the available N was 158 kg/ha. In STCR approach around 35 kg N / ha and in treatment receiving soil test based (NK ± 50%) and (P ± 25 %) around 27 kg N /ha was higher than only recommended dose of NPK. However, the available N in the soil was low in category. The pooled results showed that (Table 3) the available P_2O_5 was significantly higher with fertilizer dosage as/STCR approach (32.6 kg/ha) and was found to be superior to all other treatments. In the treatment receiving fertilizer as/package of practice (T_1) was noticed lowest available P_2O_5 (19.8 kg/ha). In STCR approach (13 kg P_2O_5 /ha) and soil test based NK (± 50%) and P (± 25 %) application (10 kg P_2O_5 /ha) with in was higher than the recommended dose of NPK. The available K_2O was also significantly higher with fertilizer dosage as/ STCR approach (499 kg/ha) and was found to be superior to all other treatments. Application of fertilizer as/ package of practice (T_1) recorded lowest available K_2O. In STCR approach (45 kg K_2O /ha) and soil test based (NK± 50%) and (P± 25%) application was higher than recommended dose of NPK. However, the available K_2O in the soil was high in category. Findings of Subba Rao and Srivastava (1998), in accordance with the present study was the findings of Srinivasan and Angayarkanni (2008)

The effect of treatments on the economics of *Bt* cotton were also studied, the results (pooled) showed that discounted net

Table 2. Effect of methods of fertilizer application on yield of *Bt* cotton

Treatments	Seed cotton yield (q/ha)			Dry matter yield (q/ha)		
	2010-11	2011-12	**Pooled**	2010-11	2011-12	**Pooled**
T_1 Recommended NPK (As/POP)	21.19	18.89	**20.04**	31.76	27.57	**29.67**
T_2 STCR Approach (yield target : 45 q/ha)	31.63	27.88	**29.76**	51.40	46.13	**48.77**
T_3 Soil test based NPK (LMH Approach or STL method)	26.09	22.88	**24.49**	41.17	35.00	**38.09**
T_4 Soil test based NPK (± 25 %)	27.47	24.53	**26.00**	43.31	38.70	**41.01**
T_5 Soil test based (NK ± 50 %) and (P±25 %)	29.44	26.39	**27.92**	47.15	42.48	**44.82**
T_6 T3 + RDP (75 %) + PSB	24.63	20.89	**22.76**	37.87	31.03	**34.45**
SEm ±	0.44	0.35	**0.28**	0.66	0.66	**0.46**
C.D (p=0.05)	1.23	0.98	**0.78**	1.84	1.83	**1.29**
CV (%)	9.28	8.40	8.93	8.85	10.06	**9.42**

Table 3. Effect of methods of fertilizer application on available N, P_2O_5 and K_2O in *Bt* cotton grown soil

Treatments	Nitrogen (kg/ha)			P_2O_5 (kg/ha)			K_2O (kg/ha)		
	2010-11	2011-12	**Pooled**	2010-11	2011-12	**Pooled**	2010-11	2011-12	**Pooled**
T_1 Recommended NPK (As per POP)	149.25	167.00	**158.13**	17.88	21.63	**19.76**	459.00	449.00	**454.00**
T_2 STCR Approach (Yield target : 45 q/ha)	179.13	208.00	**193.57**	25.63	39.63	**32.63**	498.75	499.50	**499.13**
T_3 Soil test based NPK (LMH Approach or STL method)	161.25	188.00	**174.63**	21.25	30.13	**25.69**	484.50	477.00	**480.75**
T_4 Soil test based NPK (±25 %)	164.19	194.25	**179.22**	22.44	32.63	**27.54**	484.25	482.50	**483.38**
T_5 Soil test based NK (± 50 %) and P (± 25 %)	169.75	201.25	185.50	23.50	36.00	29.75	483.25	490.38	**486.82**
T_6 T_3 + RDP (75 %) + PSB	157.63	181.25	**169.44**	19.00	27.00	**23.00**	477.94	472.50	**475.22**
SEm ±	1.48	3.28	**1.80**	0.24	0.61	**0.33**	2.18	6.24	**3.30**
C.D (p=0.05)	4.15	9.18	**5.00**	0.67	1.71	**0.91**	6.10	17.47	**9.18**
CV (%)	5.12	9.77	8.14	6.24	11..07	9.93	2.56	7.38	**5.51**

returns and B:C ratio were higher with application of fertilizer by STCR approach (Rs.166788 and 4.55/ha, respectively)as compared with all other treatments. However, it was followed by soil test based (NK + 50%) and P (+ 25 %) (Rs. 155896 and 4.43/ha, respectively). On the other hand the lowest discounted net returns and B:C was recorded where recommended NPK + FYM (As/POP) (T_1) was applied (Rs.99086 and 3.23/ha, respectively). It can be concluded that among the different methods of fertilizer application, STCR approach performed better in irrigated *Bt* cotton by increasing the yield ,available nutrients in soil, net returns and B:C as compared to the other methods and also helped maintaining the soil fertility.

Table 4. Effect of methods of fertilizer application on economics of *Bt* cotton

Treatments	Cost of cultivation (Rs/ha)			Gross returns (Rs/ha)			Net returns (Rs/ha)			B:C ratio
	2010-11	2011-12	Discounted cost of cultivation	2010-11	2011-12	Discounted GR	2010-11	2011-12	Discounted NR or NPV	
T_1 Recommended NPK (As/POP)	25408	25713	44335	89998	74592	143421	64590	48879	99086	3.23
T_2 STCR Approach (Yield target : 45 q/ha)	26731	27462	46982	135114	110111	213770	108383	82649	166788	4.55
T_3 Soil test based NPK (LMH Approach or STL method)	25512	25825	44522	112136	90370	176577	86624	64545	132055	3.97
T_4 Soil test based NPK (+ 25 %)	25708	26028	44868	117713	96892	187034	92005	70864	142166	4.17
T_5 Soil test based (NK + 50) and P (+ 25 %)	26003	26338	45392	126716	104241	201288	100713	77903	155896	4.43
T_6 T3 + RDP (75 %) + PSB	25172	25430	43887	105484	82501	164031	80312	57071	120144	3.74

REFERENCES

Gayathri, A., Vadivel, A., Santhi, R., Murugesa, Boopathi and Natesan, R., 2009. Soil test based fertilizer recommendation under integrated plant nutrition system for potato (*Solanum tuberosum.* L) in hilly tracts of nilgiris district. *Indian J. Agric. Res.,* **43 (1)** : 52-56

Gomez, K. A. and Gomez, A. A., 1984, *Statistical Procedures for Agricultural Research.* An International Rice Research Institute Book, A Wiley Interscience, John Wiley and Sons Inc., New York, USA

Jackson, M. L., 1967, *Soil Chemical Analysis,* Prentice Hall of India Pvt. Ltd.,New Delhi (India), p. 205.

Srinivasan, S. and Angayarkanni, A. 2008. Fertilizer potassium doses based on STCR for an yield target of 70 q/ha or rice cv. ADT 36 . *An Asian Jour. Soil Sci.* **3(2)** , 246-48

Srinivasan, S. and Angayarkanni, A. 2008. Effect of INM on yield and nutrient uptake by rice in STCR experiment. *Agric. Sci. Digest*, **28 (2) :** 130 - 32,

Stalin, P. and Thiyagirajan, T. M, 2000. Comparing management techniques to optimize fertilizer N application in rice in the Cauvery Delta of Tamil Nadu, *India. Soil, nutrient water manag.* IRRN **25 (2)** : 25-26

Subba Rao, A.and Srivastava, S. 1998. In: 15th *Annual Report*. All India Coordinated Research Project for Investigations on Soil Test Crop Response Correlation, IISS, Bhopal. p.16.

Subbaiah, B. V. and Asija, G. L., 1956, A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.,* **25** : 259-60.

Heritability and genetic advance in Asiatic cotton (*Gossypium arboreum L*) genotypes

RUMESH RANJAN*, R. S. SANGWAN, S. S. SIWACH, O. SANGWAN, NANCEE, MITALI SAH AND J. N. SAH
Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar - 125 004
**E-mail : rumeshranjan5@gmail.com*

Abstarct : Sixty *Gossypium arboreum* genotypes were studied to observe genetic variability, heritability and genetic advance for seed cotton yield and its contributing characters. The analysis of variance revealed that the sufficient variability was present in the material for all the characters. The value of phenotypic coefficient of variation (PCV) is greater than genotypic coefficient of variation (GCV); it meant that the apparent variation was not only due to genotypes but also due to influence of environment. Seed cooton yield/plant provided high estimates of genotypic and phenotypic coefficients of variation coupled with high heritability and high expected genetic gain as a per cent of mean, which provided better scope for advancement through direct selection. Similar results were also observed for number of monopods. Hence, improvement in seed cotton yield due weight age should be given on number of monopods.

Key words: Genetic advance, *G. arboreum,* heritability, seed cotton yield, variability

Cotton is one of the most important cash crops in India. On account of its agricultural, as well as industrial importance, it is also called as 'White Gold'. In India, cotton is grown on about 12.19 million ha, which represents 30 per cent of the world cotton area. The average cotton productivity of cotton in India is about 481 kg/ ha which is about 70 per cent of world average of 740 kg/ha (CICR database, 2011-12). Millions of people depend on cotton cultivation, trade, transportation, ginning and processing for their livelihood. The productivity of cotton has not made headway particularly in *Gossypium arboreum*. Therefore, there is a need to break plateau of yield potential by developing a high yielding cotton varieties or hybrids.

Information on the nature and the extent of genetic variability, heritability and genetic advance is an important prequisite in framing any crop improvement programme. Genetic variability alongwith heritability of a character indicates the possibility and extent to which improvement was feasibile through selection on phenotypic basis. Furthermore, high heritability coupled with high genetic advance would bring out the progress expected from selection (Johnson *et al.*, 1955). Therefore, the present study was under taken to find out the genetic variability, heritability and genetic advance of various yield and its components traits in *G. arboreum.*

MATERIALS AND METHODS

The present investigation was carried out in. Research Area, Cotton Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar during *kharif,* 2011. Sixty diverse cotton genotypes from different cotton growing states were raised in a randomized block design (RBD) in three replications. There were two rows of each genotype of three meter length. Rows were spaced 67.5 cm apart and plant to plant distance with in a row was 30 cm. The data were recorded on five competitive plants selected randomly from each replication. The mean of five plants was used for statistical analysis. Recommended package of practices were followed for raising the crop. The data on the nine parameters were recorded *viz,* days to first flower, plant height (cm), monopods, bolls/plant, boll weight (g), seed cotton yield/plant (g), ginning outturn (%), seed index (g) and lint index (g). The genotypic coefficient of variability (GCV), phenotypic coefficient of variability (PCV), heritability in broad sense and genetic advance were estimated as per the standard procedure cited by Singh and Chaudhary (1977).

RESULTS AND DISCUSSIONS

Analysis of variance indicated highly significant differences among the genotypes for all the characters studied indicating existence of sufficient amount of variability in the material. Genetic variability was assessed among all the genotypes for the purpose of comparison across different traits. Comparison of variability parameters are presented in Table 1. Perusal of data in Table 1 showed that values of PCV were greater than GCV; it meant that the apparent variation was not only due to genotypes but also due to influence of enviroment. Selection of such plants on phenotypic basis may not be fruitful. The result of the present study revealed that maximum phenotypic (30.80) and genotypic (28.28) coefficient of variation were observed for number of monopods per plant. Different workers like Mane and Bhatade (1992), Reddy and Pradeep (2001), Kale and Annapurve (2007), Do Thi *et al.,* (2008), Patnaik and Sial (2010) and Kulkarni *et al.,* (2011) also observed wider genetic variability for this trait in cotton. High GCV and PCV were also observed for seed cotton yield / plant with phenotypic (20.85) and genotypic (20.01) coefficient of variation. Similar result had been reported by Gitte *et al.*, (2006), Do Thi *et al.*, (2008), Khan *et al.*, (2009), Patnaik and Sial (2010) and Kulkarni *et al.,* (2011). Values for GCV and PCV were found moderate for rest of the characters except seed index (7.50% and 9.954%) and ginning outturn (5.70 % and 8.09 %), respectively.

Heritability estimates in broad sense were relatively higher for almost all the characters under investigation (Table 1). Among the characters studied the highest estimate of heritability was recorded for days to first flower (95.500 %). Similar trend of heritability was reported by Reddy (2001) and Neelam and Potdukhe (2002). High heritability was also observed for seed cotton yield/plant (92.1%), number of monopods (84.3 %), plant height (84.2%), boll weight (80.3%), number of bolls (79.0%) whereas, seed index (56.9%), ginning outturn (49.8%) and lint index (41.4%) exhibited moderate estimate of heritability (30-60%). These finding are in accordance with the findings of Patnaik and Sial (2010) for seed cotton yield/ plant, number of monopods and boll weight and with Kale and Annapurve (2007) for plant height and number of bolls. Similar results for seed index, ginning outurn and lint index were also reported by Reddy and Pradeep (2001) and Sambamurthy *et al.,* (2006). These findings of high heritability indicated that enviromental effects less influenced these characters and hence additive gene effects were substantially contributing for these traits. Hence, selection for these traits would be helpful for improvement in seed cotton yield.

In the present investigation, high heritabilitry estimates coupled with high genetic advance were recorded for the traits like seed cotton yield/plant and plant height. These

Table 1: Variability parameters for different characters in *Gossypium arboreum*

Variability parameter	Days to first flower	Plant height (cm)	Bolls/ plant	Monopods/ plant	Boll weight (g)	Seed cotton	Ginning outturn	Seed index	Lint index yield/ plant
Grand Mean	**56.28**	**172.14**	**34.14**	**4.53**	**2.32**	**72.26**	**38.22**	**5.14**	**3.20**
Range	44.67-68.33	133.67-211.33	21.33-50.33	2.33-7.33	1.77-3.00	44.00-115.33	34.03-43.47	4.23-4.27	2.23-4.27
Genotypic variance	30.30	486.65	26.55	1.64	0.07	208.99	4.76	0.15	0.10
Phenotypic variance	31.73	577.94	33.62	1.95	0.09	226.96	9.55	0.26	0.25
GCV (%)	9.78	12.81	15.10	28.28	11.85	20.01	5.71	7.50	10.00
PCV (%)	10.01	13.96	16.98	30.80	13.22	20.85	8.09	9.95	15.55
h^2_{bs} (%)	95.50	84.20	79.00	84.30	80.30	92.10	49.80	56.90	41.40
GA	11.08	41.70	9.43	2.42	0.51	28.58	3.17	0.60	0.42
GAM (%)	19.69	24.22	27.63	53.48	21.87	39.55	8.30	11.66	13.25

findings were in agreement with the findings of Do Thi *et al.,* (2008), Patnaik and Sial (2010) and Kulkarni *et al.*, (2011) for both traits. Thus, it can be concluded from above findings that the selection for these traits may accumulate more additive genes leading to further improvement of the characters. Genetic advance percentage of mean (GAM), togetherwith high heritability estimates indicated there would be a close correspondance between the genotype and the phenotype due to a relatively smaller contribution of the enviroment to the phenotype and hence selection for the character is easy. Such situation, genetic improvement in different traits should be made considering heritability and GCV values higher. Johnson *et al.*, (1955) suggested that effectiveness of selection depend upon heritability but heritability itself was not a true measure of genetic advance.

Thus, in present investigation when variability, heritability and genetic advance considered together, seed cotton yield/plant, number of monopods and to some extent plant height may be the best reliable traits that would be exploited through hybridization and selection, since these characters recorded high magnitude for two or three variability parameters.

REFERENCES

Do Thi Haan, Ravikesavan, R. and Iyanar. **2008**. Genetic advance and heritability as a selection index for improvement of yield and quality cotton. *J. Cotton Res. Dev.* **22** (1): 14-18.

Gitte, V. K., Misal, M. V. and Kalpande, H. V. 2006. Correlation path analysis in cotton (*Gossypium hirsutum* L.). *J. Cotton Res. Dev.* **20** (1): 50-54.

Johnson, H. W., Robinson, H. F. and Comstock, R. E. 1955. Estimate of genetic and environmental variability in soyabean. *Agron. J.* **47**: 314-18.

Kale, U, V. and Annapurve. 2007. Yield components analysis in American cotton (*G. hirsutum* L.), *Madras Agric. J.* **94** : 156-61.

Khan, B. M., Khan, N. U. and Khan, I. **2009**. Genetic variability and heritability in upland cotton. *Pak. J. Bot.* **41** (4): 1695-1705.

Kulkarni, A. A., Nanda, H. C. and Patil, S. G. 2011. Studies on genetic divergence in upland cotton *(Gossypium hirsutum* L.). *J. Cotton Res. Dev.* **25**(1) : 9-13.

Mane, S. S. and Bhatade, S. S. **1992**. Combining ability analysis in F_1 and F_2 diallel for yield and quality in cotton (*Gossypium hirsutum* L.). *Madras Agril. J.* **79:** 563-70.

Neelam, G. D. and Potdukhe, N. R. **2002.** Studies on variability and correlations in upland cotton for yield and its components. *J. Indian Soc. Cotton Improv.* **27**(3): 148-52.

Patnaik, R. K. and Sial, P. **2010**. Genetic variability, character association and component analysis in upland cotton (*Gossypium hirsutum* L.) under rainfed condition. *J. Cotton Res. Dev.* **24** (2): 155-59.

Reddy, M. and Pradeep. **2001**. Correlation and path analysis in upland cotton (*Gossypium hirsutum* L.). *Madras Agic. J.* **88**(1): 205-08.

Sambamurthy, J. S. V., Ratna Kumari, S. and Chamundeshwari, N. **2006**. Studies on variability correlation path analysis over environments (*Gossypium herbaceum* L.) cotton under coastal saline soils. *J. Maharashtra Agric. Univ.* **31** (1): 60-64.

Singh, R. K. and Choudhary, B. D. **1977**. *Biometrical Methods in Quantitative Genetics Analysis.* I Edn. Kalyani Publishers, New Delhi.

Proceedings on "Global Cotton Production Technologies *vis-a-vis* Climate Change" 271-279

Impact of climate change on cotton and its production in India

R. S. JAGLAN, NAMITA SINGH* AND KANU PRIYA
Guru Jambheshwar University of Science and Technology, Hisar - 125 001
**Email : namitasingh71@gmail.com*

Abstract : Cotton (*Gossypium spp.*) is a major cash crop, being the world's leading natural fibre for the manufacture of textiles and edible oil. Climate has changed many times in response to a variety of natural causes but the term climate change usually refers to those changes that have been observed since the early 1900s and includes anthropogenic and natural drivers of climate. Increasing temperature can have both positive and negative effects on cotton growth depending on the location of the region. Higher CO_2 levels in the immediate surroundings of the cotton plant will increase photosynthetic activity. Pests are a threat to the cotton production worldwide. Water availability is another important factor in cotton cultivation. India is the third largest cotton producing and consuming country in the world following USA and China. This review discusses thorough impact of climate change on cotton production and recommendation for minimizing the impact of climate change.

Key words: Climate, cotton, CO_2, temperature, water availability.

Since its discovery for about 4000 years ago in Coastal Peru and at Mohanjodaro in the Indus Valley, Cotton *(Gossypium spp.*) is closely linked to human civilization and is popularly knowh as "King of fibre". Cotton has played a vital role in flourishing Indian economy. Until the middle of the 18^{th} centuries only ideogram *arboreum* and *herbaceum* varieties of cotton were grown in different regions of the country. American Cotton (variety Combodian) was introduced in India in 1904. Prior to 1914, *desi* cotton with short staple length (below 19 mm) was mainly produced in India (40-50 lakh bales).

Man has been utilizing cotton for his benefits since ancient times (Fryxell, 1992). Cotton is a multipurpose crop that supplies five basic products such as lint, oil, meal and seed hulls. Lint is the most important product of the cotton plant and provides much of the high quality fibre for the textile industry. Cotton supports millions of people through cultivation, processing and trade and contributes Rs.360 billion (US$8 billion) to the export income.

The area occupied by cotton under cultivation is between 8 to 9 million ha in India. While India has the largest area under cotton in the world (representing 20 to 25 per cent of the global area), it ranks only third in terms of production after China and USA.

One of the great development challenges is to guarantee food security for the world's poor while also ensuring greater sustainability of food and fibre production and consumption. Cotton is an important crop for the world's poor. Exports of the crop from developing countries reached US$ 2.8 billion in 2009–2010, providing incomes to millions of farmers. The cotton value chain both contributes to climate change and is at risk from its impacts. We currently releasing 70 million tons of CO_2 in the atmosphere and causing rise in surface temperature on earth. Over the past 100 years the earth's surface has warmed by approximate 6°C. Scientists warned that if the current rate of green house emission continues, global air temperature could rise between 1.5-4.5°C by the year 2100. Climatic change is a serious environmental challenge that could undermine the drive for sustainable development. Agriculture is highly sensitive to climate variability and extreme weather such as drought, flood etc which severely impact our agriculture production. This review examines the threats for cotton production due to the changing climate and the options for improvement and adaptation.

Impact of specific climatic changes : Agriculture is the major sector that is influenced by climate change due to the effects on plant growth and yield. Enormous attention has been paid in the last decade or so to find the economic impact of climate change and global warming in the agricultural sector.

Cotton plants respond to the changing

environment at different stages of development. Key stages in cotton plant development are: a) conditions at the time of planting; b) plant development in early season; c) flowering, d) boll formation and e) conditions towards the end of the season.

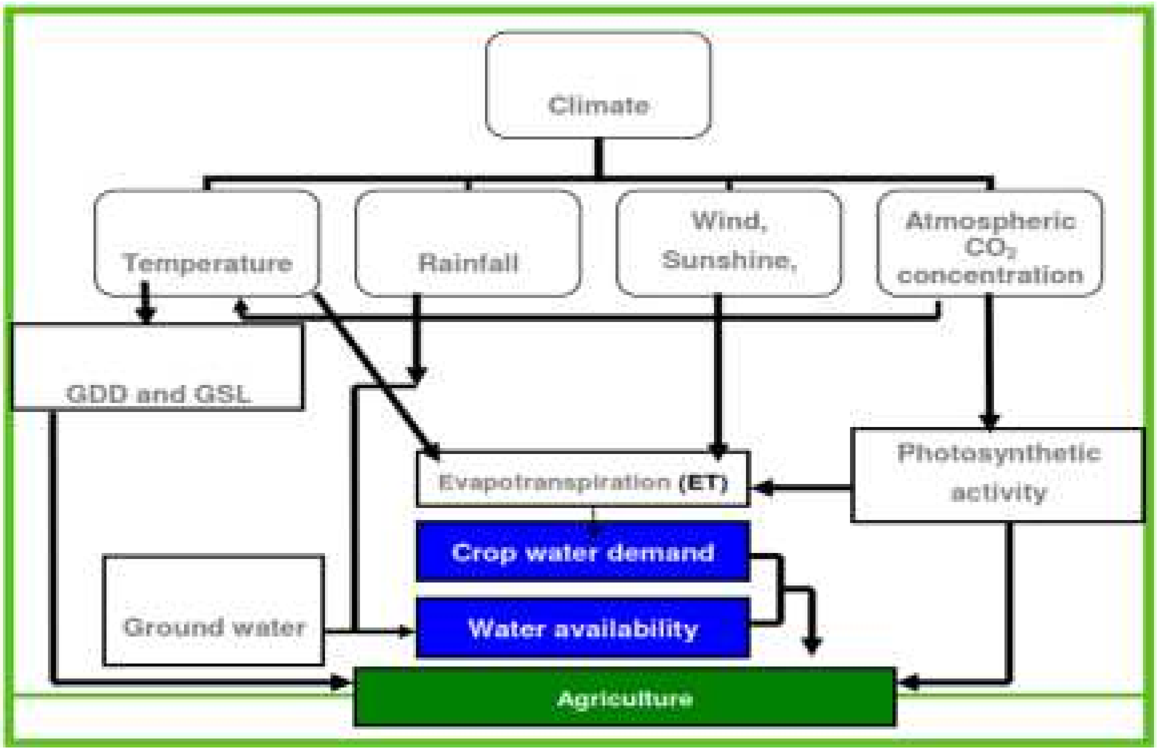


Fig. 1. The impact of climate on water availability and then their combined impact on agriculture (crop yield). GDD: growing degree days; GSL: growth season length. (Adapted from M.A. Goheer, Global Change Impact Studies Centre (GCISC), Pakistan)

Effect of temperature : Global food production is projected to increase overall with increases in average (local) temperatures of 1–3°C, but if temperature rises are above 3°C then global food production will decrease. Temperature is an important parameter in determining crop quality, quantity and where it can be grown. As biology and ecology are inter related, any change in temperature through climate change will have large impacts on crop (commodity) production.

Development stages accelerated in a linear fashion within certain temperature boundaries (*e.g.* between 10°C and 30°C for wheat), but with extreme temperatures the relationship becomes non-linear. Higher temperatures often lead to heat stress which can result in increasing sterility and lower overall productivity in crops. Increasing temperature enhances the rate of transpiration in plants and evaporation of water from soils resulting in lowering of water table and further leads to stress to the crop. Higher temperatures may lead to a longer growing season and more rainfall or to lower rainfall and a shorter growing season depending on the region. Low soil temperatures at planting time hamper timely planting of cotton in many countries. Rising temperatures benefit some countries as they will be able to plant cotton much earlier than they do now. However, higher temperatures in cotton producing areas with already high temperatures could have a negative impact as a result of increased shedding of flower buds. The regions where the effective fruiting period is squeezed between two phases of lower temperatures, rise in temperature could have positive effects on yields. Boll retention is highly sensitive to high temperatures. It is not possible to avoid the effects of high temperatures, this condition can produce bud shedding, which is the most common reason for loss of fruit forms (Reddy *et al.,* 1999). Reddy *et al.,* (1999) also observed that temperature regimes alter boll development: boll size and the maturation period both decreased as the temperature increased.

Reddy *et al.,* (2000; cited in ICAC, 2007) determined that boll growth decreases significantly and fruit is shed 3–5 days after blossom in temperatures over 32° C. Thus, the upper limit of cotton for blossom and fruit period is 32° C. However, refering to the monthly average maximum temperature, ICAC (2009) stresses that cotton production is currently viable also in hotter environment. Data in Table 1 show that cotton is successfully grown at 28.2° C in China and 37.6° C in India, 36.8° C in Pakistan and 41.8° C in Sudan. Further it is concluded that heat stress is a big constraint to increasing yields. The countries listed above cover almost three-quarters of the world cotton area. If global warming continues, the first five countries could experience a positive impact on yields as a result of a rise in temperatures of only a few degrees Celsius. Regions that are already producing cotton at close to 40° C would seem to be at a disadvantage. They already have longer growing seasons and any rise in temperature could induce sterility and inhibit boll formation. Breeding in these countries will have to focus on heat tolerance (ICAC, 2009). Rising temperatures have a complex effect on fibre characteristics too. Literature reveals that increased temperatures could result in higher micronaire values (the size of an individual cotton fibre taken in cross-section), stronger fibre and more mature fibres. While higher micronaire values are not a desirable characteristic when they are already close to the upper limit, they could have a desirable effect in areas characterized by low-micronaire and low maturity cotton (ICAC, 2007).

Table 1. Monthly average maximum temperature (in °C) for a six month cotton season

Country	Months						Mean
	1	2	3	4	5	6	
Turkey (South East Anatolia)	20	27	33	38	38	33	31.5
China (Henan)	21	28	32	31	30	27	28.2
United States of America	24	28	32	34	33	30	30.2
Australia	27	30	33	34	33	31	31.3
Argentina (Chaco and Formosa)	30	33	34	34	32	32	32.5
India (North)	36	41	40	36	36	36	37.5
Pakistan (Punjab)	40	40	37	36	35	33	36.8
Sudan (Gezira)	41	42	42	42	42	42	42

Source: ICAC (2009), Global warming and cotton production – Part 2.

Effect of Co_2 level : Carbon dioxide is essential to plant growth. Rising Co_2 concentration in the atmosphere can have both positive and negative impacts. The effects of elevated Co_2 on plant growth and yield will depend on species, photosynthetic pathways (C3 and C4 plants have enzymatic differences for carbon fixation), growth stage and management regime, such as water and nitrogen applications. Elevated Co_2 increases the size and dry weight of most C3 plants and plant components and increase crop yield to 550 ppm. Relatively more photoassimilate is partitioned into structural components (stems and petioles) during vegetative development in order to support the light-harvesting apparatus (leaves). The harvest index tends to decrease with increasing Co_2 concentration and temperature. Co_2 in the range of 10–20 per cent for C3 crops (*e.g.* rice, wheat) and 0–10 per cent for C4 crops (*e.g.* maize, sugarcane, sorghum) s reqiored. Observed increase of above-ground production in C3 pastures is about 10 per cent.

The rise in atmospheric carbon dioxide (Co_2) concentration from about 280 m mol/mol before the industrial revolution to about 360 m mol/mol currently is well documented, Baker and Enoch, 1983; Keeling *et al.*, 1995). Cotton will grow more vigorously as the amount of Co_2 in the air increases because leaves will likely be larger with increased growth, thereby giving plants a greater photosynthetic surface area and also fruiting sites will likely develop, and this, in turn, provide for higher lint yields (ICAC, 2007). However, increased photosynthesis will first foster vegetative growth which may translate into an increase in fibre yield but reproductive growth is not automatic.

According to Reddy *et al.,* (1998), at temperatures greater than 30° C most of the fruit was aborted regardless of Co_2 concentration (ICAC, 2007). Higher levels of photosynthesis expressed in the form of greater growth may lead to an increased demand for inputs, including water and soil nutrients, particularly if the balance is inclined towards vegetative growth. Especially in marginal production areas where water is not available in sufficient quantities, the result could then be quite negative (ICAC, 2007).

Another impact of higher atmospheric Co_2 is that weeds will be growing more vigorously as well. When cotton is in the seedling stage, competition with weeds is critical. In spite of the fact that cotton planting and development will start earlier as temperatures rise, the same development will be observed in weeds. The critical period in the development of cotton and weeds will coincide. Cotton can compete with weeds more effectively under conditions where there is enough water and nutrition (Kaynak, 2007). Yet, climate change will affect the entire cotton-weed relationship. Climatic change will likely be more beneficial to weeds due to the fact that genetic variations and selective ecological adaptations are more developed in weeds than in cultural plants. Some weed species may already exist in cotton areas but not yet be considered important species. Weed species carrying tropical characteristics can benefit from increasing temperatures and may turn into dangerous species (Kaynak, 2007). Weed control will then become more critical to achieving optimal cotton plant development and yield. Furthermore, increases in atmospheric Co_2 will decrease the nutritional value of leaves for pests due to an increasing ratio of carbon to nitrogen in plant tissues. That is why increasing Co_2 levels and temperature fluctuations were assumed to affect pest population. Several studies have exhibited that global warming will influence the pest's metabolism and increase their population rate, spreading to the cooler terrains in the North and South, and resulting in the existence of different plant variations and novel species. An increase in pest pressure is expected (Karl *et al.*, 2009). Wu *et al.,* (2007) reported that genetically modified Bacillus thuringiensis (*Bt*) cotton showed less *Bt* toxin after exposure to elevated Co_2, which might affect plant-bollworm interactions. Karl *et al.,* (2009) state that higher temperatures reduced the effectiveness of certain classes of pesticides (pyrethroids and spinosad).

Water availability : Plants need adequate water to grow and to maintain their temperature within an optimal range. Water scarcity may lead to heat stress. Thus, the amount and timing of water availability during the growing season, through precipitation or irrigation, are critical for cotton. If water supply variability increases, it will affect plant growth and cause reduced yields (Karl *et al.*, 2009).

Cotton surface that is dedicated to irrigation is already high; about 53 per cent of the total area (Soth *et al.*,1999). However, yields for irrigated cotton are much higher (3,000–4,000 kg seed cotton/ha) than in rainfed cotton (1,000–2,000 kg of seed/ha). With increasing demand and competition for freshwater supplies, water availability may in many countries become an important factor limiting cotton production. Globally, agriculture is by far the heaviest user of freshwater, primarily for irrigation, with about 70 per cent of the total. The sheer size of agricultural water use for irrigation implies that any pressure on freshwater resources from other sectors of society will translate immediately into pressure on agriculture to cut down its current water footprint. Cotton's share of the global agricultural water footprint is estimated at 3 per cent (Hoekstra and Chapagain, 2007). This is proportionate to cotton's global land use footprint of 2.5 per cent but will of course be very pronounced in large irrigated production areas. Cotton affects freshwater both quantitatively and qualitatively, through fertilizers and pesticides in effluents, and it also plays a significant role in soil degradation through a rising water table and salt build up in surface soils (WWF, 2005).

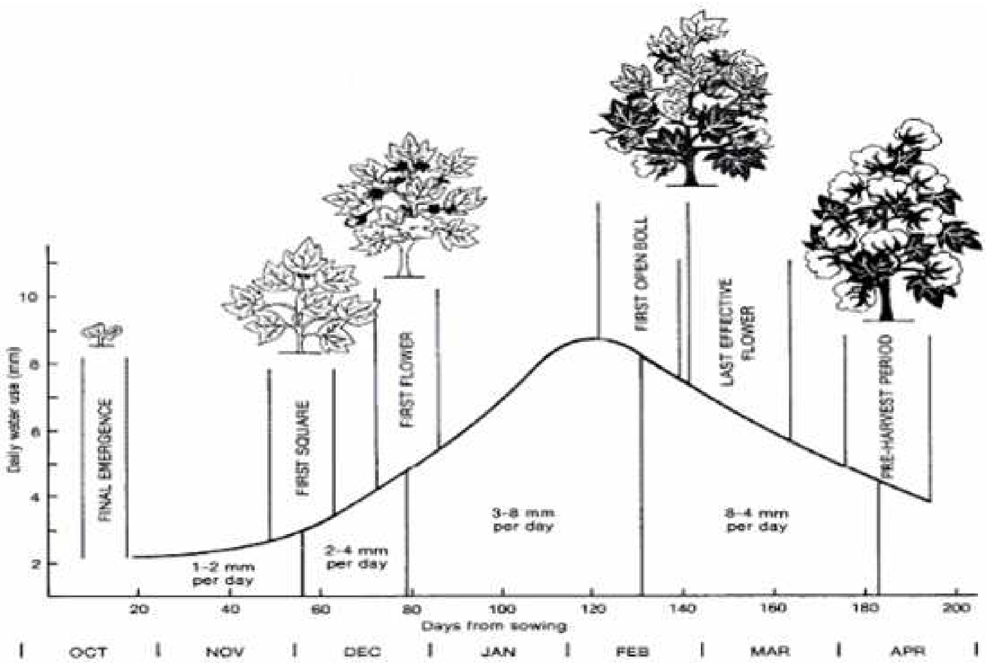


Fig. 2. Shows the different stages for cotton and their demand for water. The highest demands coincide wtih flowering until preharvest period. **Source :** Freeland *et al.,* 2007.

Pests and diseases : Due to the infestation of insect pests and diseases, the yield of cotton is declining. Insects are a recognized threat to cotton production throughout the world. Most insects can adapt their body temperature to the temperature of the environment. The effect of global warming on living organisms is slow enough for cotton insects to adjust to rising temperatures and other changes accruing from global warming. Thus, the insects currently plaguing cotton are expected to continue to be live and possibly thrive in new environmental conditions (ICAC, 2007). Sucking pests are deleterious during early season of the cotton plant growth and development. Cotton stainer, leafhopper, aphids, white flies and thrips are important pests of cotton.

Dysdercus cingulatus (Fab.) (Hemiptera:Pyrrhocoridae) is a serious pest of cotton distributed in all the cotton growing regions of India (David and Ananthakrishnan, 2004; Sahayaraj and Ilayaraja, 2008). It is commonly known as red cotton bug. Nymphs and adults of *D.cingulatus* feed mainly on developing or mature cotton seeds. Synthetic insecticides failed to control this insect because, both the nymphs and adults move from place to place very rapidly. So there is a need for alternative method. For the past two decades, extension workers and pest management workers have been using fungal pathogens in pest management programme where *Beauvaria bassiana* and *Metarhizium anisopliae* have play an important role (Arnold and Lewis, 2005).

It may be possible that global warming will affect insects' metabolism, allowing them to increase their multiplication rate. Increases in the populations of currently important insects, such as bollworms, may also take place as a result of higher multiplication rates, alongwith the elimination of the need to go into diapause during winter to avoid colder temperatures. The effects could be further amplified under conditions where alternate host plants are already available for wintering (ICAC, 2007). It is feared that global warming will affect some disease control methods as a result of changes in the pathogen emergence time. Chemical control methods may also become less effective due to the possibility of faster decomposition of chemicals under higher temperatures. According to Chakraborty *et al.* (2002), higher Co_2 levels will increase the severity of diseases, induce fungal growth and spore formation, and will destroy more plant tissue. In general, the disease problem will become more important (ICAC, 2007).

Climate change vs cotton production : The weakness of Indian agriculture to climate change is well known. According to Indian Council of Agricultural Research, climate change predictions in the medium term have predicted the likely reduction in crop yields due to climate change at between 4.5 and 9 per cent by 2039. The long run predictions paint a scarier picture

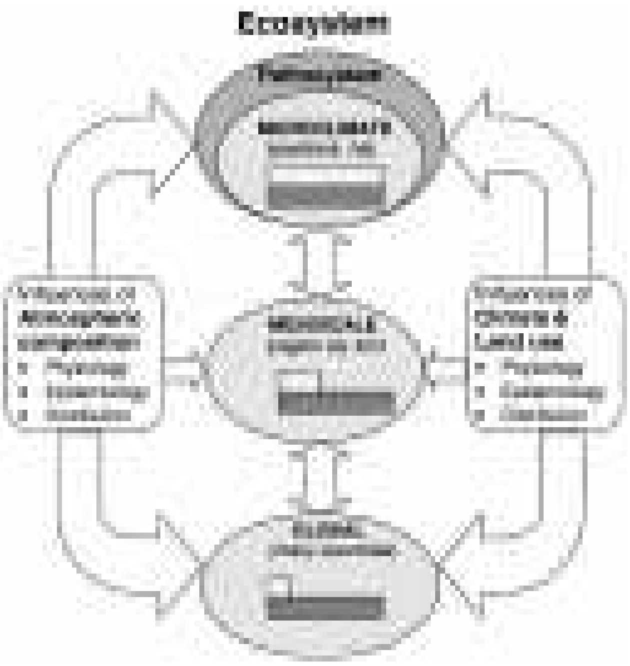


Fig.3. A summary of major influences due to changes in atmospheric composition, land use and climate on plant diseases and the level of understanding of disease (dotted) and climate (dark).The understanding of disease and climate is highest at the paddock scale but the knowledge gap is wider at regional and global scales. (S.Chakrabortya *et al.*, 1999).

with the crop yields anticipated to fall by 25 per cent or more by 2099. Climate change is also reflected in the widely fluctuating weather cycle with unpredictable cold waves, heat waves, floods and exceptionally heavy single day downpours. All these events took a heavy toll on crop output. Indeed, the silver lining in this dismal scenario is the National Action Plan on Climate Change, launched in 2008, which aims at developing technologies to help rainfed agriculture adapt to the changing climate patterns.

India is the third largest cotton producing and consuming country in the world following USA and China. Climates vary from humid in the northeast (about 180 days of rain/year) to arid in Rajasthan (20 days). A semiarid belt extends between the humid west coast and the central and eastern parts of the country. The most important feature of India's climate is the monsoon; *i.e.* the season of concentrated rain from May-September (India, 2004). Cotton is grown in India in three distinct zones: central zone (65% of total area; Gujarat, Madhya Pradesh, Maharashtra), the south (20%; Karnataka, Andra Pradesh and Tamil Nadu) and the North (14%; Punjab, Haryana and Rajasthan). Maharashtra has the highest area under cotton cultivation, followed by Gujarat and Andhra Pradesh The central zone has a hot semi arid climate, and comprises more dry land cotton (93 per cent of total in Maharashtra, 66 per cent in Gujarat and about 60 per cent in Madhya Pradesh). Yields are of course much lower (800–1,500 kg seed/ha) than in irrigated cotton (2,500–4,000 kg/ha, in western Maharashtra, parts of Madhya Pradesh and Gujarat). Monsoon rains are scantly and ill-distributed in parts of Maharashtra and Madhya Pradesh, and the shallow black soils (murrams) of poor fertility and moisture retaining capacity. Here, even hardy crops like sorghum and millet cannot compete with cotton despite low yields (500–600 kg/ha). In the southern zone, both rain-fed and irrigated cotton are grown, including high-quality long and extralong staple cotton. The agro-climate is more suitable for cotton, with bimodal rainfall in parts of Karnataka, southern Andhra Pradesh and Tamil Nadu. Yield in irrigated cotton is about 2,500–3,000 kg/ha, and 1,000–1,500kg/ha in dry land cotton. All cotton in the northern zone is irrigated. The climate is adverse at sowing season, with high temperatures, and the growing period is limited to six months. Double cropping cotton wheat is common with little time for tillage between the two crops (International Trade Centre (ITC, 2011). Cotton yield potential is 1,500–2,000 kg seed/ha due to adverse climate and pest damage (Venugopal *et al.*, 1999). Water availability for irrigation is a big issue in the northern zone. Soils have become saline and crust prone, and germination is hampered by high soil temperatures (CICR, 2009). Cotton cultivation in India, especially rain-fed cotton, is a combination of mixed cropping and intercropping; while in irrigated areas and in high rainfall zones, cotton is grown in sequential cropping or through intensive relay cropping. This results in a mosaic of varied cotton-based cropping systems (Venugopal *et al.,* 1999).

• Statewise cotton acreage in India, 2008-2009

Cotton yields, India : Indian cottonseed yields have dramatically increased since 2002-2003,

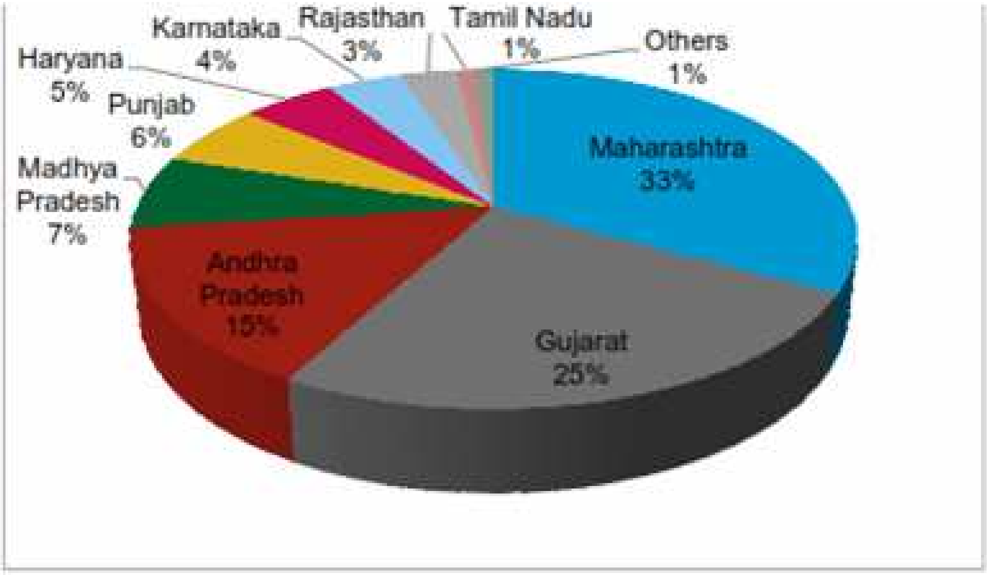


Fig. 4. Source : Ministry of Textiles (2010), Cotton fibre policy. Draft version. Yields World cotton yields (seed cotton and cotton fibre), 1990-1991 to 2006-2007

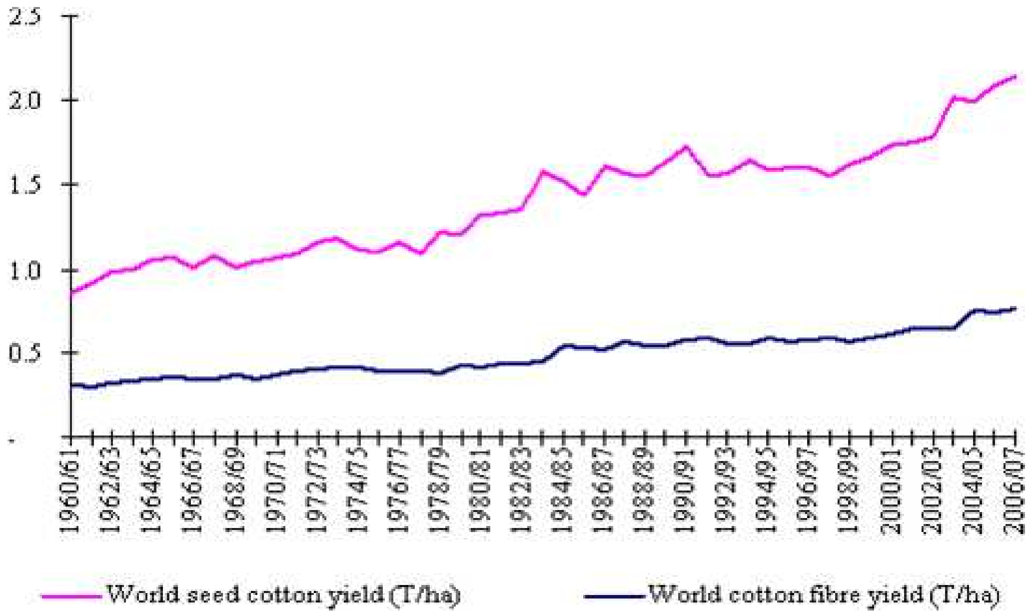


Fig. 5. Source : UNCTAD secretariat (Data: Food and Agriculture Organisation (FAO) for seed cotton; the International Cotton Advisory Committee (ICAC) for cotton fibre)

Table 2. Source: UNCTAD secretariat (Data: ICAC (fibre yields) and FAO (seed yields)

	1990-2000	2000-2007	2007
Seed cotton yield (t/ha)	0.71	0.99	1.02
Cotton fibre yield (t/ha)	0.30	0.43	0.52
Ginning output (%)	42%	44%	51%

the average yield from 2003-2004 to 2006-2007 jumped by more than 50 per cent compared to its level over the previous period (1990-1991-2002-2003). Indian ginning output is particularly high compared to other major producing countries.

Options to adapt to climate change : Climate change is changing the economics of production, forcing rural cotton farming communities to consider multiple livelihood strategies including planting different crops and seeking alternative non farm income streams. This entails complex and resource intensive responses from government and international aid flows. With respect to production, cotton has limited capacity to respond to heat stress, through compensatory growth. The cotton plant's genetic makeup allows it to make limited adjustments to changes in climatic conditions at the production level (ICAC, 2007). Its vertical tap root also provides flexibility against drought, but also makes it susceptible to water-logging. Cotton relies heavily on irrigation. This makes cotton particularly vulnerable to the availability of freshwater or groundwater for irrigation. (International Trade Centre (ITC, 2011)

To mitigate climatic change effect on cotton production following potential adaptation measures has been identified in ITC report (2011):

- Maximizing plant diversity
- Linking of climatic predictions with cotton production systems
- Evaluation of impact of climate change in selected location
- Flexibility of sowing dates
- Maintaining soil cover
- Development of Model for Pest population dynamics and climatic change with special reference to cotton
- Minimizing soil tillage
- Breeding more resistant cotton varieties

REFERENCES

Arnold, A. E. and Lewis, L. C. 2005. Ecology and evolution of fungal endophytes, and their roles against insects, **In:**(Vega F. E., Blackwell, M. eds), Insect–Fungal Associati ns: Ecology and Evolution. Oxford University Press, New York, 74–96 **PP**.

Baker, D.N. and Enoch, H.Z. 1983. Plant growth and development. In: *Co_2 and Plants.* E.R. Lemon (ed.). Westview Press, Boulder, Colorado. pp. 107-130.

CABI Bioscience 2000. Learning to cut the chemicals in cotton; case studies and exercises in farmer focused cotton IPM from around the world. CABI Bioscience Technical Support Group to the Global IPM Facility, Ascot, UK and PAN-UK, London, UK, 92 pp.

David, B.V. and Ananthakrishnan, T. N. 2004. *General and Applied Entomology.* Tata Mc Graw - Hill publishing company Limited, New Delhi.

Fryxell, P. A., 1992. A revised taxonomic interpretation of Gossypium L. (Malvaceae). Rheedea 2: 108–165.

Freeland, B.T. Pettigrew, B. Thaxton, P., and Andrews, L.G., 2007. Chapter 13A: Agrometrology and cotton production. Draft 3rd Edition of the Gamp (2007). WMO/CAgM Guide to Agricultural Meteorological Practices (WMO No. 134).

Hoekstra, A.Y. and Chapagain, A.K. 2007. The water footprints of Morocco and the Netherlands: Global water use as a result of domestic consumption of agricultural commodities, *Ecological Economics* **64** : 143-151.

ICAC, 2007. Global warming and cotton production – Part 1. In: *ICAC Recorder*, 25 : 12–16. International Cotton Advisory Committee (ICAC). United States of America.

ICAC, 2009. Global warming and cotton production – Part 2. In: *ICAC Recorder*, 27 : 9–13. International Cotton Advisory Committee (ICAC). United States of America.

IPCC, 2007. Climate Change 2007: Synthesis Report. Intergovernmental Panel on Climate Change (IPCC). Germany, 52 p.

International Trade Centre (ITC), 2011. 'Cotton and climate change- impacts and options to mitigate and adapt'. Geneva: ITC, 2011. xii, 32 p. (Technical paper), Doc. No. MAR-11-200.E.

Keeling, C.D., Whorf, T.P, Wahlen, M. and van der Plicht, J. 1995. Interannual extremes in the rate of rise of atmospheric carbon dioxide since 1980. *Nature* **375**: 660-70.

Kaynak, M.A. 2007. Production problems in 2025. In: ICAC (2007). The vision for technology in 2025, pp. 3–7. International Cotton Advisory Committee (ICAC). United States of America.

Karl, T.R., J.M. Melillo and T.C. Peterson 2009. *Global climate change impacts in the United States.* Cambridge University Press, United States of America, 196 p.

Reddy, K.R., Hodges, H.F., McKinion, J.M., 1995. Cotton crop responses to a changing environment. In: Rosenzweig, C., Allen, L.H., Harper, L.A., Hollinger, S.E., Jones, J.W. (Eds.), *Climate Change and Agriculture: Analysis of Potential International Impacts.* American Society of Agronomy, Madison, USA, pp. 3±30.

Reddy, K.K., Davidonis, G.H., Johnson, A.S., and Vinyard, B.T. 1999. Temperature regime and carbon dioxide enrichment alter cotton boll development and fiber properties. Agronomy Journal 91:851-858.

Reddy, K.R., Robana, R.R., Hodges, H.F., Liu, X.J. and Mc Kinion, J.M. 1998. Interactions of CO_2 enrichment and temperature on cotton growth and leaf characteristics. Envir. Experi. Bot. **39** :117-29.

S. Chakrabortya, A.V. Tiedemann and P.S. Teng, 1999. Climate change: potential impact on plant diseases. Environmental Pollution 108 (2000) 317±326.

Sahayaraj, K. and Ilayaraja, R. 2008. Ecology of *Dysdercus cingulatus* (Fab.). *Egyptian Jour. Bio.* **10** : 122– 25.

Soth, J. 2009. Impact of carbon markets on the cotton industry. Presentation (.ppt) to 68 ICAC Plenary Meeting. Helvetas, Switzerland. September 2009.

Uthamasamy, S., Kannan, M. and Mohan, S. 2004. Impact of insecticides on sucking pest s and natural enemy complex of transgenic cotton in India. *Curr. Sci.* **86** : 726-29.

UNCTAD secretariat (Data: Food and Agriculture Organisation (FAO) for seed cotton; the International Cotton Advisory Committee (ICAC) for cotton fibre).

UNCTAD secretariat (Data: ICAC (fibre yields) and FAO (seed yields).

Wu, G., Chen, F. J., Ge, F. and Sun, Y. C. 2007. Effects of elevated carbon dioxide on the growth and foliar chemistry of transgenic Bt cotton. In: Journal of Integrative *Plant Biology* **49 (9)** : 1361–69.

Impact of salinity on different cotton genotypes (Desi, American and *Bt* cotton)

KAVITA*, PROMILA KUMARI, RENU MUNJAL. S. K. SHARMA AND S. S. SIWACH
Department of Botany and Plant Physiology, CCS Haryana Agricultural University Hisar- 12 5004
**E-mail : kpoonia9@gmail.com*

Abstract : A screen house experiment was conducted in pots in the Department of soil science CCS Haryana Agricultural University Hisar to study the impact of salinity on different cotton genotypes. Saline water of different EC *i.e.* 0, 4, 8 and 12 dS/m was applied for irrigation. In the present investigation six cultivars of cotton namely, HD 123, AAH 1 (*Desi* cultivars), RCH 134, Bio 6488 (*Bt* cultivars), H 1236 and HHH 223 (*American* cultivar) were sown in the month of May. Per cent germination of all the cotton cultivars decreased with increasing levels of salinity. *Bt* cotton cultivars (RCH 134 and Bio 6488) showed maximum germination percentage, while *desi* cultivars (HD 123) and its hybrid (AAH 1) showed minimum seed germination at all the levels of salinity. A significant reduction in chlorophyll content of leaves was found with increasing salinity levels and reduction was found to be maximum in *Desi* cotton cultivars while minimum in *Bt* Both *Bt.* hybrid cultivars had more chlorophyll content as compared to *desi* cultivars and *American* cultivars. Photosynthetic rate, transpiration rate and stomatal conductance of all the cotton cultivars decreased with increasing salinity levels. Significantly higher assimilation rate was recorded in both *Bt* cultivars, RCH 134 and Bio 6488 at zero salinity level *i.e* control. Although the photosynthetic rate decreased with increasing salinity in all the cotton cultivars but *desi* cultivar HD 123 showed a remarkable decrease in photosynthetic rate as compared to its corresponding *desi,* its hybrid and *American* cultivars at 12 dS/m. Maximum stomatal conductance was recorded in *desi* where as minimum stomatal conductance was recorded in *American* and *Bt* cotton cultivar. Different cotton cultivars were identified on the basis of Protein banding pattern.

Key words : Chlorophyll content, germination per cent, photosynthetic rate, protein banding pattern, transpiration rate, salinity and stomatal conductance

High salinity is the most widespread abiotic stress and constitutes the most stringent factor in limiting productivity (Iqbal and Ashraf 2005, Yildirim *et al.,* 2009). The reduction in growth under saline conditions is a consequence of several physiological responses and photosynthesis is thought to be the most important aspect. (Stepien and Klbus 2006). Salinity induced oxidative stress could be a reason for germination inhibition (Amor *et al.,* 2005). Soil salinity is a major constraint limiting agricultural productivity on nearly 20 per cent of the cultivated area and half of the irrigated area worldwide (Zhu, 2001). Salt stress has been reported to cause an inhibition of growth and development, reduction in photosynthesis, respiration and protein synthesis in sensitive species (Boyer, 1982; Meloni *et al.,* 2003; Pal *et al.,* 2004). Problem of soil salinity is further increasing because of use of poor quality water for irrigation and poor drainage, hence it can cause immense problem to food security in developing countries like India due to high rate of population growth and stagnation due to declining crop productivity in high production areas (Kamaludin and Abdin, 2006). Cotton is the most preferred source of natural fibre and economically important for farmers globally. Cotton is more sensitive to salinity during the emergence and early growth stages than the later developmental stages (Chen *et al.,* 2010). Although agricultural aspects of cotton are well known, little information exists on physiological characteristics of cotton with particular reference to germination, photosynthesis and stress metabolism, which control productivity and survival. Several new proteins which are synthesized in response to an altered environment have been reported as 'stress proteins' or shock proteins in plants (Ericson and Alfinito, 1984; Kanabus *et al.,* 1984; Oliver and Bewley, 1984). Elavumoottil *et al.,* (2003) reported that salt tolerant calli of *Brassica oleracea* var. *botrytis* exposed to 225 mM NaCl for six months synthesized a 27 kDa polypeptide which was absent in the control calli maintained on the non saline stock culture medium. Therefore the main objectives of the present study were i) to assess the impact of salt stress on different cultivars of cotton ii) to screen salinity resistant cotton cultivars and iii) to evaluate the genotypic differences of cotton species for germination and early growth under saline conditions. (v) to study the effect of salinity on some physiological parameters at early stage of growth as (vi). to identify different cotton cultivars on the basis of protein banding pattern.

MATERIALS AND METHODS

The crop was raised during first week of June, 2011 in polythene bags (16x18 inches) filled with 5 kg of dune sand in a screen house under natural conditions. The nutrient solution was mixed in the soil in the form of N, P and K in the ratio of 10:3:3. Plants were grown at three level of salinity 4, 8, and 12dS/m along with control (zero Ec), which was applied with distilled water before sowing. Ten seeds were sown at equidistance in each pot at depth of 2 cm for all the cultivars and thinning was done after 12 days leaving behind 3 plants/pot. Each treatment was replicated five times for all the cultivars. The mixed salts used to obtain the required salinity NaCl, $CaCl_2$, $MgCl_2$ and $MgSO_4$ were applied to the soil as a basal dose. These salts were used on milli equivalent basis. Germination was recorded in all pots upto 12 days. Plants were irrigated with distilled water to maintain the salinity levels. Per cent germination was calculated for each treatment. Normal seedlings were expressed as percent germination. The criterion for seed germination was the emergence of radicle. Chlorophyll was extracted by the non-destructive method described by Hiscox and Israelstam (1979) using dimethyl sulphoxide (DMSO). Photosynthetic rate (μ mole m^{-2}/sec), transpiration rate (m mole m^{-2}/sec) and stomatal conductance (μ mol m^{-2}/s) were measured by using portable Infra Red Gas Analyser (IRGA) between 10:00 to 11:00 a.m. 500 mg seeds. All the six cultivars were taken to study protein profile by using discontinuous buffer system of Laemmli (1970). Samples were prepared by crushing 500 mg of seeds in 2.5 ml of chilled tris buffer (0.1 M, pH 8.0) containing 0.1 per cent polyvinyl pyrrolidone (PVP) with the help of chilled pestle and mortar (rinsed with D.D.W. and dried). These were then centrifuged at 10,000 rpm at 4°C for 15 min in a refrigerated centrifuge. The supernatant containing the proteins was taken in a chilled test tube and pellet was discarded. Supernatant was stored at 20°C. The protein quantification was done by the method of Bradford (1976). The protein extract was transferred to an equal volume of 2X sample buffer (Laemmli's 2X sample buffer) heated at 100°C for 3 min, cooled and used for SDS-PAGE. Total soluble proteins were determined by Bradford (1976) method using supernatant.

In 25 μl of the supernatant, 5 ml of the reagent was added and mixed either by inversion or vortexing. The optical density (O.D.) was measured at 595 nm after 2 min and before 1h against reagent blank. Standard curve was prepared using graded concentration of bovine serum albumin.

SDS-PAGE : All steps were performed according to the method used bye Laemmli (1970). 500 mg seeds of all the six cultivars were taken to study protein profile. Samples were prepared by crushing 500 mg of seeds in 2.5 ml of chilled tris buffer (0.1 M, pH 8.0) containing 0.1 per cent polyvinyl pyrrolidone (PVP) with the help of chilled pestle and mortar (rinsed with D.D.W. and dried). These were then centrifuged at 10,000 rpm at 4°C for 15 min in a refrigerated centrifuge. The supernatant containing the proteins was taken in a chilled test tube and pellet was discarded. Supernatant was stored at 20°C. The protein quantification was done by the method of Bradford (1976). The protein extract was transferred to an equal volume of 2X sample buffer (Laemmli's 2X sample buffer) heated at 100°C for 3 min, cooled and used for SDS-PAGE.

RESULTS AND DISCUSSION

Desi cotton cultivar HD 123 showed the maximum per cent reduction in seed germination (92.17) while *Bt* Bio 6488 showed minimum per cent reduction in germination (47.10) percent at highest level of salinity over control as shown in Fig.1.

The interaction effect of cultivar *verses* salinity was statistically significant. The experimental results also depict a decline in the speed of seed germination in cotton with the increase in salinity in the germinating medium.

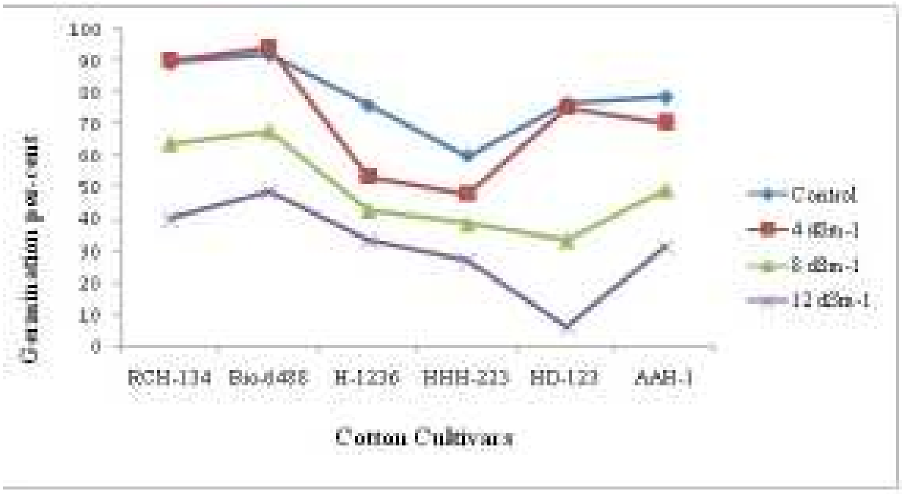


Fig. 1. Effect of salinity on seed germination (%) in different cotton cultivars at 12 DAS

These results are in conformity with the findings of Rajkumar (1996) in Albizzia lebbek and Leucaena leucocephala and in guar (Surajkala, 2010).

Salinity effects on chlorophyll contents : Our results showed that the chlorophyll content of the all cotton cultivars decreased at different salt concentrations (8, and 12dS/m) under test except at 4dS/m where the chlorophyll content was higher than control in all the cultivars. A continuous and significant decrease in Chlorophyll content in leaves of all cotton cultivars due to salt stress was detected (fig 2). The rate of decrease in these parameters was greater at the higher salinity level compared with the control. Both the *Bt* cultivars had more chlorophyll content as compared to other cultivars. The interaction effect of cultivars verses salinity (G×S) was found significant.

Salinity effects on photosynthetic rate : Result shown in Fig. 3 revealed that the hotosynthetic rate of the cotton cultivars measured at different salinity levels varied significantly. Significantly higher photosynthetic rate was recorded in both *Bt* cultivars, RCH 134 and Bio 6488 at zero salinity level *i.e* control.

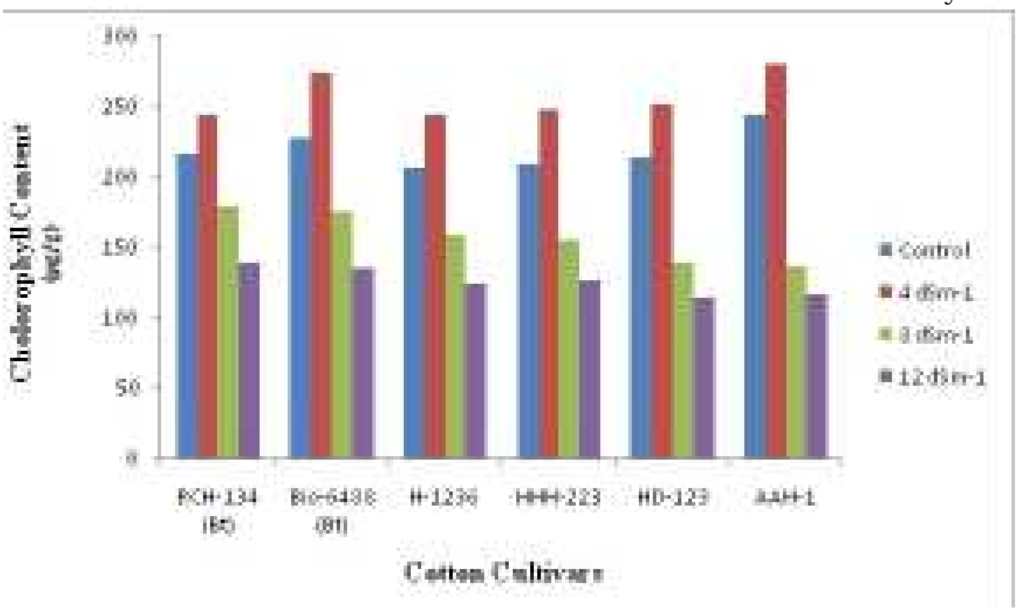


Fig 2. Effect of salinity on chlorophyll content (μg/g) in leaves at 60 DAS in different cotton cultivars

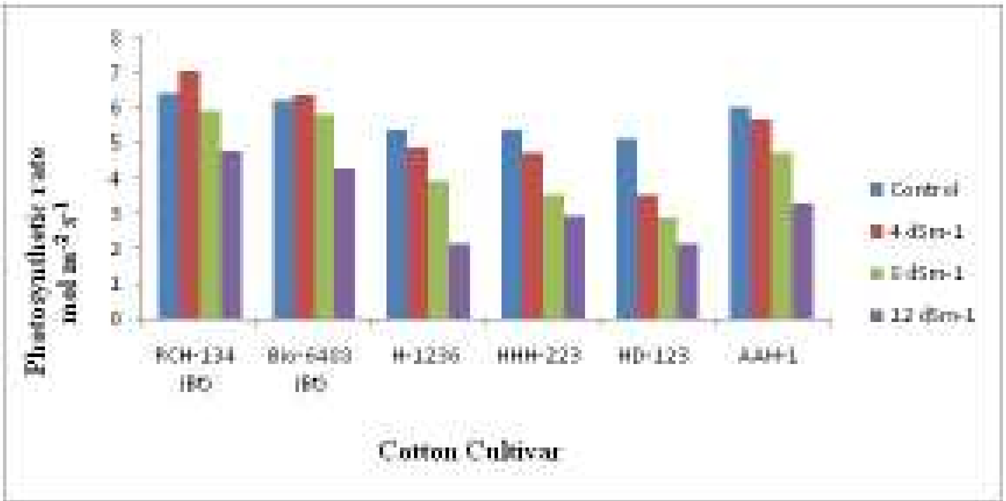


Fig 3. Effect of salinity on photosynthetic rate (mol m^{-2} s^{-1}) in leaves in cotton cultivars.

Photosynthetic rate continuously decreased with the increase of salinity levels; however, there was a significant difference this increase.

Although the photosynthetic rate decreased with increasing salinity in all the cotton cultivars but *desi* cultivar HD 123 showed a remarkable decrease in photosynthetic rate compared to its corresponding *desi* hybrid at 12dS/m. The interaction effect between cultivars and treatment was significant.

Effect of salinity on transpiration rate : The effect of salinity on transpiration rate in various cultivars of cotton is shown in Fig 4. Significant higher rate of transpiration was recorded in RCH 134 *Bt* than in Bio 6488. The interaction effect between cultivars and treatment was significant. Cultivars differed significantly with respect to rate of transpiration. In all the *Gossypium* species studied, the rate of transpiration decreased as the growth stage advanced and it was highest in RCH 134 *Bt* although the transpiration rate decreased with the increasing levels of salinity but the stimulatory effect on transpiration was observed at 4dS/m.

Maximum transpiration rate was recorded in *Bt* cotton cultivars while minimum was recorded in American cultivars. The

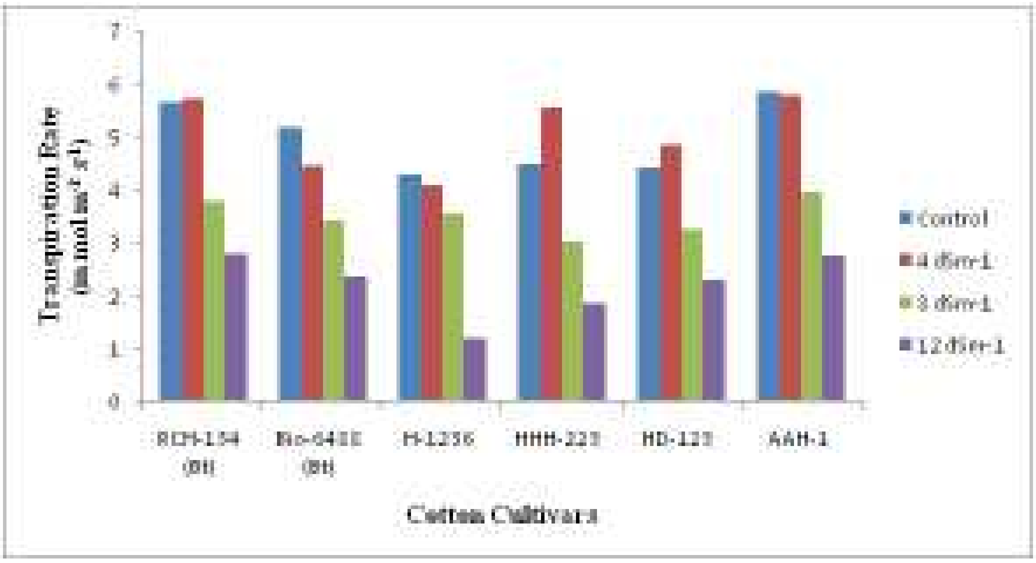


Fig 4. Effect of salinity on transpiration rate (m mol m^{-2} s^{-1}) in leaves at 60 DAS in different cotton cultivars

interaction effect between cultivars and treatment was significant.

Effets of salt stress stomatal conductance : Result depicted in Fig. 5 showed the effect of salinity on stomatal conductance in various cultivars of cotton decreased with increasing level of salinity

Stomatal conductance was quite low at the highest level of salinity (12dS/m). Minimum conductance of stomata was recorded in *Bt* cotton cultivars at all salinity levels. Similar trend of decrease in stomatal conductance with increasing salinity was observed in American cultivars.

Analysis of protein profile by SDS-PAGE in seeds of different cotton cultivars : The protein profile pattern using SDS-PAGE showed differential expression of proteins in different cotton cultivars as shown in Fig. 6. The *Bt* cotton cultivars RCH 134 and Bio 6488 showed a total number of 14 polypeptides of molecular weight ranging from 13.49 kDa to 77.62 kDa. The *desi* cultivars of cotton AAH 1 and HD 123 showed differential banding pattern with 12 and 14 polypeptide bands, respectively. Both the genotypes showed the presence of one new polypeptide band of 32.90 kDa and absence of 2 polypeptide bands of 33.11 and 61.66 kDa. HD 123 showed the presence of unique polypeptide of 27.54 and 37.15 kDa which were absent in *Bt.* cotton as well as *desi* cotton hybrid AAH 1. The American cotton cultivars also showed banding pattern different from that of *Bt* cotton cultivars as well as from *desi* cotton cultivars having 13 polypeptide bands. The cultivar H 1236 showed the absence of one polypeptide of molecular weight 30.54 kDa, while hybrid HHH 223 showed the presence of 3 new polypeptide bands of 69.77, 71.6 and 74.13 kDa. However it (HHH 223) did not show the expression of polypeptides of molecular weight (27.54, 30.54 and 33.11 kDa) which were present in the American cotton cultivars H 1236. This suggested that polypeptide expression varied depending upon the different cotton cultivars and the differential gene expression of concerned structural or regulatory gene (s). Polypeptides for presence or absence could be potentially used as marker to decipher selection of organogenic potential tissue.

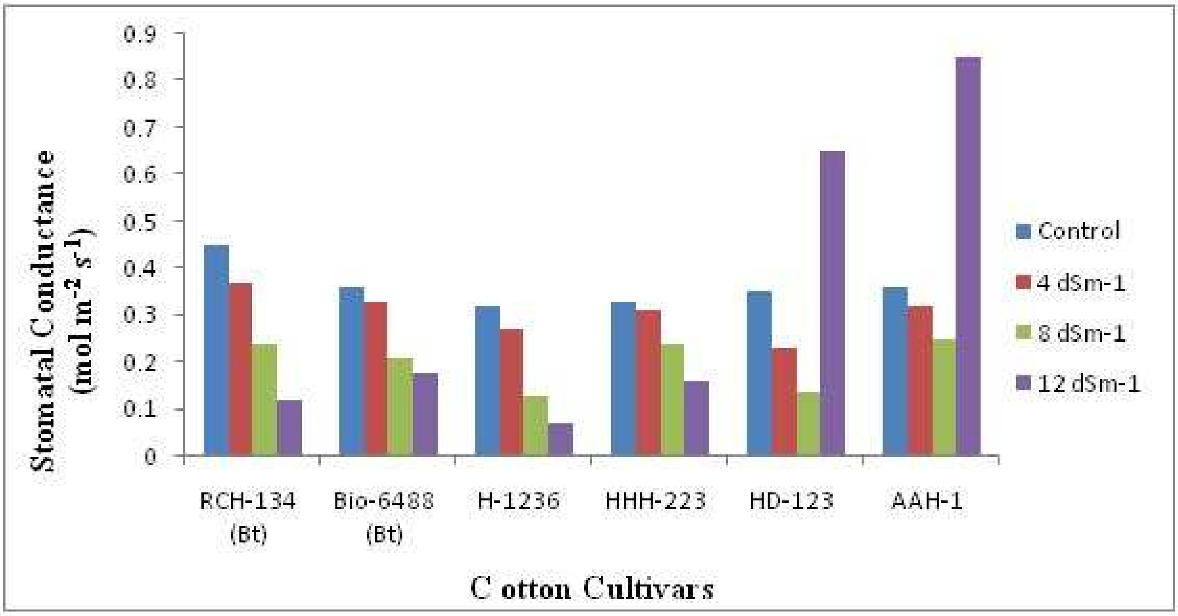


Fig 5. Effect of salinity on stomatal conductance (mol m^{-2} s^{-1}) in leaves at 60 DAS in different cotton cultivars

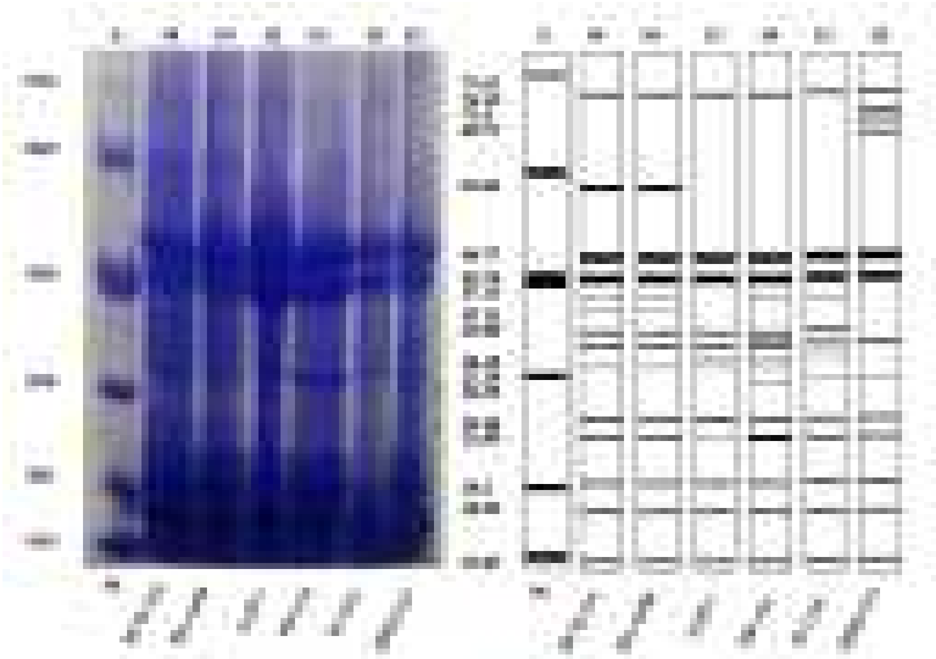


Fig. 6. Polypeptide pattern of cotton cultivars by SDS-PAGE.

Table 1. Score board of various physiological parameters for salinity tolerant cultivars

Parameters	*Bt.* cotton genotypes (RCH 134, Bio 6488)	*American* cotton genotypes (H 1236, HHH 223)	*Desi* cotton genotypes (HD 123, AAH 1)
Seed germination	•		
Chlorophyll content	•		
Photosynthetic rate	•		
Transpiration rate	•		
Stomatal conductance			•

CONCLUSION

Salt stress is the main factor affecting the plants growth and development. With increasing salinity stress, various physiological parameters were highly affected per cent germination of all the cotton cultivars decreased with increasing level of salinity. *Bt* cotton genotypes (RCH 134 and Bio 6488) showed maximum germination percentage. A significant reduction in chlorophyll content of leaves was found with increasing salinity levels and reduction was found to be maximum in cultivars H 1236 and AAH 1 while minimum in *Bt* Bio 6488 at both the sampling stages at higher levels of salinity over control. Photosynthetic rate (assimilation rate), transpiration rate and stomatal conductance of all the cotton cultivars decreased with increasing salinity levels. Maximum decrease was recorded in HD 123 and H 1236. Salinity adversely affected most of the physiological parameter in all the cultivars and magnitude of this effect was more severe with increasing levels of salt stress. The data in the present study demonstrated that Both the *Bt* cultivars (RCH 134 *Bt* and Bio 6488) were found to have higher adaptive potential under salinity stress as compared to *American* and *desi* cultivars, as judged by photosynthetic rate (assimilation rate), transpiration rate and stomatal conductance and germination percentage. In SDS-PAGE the protein profile of seeds of *Bt* cultivars (RCH 134 and Bio 6488) and *American* showed total number of fourteen and thirteen polypeptide bands respectively while *desi* cultivars had twelve in AAH 1 and fourteen in HD 123. Polypeptide bands of 77.62 kDa were synthesized in all cultivars of cotton. Salinity adversely affected most of the physiological parameter in all the cultivars and magnitude of this effect was more severe with increasing levels of salt stress.

Score card for ranking of various physiological parameter in different cotton cultivars. It is obvious from the score card (Table 1) that both the *Bt* cultivars RCH 134 and Bio 6488 *Bt* cultivars had maximum score as compared other.

REFERENCES

Amor, N.B., Hamed, K.B., Debez, A., Grignon, C.Crabbedly 2005. Physiological and antioxidant responses of perennial halophyte *Crithmum maritimum* to salinity. *Plant Sci.* **4** : 889-99.

Boyer, J.S., 1982. Plant productivity and environment. *Science.*, **218**, 443-48.

Bradford, M.M. 1976. A rapid and sensitive method for quantification of microgram quantities of protein utilizing and principle of protein dye binding. *Anal. Biochem.* **72** : 248-54.

Chen , W., Hou, Z., Wu, L., Liang, Y. and Wei, C. 2010. Effects of salinity and nitrogen on cotton growth in arid environment. *Plant Soil.* **326** : 61–73.

Elavumoottil, O.C., Martin, J.P. and Moreno, M.L. 2003. Changes in sugars, sucrose synthase activity and protein in salinity tolerant callus and cell suspension cultures of *Brassica oleracea* L. *Biol. Plant.* **46**: 7-12.

Ericson, M.E. and Alfinito, S.H. 1984. Protein produced during salt stress in tobacco cells cultures. *Plant. Physiol.* **74**: 506-09.

Hiscox, J.D and Issaelstam, G.F. 1979. A method for extraction of chlorophyll from leaf tissue with out maceration. *Can. J. Bot.* **57** : 1332-54.

Iqbal, M. and Ashraf, M. 2005. Changes in growth, photosynthetic capacity and ionic relations in spring wheat (Triticum aestivum L.) due to pre sowing seed treatment with polyamines. *Plant Growth Regulation*, **46** : 19–30.

Kamaludin and Abdin, M.Z. 2006. Molecular mechanism of salt stress tolerance in plants and their significance in crop improvement. *J. Plant Biol.* **33** : 15-28.

Kanabus, J.; Pikaard, C.S. and Cherry, J.H. 1984. Heat shock proteins in tobacco cells suspension during growth cycle. *Plant Physiol.* **75**: 639-44.

Laemmli, U.K. 1970. Cleavage of structural proteins during the assembly of the head of bacteriophage Ty. *Nature* **277**: 680-85.

Meloni, D. A., Oliva, M.A., Martinez, C.A. and Cambraia, J., 2003. Photosynthesis and activity of superoxide dismutase, peroxidase and glutathione reductase in cotton under salt stress. *Environ. .Exp. Bot.,* **49** : 69-76.

Oliver, M.J. and Bewley, J.D. 1984. Plant desiccation and protein synthesis changes in protein synthesis elicited by desiccation of the moss *J. Ruralis* case affected at the translational level. *Plant Physiol.* **74** : 923-27.

Pal, M., Singh, D.K., Rao, L.S. and Singh, K.P., 2004. Photosynthetic characteristics and activity of antioxidant enzymes in salinity tolerant and sensitive rice cultivars. *Indian J. Plant Physiol.,* **9** : 407-12.

Raj Kumar 1996. Effect of certain abiotic factors on the seed germination and early plant growth of Albizzia lebbek (Linn.) Benth and Leucaena leucocephala (Lam.) de Wit. *M.Sc Thesis*, CCS Haryana Agricultural University, Hisar.

Surajkala, 2010. Studies on salinity tolerance in clusterbean [Cyamopsis tetragonoloba (L.) Taub.] genotypes. *M.Sc. Thesis,* CCS Haryana Agricultral University, Hisar.

Stêpieñ P. and K³bus G. 2006. Water relations and photosynthesis in Cucumis sativus L. leaves under salt stress. *Biologia Plantarum,* **50** : 610–16.

Welburn, R. W. 1994. The spectral determination of chlorophyll a and b as well as total carotenoids using various solvents with spectrophotometer of different resolution. *J. Plant Physiol.* **144**: 307-13.

Yildirim E., Karlidag H. and Turan, M. 2009. Mitigation of salt stress in strawberry by foliar K, Ca and Mg nutrient supply. *Plant Soil Environment*, **55** : 213–21.

Zhu, J.K., 2001. Plant salt tolerance. *Trends Plant Sci.*, **6** : 66-71.

SESSION PROCEEDINGS AND RECOMMENDATIONS

Silver Jubilee International Symposium
on
"Global Cotton Production Technologies *vis-a-vis* Climate Change"

at
CCS Haryana Agricultural University,
Hisar - 125 004
Organised by
Cotton Research and Development Association (CRDA)
CCS Haryana Agricultural University, Hisar-125 004
and
CCS Haryana Agricultural University, Hisar - 125 001
In collaboration with
Indian Council of Agricultural Research, New Delhi-110 001

PROGRAMME

Wednesday, October 10, 2012

9.00 a.m.	:	Registration	
10.00 a.m.	:	Lighting of Lamp	
	:	Vande Matram	
		Welcome the delegates and Achievements of CCS HAU	**Dr. S.S. Dhamija** Additional Director Research
	:	About the Association and Symposium	**Dr. C.D. Mayee** President, CRDA
	:	Release of Publications	
		a) Book of Papers	**Dr. S.K. Datta** Dy Director General, ICAR, New Delhi
		b) Book of Abstracts	**Dr. K.S. Khokhar** Vice-Chancellor, CCS HAU, Hisar
	:	Felicitations Life Time Achievement Awards	**Dr. H. S. Kalsy** Fomer Director PAU, Regional Staton, Faridkot **Late Dr. B. P. S. Lather** Former Head, Cotton Section CCS, HAU, Hisar **R. K. Malhotra** Chief Executive Officer and President

	Indofil Industries Ltd., Mumbai **K. N. Gururajan** Former Principal Scientist CICR, Regional Station, Coimbatore **Dr. S. S. Mehetre** Former Director of Research M.P.K.V. Rahuri **Raju Barwale** Chairman and Managing Director Mahyco Seeds Limited, Jalna **Dr. B. V. Patil** Vice Chancellor University of Agri. Sciences, Raichur
Public Private Partnership Awards	**Seeds Industry** M/s Nuziveedu Seeds, Hyderabad **Pesticide Industries** Indofil Industries, Mumbai **Ginning Industry** Bjaj Steel Industries, Nagpur **Budding Industry** Shakti Vardhak, Hisar
Corporate Advisors	**Dr. M. Ramasami** Rasi Seeds, Attur **Dr. M. Parbhakar Rao** Nuziveedu Seeds Ltd., Hyderabad
Presidential address	**Dr. K. S. Khokhar** Vice Chancellor, CCS HAU, Hisar
Address by Chief Guest	**Dr. S. K. Datta** Dy. Director General, ICAR, New Delhi
Presentation of Memento to the Guests	**Dr. S. Datta** **Dr. K. S. Khokhar** **Dr. C. D. Mayee**
Vote of Thanks	**Dr. M.S. Chauhan** Secretary, CRDA
National Anthem	

Inagural Session

Chief Guest : Dr. Swapan Kumar Datta
Dy. Director General, ICAR, New Delhi

Presided over : Dr. K. S. Khokhar
Vice-Chancellor, CCS HAU, Hisar

The Silver Jubilee International Symposium on "Global Cotton Production Technologies *vis-a-vis* Climate Change" was jointly organized by Cotton Research and Development Association and CCS Haryana Agricultural University, Hisar in Collaboratiion with Indian Council of Agricultural Research (ICAR), New Delhi from October 10-12, 2012 at CCS Haryana Agricultural University, Hisar. Dr. Swapan Kumar Datta, Dy. Director General. Indian Council of Agricultural Research (ICAR) was the Chief Guest and Dr. K. S. Khokhar, Vice-Chancellor, CCS Haryana Agricultural University, Hisar prescribed over the inaugrual function. The symposium started tiwth "Saraswatgi Vandna", Dr. Sawapan Kumar Datta, the Chief Guest inaugurated the symposium by lighting of the lamp. Dr. S. S. Dhamija, Additional Direct of Research, CCS HAU, Hisar welcomed the delegates and gave a brief account of the achievements of the university. Dr. C. D. Mayee, former Chairman, Agricultural Sceintists Recruitment Board, New Delhi cum President Cotton Research and Development Association (CRDA) spoke on the aims, objectives and achievements of CRDA and also spoke on the objectives of the symposium and gave a brief account of the role of climate change in the sustainability of the Cotton production in India and abroad. Two publications were released namely "Book of papers" and "Book of Abstracts". Dr. Swapan Kumar Datta released the publication of "Book of Papers" while Dr. K. S. Khokhar released the publication of "Book of Abstracts". The Association presented "Life Time Achievement Award" to seven cotton scientists/officers/administrators for thier dediated services to the upliftment of cotton production in the country namely; Dr. H. S. Kalsy, Former Director, PAU, Regional Station, Faridkot, Late Dr. B.P.S. Lather, Former, Sr. Cotton Breeder cum Head Cotton CCSHAU, Hisar (The award was received by his wife); Mr. R. K. Malhotra, Chief Executive Officer cum President Indofil Industries, Mumbai; Mr. K. N. Gururajan, Former Principal Scientist, Cotton Breeding, CICR, Regional Station, Coimbatore, Dr. S. S. Mehetre, Former Director of Research, MDKV, Rahuri, Mr. Raju Barwale, Managing Director, Mahyco Hybrid Seeds, Jalna and Dr. B. V. Patil, Vice-Chancellor, UAS, Raichur. The "Life Time Achievement Awards" were presented by Dr. Sawpan Kumar Datta, the Chief Guest. For the first time the Association has started the "Public Private Partnership Award" in eight different categories covering different aspect of cotton Production Technologies. The Association has received achievement application in four different categories namely; Seed Industry, Pesticide Industry, Ginning Industry and Budding Industry. Dr. K. S. Khokhar presented the "Public Private Partnership Award" to M/s Nuziveedu Seeds, Hyderabad-Seed Industry; M/s Indofil Industries, Mumbai-Pesticide Industry, M/s. Bajaj Steel Indust4ies, Nagpur-Ginning Industry and M/s Shakti Vardhak, Hisar Budding Industry. The Association also felicates its corporate advisiors and these awards wre presented by Dr. C. D. Mayee, President of the Association. To Mr. M. Prabhakr Rao; Managing Director, Nuziveedu Seeds, Hyderabad and Dr. M. Ramasami, Managing Director, Rasi seeds, Attur. Dr. K. S. Khokhar gave the presidental address. He highlighted the hybrid Bt cotton scenario since 2002. He expressed his concern on the development of resistance in bollowrm and stress on the newer area of study namely development of sucking pest tolerant, herbicide tolerant, drought and wilt resident genotypes, identification and incorpration of Tricoderma fungal genemi cotton, Dr. Swapan Kumar Datta, the Chief Guest, addressed the cotton also gave an overview of the prevailing Bt cotton trend n India and abroad in term of area, production and productivity. He also emphasized that at the scientist should also work on cotton genomics, idiotype of cotton, improvement in firbre quality, apomixes, use of marker asisted genes etc. Dr. S. S. Siwach, Organizing Secretary of the International Symposium also addressed the gatherings. About 350 delegates working on different aspects of cotton production technologies, value addition industries, pesticides, policy markers, extension functionaries and agricutlural scientist both from public and private sectors attended and shared their experiences. To conclude the inaguaral session Dr. M. S. Chauhan, Secreatry CRDA presented the vote of thanks. He thanked to ICAR for permitting CRDA to organize the International Symposium at CCS HAU, Hisar. He also thanked the local orgnizing committee, Government organization CICAR, CSIR, DST, NABARD), seed and pesticides industries for generailing finacing the symposium. He also thanked the abroad scientists from cotton section and Dr. S. S. Siwach in particular for nice cordination and cooperation during the Sympoisum.

The Symposium ended with National Anthem.

Session I : Lead Papers

Chairman : Dr. S. K. Datta, DDG, ICAR
Co-Chairman : Dr. R. G. Dani, Vice-Chancellor, Dr. P.D.K.V., Akola
Rapproteur : Dr. O. P. Tuteja, Principal Scientist, CICR, Regional station, Sirsa

Dr. S. K. Datta welcomed the delegates attending the first session of lead papers. Only two papers were listed in the session before Lunch nd both the paper were presented. **Dr. Keim Don L.** He is a Scientist in Mansanto at USA. He presented his paper entitled, "Utilizing genetic diversity, Molecular breeding and biotech traits to increase sustainability of Indian Cotton Production in an era of chaning climate and cultural practices". He said that Indian agriculture is vutnerable to climate change i.e. increased droughts and floods are likely to increase production variablity, considerable effect on microbes, pathogens and insects. He also pointed out that the production of most of the crop will decrease by 10-40 percent by 2100. He also said that the reduced availability of ground water for agriculture use is of major convern both from climate change and over use. He also pointed out that Monsanto has been working for many years to evolve Bt technology which will help dramatically in improve sustainability of cotton production in India. He also emphasized that by IRM strategy also includes wide scale monitoring for resistance. Promoting compliance in eritical to sustain new technology. He also said that hybrid cotton breeding at Monsanto India levenages a global network of breeding support, expertise and germplasm. Several breeding technologies are utilized to meet the rapidly envolving changes in cotton agricultural, like molecular breeding technologies, rapid generation advance (use of green house and off sesaon nurseries); building broad germplasm base that contain useable diversity for; disease resistance (CLCuV), insect resistance (jassid); water stress toerlance, enhance yield and fibre, and heat and stress tolerance. In the end he summarized his talk by saying that many challanges for Indian cotton agriculture lay ahead in light of expected cuconges brought about by climate change and cultural practives. We have a great opportunity as a cotton sicentists to look ahead and begin efforts to address the challanges. Both priate and government efforts are critical to this sucess. Monsanto is committed to Indian cotton agriculture, as evidenced by our young efforts to meet the needs of the Indian cotton farmer.

D. Steven Calhoun - The second speaker was Dr. Calhoun from Bayer Crop Science, International Cotton and Asia Rice Breeding Mgr., Lubbook Tx, USA. He spoke on the topic entitled "Chemical aids for mechanical harvest". At the outset he said that when it comes to mechanical harvest of cotton, India represents new frontier, Indian use of hybrid varieties in wiede plant spacing in unique in the world. He also pointed out that for adopting cultivation practices for mechanical picking several wide range of measures will be required namely, potentially, including changes in the genotypes sown, plant spacing, fertilization, insect control practices, irrigation, chemical and plant growth regulators, chemical harvest aids and post harvest processing. He said that I will focus on chemical tools helpful for mechanical harvest, but I do not want ot lose sight of the fact that moving to mechanical harvest requires on nolishe, multidiscplinary approach.

He said that my talk will fall into two general categories i) plant growth regulators and ii) harvest aids.

He said that plant growth regulators have a elefinde primary purpose and function is to reduce the internode length and thus total plant height in order to achieve more efficient mechanical harvest but there are more additional subtle effects a well. Among the PGR, mepign at chloride has the longest history of its use and it inhibits the production of gibberellin, the plant harmone, responsible for cell enlargement and elongation and as a result of treated plants become generally smaller and/or shorter. He also pointed that the effect of mepignet chloride treatment depends on i) rate, ii) timing iii) target genotype and iv) environmental conditions. On the discussion of harvest aids, heoaid that these fall in two different categories i.e. defoliants and bool openers. He said that defoliants are used to induce leaf absussion and reduce the amount of leaf trash in mechanical harvest. The objective of difolionts is to encourage leves to drop "naturally" by upsetting the balance of ausin in leaves v/s stems. Herbicided defoliatns decrease auxin production in leaves by slicing killing the leaf tissue, resulting in formation of leaf absussion layer. He also discussed on boll opners and said that these are used to promote opening of green bolls that are nbear maturity, making them available for mechanical harvest. In the end he summarized and said that conversion to mechanical harvest system in India will requrie a holistic and multi disciplinary approach. Crop management chemicals alone will not get us to the goal.

Several quarries from the delegates was replied by Dr. Calhoun. The session ended with vote of thanks by Dr. M. S. Chauhan, Secretary CRDA and the membrs were given to the speaker, chariman and co-chairman were given by the Cotton Research and Development Association (CRDA) as a token of love.

Chairman also thank the delegates for smooth conductiance of the first session of lead papers before Lunch.

Session 2 : Lead Paper

Chairman : Dr. B. V. Patil
Co-Chairman : Dr. B. S. Janagudar
Rapporteurs : V. K. Sikka, Jaganthi Tokkas

There were two presentations one by session chairman Dr B V Patil and the other by co-chairman Dr B S Janagoudar.

Dr. B. V. Patil the emergence of sucking pest after *Bt* cotton becoming popular was highlighted. He emphasised at intensive scrutiny during 60-90 days of crop as there was maximum pest attack in this phase. He elaborated upon various strategies for management to control the pests. Dr. B. V. Patil presentd his lead paper on "Status of emerging pests on *Bt* cotton in Karnatka and their management. *Bt* cotton was introduced in the year 2002-2003 in Karnataka and since then the area under cotton and yield levels increased drastically. *Bt* cotton has suppressed bollowrms which were major threat but at the same time minor sucking pests have become major pests in the recent past. Among them important emerging pests in *Bt* cotton are mealybug. *Phenacoccus solenopsis,* mirid but, *Poppiocapsidea biseratense* and yellow mite, *Polyphagotarsonemus latus.* He dicussed the distribution, seasonsal incidence, bio ecology and management of these pests in detail. He also said that these three emerging pests. On cotton has made farmers to intervene with incecticdies/acaricides sprays in Karnataka and once agin use of insecticides and cost in increasing on *Bt* cotton for the management of sucking pests and taking us to non *Bt* era where several insecticide interventions were made to manage both bullowrms bollowrms and sucking pests. The management of mealybug should be airmed at ecofriendly method asince much parasitoid activity was found in all the infected fields.

The topic being of wide acceptance invited a battery of querries:

Dr. S. K. Shukla of CICR Nagpur wanted to know the reasons for increase in pests on *Bt* cotton in last few years - to which Dr Patil replied that the nature of varieties used for *Bt* introduction were inherently susceptible to sucking pests which hitherto had not been managed for a breeder. Entomologist's integrated approach was suggested for future varieties. *Dr. Pethani from Ahmedabad* also touched upon this aspect and suggested that such approach may work for varieties instead of hybrids.

Dr. A. R. Raju from CICR wanted to know about the role of salt in spray for which exact mechanism was unknown but several delegates in the house touched upon Na/K pump at cell membrane to be involved. *Dr B R Patil from Akola* enquired about the pest management practices to which Dr Patil suggested use of resistant varieties.

Dr. B. S. Janagoudar presented his study of 228 genotypes on their water use efficiency and based upon several morpho-physiological criterion, he suggested at a cotton ideotype with a compact nature to be able to have better moisture utilization and being more suited for rainfed cultivation in upper Karnataka. He also proposed ideotype charactersistics for rainfed conditions namely short compact plant structure with open canopy; smaller leaves will inclined to intercept maximum light and showing heliotropic movements; short multinodal sympodia (2-4 rides); moderate deep root system; semi dwarf structure reaching not more than a meter with ameability to close spacing. Leaf anatony with thick palisade than spong parenchyma and thinner epidermal layers; crop duration around 130-150 days; balanced growth, high fruiting coefficient and economic utilization of observed nutrients; high potosynthetic efficiency and specific leaf weight, low transpiration with higher turgidity of leaves.

Dr. S. S. Patil remarked that such concept shall escalate seed cost of already high priced *Bt.* On that it was replied that such approach again may be for not *Bt hirsutum* varieties.

Momentos were presented by Dr. B. V. Patil to speakers and to the chairman and co-chairman by the Association as a token of love.

Recommendations

I It was emphasised that future cotton variety breeding should involve entomologists to screen for pest resistant genotypes.

II Inclusion of physiological parameters for evaluation of genotypes must be included for inclusive varietal development efforts in cotton. High leaf mass/area and moderate total dry matter were the deciding factor for rainfed cotton.

Session 3 : Poster Presentation

Chairman :
Co-Chairman :
Rapporteurs :

The poster presentation was assessed by a panel of judges from different disciplines and places namely Dr. A. K. Dhawan, Former HOD, Entomology, PAU, Ludhiana; Dr. A. S. Dhindwal, HOD, Agronomy, CCS HAU, Hisar; Dr. R. R. Perane, Sr. Plant Pathologist, MDKV, Rahuri; Dr. D. B. Deosarkar, HOD, Agril Botany, MAU, Parbhani; Dr. R. K. Saini, HOD Entomology, CCS HAU, Hisar, Dr. S. K. Gandhi, HOD Plant Pathology, CCS HAU, Hisar and Dr. (Mrs.) S. L. Bhattipralu, Principal Scientist (Plant Pathology) ANGRAU, Regl. Agril. Res. Statiion, Guntur. A Total of 175 posters were evaluated (Crop Improvement and Biotechnology 53, Crop Production and Mechanization 42; Crop protection and Biosefty 47 and Post Harvest Technology and Socio Economic Development 33). The committee critically gone through these posters and dicussed the quarries/clarification from the presentors. All the posters were beautifully depicted the findigns through Tables, graphs and photographs.

Session 4 : Lead Paper and Abstract-oral presentation

Chairman : Dr. Joginder Singh
Co-Chairman : Dr. K. S. Boora
Rapporteurs : Dr. Anil Kumar and Dr. Samunder Singh

At the outset, Chairman welcomed all the delegates, guests and speakers for this important session. *Dr. (Mrs.) Saroj Jeet Singh delivered* a lead talk on the "Ecological impact of cotton textile production". The impact of cotton production on the environment is discernible when 250 million people are associated worldwide at different stages of cotton production and processing.

Major concern at the production stage the is about excessive use of pesticides, whereas water requirement is a serious concern both for production and industrial stage with direct consequences on environment and human health.

An ecofriendly and sustainable production system is desired as every year 3 million people are poisoned with 20 000 fatalities, other than pollution of soil and ground water affecting biodiversity. The speaker suggested adoption of technology to raise organic cotton, GM cotton, JPM, ICM and low input sustainable agriculture.

Cotton processing utilizes a large array of chemicals at different stages of cotton processing which generate plenty of solid and liquid waste which could be catastrophic to environment if not handled properly.

Adoption of minimum standards prescribed by JFOAM and GaTS and self contained waste recovery system at industry level is desired to lower the effluent load in the environment.

Industry should adopt primary, secondary and tertiary processes of pollutent's filtrations to lower the BOD and COD levels.

The second oral paper was presented from Abstract by *Dr. Shekhar Babu from IARI New Delhi* on the "Study of heterosis for fiber quality characters in GMS based diploid cotton hybrids".

Two third of the cotton is grown under rainfed conditions in India. Effect of climate change particularly rainfall pattern and length of drought playa significant role on plant growth and yield. Diploid cotton hybrids are more suited under changing climate as they have deep root system and can better tolerate stress. yield. Diploid cotton hybrids are more suited under changing climate as they have deep root system and can better tolerate stress.

Several GMS based hybrids were tested for heterosis and they were found better than the existing standards.

The third oral talk was delivered *by Dr. O. P. Tuteja, Central Cotton Research Institute, Sirsa* on. the "Genetic variance and combining ability estimates in upland cotton for yield and quality characters" (*Gossypium hybrids*).

As majority of cotton in India is *Bt* (94%) and many farmers use two packets of 450 g seed/ac requiring 30 million packets to meet the seed demand of Indian cotton growers which is a herculean task going by the method of hand emasculation and pollination.

The GMS method for hybrid seed production lowers the cost by 50 per cent compared to CMS and there is increased seed setting which can lower the cost of hybrid seed production. This was tested in dozens of parent lines and significant correlation was recorded.

Dr. (Mrs.) Rajesh Dahiya and Dr. (Mrs) Nirmal Yadav presented a talk on "Picking bags - a need based technique for farm women to lower the drudgery in cotton picking", selected from abstract to present as oral presentation.

The cot designed by using body friendly material (cotton) was easy to work with and resulted in higher efficiency of the pickers. It was found cheaper, had higher adaptability, simplicity and practicability. It can be locally stitched by ladies with the paper pattern cutout.

The new cot was highly popular among the female cotton pickers in the cotton growing districts of Fatehabad and Sirsa and a new one is being designed for male pickers.

There was lot of interest in its commercialization and use in different parts of India.

The fifth speaker was *Dr. (Mrs.) Vinita Gotmare from Nagpur* who presented paper on the "Evaluation of pre-released cotton genotypes for high density planting system". This paper was selected from the abstact to present it orally.

Eighteen *hirsutum* and nine *arboreum* genotypes were compared with standard checks for high/low input and variable spacing. Some of the new genotypes were found promising and will be evaluated under field conditions. There were some concerns about very narrow spacing as that may hinder agricultural operations including manual weeding and picking.

The meeting ended with thanks to the Chair.

Session 7 : Post harvest Technology and Socio economic Development

Chairman : Dr. Saroj S. Jeet Singh
Co-Chairman : Dr. S. Shukla, Dr. Nirmal Yadav
Rapperteurs : Dr. A. R. Reddy

There was two invited papers and four oral presentations in the session

First invited papers was on status of "Mechanical harvesting of cotton in India" presented by *Er. G. Majumdar, CICR, Nagpur*. In this presentation he reviewed the evolution process of cotton picker from the oldest house drawn picker to modern spindle type picker. He also celebrated about the work going on in India to develop cotton picker suitable to Indian conditions.

Second invited paper was as quality assessment of Indian cotton harvested using spindle pciker vis-a-vis effectiveness of cleaners in its processing presenting by the *S. K. Shukla*. In this presentation the authors elabarated about the quality of machine picked cotton and the efficiency of cleaners. The study informs that the machine pciker cotton contains 19.26% train and the efficiency of various cleaners ranged from 20.45-41.86 per cent. This tudy found that pre cleaning operation did not make any significant efficience in the fibre propertion.

In the first oral presentation *Dr. A. R. Reddy* elaberated about changes that have taken place in the cost structure, input use, prices and returns in cotton cultivation in Gujarat after the introduction of Bt cotton. As per this study there was not major changes in the cost structure but total cost increased by per cent during the post *Bt* period. Similarely quantity of human labor mid fertilizers increased while the quantity of seed, insicticides and mannures dcreased. There was an increase in the yield, gross income and net income in cotton production during post *Bt* period when compound with pre Bt period in Gujarat.

In the second presentation *Dr. V. G. Arude* with the energy consumption and improving energy efficiency in cotton bale pressing. The study examined the energy requirement for different types of processes and found that up packing person requires compentively less power and energy than down packing pess. This study also suggested intensions for improving the energy efficiency.

The third presentation was by *Dr. S. M. Wasnik* about the impact of inter empping technology transfer on knowledge, adoption and profit of the cotton farmers in Vidarbha region of Maharashtra. This presentation elebrity brought about the technology adoption process of inter cropping technology and how it influenced the knowledge of the adopters and net profit of the cotton farmers.

The last presentation was by *Dr. Chitranayak* who delt about assessment of cotton fibre attributes for took and export. He explained about the fibre qualities of the various cotton samples analyzed at CIRCOT. He also explained about the required qualities needed for the export of the cotton fibre.

In their concluding remaines charmaning and Co-charimen of the seesion thanked the speakers for the inforamtive presentations.

The Young Scientist Award chaired by Dr. R. P. Narwal, Former Director of Research, CCS HAU, Hisar and Co-chaired by Dr. B. R. Patil, Sr. Scientist cum Incharge AICCIP unit of Dr. P.D.K.V. Akola and the Rapporteurs were Dr. Pankaj Rathore of PAU, Regional Station Faridkot and Dr. M. K. Rana of NBPGR, IARI, New Delhi

Chairman : Dr. R. P. Narwal
Co-Chairman : Dr. B. R. Patil
Rapperteurs : Dr. Pankaj Rathore, Dr. Dr. M. K. Rana

Eight Scientists preseneted their work for the award.

The first speaker was *Mr. L. Sekhar of UAS, Dharwad*. He presented his work on genetic, biochemical, histological and neocule analysis of thermosensitive genetic male sterbility (TGMS) his cotton (*Gossypium arborium* L.). He sand that lirmo senstive genetic male steribility is innovative male steribility system in cotton and its a firit kind of report. Timing of collase activity plays role in this formation and degradation of cell wall during mitrosporogen asis. The abnormal pollen development in the sterile another was the vacoulation of microspire, associated with crushing of chromation material coupled with shrinkage of micropore cytoplam. Finally from this investigation NAU 2176 and NAU 2096 markers can be used as linked markers for this TGMS trait in cotton as evident from their differential exforession in fertile and sterile anthors of some plant during differential temperature regions.

The second award paper was preseneted by the *Mr. Sekhar Babu Geddam of UAS, Dharwad.* He preseneted the paper on molecular co-ordianation of genetic male sterility genotypes in deploid cotton (*Gossypium arboreum* L) and development of male sterility specific eco marker the explained that genetic male sterility in the (*Gossypium arboreum* L) was found to be under the control of recessive gene. This GMS system has been used for diploid cotton hybrid breeding in India. He said that in the present study RAPD marker system to characterize the Hisar GMS and SRT 1 GMS lines which were derived from the repeated back grosses and the male sterility in these genotypes is governed by the single recessive gene. He explained that dendrogram revealed two district clusters in which all the male sterile plants mode independent cluter and similarly the sterile plants mode indenpendent cluster and similarly the fertile plants indicating genetic differences between them for sterility. He also said that the RAPD markers associated with male sterility and putative SCAR marker specific to male sterility facilaite the utilization of the GMS system in hybrid breeding in the Asiatic cotton.

The third speaker was *Dr. G. N. Hosagoudar of UAS, Dharwad.* He presented his paper on epidmiology of Althernaria leaf sp on Bt Cotton. He souel that through aerobiological studies that the spoke load of the pathogen we found maximum during August to October rnorties He also said that maximum temperature had positive. Correlation while remaining weather parameters like maximum temperature relative humidity, rainfall and rainy days had negative correlation with sporeload. The aerobiological studies also revealed that PDI was progressing at linear rate throughout the plant growth and it was negatively correlated with maximum comparative and relative humidity.

The fourth speaker was *Neeta Singh from G. B. Pant University of Agriculture and Technology, Pantnagar*. She presented her paper utilizaton of *Seebania Ciculeata* (*Dhaincha*) non woven fire on mulen material. She said that needle punched non woren fabric prepared from processed sesbonra a culeala fibres were tested for physical properties namely fabric weight, fabric thickness, abrasim resistance, fabric stiftness tensile length and elongation, tearing strength, bursting strength and air permebility. It was judged suitable for argiculture secor like in mulching,, air layering, propasation of plant, packaging, filtering etc. She said that *S. aculeata* non woven fabric can be used as mulch material for increasing the production of cotton according to climate change.

The fifth speaker was *Dr. G. Y. Vidyavathi from College of Agriculture, Bheemarayanashoh (Karnataka)* and the presented her paper on different method of fertilizer application with irrigated conditions in dry zone of Karnataka. She said that cotton seed and dry matter yield was significantly hisar the STCR approach as compare to other methods. The said the by this method seed cotton yield can be increased upto 49 per cent. The discounted net returns and Bio ratio were significantly higher in the treatments receving fertilizer by STCR approach. She said that by this method soil available nutrients were also found significantly higher with STCR approach fertilizer recommondation.

The sixth speaker was *Mr. Rumesh Ranjan from CCS Haryana Agricultural University, Hisar.* He presented his paper on heritability and gene advance in Asiatic cotton (Gossypium arboreum L.) genotypes. He said that the analysis of variance revealed that sufficient variability was present in the material for all the characters. He also explained that apparent variation was not only due to genotypes but also due to the influence of environment.

The Seventh speaker was *Kanu Priya from Guru Jambheshwar Univeristy of Science and Technology, Hisar.* She presented her paper on the impact of climate change on cotton and its production in India. She said that increasing temperature can have bola positive and negative effects on cotton growth. Higher can levels in the immediate surroundings of the cotton plant will increase photosyntheitc acitivities. She said that this review discussion the impact of climate change on cotton production and recommendations for minimizing the impact of climate change.

The last speaker was *Kavita from CCS Haryana Agricultural University, Hisar.* She presented her paper on impact of salinity an different cotton genotypes. She said that Bt cotton genotypes renowed maximum germinaton percentage while desi cotton cultivar showed the minimum germination percentage at cultivar showed the minimum germination percentage at all the levels of salinity. A significant reduction chlorophyll content of leves was focinowith increasing salinity levels and the level was found maximum in desi cultivars that Bt hybrids. Photosynthetic rate, transpiration rate and stomatal conductance of all the cotton cultivars decreased with control. Maximum stomatal conductive was recorded in desi. Whereas minimum stomatal conductarve was recorded in American and Bt cotton cultivars. She also said that lift cototn cultivars were identified as the basis of protein bonding pattern.

Session 8 :

Chairman	:	Dr. G.S. Buttar
Co-Chairman	:	Dr. A.S. Dhindwal
Rapporteurs	:	Dr. P. Nalayini, Dr. Satyajeet

The session on Crop Production and Mechanization was chaired by Dr. G.S. Buttar and Co-chaired by Dr. A.S. Dhindwal. Dr. P. Nalayini and Dr. Satyajeet acted as rapporteurs.

Seven papers were presented in this session and varied topics like multitier cropping, drip irrigation, fertigation, physiological screening procedures for drought, inter-cropping for sustainability, quality of irrigation water on cotton crop were covered in detail by various speakers.

Dr. K. Sankaryanarayanan, CICR, Regional Station, Coimbatore spoke on the topic entitled, “Multitier cropping systems and its weed control methods for higher resource utilization, profitability and sustainability in *Bt* cotton”. He said that keeping in view the climate vulneratality, market fluchiations and better resource use, cotton baked multitier vegetable intercropping system was evaluated with integerated used management. He said that cotton yield was not significantly influenced by multitier system as compared to sole cotton. He also pointed out that hand weeding thrice 15, 30 and 60 DAS had been harvected significantly highest seed cotton yield. He said that among the weed control methods the highest net return had been calculated with weed control by pre emergance application of pendimethalin @ 0.75 kg/ha followed by hand weeding at 30 DAS. He also said that nutrient uptake had been significantly higher with multi tier sysmtems and significantly highest soil available nitrogen status was analysed by cotton+coriander+vegtable cowpea and cluster beean.

Dr. B. S. Yadav, Zonal Director, RAU, Agril. Research station, Sriganganagar spoke on the topic “Studies on drip irrigation, fertigation and spacing in *Bt* cotton. He discussed that drip irrigation can help to use water efficianctly. A well designed drip irrigation systerm loose practically no water to run off, deep percolation or evaporation. He also said that paired row planting of 120x60 cm was found optimum of *Bt* cotton. The water use efficiency was always higher in the drip irrigation treatments as compared to flood irrigation. The maximum seed cotton yield was recorded at 120 per cent RDF. This method of fertigation gave 15.6 per cent higher seed cotton yield over conentional method of fertilizer application and irrigation.

Dr. P. L. Nehra of Agril. Research Station, Sriganganagar presented his work on “Agronomic studies on promising *hirsutum* varieties in relation to spacing and fertilizer levels. He narrated that significantly higher seed cotton yield was recorded by LH2107 over F 2164 but it was statictically *at par* with LH 2108. As regards spacing, both the varieties were statictically *at par*. He also pointed out that increasing dose of fertilizer from 100 per cent RDF to 125 per cent RDF could not show any impact on seed cotton yield.

The next speaker was *Dr. B. C. Patil, UAS Agril. Research Station, Dharwad,* presented his paper on the subject “Screening of *Gossypium hirsutum* genotypes foe drought tolerance by studying genotypic variablity for growth and biophysical parameters”. He said that drought stress is a complex Phenomenon affecting the physiology of cotton plant and in turn reduces crop growth and yield. He also discussed that overall BS279, ARBH 813, ARBH 2004 and Sahana proved better as they recorded highest seed cotton yield both under irrigated and rainfed conditions and least to moderate drought suscetirly indices. He also emphasised that these genotypes can be used as desirable genotypes for drought situations.

Dr. A. Ravinder Raju, CICR, Nagpur spoke on the topic, “Improving the profitability of rainfed *Bt* hybrid cotton based intercropping systems with changing climate”. He said that intercropping with soyabean, field bean and marigold did not reduces seed cotton yields in excess rains. The most profitable intercropping systems were *Bt* hybrid cotton with African tall marigold, field bean followed by soyabean variety JS 93-05 with 11.3, 8.7 and 3.5 thousand/ha respectively over sole *Bt* hybrid cotton in assured rainfall area. He also pointed out that a multi purpose tool bar was developed which can plant, place fertilizer and conseues oil moisture along with interculture operations for weed control.

The another speaker was *Dr. Sukhpal Singh from PAU, Ludhiana* and he spoke on the subject. “Trends and instability in area, production and yield of cotton in northern India”. He said that although cotton is cultivated in large number of states in the country, the nine states were of Punjab, Haryana, Rajasthan, Gujarat, Maharashtra, Madhya Pradesh, Andhra Pradesh, Tamil Nadu and Karnataka accounts for more than 95 per cent of area and out put. The northern cotton region of India includes states of Punjab, Haryana and Rajasthan which occupies only 16 per cent of the total cultivated area but contributes about 21 per cent of the production. In the end he summarized his take by saying that the cotton cultivation remained a risky crop in northern region of India. The cv. and instabi,lity index were high for production. Which is mainly because of high variability in yield rather than area. Inspite of high rowth rate of yield and production after the introduction of *Bt* cotton. The area under cotton cultivation remained stagnant in northern state of India.

The last speaker was the Chairman of the session *Dr. G. S. Buttar from PAU, Ludhiana*

The major recommendations like enhanced water use efficiency, nutrient use efficiency and profits by the adoption of multi-tier cropping, saving of lateral costs by paired row technique of 120/60 x 60 em and the scheduling of irrigation at 1.0 ETc and fertigation upto six splits, intercropping for sustainability in rainfed agro-ecosystem of Central India, need for good quality water for pre-sowing irrigation of Punjab condition for maintaining the required plant-stand and enhancing the yield of cotton were the recommendations of this session.

The chairman and co-chairman stressed the need for precision agriculture and site specific recommendations for enhancing the resource use efficiency in cotton based system.

Session 8 :

Chairman : Dr. (Mrs.) Santosh Dhillon
Co-Chairman : Dr. R. K. Gumber
Rapporteurs : Dr. S. K. Pahuja, Dr. Omender Sangwan

The session was Chaired by Dr. (Mrs.) Santosh Dhillon, Dean COBSc. and Humanities and Co-chaired by Dr. R. K. Gumber, Sr. Cotton Breeder cum Regional Director, PAD, Reg. Station Faridkot. Myself, Dr. Surender Pahuja and Dr. Omender Sangwan acted as rapporteurs. There were four presentations in all.

Dr. Muhammad Saeed from GCD, Faisalabad, Pakistan was the first speaker of the morning session. He delivered his talk on molecular approaches for climate change scenario. He stressed on the need of changing our breeding strategies in view of change in climate and heat, drought and salt stress to be more important in the present and future scenario in cotton research. He cited the example of cotton leaf curl virus disease and shared his experience of Pakistan where early sowing in March or 15th Feb. may result in escape of CLCuD disease and can yield up -to 50-60 q /ha and single crop is more economical than two crops. In molecular approaches, he emphasised the need of adopting new techniques like association mapping in which there is no need of RILs, NILs, F2 populations and even varieties can be analysed. The QTL technology can reduce the time taken in conventional approach. He also cited the example of marker trait association work being carried out in Pakistan for salt tolerance where few markers have been identified.

Dr. Shreekant S. Patil from DAS, Dharwad delivered his talk on the challenges for breeders and need for breeding system research in cotton. He stressed that in the changed scenario of bt cotton hybrids the incidence of sucking pests has increased and there is need for developing conventional mechanism of resistance. He also stressed on promotion of organic cotton and development of genotypes suitable for machine picking. We are utilizing the conventional breeding methods and there is a need for reorientation of breeding methods by following Maize breeding approach of heterotic pools through recurrent selection programme and also shared his experience of work on formation of heterotic groups (stay green and compact heterotic pools etc.) and exploiting them.

Dr. KV Pethani from Saga Seeds Company in his talk on Biotech Seeds Genes Taxonomy [BSGT] and Biotech Research Steps, Aspect and Direction [BRSAD] and Methods of Extension stressed on the need to simply standardise and categorise source of genes, their action and benefit in improvement of particular output & input traits and steps of gene insertion program in various level of available germplasm.

Dr. Pankaj Rathore from PAD, RRS Faridkot while speaking on breeding American cotton genotypes suitable for high plant density emphasised the benefit of high plant density through a study conducted at their research station. Even the lowest yielding genotype under normal spacing was able to give up to 118 % increase in yield under high plant density of 75 x 15 cm spacing.

In the end Chairman concluded the session with remarks on the use of integrated technologies of molecular and conventional breeding and need for their utilization under the present circumstances.

Session 8 :

Chairman : Dr. A. S. Antil
Co-Chairman : Dr. P. L. Nehra
Rapporteurs : Dr. M. S. Bhattoo, Dr. Parvinder Sheoran

This session chaired by Dr. A. S. Antil HOD Soil Science and Co-chaired by Dr. P. L. Nehra Sr. Agronomist RRS, Sriganganagar.

Dr. Sunita Kataria emphases the role of UV-AUVAB exlusion increase the growth and yield in cotton. She said that excluding UV-B and UA-A/B significantly increased plant height, leaf area, dry weight accumulation and yield parameters in all the four varieties of cotton. She also pointed out that the photosynthetic trigments were significantly enhanced while UV-B absorbing substances were significantly increased by the exclusion of solar UB-B and UB-A/B. Exclusion of solar UV proved to be banificial in enhancing the growth and yield of cotton plant. She also pointed out that the experiment results indicated that suppressive action of ambeint UV on carbon fixation and yield of cotton plants.

Dr. A. Lalita Kumari emphares the adverse effect of weather change on deplition on soil OC and nutrient status. She said that when the initial soil samplex were compared with the post harvest soils of previous crop, they indicated that there was an increase in the soil pH from March to July during summer in both organic and inorganic plots, however the pH values were lower in inroganic plots as compared to organic plots at both sampling times. Heavy rainfall during July and September could reduce the soil pH and EC. She also narrated that by the investigation of many scientists revealed that organic carbon and available P status of the soils improve under organic method of cultivation.

Dr. P. Nalayini (Coimabatore) for adoption of Stale Bed Technnique in key benifical for weed management. Effective chemical were control in SSB Technique. Dr. Nalayini pointed out that cotton is sensitive to seed competition due to its slow initial growth and wider spacing. *Bt* cotton in high yielding and response to higher level of inputs like fertilizers, irrigation etc and is grown under intensive cropping system and all these factors promole luxurious growth of weeds which gfrow more quickly than cotton and compete strongly for soil moisture, nutrients, light and space. She said that the naval approach of exhausting weed seed bank before the crop emergence by stale seed bed approach which has been standizied for *Bt* cotton based inter cropping system.

Dr. Dev Raj gave the lecture on "Effect of weather variables on productivity by of American cotton under field conditions. He said that boll matisration period, which determines the productivity is a critical stage in the life cycle of cotton. During this period the boll grows, fibre develops and seed matures. Great atention is being paid to be factors affecting this period. Int eh field, weather conditions are different and complicated. Thus only the field studies can provide realistic assessment of what will happen to the crop growing under field conditions due to chagne in weather. He also pointed out that night temperature and vapor pressure of morning were identified as most critical weather variables influencing seed cotton yield and some management practices such as sowing dates, irrigation etc must be taken care of to mitigate the adverse effect of weather variables to improve the production and productivity of cotton on sustainable basis. The other weather variables nq. much influenced the seed cotton yield.

Dr. Sumender Singh "Stage on weed management in cotton" emphasised the proper care of helicaide for the specific and tested weed to avoid herbicide senstives. The chairman and co-chairman stressed the need for proper care of climate change and rise in temp i.e. 1-2^{0}C rise in temperature cause 2-6 per cent GOP reduction. For weed management cultural practices with herbicides should be target weed management.

Session 10 : Crop Protection and Biosafety

Chairman : Dr. S. K. Gandhi
Co-Chairman : Dr. K. R. Dabur
Rapporteurs : Dr. K. K. Verma, H. S. Sheoran

The session was held in Lead Room No. 8 of Deptt. of Plant Pathology. This session was chaired by Dr. S. K. Gandhi, Prof. and Head Deptt. of Plant Pathology and co-chaired by Dr. K. R. Dabur, Prof. and Head, Deptt. of Nematogloy alongwith Dr. K. K. Verma and Dr. H. S. Saharan as rappoteurs. The session started with welcome note by the chairman. There were two invited papers and five oral presentations. The first invited paper was presented by *Dr. K. K. Verma* on the title "Nematode pests of cotton and this management in India". The root-knot nematode Meloidgyhne intognita was stated to be most damaging amongst plant parasitic nematodes. Symptoms, losses distribution, life cycle and management of important nematodes was discussed. He said ranly a few nematods are important namely, root knot nematode, reniform nematode, lance nematode, string nematode and a few other nematodes of minor importance such as lession nematode stubby root nematode. Root knot nematodes are major problems in many cotton growing area of India while reniform nematode has only the regional importance. On an average 10.7 per cent loss in cotton yield on world wide basis has been reported due to phytoparasitic nematodes. In the end he emphasized the future thrusts namely host parasite relationship, nematode interactions with other cohabiting micro organsims; nematodes of *Bt* cotton; screening transgenic plants to nematodes and identification of resistant genes to reniform and root knot nematodes in cotton.

Second invited speaker was *B. Shree Lakshmi*. She delivered her talk on "Avoidable losses due to cotton diseases in India". The losses was 25.2-46.6 per cent due to cotton leaf curl virus disease. The discribed leaf rut also from southern India. She summarized the work done under All India Co-ordinated Cotton Improvment Project at different statrous for a variable losses due to improvement diseases like cotton leaf curl visus disease, bacterial blight, Alternaria leaf spot, grey mildew, Myrothecium leaf spot, Helminthospon with leaf spot and nuts. Losses due to leaf curl on *Bt* cotton hybrid in north zone during 2009-2012 ranged between 25.4-46.56 per cent. Five spacings of copper oxychloride+streptocyclive showed reduction of bacterial blight PDI from 28.8-120 and reduction of yield loss upto 22 per cent five sprays of Propiconazole (0.1%) reduced PDI of alternanic leaf blight from 31.59 to 20.85 per cent and from grey mildew upto 29.2 per cent by applying five sprays of carbendazium. The redution in loss upto 29.1 by five foliar sprays of Propiconazole (0.1%). She also said that the pooled data of three years for the control of rusts indicated the reduction in PDI from 31.8 to 7.7 and 29.0 to 10.7 reduction in yield loss. She also pointed out the implications of these studies in disease management of cotton.

Dr. Sunita Yadav gave a talk on "Pollinattors, diversity and their role in pollination in cotton". She described that bee is the ideal poolinator among all. Pollination is greater under dry land conditons than under irrigated conditons and is more in early flowers than in later stage flowers. She said that out of eight *Apis* species, six (*A. Cerana; A. florea*; *A. dorsata; A. Andreniformis; A. laboriosa' A.*

koschovnikovi) are indigenous of India and *A. mellifera* has been introduced to India most of the pollintion studies and management bee pollination work in India are done on hive bees *i.e.,* Indian honey bee (*A. cerana indica*) and Italian honey bee (*A. cerana indica)* and Italian honey bee (*A. mellifera*) because they are manageable in any number, season and at any place and show behavior of floral fidelity/constancy. She also said that bee pollinators play a key role in emhancing the cotton yield qualititaively as well as quantitatively.

The next speaker was *A. V. Kohle from P. D. K. V. Akola* who presented and talk on "Evaluation of popular Bt and non-Bt transgenic cotton hybrids against major pests". It was pointed out that no significant differences were noticed amongest *Bt* and their non *Bt* counter parts as regards major sucking pests. He also pointed out that the lower leaf hopper population was recorded in PKV hyin2 and PKV-Rajat as compared to rest of the hybrids Highest population of leaf hoppers and lowest count of whitefly and thirps was recorded in RCH-2 *Bt* and non *Bt*. Sympodial branches and height was statistically equal except RCH-2 *Bt* and non *Bt*. Plant stand was uniform. Under unprotected conditions. There was increase of 3385, 11.47 and 7.04 per cent seed cotton yield in *Bt* transgenics hybrids *viz.*, RCH 2, KDCH 632 and Bunny over their non *Bt* counterparts, resepectively.

Nandini Gokte-Narkhedkar presented a talk on "Insectidial toxin genes from bacteria *Paenicillus* spp potent against insect pests potential under climate change". She spoke on the molecular characterisation and biochemicals tests and smplification of the toxic gene. She pointed out that Entomopathogenic nematodes (EPN) and their bacterial symbiont have been recognized as a potent management tool against insect pests of cotton. An bacterial insolate associated with EPN isolate was characterized based on biochemical and molecular parameters and work over initiated to clone insecticidal toxin gene from this bacteria as it has potential for use against sucking pests which are fast emerging on major insect pest of crops under climate change.

The next talk was given by *A. G. Sreenivas from UAS, Raichur* which the emphasized the efficacy of the thiamethoxam, clothianidin and imidacloprid against leaf hopper. He said that among different insecticides tested for bioassay studies under laboratory conditions revealed that thiamethoxan (25% WDB) @ 2 g/l;l imidachoprid (17.8SL) @ 3 ml/l and clothnianidin (50 WDG) @ 0.12 g/l showed the highest mortality which proved their superiority over other standard checks. The low concentrations of insecticides show the susceptibility status of the insect.

Dr. Satnam Singh presented a talk on "Performance of different Bt cotton hybrids with respect to sucking pests" dises and productivity. He empharized that inform screening protocal may be evolved to avoid mushromming of hybrids since Bt hybrids provide varying degree of reaction to insect-pests and disease.

Session 10 : Crop Protection and Biosafety

Chairman : Dr. (Mrs.) Raj Bala
Co-Chairman : Dr. Ombir Sangwan
Rapporteurs : Dr. (Mrs.) Savita Vermani, Dr. (Mrs.) Usha Rani

Session No. XI on Post harvest technology and socio-economic Development was chaired by Dr. (Mrs.) Raj Bala Dean PHS and Co chaired by Dr. Ombir Sangwan first of all *Dr. Krishna Khambra* presented a very good paper on effect of spinning mechanism on blended fabric. She included that problem of pilling could be sedead by using more netureal fabirc than sythetics (acrylic) for knit wear. Pill can also be minimized by ring span yarn than of. OF acrylic and sub acrylic blend acrylic showed more piller, it may be brows of high modules of acrylic. With increase of sub in the blends, the pilling decreased the blended fabrics with less weigh and thickness had less number of sill.

Another through provoking paper was presented by *Dr. Usha Rani* from Coimbatore on socio-economic assessment of Cotton growers awareness about climate change and adpotion streligins.

She concluded that farmers especially cotton growers were not much aware of climate change unknownly. They all adopting indigneneous stregies to cope up with climate change Hence the farmers should know about climate change throughj appringate extension methods. She also made to educate the farmers about the adaption stregies developed by NARS (ICAR +SAU) to cave up with the climate change.

Cotton Research and Development Association
Silver Jubilee International symposium
on
"Global Cotton Production Technologies vis-a-vis Climate Change"
10-12 october, 2012
CCS Haryana Agricultural University, Hisar

Courtesies Sponsors (Industries)

1. Indofil Industries, Mumbai
2. Rasi Seeds, Attur 3. Mahyco, J alna
4. United Phosphorus Ltd., Mumbai
5. Nuziveedu Seeds Pvt. Ltd., Hyderabad
6. Bayer Crop Science, Hyderabad
7. Bioseeds, Hyderabad
8. Makhteshim Agricultural
9. Shakti Vardhak, Hisar
10. Tulasi Seeds
11. Ankur Seeds, Nagpur
12. Monsanto Mahyco
13. Dhanuka, Gurgaon

Govt. Grants

1. ICAR, New Delhi
2. NABARD,Mumbm
3. DST, New Delhi 4. CSIR, New Delhi

AUTHOR INDEX