7 ACRDN Meeting

Seventh Asian Cotton Research and Development Network (ACRDN) Meeting

Le Meridien, Nagpur, India, September 15-17, 2017

Theme

Production of Quality Fibre and Doubling Cotton Farmers' Income

Book of Abstracts

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PREFACE

The Indian Society for Cotton Improvement, Mumbai, India, in collaboration with the International Cotton Advisory Committee (ICAC), Washington DC, USA, ICAR-Central Institute for Cotton Research (CICR), Nagpur and ICAR-Central Institute for Research on Cotton Technology (CIRCOT), Mumbai is organizing the 7th Asian Cotton Research and Development Network Meeting at Nagpur, Maharashtra, India during September 15-17, 2017. The 1st ACRDN meeting was first held in 1999 in Pakistan followed by Uzbekistan, India, China, Pakistan and Bangladesh every three years. Deliberations during all the previous ACRDN meetings have strongly influenced the regional cotton research agenda. These meetings also provided an excellent opportunity for cotton researchers, policy makers and experts from the industry to interact on challenges and opportunities along the cotton value chain and evolve joint strategies.

The cotton scenario across Asian countries, despite geographical diversities has several similarities. The common challenges include small size holdings and low level of mechanization, rising production costs and dwindling profits, climate change induced biotic and abiotic stresses, restricted access to modern technologies, poor fibre quality and contamination. On the other hand, science is progressing at a tremendous pace and new technologies are being continuously developed to tackle current and emerging problems confronting cotton across the globe. The ACRDN-7 provides an opportunity to showcase these advances and the technical sessions have been carefully designed keeping the most challenging issues in mind. This book contains 126 abstracts of the theme wise presentations arranged during the ACRDN-7.

The organizing committee is extremely grateful to all the speakers for contributing their abstracts and participating in the meeting. We thank all the members of the editorial team, technical and publication committees for their help in compiling and editing the abstracts. The secretarial help provided by Ms. Vandana Satish and Ms. Rita Dhanole and the assistance provided by Ms. Aarti Ahire, Ms. Sonali Ghane and Mr. Samir Chalkhure in designing the cover page are gratefully acknowledged.

Organizing Committee

7th ACRDN Meeting

CONTENTS

Technical Session : 1 : Global Best Practices for High Yields

Abstract No. Oral: 1

BEST PRACTICES FOR HIGH YIELDS IN AUSTRALIA

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Cotton is a relatively new crop in Australia, with most of the growth in area occurring from the early 1960s. Australia grew 460,000 ha of cotton last season, mainly in New South Wales and Queensland. Two thirds of the crop is irrigated and almost all is exported, mainly to China. Farms are large (averaging 331ha but some are very much larger) and heavily mechanised, with an average farm gross income over $2 million. When coupled with the very small number of growers (<900) and very strong R&D support through the industry funded Cotton Research and Development Corporation, Cotton Australia and Cotton Seed Distributors, Australian growers have ready access to the best current science on all aspects of crop planning, production, post-harvest processing and marketing. This advice is summarised annually in the Australian Cotton Production Manual and a range of technical publications including the Cotton Pest Management Guide (all freely available at *www.crdc.com.au/publications*) and is communicated to all farmers via the extension and Best Management Practices teams at Cotton Info (*www.cottoninfo.com.au*) with access to a range of models, calculators and prediction tools plus individualized BMP planning support available at *www.myBMP.com.au*. Over a third of all farmers have direct involvement in CRDC research trials on their farms. The underlying BMP principles are those of the global cotton industry but the level of uptake and compliance is extremely high, resulting for example in a reduction in insecticide use of 92% and improved water use efficiency of 40% over the last 15 years and yields that are among the highest in the world at a national average of 2364 Kg/ha (2815kg lint/ ha for irrigated cotton and 817kg lint/ha for dryland cotton) in 2016.

Abstract No. Oral: 2

BEST PRACTICES FOR HIGH COTTON YIELDS IN EGYPT

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- Egypt exclusively produces *Gossypium barbadense*, a type of extra fine cotton that generally has a longer and finer staple than Upland cotton.
- The current productivity is 3.45 bales/ha and the expected increase in yields from 3.2 bales/ha to 4.4 bales/ha.
- Cotton was the main summer crop in Egypt, but nowadays it comes third, after maize and rice, regarding the cultivated area. However, because it occupies the land for about 6-7 months while maize occupies it for about four months.
- In the past two years, the government has taken control over the production and distribution of cottonseed, which used to be handled by the private sector, in an effort to restore seed purity and cotton quality. The government was forced to intervene as Egyptian cotton's reputation and quality had deteriorated significantly, due to seed companies' lack of effective quality assurance systems that

resulted in inferior, mixed variety output.

- In early 2017, the government announced a new policy that aims to reverse Egypt's cotton industry's decline. The policy, which consists of 19 steps, will be implemented starting with the 2017 planting season. This includes:
  I. Encourage contract farming to solve marketing bottlenecks.
  II. Provide high quality seeds to increase yields and quality.
  III. Identify the areas suitable for each cotton variety.
- Cotton practices requires planning and timely action throughout the season. Best Practices are agricultural practices which optimize the three pillars of sustainability: social responsibility, environmental integrity and economic viability by binding together, the financial requirements for agriculture, such as high yield with environmental and social concerns, such as water and pesticide use.
- The largest proportion of cotton cultivated area is planted after temporary berseem, a sizeable proportion after broad beans, smaller areas after potatoes and other minor crops, and sometimes some farmers grow cotton after wheat.
- Delta and Nile valley are suitable for growing cotton if irrigation and fertilization is provided properly. Growing cotton in these soils have the advantage of early maturity, however yield is relatively higher.
- In new lands, where the soils are generally sandy, cotton could be grown successfully only if modern irrigation systems, especially drip irrigation, are used.
- Land preparation and weed control is important to reach yield potential.
- There is a loss in cotton yield incurred by delayed sowing. Recent experiments carried out by the Cotton Research Institute, demonstrated the magnitude of loss in yield due to delaying sowing date in Middle and Delta Egypt. In Middle Egypt, one month delay in date of sowing resulted in about 30% loss in yield, while another one month delay in sowing brought yield down by about 50%. In the Delta, when sowing was delayed further for another 30 days till 1st of June, the loss amounted to about 57%. It appears that varieties, and probably regions, differ in their response to delayed sowing. It seems that delaying has more deleterious effects on yield in Delta and Upper Egypt, probably because of difference in climatic conditions.
- Because large number of seeds per hole is usually used, when germination is normal , there will be a large number of seedlings per hill which makes thinning to a required number of 2-3 plants per hill a necessity.
- CRI recommended 75cm distance between ridges and 45 cm distance between hills. when leaving two or three plants per hill after thinning, these distances give approximately plant densities of 8-10 plants per square meter, i.e. 35.000-45.000 plants per feddan (0.42 ha).
- The cotton plant daily water requirements start from the moment the seedlings emerge on soil surface and continues until shortly before picking the crop. However, it varies in quantity according to many factors but mainly growth stage and air temperature and humidity which affect transpiration.
- Nitrogen fertilization is the limiting nutritional factor for cotton production in Egypt. The increase in yield due to phosphorous fertilization is moderate but is economical when phosphorous is used at moderate rates, while potassium fertilization showed no sizeable effect in most of the experiments.
- On of the average, the optimum rate for nitrogen application is 60 Kg /F, however some varieties respond positively to higher rates up to 75 Kg/F. Phosphorous fertilization is recommended at the rate of 15 Kg P_2O_5 / F.
- However, varieties differ substantially with regard to yield potential, their response to fertilization did not show similar wide difference. Response to fertilization varies according to differences in soil productivity. Response to nitrogen was higher in soils of lower productivity than in soils of higher productivity.

- Under Egyptian conditions, weed control in cotton fields is a must, otherwise a substantial proportion of the yield might be lost.
- Cotton in Egypt is normally handpicked.
- Cotton transplanting is known to be possible from the technical point of view as transplanted seedlings could revive and grow into normal cotton plants.
- Intercropping "cotton (a summer crop) - onion (a winter crop)" has been practiced by small cotton farmers in the Delta for reversal decades.
- Successful cotton production in Egypt relies, on the effectiveness of plant protection against the various insects and diseases that attack it throughout its lifetime and cause a good deal of losses.

Abstract No. Oral: 3

REFINING AND ADAPTING GLOBAL BEST PRACTICES FOR ENHANCING THE PRODUCTIVITY OF INDIAN COTTON

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Despite being the largest producer of cotton, the productivity of Indian cotton is only 500-550 kg lint/ha, as against the global average of 750-780 kg/ha. The productivity of cotton in some major cotton growing countries like Australia, China, Brazil, Turkey and Mexico is above 1500 kg lint /ha. To improve productivity and compete in the global market, we need to quickly change the way cotton is grown today.

Good agricultural practices across the globe have evolved through a blend of traditional wisdom and scientific breakthroughs translated into technologies. The choice of best technologies for a region is local in context and depends upon the agro-climatic features and the socio-cultural backdrop. But universally, these technologies are based on the principles of sustainability in the ecological and socio-economic context.

This paper summarizes the recent R&D efforts initiated by the ICAR- Central Institute for Cotton Research and the All India Coordinated Research Project on Cotton to establish some alternate sustainable cotton production systems based on lesson learnt from across the globe on best practices to improve cotton productivity with low production costs. Some of these include – High Density Planting System (HDPS), intercropping with legumes (black gram, pigeon pea, cowpea, groundnut, cluster bean), plant training and manipulation of canopy architecture, stale seed bed and cover crops for weed management, window based Insecticide Resistance Management, short and long staple *desi* (*Gossypium arboreum*) cotton production under HDPS, mechanization of planting and picking, mulching and crop residue management, raising nursery and transplanting cotton seedlings, synchronizing N delivery with crop demand etc.Early maturing (150-160 days) semi-compact varieties with short sympodia such as Suraj, Anjali, PKV-081, NH-615, F2383, ADB 39 (*G. hirsutum*) and Phule Dhanwantary, AKA07, HD 123,CICR 1 and CICR 3 (*G.arboreum*) have been identified as amenable for HDPS and can be planted at 1,50,000 to 2,00,000 plants/ha. IRM strategies involving judicious selection of insecticides based on resistance data, WHO and IRAC ratings have been developed and disseminated. Both HDPS and IRM strategies have been up-scaled recently and are now being adopted by several farmers. Placing appropriate technologies based on agro-ecological zones and up-scaling them would enable India to improve productivity to global average and double the income of cotton farmer.

Abstract No. Oral: 4

SMALL HOLDER COTTON MECHANISATION: BANE OR A BOON

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Cotton cultivators in India, China, Pakistan and countries in Africa are predominantly small holders. An average farm size is 1.5, 0.3 and 4 hectares in India, China and Pakistan, respectively. Similarly, in Chad, Mali and Uganda, it is 1.0, 2.9 and 0.5 hectares, respectively. These are also the places where cotton cultivation is the least mechanized. As a case in point, these countries harvest their cotton manually. Whereas, countries like USA, Brazil and Australia, with an average farm size of 584, 3300 and 1800 hectares, have their entire cotton area machine harvested. The exception to this case is Israel and Greece where farm holding is lesser than USA, Brazil and Australia. In Greece, 92% area is mechanically harvested but the average farm size is only 5.3 hectares. Presently, 70% of the world's cotton cultivated area is hand harvested. Throughout history, cotton machines were developed for large farm sizes because of huge labour requirement to cultivate the land, if it were to be done using human and animal power. Naturally, the developed machinery was huge, requiring large operating powers, complex and required a high degree of technical skill to operate and maintain. The authors argue that recent labour shortages coupled with high wage rates has made cotton cultivation unviable in India. This will eventually lead to greater mechanization of small holder situation in the world. The paper describes advances made in this direction for cotton cultivation under small farm situations, and the significant advantages in terms of cost reduction and timeliness of operations accrued wherever mechanization was introduced.

Abstract No. Oral: 5

EFFECT OF VARIOUS GINNING TECHNOLOGIES ON FIBRE PROPERTIES OF MACHINE HARVESTED COTTON

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With reduced farm labour availability and significant increase in manual cotton picking cost, demand for mechanisation of cotton harvesting is growing day by day in India. In India, considerable work towards development of viable and appropriate picker and stripper prototypes are going on for over last two decades. Field evaluations of the 1-row cotton picker and the finger type stripper demonstrated that the cotton harvesters developed in India are performing at par with that of commercially available pickers and strippers used in USA, Australia, etc. However, availability of suitable cotton hybrid/variety, defoliants, viable cleaning

and ginning machinery are still areas to be researched and fine-tuned for making cotton mechanisation a reality in India.

In this work, picked cotton harvested using 1-row cotton picker developed by John Deere India was ginned using lab model Single Roller (SR), commercial size Double Roller (DR) and Saw gins. Trash content and fibre properties of the ginned cotton was analysed on HVI and AFIS. The harvested cotton contained about 1.0%, 1.2%, 1.1%, 6.9% bracts, sticks, green leaves and pin trashes, respectively. The pin trashes were mainly crushed dry leaves picked by the harvester. A tower drier was used to maintain 6% moisture content before pre-cleaning operations whereas the uniform rate of cotton feeding was ensured by using a regulated dispensing unit. The picked cotton was cleaned using a set of cleaning machinery comprising of 6-cyclinder CIRCOT-Bajaj inclined cleaner, 2 stage stick machine and impact cleaner. In this study, Saw gin yielded about 0.2 and 0.13 mm higher staple length as compared to DR and SR gin. It is probably due to interaction between fibres and trash material while ginning under high pressure (in between rollers and fixed knives) in DR gin resulting in damaging of fibre parameters in DR gin. Moreover, the trash content in the saw ginned cotton was also less as compared to DR and SR gins. It may be concluded that saw ginning would be best suitable system for processing of machine harvested cotton.

Abstract No. Oral: 6

ECONOMIC EVALUATION OF MECHANIZATION POTENTIAL OF COTTON FARMING IN INDIA

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Although agriculture has met significant challenges in the past, targeted increases in productivity to 1000 kg/ha lint yield by 2020 will have to be made in the face of stringent constraints—including limited resources, less skilled labor, and a limited amount of arable land, among others. India is lagging behind many other large producers of cotton in mechanization of harvesting the crop. To cope up with the shortage of labour and to increase the productivity, mechanization at certain stages of the crop cycle might be a probable solution. There has been an increase in the use of farm machinery in Indian agriculture as it contributed to the increase in output due to timeliness of operations and increasing precision in input application. Farm mechanization is the process through which agricultural activities can be improved in a cost effective manner to achieve optimum crop production. The present study was initiated with the following specific objectives: To compute the intensity of labour shift from cotton to other sectors and to estimate the economic viability of mechanized methods of cotton cultivation. There is a significant shift towards high value crops between 2000-01 and 2013-14 wherein labour demand is high. In next 10 years, we can expect 5 to 10 per cent of the cotton planted area to get mechanized in India after identification of farm mechanization zone. A policy of selective mechanization will be most suitable where the labour displacement effects are minimum. There cannot be going back from mechanization but we have to frame suitable policies such as encouraging cooperative management or contract farming and custom hiring of machinery, imparting training to the farmers regarding such investments and encouraging standard service inputs without affecting the human labour.

Abstract No. Oral: 7

TECHNOLOGICAL ADVANCES IN DOUBLE ROLLER GIN PLANT MACHINERIES IN INDIA DURING 2010-2016

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India is the largest producer of cotton in the world and complete quantity of cotton produced in India is ginned in Double Roller (DR) Cotton Ginning Technology based plants. After the modernization of majority of cotton ginning factories in India under Technology Mission on Cotton (TMC) and Technology Up-gradation Fund (TUF) etc. started in the year 2000 and completed in the year 2010, the prime concerns of cotton ginners in India had been higher cost of electricity and higher manpower cost of ginning plants. Further, due to increase in number of cotton ginning factories, the size of new plants has reduced to 5 bales to 10 bales per hour in place of earlier 15 to 20 bales per hour plant for majority of the plants.

To address these concerns and changes, various technological advances have taken place in the machineries for DR Ginning Plants in India during year 2010 to 2016, some of which are as below:

(A) For Electrical Power Reduction:

(a) Seed Cotton Suction Systems to Seed Cotton Dispenser Systems
(b) Individual DR Gin Feeding Distribution Conveyor to Central Distribution Conveyor System
(c) Lint Suction System to Intermittent Lint Suction Systems
(d) Conveying of Seed cotton and lint by suction to Belt Conveyors etc.

(B) For Manpower Reduction:

(a) Raw Cotton Suction Feeding to Tractor mounted buckets
(b) Online bagging and weighing of cotton bales
(c) Online bagging and weighing of cotton seed
(d) Automatic Roll Grooving Machine
(e) Atomization of various other handling processes etc.

The development of smaller capacity equipments such as 5 and 10 bales per hour Up and Down packing baling presses and all other related equipments for ginning and pressing factories.
These technological advances have significantly saved the electrical and manpower costs while providing solution to small capacity ginning plants requirement.

SAARC SPECIAL Panel Discussion Session 3 : GERMPLASM EXCHANGE

Chair : Dr. Tayan Raj Gurung ; Co-chair : Dr. R. K. Singh	
Tayan Raj Gurung	SAARC initiatives on germplasm exchange
Yusuf Zafar	Promising germplasm of Pakistan for SAARC Nations
RK Singh	Germplasm exchange through Biodiversity, PPVFR & ITPGRFA
Md. Farid Uddin	Cotton germplasm needs for Bangladesh
Md. Ibrahim Jalil	Cotton germplasm needs for Afghanistan

Abstract No. Oral: 8

SPATIAL AND TEMPORAL DISTRIBUTION ANALYSIS OF THE CULTIVATED-WILD PLANT HOST INTERFACE REVEALS EXTREME GENOMIC DIVERSITY AMONG GEMINIVIRUSES IN PAKISTAN

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Analysis of the spatial and temporal distribution during 2011-2014 of cotton-infecting geminiviruses in Pakistan, indicated that *Cotton leaf curl Kokhran virus*-Burewala (CLCuKoV-Bu), a recombinant strain that emerged in 2001 as the causal agent of the 'Burewala epidemic' remained widespread. Leaf samples were collected from symptomatic cultivated and wild plant species in the cotton-producing areas of Punjab and Sind Provinces, with most from Multan and Vehari. The *Cotton leaf curl Multan virus* (CLCuMuV), the species associated with cotton leaf curl disease (CLCuD) in the 'Multan' epidemic of the 1990s, was detected only from two locations in the southern provinces of Punjab and Sindh. The CLCuMuV and two other CLCuD-associated begomoviruses, *Cotton leaf curl Alabad virus* and CLCuKoV-Kokhran strain, also known to occur in cotton during the Multan epidemic, were identified in cotton and non-cotton hosts where CLCuMV-susceptible cotton varieties were planted. Gemini viruses, previously unassociated with cotton, herein reported from cotton, were *Okra enation leaf curl virus*, *Tomato leaf curl New Delhi virus*, *Squash leaf curl virus,* and *Chickpea chlorotic dwarf virus*. Among the betasatellites associated with cotton-infecting gemini viruses, Cotton leaf curl Multan betasatellite was the most prevalent, infecting both cotton and non-cotton species. Further, SPREAD analysis of the CLCuD associated-begomoviral genome sequences indicated that CLCuMuV originated in Pakistan, whereas the recombinant, CLCuKoV-Bu, originated in India, each spreading in the reciprocal direction, dispersed by whiteflies on bi-directional winds that travel across the Punjab region with shifting trajectories, depending on time of year.

Abstract No. Oral: 9

POPULATION GENETIC CHARACTERISTICS OF *COTTON LEAF CURL MULTAN VIRUS* AND IDENTIFICATION OF ITS TRANSMISSION VECTOR IN CHINA

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Cotton leaf curl Multan virus (CLCuMuV) is a causal agent of cotton leaf curl disease, a major constraint to cotton production in south Asia. In 2006, we first found CLCuMuV infecting *Hibiscus rosa-sinensis* exhibiting leaves curling upward, vein deep-greening and vein swelling in Guangzhou, China.

Since then, CLCuMuV spread rapidly in southern China. It has infected five malvaceous plant species, *H. rosa-sinensis*, *H. esculentus*, *Malvaiscus arboreus*, *Gossypium hirsutum* and *H. cannabinus*. Complete nucleotide sequences of 34 geographically and/or temporally distinct CLCuMuV isolates occurring in China were determined. All of the isolates shared more than 99% nucleotide sequence identity with each other. In all the cases tested, the CLCuMuVs were associated with cotton leaf curl Multan beta satellite (CLCuMuB). All of the CLCuMuBs shared more than 98% nucleotide sequence identity. By agro-inoculation of infectious clone method, we proved that complex of CLCuMuV / CLCuMuB was the pathogen of cotton leaf curl and kenaf leaf curl in China. The whitefly populations consisted of two cryptic species, invasive MEAM1 and indigenous Asia 7 in the fields infested with leaf curl disease of cotton, okra and kenaf in Guangdong. The whitefly transmission experiment showed that four cryptic species of MEAM1, MED, Asia-7 and Asia-1 could acquire CLCuMuV and CLCuMuB from the diseased cotton plants, but only Asia-7 and Asia-1 could transmit CLCuMuV and CLCuMuB to infect cotton, kenaf and okra plants, and cause leaf curl disease. The transmission efficiency of the former was 25% -100%, while that of the latter was 33% -100%, respectively.

Abstract No. Oral: 10

INTROGRESSION OF DESIRABLE CHARACTERS FOR GROWING COTTON IN CLCuV PRONE AREAS UNDER CLIMATE CHANGE SCENARIO

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In Pakistan, cotton crop has to face enormous challenges such as biotic and abiotic stresses. A comprehensive breeding programme was initiated to develop cotton varieties which can withstand changing environment; especially high temperature (upto 48°C) and Cotton leaf curl virus (CLCuV) conducive conditions. The parental lines for CLCuV tolerance were selected from a series of experiments and pyramiding techniques was used to combine the CLCuV tolerant genes from various sources. Screening of breeding material was carried out in CLCuV hot spot areas. Varieties/lines were developed having heat and CLCuV tolerance like MNH-886, FH-142, FH-Lalazar, FH-Noor, VH-327 etc. Moreover, high temperature tolerance, earliness to fit in cotton-wheat cropping system, good fiber quality, climate resilient varieties having okra type leaves, longer root system and low input requirement were also considered. In this breeding programme, desirable characters were combined in resulting breeding material. The lines FH-Noor and VH-327 exhibited excellent fiber quality under changing climate scenario with staple length of 29.7 and 30.2 mm, respectively. These varieties are also short duration, early fruit bearing and well suited in cotton-wheat cropping system at high temperature. Variety like FH-Noor requires about 160 days for maturity. For low input situation, varieties like FH-113 and FH-942 were developed. The variety FH-114 showed good performance under high density planting of cotton. The breeding material for moisture stress tolerance having longer root system has been identified and will further be exploited in varietal development programme. The varieties developed during these studies exhibited the highest yield with good fibre quality in CLCuV affected areas. It is expected that improved germplasm will be available in future, which will enhance the productivity of cotton in Pakistan and will be a source of desirable genes for breeding programme of other cotton producing countries.

Abstract No. Oral: 11

BREEDING COTTON FOR CLCUV RESISTANCE

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A CLCuV outbreak devastated the 2015 cotton production in Pakistan. In combination with other factors, yield was reduced by 30-35%. A joint USDA-Pakistan screening program identified a source of resistance from a US germplasm line designated as MAC7. Dr. Jodi Scheffler registered reselections from this line, as GVS8 and GVS9 cotton germplasm in the USDA GRIN system.

A fast-tracked breeding program was initiated to transfer this resistance into commercial germplasm by SANIFA Seeds in their research station at Rahim Yar Khan in southern Punjab Province. The breeding method used is a modified bulk-pedigree using two generations per year. The winter nursery utilizes tunnel houses to protect from frost. The paper will discuss how the project is evolving as we move forward based on observations generated in the field.

Abstract No. Oral: 12

COTTON LEAF CURL VIRUS DISEASE IN INDIA - INTEGRATED MANAGEMENT STRATEGIES AND THE WAY AHEAD

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Cotton leaf curl disease (CLCuD) is caused by a complex of whitefly (*Bemisia tabaci*) transmitted Begomoviruses having monopartite genome with circular ssDNA associated with satellite (beta and alpha satellite) DNA molecules. The initiation of disease is characterized by small vein thickening (SVT) type symptoms on young upper leaves of plants followed by upward/downward leaf curling and leaf / vein thickening. Severely infected plants later develop leafy enations on the underside of leaf and become stunted leading to severe yield reduction. Planting of 150 Bt cotton hybrids in north India at five locations at normal and late sowing conditions during 2014 season revealed much higher percent disease intensity (PDI) when the hybrids were sown late. This led to a recommendation of sowing of cotton before 15th of May in around 15 lakh hectares area where the disease is presently prevalent. A uniform system of screening and evaluation of hybrids against CLCuD at five locations was developed. Based on screening trials results, the seeds of susceptible hybrids were stopped for sale in the market. Other disease management strategy included weed eradication program taken up by State Departments of Agriculture on a war footing prior to cotton season to reduce the initial inoculum as large number of weeds were identified as Cotton leaf curl virus (CLCuV) hosts through PCR in earlier studies. Studies carried out through ICAR-All India Coordinated Research Project on Cotton for developing whitefly management module at five locations in north India showed maximum reduction in whitefly (51.4%) and CLCuD (23.5%) as well as yield improvement (28.8%) in module where Nimbicidine followed by *Verticillium lacanii*, *Metarhizium anisopliae*, Difenthiuron, Horticulture mineral oil, Triazophos and Spiromecifen were sprayed at biweekly interval starting from 35 days after sowing (DAS). In another experiment on innovative interventions for the management of CLCuD, PDI was lowest in cow urine

treatment followed by kresoxim methyl, neem oil, calcium nitrate and buttermilk after five interventions at fortnightly interval staring from 30 DAS. Additionally, efficient strains of entomopathogens for effective whitefly management have been shortlisted. In India, from among 5000 *G. hirsutum* lines during 2013-14 and 2128 lines during 2014-15 screened against CLCuD, none of the line was found to be resistant/ immune. However, lines identified as tolerant to disease are being used in pyramiding resistance against this disease. Recently two *G hirsutum* lines GVS8 & GVS9 received from USA have shown immune reaction towards CLCuD and are being used for transfer of resistant sources. Introgression of CLCuD resistance from *G. arboreum* is also being attempted.

Abstract No. Oral: 13

INTER-SPECIFIC HYBRIDIZATION FOR COTTON LEAF CURL DISEASE RESISTANCE IN UPLAND COTTON

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Cotton leaf curl disease (CLCuD) is a serious threat to American cotton in the North Western Indian cotton growing states as well as Pakistan and China. The disease causes heavy losses in seed cotton yield, especially if it appears at early stages of crop growth. Genetic resistance is the most viable solution to fight this menace. Currently, sources of CLCuD resistance in Upland cotton are rare as most of the accessions have become susceptible due to the continuous appearance of recombinant virus strains. Recently, we have identified new sources of CLCuD resistance namely *G. armourianum* (DD), a related non-progenitor diploid wild cotton species and a synthetic amphiploid (AD). The respective F_1 hybrids between these donors and Upland cotton were found to be free from CLCuD. Backcross derivatives from these crosses have been developed and resistance to CLCuD is being transferred and mapped employing cotton specific molecular markers in Upland cotton.

Abstract No. Oral: 14

EVALUATION OF ADVANCE GENERATION POPULATION OF G. *hirsutum* COTTON FOR HIGH GOT AND HIGH YIELD UNDER NORTH ZONE IRRIGATED CONDITIONS

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Nineteen F_5 populations selected from two crosses involving North Zone *G. hirsutum* varieties RS-875 and F-1861 with South American germplasm lines SA-524 and SA-668 were evaluated in randomized block design in three replications in the *Kharif* season of 2016-17. The objective was to develop high yielding (>2000 kg/hectare) and high GOT% (>35) varieties for North Zone of India. Three F_5 populations *viz.*; RS-875xSA-524(P-12), F-1861xSA-668(P-15) and RS-875xSA-524 (P-4) gave seed cotton yield more than 2000 kg/hectare and were at par in seed cotton yield with both the local Checks *viz*; H-1226 (1717 kg/hectare ± 392.2) and F-1861 (1951kg/hectare ± 392.2). The three F_5 populations *viz.*; RS-875xSA-524(P-12), F-1861xSA-668(P-15) and RS-875xSA-524 (P-4) possessed GOT% 40.6, 38.5 and 39.0 and lint yield 935.6, 848.0 and 772 kg per hectare, respectively which was significantly higher than the local checks *viz.*; H-1226 (GOT%=34.5 ± 1.0 and lint yield 592kg/hectare ± 80.1) and F-1861 (GOT%=34± 1.0 and lint yield 663.3 kg/hectare ± 80.1). The PDI (Percent Disease Index) for Cotton leaf curl disease CLCuD was 23.89, 22.22 and 21.11 for these populations, respectively which was equivalent to the highest yielder local check F-1861 (22.22). The Jassid grade injury recorded was one in these high GOT% populations.

Abstract No. Oral: 15

ADDITIVE MAIN EFFECTS AND MULTIPLICATIVE INTERACTION ANALYSIS IN UPLAND COTTON

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Twenty genotypes of upland cotton (*Gossypium hirsutum* L.) were evaluated in three cotton research centers of Cotton Development Board located at Jagadishpur, Jessore; Mahigonj, Rangpur and Sadarpur, Dinajpur to assess the genetic variability, character association and genotype **x** environment interaction effect on cotton yield contributing characters, insect infestation and seed cotton yield. High heritability (88.48%) along with the highest genetic advance (25.74) was estimated for bolls per plant and the boll weight (g) showed the high heritability (92.74%) and the highest genetic advance as percentage of mean. The insect infested bolls/plant had low heritability coupled with low genetic advance. Plant height, days to 1st flowering, bolls/plant and boll weight were strongly associated with seed cotton yield, whereas secondary fruiting branches/plant, unburst bolls per plant and insect infested bolls per plant exhibited negative and significant relationship with seed cotton yield. The highest positive direct effect (0.635) was exerted by boll weight, while secondary

fruiting branches per plant, days to 1st boll splitting, un-burst bolls per plant and infested bolls per plant showed negative direct effects on seed cotton yield. The estimated (132.35) highest EI (environmental index) suggested that Jagadishpur, Jessore was most suitable to cultivate upland cotton. Significant genotype x environment interaction was found for all the studied characters. The highest seed cotton yield (3500 kg ha^{-1}) was recorded from JA-08/D1 followed by JA-08/E (3100 kg ha^{-1}). Infested bolls per plant ranged from 0.0-15.6 and no boll was infested in JA-08/D1, followed by JA-08/E (IB/P=3.4) and JA-08/B (IB/P=5.7); hence, these genotypes apparently showed insect resistance. The estimated phenotypic indices (PI) revealed that eight genotypes viz. JA-08/D1, JA-08/E, CB-11, JA-08/B, JA-08/C, JA-08/9, JA-08/A and BC-0406 could be used in future breeding program to evolve insect resistance and high seed cotton yielding varieties.

Abstract No. Oral: 16

COMBINING ABILITY ANALYSIS FOR SEED COTTON YIELD AND ITS COMPONENT TRAITS IN COTTON (*Gossypium hirsutum* L.)

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The present study is aimed to estimate general combining ability of the parents and specific combining ability of hybrids for seed cotton yield and component traits. Combining ability analysis for seven characters was studied using diallel mating design involving nine genotypes of cotton (Gossypium hirsutum L.). Combining ability analysis revealed that non-additive gene action was important in the inheritance of various traits. Among the parents, GN.Cot-22, GJHV-337 and EC-10786 were observed as the best general combiner for most of the characters under study. Six best combinations viz.,GJHV-337 x GN.Cot-22, GJHV-337 x EC-10786, GN.Cot-22 x KH-119, GN.Cot-22 x EC-10786, DELTA-15 x EC-10786 and GSHV-97/13 x GJHV-337 had high per se performance coupled with significant high specific combining ability can be exploited for hybrid vigour or to be utilized for the future cotton improvement programme.

Abstract No. Oral: 17

GENETIC VARIATION FOR HARVEST INDEX IN UPLAND COTTON (*G. hirsutum* L.)

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Harvest index describes the plant's capacity to allocate biomass (assimilates) to reproductive parts. In cotton (*Gossypium* spp.), it is the ratio of harvested product (lint and seed) to the above ground plant dry weight or biomass (stem, leaves and fruits). The improvement of the harvest index is of critical importance in cotton breeding programme under rainfed conditions. In this direction, efforts were made at ICAR – CICR, Nagpur, India for developing breeding lines of upland cotton with improved plant type and better fibre properties. During the year 2016-17, an experiment was conducted using 14 advanced breeding lines along with four released varieties for evaluation of yield components and fibre properties under rainfed conditions. The

biomass (stems, leaves and fruits) was collected at the time of harvesting at 150 days after sowing. Lint samples were prepared from each advanced breeding lines and released varieties for testing fibre properties using HVI. Amongst the breeding lines, CNH 09-9 and CNH 09-77 recorded highest harvest index (HI) of 0.6 compared to CNH 09-78 and CNH 712-13 which recorded harvest index of 0.2 and 0.3, respectively. Breeding lines CNH 10-6-1, CNH 12-12-4 and CNH 12-4-2 recorded harvest index of 0.3 which had greater plant height (> 100 cm), while the released varieties LRK 516 had recorded HI of 0.6 followed by NH 615, LRA 5166 and Suraj with HI of 0.5 indicating the importance of plant architecture while selecting desirable plant type for improving yield per plant under rainfed situations. The varieties LRK 516, NH 615, LRA 5166 and Suraj had recorded plant height of less than a meter. Breeding lines CNH 09-4 and CNH 09-7 recorded harvest index of 0.5. The results suggest that selection of relatively determinate and fully indeterminate parents in breeding programme generates large amount of variability for plant type suitable for rainfed situations.

Abstract No. Oral: 18

HETEROSIS AND HETEROBELTIOSIS FOR SEED COTTON YIELD, YIELD CONTRIBUTING CHARACTERS AND QUALITY PARAMETERS

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Hybridization is the conventional global best practice for high cotton yields without controversies of modern tools. In order to develop stress tolerance, three hybrids {L 604 x NA 1325 (H1), L 762 x LK 861(H2) and NA 1325 x LK 861 (H3)}were developed from four parents (L 604, L 762, LK 861 and NA1325) and evaluated for seed cotton yield and six yield contributing characters viz., final plant stand, number of bolls /plant, plant height (cm), number of monpodial branches/plant, number of sympodial branches/plant and boll weight (g). Analysis of variance indicated significant differences for all characters except number of monpodial branches/plant.

No heterosis was observed for number of monpodial branches/plant and boll weight. High heterosis (99.42%) and low heterobeltiosis (4.89%) was noted only in H3 for number of bolls per plant. Less heterosis of 2.48% and 7.12% was recorded for plant height in H1 and H2, respectively. All the three crosses (H1, H2 and H3) exhibited only heterosis *i.e.* 5.39%, 32.86% and 17%, respectively, for number of sympodial branches/plant. The three hybrids studied (H1, H2 and H3) got hybrid vigour {both heterosis (47.6%, 49.8% and 57.6%) and heterobeltiosis (39.7%, 4.6% and 1.1%)}for seed cotton yield, respectively.

Quality parameters such as 2.5% span length (mm), uniformity ratio, micronaire (10^{-6} g/inch) and bundle strength (g/tex) were estimated in Central Institute for Research on Cotton Technology, Guntur. No heterosis was observed for uniformity ratio. Less heterosis of 2.23% and 6.11% was recorded for 2.5% span length in H2 and H3, respectively. All the three crosses (H1, H2 and H3) exhibited relatively more heterosis i.e. 2.06%, 2.35% and 16.18%, respectively, for micronaire. The three hybrids studied also got hybrid vigour for bundle strength (2.13%, 10.23% and 8.17%, respectively).

The results of the study indicate the possibility of producing quality cotton fibre with good production potential.

Abstract No. Oral: 19

G X E INTERACTIONS AND STABILITY ANALYSIS IN TETRAPLOID COTTON (*G. hirsutum* and *G. barbadense*)

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Cotton, the king of fibre, is one of the important cash crops having profound influence on economics and social status of the country. In India, cotton is grown under diverse agro-climatic conditions. For the systematic and successful breeding programme, the knowledge of G x E interactions and stability parameters is of immense value and provides useful guidance in the selections of stable and high yielding genotypes and hybrids. The experiment was therefore planned and executed to examine the G x E interactions and stability of parents and resultant hybrids using Eberhart and Russell (1966) model. A set of 38 entries including six parents of which three belong to *G. hirsutum* species and remaining three to *G. barbadense* species. Thirty crosses and two check hybrids were grown at the three cotton research stations *viz*., Surat, Hansot and Achhalia during *kharif* 2011-12. The hybrids were developed adopting complete diallel mating design. The characters studied were plant height (cm), sympodia per plant, bolls per plant, boll weight (g), seed cotton yield per plant (g), ginning outturn (%), 2.5% span length (mm), fibre strength (g/tex) and fibre fineness (mv).

Pooled analysis of variance revealed significant differences for mean squares among the genotypes and environments for all the characters studied and indicated the variable nature of various entries and locations involved in the study. The G x E interaction was significant for all the characters except boll weight, 2.5% span length, fibre strength, fibre uniformity ratio and fibre maturity coefficient which indicated that different genotypes reacted differently to different environmental conditions. Mean squares due to environment (linear) were significant for all the characters which indicated linearity of environments. The parents *G cot* 20 and *G cot* 16 for seed cotton yield and its attributes and Suvin for 2.5% span length and fibre strength were found average stable over environments. The hybrids *G cot* 20 x *G cot* 16, *G cot* 20 x BC-68-2, BC-68-2 x *G cot* 20, BC-68-2 x *G cot* 16 and *G cot* 20 x GSB-39 were found average stable over environments for seed cotton yield with one or more yield contributing and fiber quality characters.

Abstract No. Oral: 20

WATERLOGGING TOLERANT *Gossypium hirsutum* GERMPLASM ACCESSIONS

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Waterlogging is one of the major constraints to cotton production in developing countries such as India, Pakistan and China and it can result in yield reductions of up to 10% - 40% in severe cases. The effect of waterlogging is exacerbated when cotton is grown in heavy clay soil (Vertisol) with low infiltration rates and in low gradient fields. Cotton in India is grown in different agro-climatic conditions and experiences waterlogging in regions that experience spells of incessant rains. There is a strong likelihood of occurrence of waterlogged conditions in *Kharif* season at one or other stages of its life cycle. It has been classified as a susceptible crop for waterlogging. However, the occurrence and extent of any particular response depends on many interrelated factors such as the species or the cultivar, its age and stage of development, duration, depth and time of flooding, soil type etc. The physiological consequences of waterlogged conditions include altered shoot and root hormonal status and nutrient uptake. Waterlogging also decreases stomatal conductance, leaf water potential and photosynthesis. Waterlogging can accelerate cotton leaf and root senescence, increase the number of aborted flowers, squares and bolls and thereby reduce crop yield. Furthermore, waterlogging can alter the availability of nutrients in the soil environment. However, there have been no reports on the genetic variation in plant nutrient status under waterlogged conditions in cotton. Many plant species that can tolerate waterlogged conditions contain naturally occurring aerenchyma or develop lysigenous aerenchyma upon waterlogging.

At the Central Institute for Cotton Research (ICAR-CICR), Nagpur, India, seven thousand (7000) *G. hirsutum* germplasm accessions were screened against waterlogging in field conditions and we identified 150 tolerant and susceptible accessions. These were also screened at ICAR-CICR Regional Station, Coimbatore. Based on general morphological characters/reflecting growth, soil plant analysis device (SPAD) values, timing of formation of lenticels, adventitious roots, iron deficiency, Nitrate Reductase Activity and yield and yield components, identified tolerant and susceptible accessions were confirmed. Waterlogged cotton plants at the zone of submergence produced specialized cells called as 'lenticels' and adventitious roots. Lenticels were formed few centimeters above and at the zone of submergence within days of waterlogging while adventitious roots were formed from the submerged roots above soil level. The identified tolerant and susceptible lines are being further used to develop breeding populations. Based on information about submergence gene tolerance in rice, three primer sets were designed targeting submergence gene and ethylene-responsive element binding gene to identify the submergence tolerance in cotton. Tolerant and Susceptible genotypes under study showed amplification for the designed primers.

Abstract No. Oral: 21

ROOT SYSTEM ARCHITECTURE (RSA) UNDER ABIOTIC STRESS: IMPLICATIONS FOR ADAPTIVE RESPONSES IN COTTON

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Root architecture is composed of a collection of root phenes which determine the temporal and spatial distribution of roots in the heterogeneous soil matrix and the ability of the plant roots to obtain mobile and immobile resources. Cotton, being a major cash crop grown under rainfed condition in India, faces unfavorable conditions in the field due to vagaries of climate change *viz.*, drought stress, waterlogging, salinity and heat stress affecting the growth and productivity. Cotton plant has a taproot that grows quickly and under unrestrictive conditions reaches to a depth of 20-25cm even before seedling emergence. The depth of root system usually reaches about 200-250 cm depending upon soil moisture, aeration, temperature and genetic potential of variety. Existing evidences indicates that deep rooting as in case of *G.arboreum* is important to withstand dry spell and intermittent and terminal drought conditions in rainfed cotton cultivation. However, different abiotic stresses occur sequentially or simultaneously during the lifespan of *G. hirsutum* cotton plants grown under field conditions that have a significant impact on plant growth and yield. Cotton is grown in India on soils of varying depths and it has been observed that productivity is better on deep Vertisol compared to shallow soils because these soils have a better water holding capacity. The characterization of genetic diversity for root traits related to abiotic stresses such as drought, salinity, and waterlogging is very limited due to the challenges of excavating root systems for phenotyping. Therefore, existence of variability among available cotton germplasm/cultivar in response to multiple environmental stresses indicates the possibility of selecting best genotype having the ability to counteract future changing climate.

To facilitate better water uptake, traits like osmotic adjustment of roots offers potential for manipulation in the breeding of drought resistant plants. In cotton, morphological adaptive response to excess water has been seen as formation of adventitious root and hypertrophied lenticels. Shallow versus deep roots are some of the differential strategies of plants to adapt to their environments. Root length density (RLD) sets the proportion of water uptake both under wet and dry soils conditions. Thus, root responds to the altered root architecture that may counter a change in soil properties by decreasing the development of lateral roots. Cotton plant develops its own adaptive mechanism to sustain in adverse soil conditions and this gives an opportunity for manipulating the growth and development of the root system and formation of strategies for enhancing root growth in cotton. With the help of modern new screening techniques to understand cotton root system, studies on adaptive root architecture can be incorporated into cotton research programs by taking advantage of genetic variability. These advances coupled with the new concepts can be helpful for understanding an improved and more efficient cotton root capture system that is required in cultivars which may cut costs on inputs (fertilizers) and substantially increase the yields.

Abstract No. Oral: 22

BIOCHEMICAL APPRAISAL OF COTTON GENOTYPES UNDER RAINFED AND IRRIGATED CONDITION

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A study for screening of 20 hirsutum cotton genotypes using biochemical parameters was carried out at Main Cotton Research station, NAU, Surat in field under both rainfed and irrigated conditions. Biochemical parameters such as reducing sugar, free amino acid, proline and total phenol were analyzed from the leaf samples of cotton genotypes. The results showed that reducing sugar content significantly increased under stress in almost all the genotypes but in NDLH-1738, LRA-5166 and G.Cot-16, the increase ratio was less. Free amino acid was significant due to treatments as well as genotypes. Increase in proline content was significant due to treatments. The interaction between treatment and genotypes for proline was also significant. Total phenol in leaf was higher under rainfed condition compared to irrigated condition and was significant due to treatments. Genotypes GSHV-177, AKH-095, RAH-806, LRA-5166 and G.Cot-16 had showed lower drought susceptibility. Correlation of yield with different biochemical parameter indicated a significant relationship between yield and proline under irrigated and rainfed condition. The yield under stress exhibited positive significant correlation with proline, implying that higher proline content may regulate osmotic pressure in stress.

Abstract No. Oral: 23

EFFECT OF COTTON SEED OILCAKE ON COTTON YIELD AND YIELD CONTRIBUTING CHARACTERS

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An experiment was conducted at Cotton Research Center Sreepur Gazipur, during 2016 - 2017 to determine the effect of cotton seed oil cake on cotton yield and yield contributing characters. The experiment comprised of seven treatments viz. T_0 = Absolute control, T_1 = 100 % Recommended dose of chemical fertilizer ($N_{150}P_{60}K_{175}S_{30}$), T_2 = 80% RDCF ($N_{120}P_{48}K_{140}S_{24}$), T_3 = 60% RDCF ($N_{90}P_{36}K_{105}S_{18}$), T_4 = 100 % RDCF + cotton seed oil cake @ 1 t ha^{-1}, T_5 = 80% RDCF + cotton seed oil cake @ 2 t ha^{-1}, T_6 = 60% RDCF + cotton seed oil cake @ 4 t ha^{-1} and T_7 = Cotton seed oil cake @ 5 t ha^{-1} following Randomized Complete Block Design with three replications. The results showed that application of cotton seed oil cake significantly increased seed cotton yield and yield contributing characters. The highest seed cotton yield (3665 kg ha^{-1}) was obtained from treatment T_5 i.e. 80% RDCF + cotton seed oil cake @ 2 t ha^{-1}. However, the highest benefit to cost ratio (BCR) was found from treatment T_4 i.e. 100 % RDCF + cotton seed oil cake @ 1 t ha^{-1}. From our experiment, it is concluded that soil amendment with cotton seed oil cake@ 1t/ha had a beneficial effect in cotton production and can be applied for increasing cotton yield.

Abstract No. Oral: 24

TEN YEAR *KHARIF RAINFALL* PATTERN AND COTTON YIELD OF GUJARAT AND MAHARASHTRA

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Among the cotton growing states, Gujarat and Maharashtra shares 23 and 34% of cultivable area, respectively in India. To understand the water productivity in cotton, we studied the rainfall and yield over the last ten *kharif* seasons (2008-2016).) The mean monthly rainfall received was 217 and 233 mm (July to September), which is higher and peaked over crop water demand (114 -138 mm) of that specified period at semi-arid climate. Rainwater availability is higher than climatic water demand (ET_o). Heavy rains cause flooding, ponding, water logging, soil crusting and also reduces yield invariably in heavy deep black soils. Hence, surplus quantity needs to be drained and conserved effectively. On the other hand, prolonged dry spell more than 10 to 15 days adversely affect the crop growth due to faster depletion of available soil moisture in shallow soils after recession of rainfall. Rainfall is lower than ET_o during the months of October and November. Moisture stress results to square drop, decreases boll size, lowers yield and impairs fibre quality. Soil moisture storage capacity varied from 100 to 250 mm in soils with different soil depths (45- 100cm) and water requirement for full crop growing period ranged from 500 to 600 mm. The net irrigated area is increased to 57% in Gujarat, but in Maharashtra still 97% of the area remains as rainfed. In the study period, the yield has improved two times in Gujarat (684 kg ha^{-1}) as compared to Maharashtra (340 kg ha^{-1}). In Gujarat, massive investments were made to augment storage resources and structures. As a result, unlike Maharashtra where only 50% of the excess rainfall is reused, in Gujarat, 75% of the stored rainwater is used for supplemental irrigation. To achieve potential yield, the water requirement at the critical stage of boll development should be fulfilled or managed for consumptive use. Adequate *in situ* soil water conservation practices may be carried out up to 100-120 days under rainfed areas.

Abstract No. Oral: 25

COTTON SEEDLING NURSERY AS AN ALTERNATIVE METHOD FOR COTTON SOWING IN VIEW OF THE CHANGING CLIMATE SCENARIO

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Cotton is an important cash crop through which country earns revenue by way of *seed cotton*, Lint, Seed cake, Oil etc. In earlier years straight varieties/hybrids were used for raising the cotton crop. But after the introduction of Bt. cotton hybrids in 2002, the seed cost increased tremendously. Farmer had to shell out Rs. 930/-(or even more) for 450gm Bt hybrid packet and 4 packets are needed for one hectare which costs about Rs. 3720/- per hectare. When the season will be normal, farmers will harvest bumper crop but in case of climate vagaries then the farmers had to re- sow the crop which is again a costly affair. To tackle this issue an

experiment was laid out at ICAR-CICR to raise the cotton seedlings and transplant them at an appropriate time i.e when normal rains are received so that the cost on Bt hybrid cotton seed is saved.

In this experiment cotton seedlings were raised in nursery with different combinations of matrix/media and different sizes of the seedling trays (Small-104, Medium-.98 & Big-42 holes per tray). Eleven(11) different media were used viz., Soil, Sand, FYM, Vermicompost, Soilrite Mix TC, Soilrite Mix, Soilrite Mix-C, Vermiculite, Kelpeat, Kelpeat Plus and Kelbrick. They were used as sole media as well as in different combinations with other media/matrix. Thus 42 different combinations were made. Bt cotton seed was sown containing the mixtures in different sizes of plastic trays. Observations were taken for the parameters like Germination percentage, Root, Shoot, Dry weight of the seedlings at 20, 30 and 40 days after sowing. Results indicated that most of these parameters show better growth in FYM (sole) followed by Kelbrick (sole) media and also in combination of soil, sand, FYM and Vermicompost in 1:1:1:1 ratio. Better growth was observed in Big tray having 42 holes compared to medium and small trays, which may be because of the volume of the media it holds in a hole which helps in development of the seedling. Dry weight of five seedlings ranged between 2-18 gms. Weight of seedling was highest in 40day old seedling due to age of the seedling. Shoot and Root growth was better in FYM media (11.9mm & 10.2mm) followed by Kelbrick media(10.3mm & 8.6mm) in 20 days old seedling.

When transplanted, the rate of survival of the cotton seedlings was 99-100%, if it is transplanted after sufficient rain is received. Among the 11 matrix/ media, the cheapest media was Kelbrick costing about Rs.0.35, 0.38 and 0.50 small, medium and big tray respectively. By this study it is concluded that raising cotton seedlings in Kelbrick media and transplanting them at appropriate time will save Bt cotton seed cost for farmers.

Abstract No. Oral: 26

IDENTIFICATION OF MOST VIRULENT STRAINS OF ENTOMOPATHOGENIC FUNGI FOR MICROBIAL CONTROL OF SWEETPOTATO WHITEFLY (*Bemisia tabaci*) INFESTING COTTON IN NORTH INDIA

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Cotton Leaf Curl Virus Disease (CLCuD) and the sweetpotato whitefly, *Bemisia tabaci* (Gennadius), a vector of CLCuD are the most devastating problems that inflict huge economic losses to cotton yield and quality in northern India. At present, there is no source of absolute resistance against CLCuD and its vector *B. tabaci* in cotton cultivars. Thirty five chemical insecticides including six mixtures have been registered for whitefly management in India but it has acquired resistance to many of these insecticides. Alternate techniques including bio-control strategies are needed to manage whiteflies. Thus, to identify most virulent entomopathogenic strains, a total of 373 entomopathogenic isolates from Microbial Type Culture Collection (MTCC) and *National Agriculturally Important Microbial Culture Collection* (NAIMCC) were collected. Bioassay protocol for evaluating large scale entomopathogenic fungi under polyhouse conditions was standardized. Bioassay experiments were conducted against whitefly nymphs. To generate infested leaves for bioassay, pest free potted cotton plants (30 days old with 4-5 fully expanded leaves) were placed near the whitefly adult-infested plants in polyhouse for 12 h. This method provided more than 50 eggs per leaf. The adults of whiteflies were removed and the freshly infested plants were moved to another screenhouse for 10-12 days (until nymphs reached II instar). The nymph-infested leaves were spray inoculated with freshly prepared test fungal suspension @ 10^7 spore /ml. The observations on percent nymphal mortality was recorded at 3, 5 and 7 days after inoculation using Abbotts corrected formula. The comparative study was done to evaluate the top ten best selected entomopathogenic fungi and chemical pesticides recommended for whitefly management. During the study period, maximum-minimum temperature and relative humidity (%) ranged between 28-21°C and 65-45, respectively. The highest nymphal mortality was recorded by MTCC-6096 culture (*Beauveria bassiana*) (75.5%), followed by a nymphal insecticide inhibitor of lipid synthesis spiromecifen (69.6%), MTCC-4565 (*B. bassiana*) (67.8%) and MTCC-4511 (*B. bassiana*) (64.4%). The results are discussed in the context of sustainable insect pest and disease management.

Abstract No. Oral: 27

TWO CYTOCHROME P450 GENES ARE INVOLVED IN IMIDACLOPRID AND ACETAMIPRIDE RESISTANCE IN DIFFERENT POPULATIONS OF THE WHITEFLY (*Bemisia tabaci*) IN IRAN

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The cotton whitefly, *Bemisia tabaci* (Gennadius) is a serious pest that causes damage to cultivated crops throughout the world, and has been shown to be capable of developing resistance to many classes of insecticides. The neonicotinoids insecticides imidacloprid and acetamipride have been widely used to control this pest across the world. We assessed the association between imidacloprid and acetamipride resistance and the expression of five P450 genes for nine *B. tabaci* populations from nine regions of Iran (Rafsanjan, Pakdasht, Bandare-e-abbas, Karaj, Gorgan, Shahryar, Kashmar, Mashhad and Jiroft). qRT- PCR was used to compare the expression of five CYP450 genes in nine *B. tabaci* populations, resistance level was positively correlated with the expression of CYP6CM1 and CYP6CX1. Also comparison of CYP6CM1 and CYP6CX1 sequences in *B. tabaci* populations showed no difference. This study shows that resistance to imidacloprid and acetamipride in populations of *B. tabaci* may be associated with the increased expression of two cytochrome P450 genes (*CYP6CM1* and CYP6CX1).

Abstract No. Oral: 28

WHITEFLY EPIDEMICS ON COTTON IN NORTH INDIA: LESSONS LEARNT AND WAY FORWARD

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Whitefly, *Bemisia tabaci* infestation occurred in an epidemic form on cotton in north India during *Kharif* 2015-16. There have been similar outbreaks on cotton in the mid 1980s and 1990s in north India, Andhra Pradesh and Maharashtra. Amongst various factors, a combination of high relative humidity of >75% plus high temperature above 30°C, late sowing, broad spectrum insecticides, high nitrogen and susceptible varieties were considered to be the most important factors that caused outbreaks not only in India but elsewhere in the world. Whiteflies are known to damage about 600 plant species by feeding mainly on leaves, causing stickiness and sooty-mould due to honeydew excretion and transmission of a range of viruses including the family Geminiviridae. Availability of a continuous spectrum of host plants all through year was also found to facilitate survival and carry-over of the pest into subsequent seasons, thereby leading to outbreaks. Management strategies can be designed to be environmentally sustainable by integrating eco-friendly control measures along with strategies that minimize the detrimental effects of the resurgence causing factors.

Scientific evidence shows that insecticides are not particularly the method of choice for sustainable whitefly management due to several reasons. The waxy coating on the insect body renders insecticides less effective. The insect feeds on the underside of leaves and is not easily exposed to insecticide coverage. Whiteflies have high propensity to develop insecticide resistance compared to their entomophagous insects. Parthenogenesis gives the insects tremendous advantage in rapid multiplication compared to populations of their natural enemies. Whiteflies have been recorded to show hormesis and hormoligosis to several insecticides. The above features clearly emphasize the need to exercise immense care in the choice of insecticides that can control whiteflies effectively but do not cause pest resurgence or severe disruption of naturally occurring biological control.

Our field experiments showed that whitefly incidence was significantly higher in late sown crop as compared to timely sown cotton. Our resistance monitoring studies conducted during 2015-16 and 2016-17 showed that whiteflies in north India had developed high levels of resistance to most of the chemicals belonging to the list of 37 label-claim insecticides. We observed that insecticide use pattern influenced insect resistance to insecticides and resurgence. While indiscriminate use of acephate, monocrotophos, fipronil and insecticide mixtures, was found to cause resistance and resurgence, high dose of nitrogen favoured pest survival and resurgence. A few chemicals clearly caused hormesis and hormoligosis, thereby resulting in whitefly resurgence. Insecticide-influenced disruption of naturally occurring biological control (mainly comprising of parasitoids, lacewing bugs, pirate bugs and ladybird beetles) further accentuated outbreaks. Our observations indicated that whitefly outbreaks occurred more often when natural enemy populations are disrupted because of repeated insecticidal sprays during the earlier part of the season.

We developed sustainable IPM strategies with specific focus on whitefly management and disseminated them across north India for effective implementation during 2016-17. The main strategies were based on the following four aspects: 1.Timely sowing. 2. Tolerant varieties/hybrids. 3. Balanced NPK and 4. Application of IPM-compatible insecticides, preferably botanicals and insect growth regulating insecticides. Implementation of these strategies resulted in effective pest management as evidenced by low whitefly infestation during 2016-17 especially in cotton fields under IPM influence. Use of botanical neem products during the initial seasonal window coupled with cultural practices of clean cotton cultivation and balanced fertilizer application ensured optimum population of natural enemies, thereby causing significant reduction in incidence of whitefly and minimized pesticides usage. We emphasize that proactive and preemptive strategies are essential to prevent further recurrences of whitefly outbreaks in north India

Abstract No. Oral: 29

STATUS OF INSECTICIDE RESISTANCE IN *Bemisia tabaci* TO COMMONLY USED INSECTICIDES IN COTTON FROM PUNJAB

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Whitefly has emerged as a major cotton pest of the decade causing huge losses in production. The pest outbreak in north India in 2015 was the sole factor for decline in area by approximately 50 per cent in 2016. The pest incidence resulted in approximately 60-75 % losses across the state. The whitefly population remained above ETL from July to September. The average population at 20 and 15 locations surveyed in July and August was 188.8 and 185.5 whiteflies per leaf, respectively at the farmers' field. There was a complete failure of the insecticides to manage the pest as the pest may have developed resistance to major insecticides used in cotton. Keeping in view of the economic importance of the problem, the insecticide resistance studies were conducted across major cotton growing locations in Punjab such as Faridkot, Bathinda and Abohar with different groups of commonly used insecticides.

The studies indicated high level of resistance of white flies to some commonly used insecticides such as imidacloprid, acetamiprid, thiamethoxam and triazophos. We observed a large variation in susceptibility level in commonly and repeatedly used insecticides in the start of cotton season compared to middle or end of the season. The insecticide resistance has been correlated with the expression profile of the major genes involved in detoxification mechanisms such as Cytochrome P450, GSTs (Glutathione S-transferases). The resistance populations show the over expression of these genes compared to the susceptible ones. The study brings about the insecticide susceptibility profile of commonly used insecticides in cotton against whitefly and this will be helpful to determine and recommend efficient chemistries for management of cotton whitefly.

Abstract No. Oral: 30

GLOBAL BEST PRACTICE FOR HIGHER COTTON PRODUCTIVITY-CAN INDIA ADOPT AND IMPROVE?

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Historically, India has been the major cotton producing country in the world. The data from 1960-61 shows that cotton productivity in the country was lowest among leading cotton growing countries and world average. Many reasons have been attributed to low productivity in the country including natural and socio-economic conditions. There are better production practices developed and successfully adopted in many countries. Australia, China and Brazil are the front runners to develop innovative technologies for higher cotton productivity in the world.

In China, a high-yielding cultivation pattern called "short-dense-early" has been widely adopted in about 35% of total cotton planting area. This pattern is achieved through increasing plant density, reducing plant height and inducing early maturity with the help of drip irrigation under plastic mulching. Plastic mulching in China was initiated for cotton in 1979. Currently, about 70% of total cotton fields, particularly plastic film mulching with drip irrigation and seedling transplanting are adopted to promote early maturity and increased lint yield.

Agricultural liming in acidic soil of Brazil by adding industrial lime is being practiced since 1990s to reduce soil acidity levels. Brazilian farmers pioneered in no-till agriculture to retain more nutrients in the soil. Location specific cotton breeding programme exclusively for semi-humid tropical conditions made it possible to obtain much higher productivity (four fold increase between 1995 and 2007).

myBMP is the Australian cotton industry's voluntary cotton farm and environmental management system for growers to improve cotton production and productivity. A system allows the cotton growers to access the latest research and farm management information, including bio-security, energy and input efficiency, fibre quality, human resources and work health and safety, integrated pest management (IPM), pesticide management, soil health, water management modules.

With clear vision and ample support of all the stakeholders, the cotton productivity can be increased. The above mentioned practices with appropriate modification could be adopted under Indian conditions.

Abstract No. Oral: 31

IS MSP RELEVANT FOR COTTON FARMERS IN INDIA

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In each season, the Government of India announces the Minimum Support Price (MSP) for cotton and organizes purchase operations through CCI (Cotton Corporation of India) to ensure that prices do not fall

below that level. In recent years, the MSP policy has been criticized by both farmers and proponents of free trade. Farmers always demand a MSP higher than the cost of production, whereas pro free agricultural trade thinkers feel that, most of the times, MSP is not in line with the international prices as well as domestic demand and supply situation. This brings deviation in the incomes of the farmers. The present study examines the cotton MSP and production cost over last 15 years.

If we examine the MSP and weighted average cost of production (Cost C2) at the country level, it is evident that more than half of the years (8 years in 15 years), MSP is less than Cost C2. During last five years, MSP is less than Cost C2 during four years. If the cotton was sold at MSP, farmers would have incurred loss during these four years. Break even yield (i.e., the yield required to be produced to meet the cost of production at MSP) was calculated by dividing the cost of cultivation (per ha) by MSP. Comparison of actual yield with break even yield, indicated that in many of the years (8), the actual yield is below the break even yield.

Cost of production varies widely from state to state and situation to situation. Analysis of variance revealed that these differences are significant. The examination of the average cost of production per quintal during last five years (2010-11 to 2014-15) indicated that the cost of production varied from Rs. 2989 per q in Rajasthan to Rs. 4134 per q in Tamil Nadu. During the same period the average MSP was Rs. 3650 per q. The cost of production in the states of Rajasthan, Madhya Pradesh, Gujarat and Karnataka during this period is less than the MSP. The cost of production in the states of Punjab, Haryana, Andhra Pradesh, Maharashtra and Tamil Nadu is higher than the MSP. Hence, the farmers of these states will not benefit through MSP. Maharashtra experienced higher cost of production than MSP in 12 years, while Tamil Nadu and Madhya Pradesh experienced higher cost of production in 10 and 9 years, respectively. However, Rajasthan experienced higher cost of production only once during the 15 years period of analysis. Similarly, Gujarat and Haryana experienced higher cost of production than MSP in 4 and 5 times only.

This analysis clearly reveals that the present MSP policy is not always beneficial to all cotton farmers. Benefits of the MSP will vary from time to time and state to state depending on the cost of production and yield realized. Lower MSP combined with faulty procurement operations leads to further reduction in the benefits. Hence, MSP needs to be revised based on the cost of production at the end of the year. There is need to rethink about one MSP in all the states.

Abstract No. Oral: 32

ROLE OF ICTs IN PROMOTION OF BEST COTTON MANAGEMENT PRACTICES FOR ENHANCED PRODUCTIVITY

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With the growth and development of agricultural communication, there has been a shift from traditional methods of communication to technology mode communication or ICT enabled agricultural information. Information and Communication Technologies (ICTs) are changing all the spheres of human lives. Hence, it is a popular belief that agricultural extension is also no exception to this. It is also expected that the ICT led extension systems are going to act as a key agent for changing agrarian situation and farmers' lives by improving access to information and sharing knowledge. Hence, renewed enthusiasm to use new ICTs for agricultural advisory services led to mushrooming of e-initiative pilot projects in India. The new ICTs which

include digital devices such as computers, e-mail, internet, multimedia, video conferencing, mobile phones etc have the potential to provide vast amount of relevant information to rural population in timely, comprehensive and cost effective manner. With this background, the ICT component was included in CICR's TMC MM I Project on 'e- Kapas Network' & Technology Documentation (2012-2017), involving ICAR institutions and State Agricultural Universities which is an action research project implemented across country in more than 21 districts of eleven cotton growing states of India with focus on delivering cotton based technologies and advisory services through voice messages, Mobile Phone based Extension Model to more than 3.75 Lakhs registered 'e- Kapas' beneficiary farmers. Efforts were made to provide timely information regarding best cotton practices, agro-inputs, production technologies, agro processing, market support, agro-finance and management of farm agri-business and to cater the real need of farmers. The project has gained popularity among cotton growers as it has helped an average Indian farmer to get relevant information in local languages from time to time. Farmers living in remote areas were also receiving immediate solutions to their problems in local languages. The knowledge gained after exposure of voice messages to the cotton growing farmers was high. Thus, the potential of voice messages delivery for best cotton management is emerging as an area of increasing interest.

In this context, ICT plays a very important role in promotion of reliable, timely & cost effective cotton production technologies at doorsteps of the farmers. The present paper discusses the information and knowledge used by the rural masses in sustaining the confidence amongst farmers in cotton production technologies and enhanced productivity.

Abstract No. Oral: 33

BEST FARMER FRIENDLY TRANSFER OF TECHNOLOGY PRACTICES PROPOSED TO DOUBLE THE COTTON FARMERS' INCOME IN INDIA

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India is either first or second in the world in terms of production of many agricultural commodities and cotton is not an exception to that fact. The Research and Transfer of Technology (TOT) efforts taken by both the public and private cotton entities in India ensured the country to become the largest producer of cotton in the world. Proposing best practices for achieving the coveted position in productivity of this commodity and doubling the income of its growers is the concern of the hour. Indian cotton researchers have developed the best technologies to improve the yield and income of the crop and there is a pressing need for best TOT practices to translate the technologies for the benefit of cotton growers. As like package of technical practices in cotton, this paper proposes a novel integrated package of best TOT practices to be adopted step by step chronologically during various stages of cotton cultivation either by the change agents or by the farmers to deliver or get extension support for doubling the yield and income from cotton cultivation. The integrated package of best TOT practices includes Decision Support System for selecting a suitable variety / hybrid, Front Line Demonstration for cultivating a new variety / hybrid, soil sampling and soil health card before land preparation, a booklet with entire package of practices for ready reference during cultivation, weekly voice SMS during the entire crop season, weekly advisory through website for knowing the do's and don'ts in cotton cultivation, short duration video films to accurately understand a particular technology, using WhatsApp group for clarifying the suddenly occurring pests / diseases / disorders, mobile apps to know the strategies to

manage the pests and diseases, method demonstration to disseminate the best harvesting and post harvesting practices, market intelligence to sell the seed cotton for the best price, personal field visits by the Scientists and exposure visits by the farmers to see and believe the advantages of technologies, specialized training programs to improve the skill, radio broadcast and video telecast for spreading the success of this package to mass farmers. This integrated package will be a convergence of all customary and contemporary extension methods tailored for cultivation of cotton crop in India. The package will be field tested and refined through future research programs at ICAR – CICR and a final package of best farmer friendly transfer of technology practices to improve yield and income of the cotton growers will be developed.

Abstract No. Oral: 34

THE BETTER COTTON INITIATIVE: DEVELOPING BETTER COTTON AS A MAINSTREAM COMMODITY

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About the Better Cotton Initiative (BCI)

The Better Cotton Initiative (BCI) is the largest cotton sustainability programme in the world.

A well-established, multi-stakeholder initiative, BCI includes actors from the whole cotton value chain, from farmer groups to retailers, civil society and other relevant organisations. As the holder of a global standard for more sustainable cotton production, BCI's aim is to transform the entire cotton sector and to make global cotton production better for the people who produce it, better for the environment it grows in, and better for the sector's future, by developing Better Cotton as a sustainable, mainstream commodity.

The Better Cotton Standard System (BCSS) is a holistic approach to more sustainable cotton production which covers all three pillars of sustainability: environmental, social, and economic. The BCSS is made up of the following components, each of which work together to support the credibility of Better Cotton and BCI:

- Production Principles and Criteria
- Capacity Building
- Assurance Program
- Chain of Custody Guidelines
- Claims Framework
- Results and Impact

The Production Principles and Criteria provide a global definition of Better Cotton through six key principles:

1. Crop protection
2. Water efficiency
3. Soil health
4. Natural habitat
5. Fibre quality
6. Decent work

Mainstreaming Better Cotton

In line with its mission to make cotton a truly mainstream commodity, BCI focuses on growing its Retailer and Brand Membership base, which plays an important role in generating demand for Better Cotton, making sure the cotton that is grown in accordance to the Better Cotton Standard System is actually bought and sold as Better Cotton. In 2016, BCI's membership grew to 986 members representing 40% year-on-year growth including an attrition of 4.8%. In the same year, over 460,000 metric tonnes of Better Cotton was sourced globally (compared to about 250,000 metric tonnes in the previous year). BCI is working towards Retailer and Brand uptake of 2.4 million metric tonnes as Better Cotton.

Farm-level focus

Supporting farmers is at the heart of BCI's work and is the reason for its existence. Cotton is a renewable resource, but its production is vulnerable to poor environmental management and working conditions. As stewards of the Better Cotton Standard System, BCI focuses on providing training and development opportunities for farmers to adopt more environmentally, socially and economically sustainable production practices.

Last year, BCI and its partners provided training on more sustainable agricultural practices to 1.6 million farmers around the globe from 23 countries on five continents. As a result of this, BCI Farmers produced 2.5 million metric tonnes of Better Cotton lint, accounting for 12% of global cotton supply. BCI also mobilised €8.9 million in field-level investment last year.

By 2020, BCI aims that BCI Farmers will be producing 8 million metric tonnes of Better Cotton.

BCI in India

In the 2015-16 season, BCI reached out to over 400,000 farmers in India alone, resulting in almost 650,000 hectares under Better Cotton cultivation, and production of about 380,000 metric tonnes of Better Cotton lint. In the 2017/18 season, with the support of 24 implementing partners, BCI reached 650,000 farmers. Today, overall a team of over 1,500 is working with cotton farmers on the ground.

The 650,000 farmers that BCI works with are located in the states of Andhra Pradesh, Telangana, Karnataka, Madhya Pradesh, Maharashtra, Gujarat, Haryana, and Punjab. The implementing partners that BCI works with either have an existing network with the cotton farming community or are willing to create one so that farmers can be supported. Over the years, we have been steadily eliciting interest from the textile industry, several ginners and leading spinning/integrated mills have set up the necessary infrastructure to reach out to farmers.

The BCI team has been reaching out to the scientific community and engaging with them about the capacity-building of its implementing partners to ensure that a scientific temper is imbibed. Presently, BCI has Memorandums of Understanding with the Junagadh Agricultural University (Gujarat), as well as the Professor Jaya Shankar Telangana University (Telangana). BCI has also been working very closely with the Central Institute of Cotton Research (CICR), Nagpur, whose teams have been supporting BCI's capacity-building activities. In turn, BCI has been acting as the CICR's extension arm, always willing to take on trials of the technologies that are evolving, including High Density Planting Systems (HDPS) and, more recently, the planting of *Arboreum* varieties from Nanded, Maharashtra.

BCI's farm-level approach in India is best summarised by a quote by Dr. Keshav Kranthi (Head, Technical Information Section of the International Cotton Advisory Committee):

“While science lays the foundation for the best possible inputs for cotton cultivation, good sense is necessary to make informed decisions from the available options to minimise input costs and maximize profits”.

Abstract No. Oral: 35

APPLICATION OF NANOTECHNOLOGY IN COTTON

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Nanotechnology refers to understanding and manipulating the materials in the nano-scale regime (1 to 100 nm). Matter including gases, liquids, and solids exhibits unusual physical, chemical, and biological properties in the nano-scale, differing from the properties of bulk materials and single atoms or molecules. Some nano-structured materials are stronger or have different magnetic properties compared to other forms or sizes or the same material. Others are better at conducting heat or electricity. They may become more chemically reactive or reflect light better or change colour as their size or structure is altered. This theoretical capability of nanotechnology was envisioned as early as 1959 by the renowned physicist Richard Feynman and Eric Drexler popularized the word 'nanotechnology' in the 1980's by talking about building machines on the scale of molecules, a few nanometers wide-motors, robot arms, and even whole computers, far smaller than a cell.

Application of nanotechnology in cotton starts from the use of nano-particles in genetic engineering, nano-sensors in monitoring soil conditions, growth, and disease vectors under field conditions and nano-formulations in precision farming for optimized inputs (fertilizers, pesticides and herbicides). In post-harvest processing of cotton, nano-finishing of cotton textiles imparts novel and efficient functionalities including antimicrobial, UV protecting, flame retarding, self-cleaning, moisture management and electrical conducting properties. Use of nano-materials also reduced chemical load in processing & finishing. Use of electrospun nano-fibrils in cotton textiles make it usable for filtration and medical textiles. The novel material of the 21st century, Graphene, could be produced from cotton fibers. In biomass processing, cotton linters and comber noil could be converted to nano-cellulose that has diversified applications in paper, cement concrete, rubber composites, drug delivery system, paints, filters and electronics. Nano-materials and nano-filters play a crucial role to improve the efficacy of effluent treatment. To evaluate the unintended consequences to the human health and the environment, the life cycle assessment of nano-materials is very much essential. Also, the awareness is needed to be created among the customers for the safe handling and disposal.

Abstract No. Oral: 36

DEVELOPMENT OF FUNCTIONAL COTTON TEXTILES USING NANO-ZnO

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Cotton is the important member of the natural cellulosic fibres and is associated with human being right from the moment of birth to last breath. The recent improvement in living standards has increased the awareness about the performance of textiles, which has led to the development of functional cotton textiles. Introduction

of nano-science and nanotechnology has opened up a new frontier in the area of textile finishing i.e., nano-finishing for imparting various functional properties. Nano- finishing can replace traditional finishing agents applied to textile products, providing products of better quality and lower production costs. As a consequence, it is expected that in the coming decade, nanotechnology will penetrate deeply in the textile finishing sector, and an increasing number of textile companies will invest in the development of processes involving nanotechnology. Among the various nano-materials used on cotton textiles, nano-ZnO (nano zinc oxide) has gained distinctive importance and excel better than others in terms of its inertness, whiteness and cost effectiveness. Nano-ZnO can also be called a multifunctional material due to its unique physical and chemical properties. On cotton textiles, nano-ZnO not only acts as an antibacterial agent, but also as efficient UV-blockers. Also, nano-ZnO coatings do not affect the air permeability and other inherent properties of cotton textiles. This work discusses different methods of synthesis and application of nano-ZnO onto cotton textiles to develop durable functionality of antibacterial and UV protective properties on cotton textiles.

Abstract No. Oral: 37

APPLICATION OF NANOCELLULOSE IN PULP & PAPER AND COMPOSITES

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Nanocellulose refers to cellulosic materials with at least one dimension in the nanometer range. Cellulose fibers can be mechanically disintegrated to its basic structural nanoscale fibrils. Nanocellulose has broad applications in a variety of material-related domains where physical characteristics such as strength, weight, rheology, optical properties etc. are concerned. It has high tensile strength of 200 - 300 MPa and elastic moduli of 150 GPa that could be utilized for the enhancement of functional properties of pulp & paper and composites. At present, it is a major challenge for pulp and paper industry to get a virgin cellulosic fiber due to environmental footprint and stringent regulation of forest resources. Hence, nanocellulose, due to its crystalline nature could be a substitute to save some percentage of virgin pulp to acquire more strength properties. Majority of kraft paper is being used for packaging industry where tensile strength, burst factor, tear resistance are the essential requirements. At ICAR-CIRCOT, the micro-fibrillated cellulose extracted from cotton linters was demonstrated as a strength additive in unbleached kraft paper. The addition of 5% and 10% nano-fibrillated cellulose increased the tensile indices of hand sheets by 11% and 18%, respectively. Similarly, the burst factor which is an important parameter also increased to 11% and 14% on addition of 5% and 10% of nanofibrillated cellulose, respectively.

Nanocellulose also acts as a potential filler for application in various composite films. Nanocellulose as fillers in starch films could improve the tensile strength by more than 3 times and also significantly reduced the water vapour permeability. Nanocellulose as fillers in kappa-carrageenan improved the tensile strength by 88% and reduced the water vapour and oxygen transmission rate by more than 90%, making them suitable for packaging of food materials. The reduction in water vapour and oxygen transmission rate enhances the shelf life of packed food items. Nanocellulose needs to be surface modified in order to be compatible with commercial polymers like polypropylene, epoxy, polyethylene terephthalate, etc. Nanocellulose, being an organic filler, is preferred over other inorganic nanofillers and the raw materials for production of nanocellulose is available plenty in nature and they are renewable. Hence, from the point of view of sustainability, nanocellulose is the material of choice for application in pulp & paper and composites.

Concurrent panel 6A: Bollworms -IPM/IRM

Abstract No. Oral: 38

A BRIEF HISTORY OF HELICOVERPA AND PECTINOPHORA

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Species in the lepidopteran genera *Helicoverpa* and *Pectinphora* have bedevilled cotton production in the Old and New Worlds for many years. *Helicoverpa* as a genus was separated from other Heliothine moths in the genus *Heliothis* in the 1960s. *Helicoverpa zea* is the major pest species in the New World with a particular fondness for maize, as its name suggests. In our region, *H. armigera* is the villain. Although recorded from 63 plant species from 27 families, it is first recorded as a significant pest of cotton in the Indian sub-continent only in the mid 1970s, with serious outbreaks on cotton and other crops in the early 1980s and increasingly from 1990 onwards, when insecticide resistance became more problematic. *Gossypium hirsutum x G. barbadense* hybrids were first grown in our region from the early 1970s and the mid 1970s also saw the introduction of synthetic pyrethroids to Asia. From the late 1990s, the widespread introduction of Bt cotton and the simultaneous strong reduction in pyrethroid use in cotton has seen *H. armigera's* importance as a regional production constraint decline. Quite what role each of these factors has played in the rise and relative decline of *H.armigera* remains to be determined.

Pectinophora as a genus in the Gelichiidae dates only from 1917 when it was split from other species in the genus *Platyedra* which are widespread in Africa, Europe and Eastern Asia. The very earliest origins of pink bollworm (*P. gossypiella)* may be with con-generics in north-western Australia but if so it must have spread north, probably on native *Gossypium arboreum* through the Philippines, to India where it was first described by Saunders in 1843. From there it reached Celyon, Burma and Egypt by 1906 and swiftly spread globally. *P. gossypiella* was widespread in China by 1918 and spread from Egypt via Mexico to the southern and western USA and Brazil around 1913-16, although it was not a key pest in US cotton until the 1960s. The key factor in this spread is the fact that the larvae largely diapause in cotton seeds and are thus spread with poorly ginned cotton. The factors controlling diapause induction are complex, including high lipid levels in mature bolls, high and variable temperatures and declining day length but where survival of diapause larvae can be reduced strictly enforced closed seasons, by deep burial or burning of cotton trash and by the deployment of short season cottons harbouring limited generations, the insect is much more manageable. Pink bollworm is very susceptible to Cry1Ac Bt cottons and where good resistance management practices have been implemented, it has been exceptionally well controlled and indeed practically eradicated. However, where this has not been the case, resistance has been emerging requiring the deployment of new strategies.

Abstract No. Oral: 39

RESISTANCE MONITORING OF *Helicoverpa armigera* TO INSECTICIDES ACROSS DIFFERENT LOCATIONS OF KARNATAKA

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*Helicoverpa armigera*is a notorious insect pest of field crops and causes enormous economic losses, due to the excessive use of insecticides which contributes to multiple instances of insecticide resistance. Present study aims to investigate the toxicity of eight (Profenophos 50% EC, Emamectin benzoate 5% SG, Spinosad 45% SC, Methomyl 40% SP, Chlorpyriphos 20% EC, Thiodicarb 70% SP, Flubendiamide 39.7% SC and Chlorantraniliprole 18.5% SC) insecticides which include conventional and new insecticides, which are being used on a large scale in six (Raichur, Kalaburagi, Bidar, Dharwad, Ballari, Bengaluru and Gangavathi) regions of Karnataka. Test insects were collected from three different locations of Karnataka for three consecutive years. The data revealed that the lowest LC_{50} values among the tested insecticides was observed in chlorantraniliprole 18.5% SC; among different locations, it ranged from 0.17- 0.39 ppm (2014-15), 0.19-0.43 ppm (2015-16) and 0.70-0.94 ppm (2016-17), respectively and highest LC_{50} values was observed in chlorpyriphos 20% EC which ranged from 35.16-41.08 ppm (2014-15), 37.35-43.27 ppm (2015-16) and 36.02- 41.94 ppm, respectively in different locations. The order of toxicity of insecticides tested on *Helicoverpa armigera* was Chlorantraniliprole > Emamectin benzoate > Flubendiamide > Spinosad > Thiodicarb > Methomyl > Profenophos > Chlorpyriphos. Rotational use of conventional insecticides along with the new chemistry insecticides may be an effective tool in the insecticide resistance management program of *H. armigera*.

Abstract No. Oral: 40

STATUS OF HELIOTHINES RESISTANCE TO *Bt* COTTON IN THE WORLD

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The Heliothine (Lepidoptera: Heliothinae) insect pests; *Heliothis virescens*, *Helicoverpa armigera*, *Helicoverpa zea* and *Helicoverpa punctigera* are the important bollworms of cotton in major cotton growing countries; India, China, the USA, Australia, Pakistan. These insect pests have a history of developing resistance to almost all the insecticides used for their control.*Bt* insecticidal proteins; *Cry*1Ac and *Cry* 2Ab are highly toxic to *Heliothis / Helicoverpa*. Laboratory experiments to select for resistance in many countries have shown that *Heliothis* / *Helicoverpa* are capable of developing resistance to *Cry*1Ac. High levels of resistance to *Cry* 1 Ac (over 10,000 fold) were obtained to a *Heliothis virescens* colony (YHD2 1000 MVP) by selection with Cry 1 AC protoxin. *Helicoverpa armigera* was capable of developing resistance to Cry 1Ac under laboratory conditions by the end of 10^{th} generation. Resistance levels increased by 76 fold as indicated by the LC_{50} values; from 0.185 µg/ml diet in F1 to 11.50 µg/ ml diet in 10^{th}generation. In post *Bt* era, it is clearly evident from the published research from different countries on resistance development in cotton boll worms, especially *Helicoverpa spp* against Cry toxins revealed that there is a decline in susceptibility to Cry toxins; Cry 1Ac and Cry 2 Ab. For example, researchers from the USA recommended supplemental insecticides for effective management of *Helicoverpa zea* on even dual gene *Bt* cotton. Experiences from China also indicate that there is a need to develop suitable alternate strategies like deployment of cotton containing pyramid genes. However, unlike in other countries, decrease in susceptibility to *Bt* cotton is not that pronounced in cotton bollworms in Australia. It was mainly due to systematic and effective implementation of IRM strategies from the inception of *Bt* cotton cultivation in Australia. Now, *Bt* cotton occupied 22.3 m ha globally during 2016 (ISAAA, 2016); a total of 14 countries cultivated biotech cotton and four countries raised more than one million

ha. India grew around 50% of global biotech cotton during 2016. Increased farmers income by cultivating *Bt* cotton during 20 years period 1995 to 2015 was estimated US $ 52 billion and US $ 3.4 billion during 2015 (ISAAA 2016). However, the primary threat to continued success of *Bt* cotton has been evolution of resistance by insect pests particularly *Heliothis / Helicoverpa*. This paper reviews the status of *Heliothis / Helicoverpa* resistance to *Cry* toxins (*Cry* 1 Ac and *Cry* 2 Ab) in major cotton growing countries in the world; India, China, the USA and Australia.

Abstract No. Oral: 41

BIO-RATIONAL INSECTICIDES AGAINST PINK BOLLWORM, *Pectinophora gossypiella* SAUNDERS IN *BT* COTTON

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After introduction of *Bt* cotton hybrids during 2002 and its wide spread cultivation (>85 % area) in Gujarat state, there has been a change in dynamics of the pests. The pink bollworm, once a serious problem for non Bt cotton, especially in later stage of the crop was effectively controlled by Bt toxins. But pink bollworm has now become a major problem in Bt cotton hybrids appearing from flowering stage of the crop and inflicting damage if unattended. With a view to manage from the initial stage of the crop, field experiments were carried out at Main Cotton Research Station, Navsari Agricultural University, Surat, Gujarat for two seasons during *kharif* 2015-16 & 2016-17 in RBD with ten treatments and three replications. The first application of Indoxacarb 15.8 EC @ 0.0079%, Emamectin benzoate 5 SC@ 0.0025% or Spinosad 45 SC@ 0.014% at 75 DAS (days after sowing) and second application at 15 days after first spray was found economical and effective in managing pink bollworm in *Bt* cotton. Mean damage to flower was 2.91, 3.30 and 3.34 % in treatments of Indoxacarb 15.8 EC, Spinosad 45 SC and Emamectin benzoate 5 SC, respectively as against 14.80 % rosette flowers in untreated control. Average pink bollworm population was 0.78, 0.81 and 1.11 larvae/10 green bolls with 3.08, 3.84 and 4.22 per cent damage to green bolls in the treatments of Indoxacarb 15.8 EC, Emamectin benzoate 5 SC and Spinosad 45 SC as against 4.00 larvae /10 green bolls and 18.32 % damage to green bolls in untreated control. Mean damage to open boll and locules was 3.50 and 1.44, 4.12 and 2.02 and 5.70 and 2.58 % in corresponding treatments as against 24.79 and 16.97 % in untreated control. The seed cotton yield was 2394, 2330 and 2240 kg/ha in Indoxacarb, Emamectin benzoate and Spinosad treatments, respectively.

Abstract No. Oral: 42

MOLECULAR VARIATION IN THE NATURAL POPULATIONS OF PINK BOLLWORM IN SOUTH GUJARAT

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Molecular variations amongst eight geographical populations of *Pectinophora gossypiella* Saunders from

South Gujarat, India were studied using the technique RAPD-PCR. The fourteen RAPD primers generated 85 polymorphic bands across eight geographical populations showing 50 to 100 per cent polymorphism. Intra-species relationships between the populations were evaluated by generating a similarity matrix based on Jaccard's index and a phenetic dendrogram was generated by UPGMA method. Principal component analysis separated the 8 populations into two distinct clusters based on band-sharing data. Populations showed varied degrees of genetic similarity within a range of 0.36 to 0.71 through Jaccard's similarity co-efficient. The maximum similarity coefficient (0.71) was observed between Nizar (21.4897 ^{0}N, 74.2824 ^{0}E) and Olpad (21.2745 ^{0}N, 72.7585 ^{0}E) region followed by Jambusar (22.0834 ^{0}N, 72.7918 ^{0}E) and Nizar (21.4897 ^{0}N, 74.2824 ^{0}E) region (0.66). The minimum similarity coefficient (0.36) (maximum diversity) was observed in pink bollworm populations of Amod (21.9176 ^{0}N, 72.9783 ^{0}E) and Rajpipla (21.8653 ^{0}N, 73.500 ^{0}E) region followed by populations of Dediapada (21.6239 ^{0}N, 73.5741 ^{0}E) and Umarpada (21.5051 ^{0}N, 73.3540 ^{0}E). The level of genetic variation detected between the *P. gossypiella* populations with RAPD–PCR technique suggests wider genetic structure of populations which needs to be more precisely studied using specific markers which would have based in ecological adaptation of the populations.

Abstract No. Oral: 43

DYNAMICS OF INSECT PESTS OF COTTON AT NANDYAL, SCARCE RAINFALL ZONE OF ANDHRA PRADESH, INDIA

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Experiment conducted during *kharif*, 2016-17 at RARS, Nandyal with two test hybrids i.e. DCH 32 and RCH 2 Bt BG II for the incidence of sucking pests indicated that in DCH 32, the leafhopper population attained the first peak during the 34th standard meteorological week (SMW) with 20.60 leafhoppers /3 leaves and the second peak was observed during 44th SMW with 20.80 leafhoppers/ 3 leaves; whereas in RCH 2 Bt BGII, the leafhopper population attained two peaks with the first peak during the 34th SMW with 12.23 leafhoppers /3 leaves and the second peak was observed during 46th SMW with 10.50 leafhoppers/ 3 leaves. Though the incidence of thrips, aphids and whitefly was there, they have not crossed Economic Threshold Level (ETL) during the cropping period. The incidence of *Helicoverpa armigera* and *Spodoptera exigua* in the field was negligible during the cropping period. However, for majority of the bollworms, the mean trap catches attained two peaks during the season. The trap catches of *Helicoverpa* attained single peak during 36th SMW (34.86 moths/trap/week). The incidence of *Spodoptera litura* was observed throughout the season with the first peak during 37th SMW with 85.86 moths/trap per week and a second peak during 51st SMW with 35.86 moths/trap per week. The pink bollworm appeared in middle of the season and the catches above ETLs were recorded from 48th SMW onwards and declined after the harvest of the crop. The spotted bollworm (*E. insulana*) catches were higher during 46th and 50th SMW with 19.57 and 21.47 moths/trap/week, respectively. The correlation studies indicated a significant and positive correlation with the maximum temperature and relative humidity and leafhoppers in both the test hybrids. The pink bollworm moth catches showed a significant and negative correlation with maximum temperature (r= -0.577).

Abstract No. Oral: 44

EFFECT OF FOLIAR NITROGEN FERTILIZATION ON COTTON YIELD, FIBER PROPERTIES AND SEED QUALITY

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Experiment was conducted at Central Cotton Research Farm, Sreepur, Gazipur, Bangladesh to determine appropriate concentration of foliar nitrogen for improving cotton yield, fibre properties and seed quality. The effect of seven levels of nitrogen (4.5, 6.0, 7.5, 9.0, 10.5, 12, 13.5 g L^{-1} water) on cotton yield, yield contributing characters and fiber quality were compared with no foliar application in randomized complete block design with 3 replications. Foliar fertilizers were applied at ten days interval for thrice beginning at first flowering stage. Recommended doses of N, P, K, S, Zn, B and Mg (78, 37, 33, 20.5, 4.60, 2.2, 1.90 kg ha^{-1} respectively) were applied uniformly to all plots. Data on yield and yield components were recorded. Fibre quality viz. span length, uniformity ratio, micronaire value and Pressley strength were measured. Seed quality of freshly harvested cotton seeds were determined by measuring seed index, germination test and electrical conductivity test. The results revealed that application of foliar nitrogen in addition to soil applied fertilizers significantly affected seed cotton yield, yield contributing characters and fiber quality. The highest number of bolls $plant^{-1}$ (22.35), single boll weight (5.33 g) and seed cotton yield (1.292 t/ha) were obtained from foliar nitrogen application at the rate of 9.0 g N L^{-1} water. The highest 50% span length (12.19 mm) with desirable micronaire value (4.60), uniformity (46.83) and strength (83.92 PSI) were also obtained from this treatment. Furthermore, increased seed index and nitrogen content in seed under this foliar fertilization (9.0 g N L^{-1} with N enhanced seed quality as it was evident from its highest germinability (90.0%), seedling growth along with lowest electrical conductivity (108.67 µS/cm/g) value. This study demonstrates that cotton plant needs supplementary foliar N fertilization during reproductive stage for its improvement in yield, fibre properties and seed quality. Foliar nitrogen fertilization @ 9g N/l water improved boll number, boll weight, seed cotton yield, fibre length and fibre strength.

Abstract No. Oral: 45

PERFORMANCE OF DIFFERENT LEVELS OF NPKS ON GROWTH AND YIELD OF SOME NEWLY RELEASED COTTON VARIETIES

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A field experiment was conducted at Cotton Research Center, Sreepur, Gazipur during 2014-2015 growing period to investigate the influence of different levels of NPKS fertilizers on newly released cotton varieties in respect of growth, yield contributing characters and seed cotton yield. The experiment consisted of three newly released cotton varieties viz. CB-12, CB-13 and CB-14 and six levels of NPKS fertilizers viz. Control (without fertilizer), 25% less than recommended dose, recommended dose (120, 52, 131, 27 kg ha^{-1} NPKS, respectively), 25% higher than recommended dose, 50% higher than recommended dose and 75% higher than recommended dose. The experiment was laid out in a Split-plot design with three replications. The results revealed that seed cotton yield, bolls $plant^{-1}$, individual boll weight differed among the varieties. The highest seed cotton yield (1938 kg ha^{-1}), the highest bolls $plant^{-1}$(17.94) and individual boll weight (4.33 g) were obtained in CB-13 and that of the lowest recorded from CB-14 variety. Increasing levels of fertilizer gave higher values of all the parameters except days to first flowering and days to first boll splitting. The tallest plant (126.1 cm), the highest number of bolls $plant^{-1}$(21.81) and the highest seed cotton yield (2448 kg ha^{-1}) were obtained from application of 75% higher than recommended doses of NPKS fertilizers. The interaction effects of cotton varieties and NPKS rates on cotton yield and yield contributing characters were found significant. Due to the interaction effect, the cotton variety CB-13 in combination with 75% higher NPKS fertilizers than the recommended doses showed the highest plant height (128 cm), bolls $plant^{-1}$ (23.9) and seed cotton yield (2676 kg ha^{-1}).

Abstract No. Oral: 46

EVALUATION OF SOIL MOISTURE CONSERVATION MEASURES AND NITROGEN REQUIREMENTS FOR COTTON UNDER HIGH DENSITY PLANTING SYSTEM

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An experiment was conducted during 2015-16 (*kharif*) to evaluate the effect of Soil Moisture Conservation (SMC) methods and nitrogen levels under high density planting of cotton variety *G Cot* 16. The experiment was laid in FRBD with treatments involving three SMC, S_1: Normal flat sowing S_2: Ridges and Furrows at 40 DAS, S_3: Mulching with paddy straw, while four N levels included were N_1: 80 kg N/ha (RD of N), N_2: 80 kg N/ha (RD of N) +15 kg $ZnSO_4$/ha, N_3: 100 kg N/ha (125 % RD of N) and N_4: 100 kg N/ha (125 % RD of N) + 15 kg $ZnSO_4$/ha. Each treatment was replicated three times. Results of the experiment indicated that plant height (cm), boll weight and seed cotton yield (kg/ha) were significantly affected by different soil moisture conservation techniques. Treatment S_3 recorded significant higher plant height (89.4 cm) as compared to S_1 (77.8 cm) but was found at par with S_2 (86.6 cm). Same value of boll weight (2.73 g) was recorded by treatments S_2 and S_3 which was significantly higher than that of S_1. Significantly highest seed cotton yield (1594 kg/ha) was recorded by the treatment S_3 which was statistically at par with treatment S_2 (1403 kg/ha). Number of bolls per sqm was not significantly affected by different moisture conservation techniques and N levels.

Plant height (cm), number of bolls/square m and seed cotton yield (kg/ha) were significantly affected by different N levels. However, boll weight was not significantly affected by different treatments. Significantly highest plant height (89.0 cm) was recorded by treatment N_4 as compared to its lower N levels. The same treatment also recorded significantly higher number of bolls per sqm (71.4) but was statistically at par with N_3 (64.8). Boll weight was not significantly affected by N treatments. Significantly highest cotton yield (1596 kg/ha) was recorded by the treatment N_4 which was statistically at par with treatment N_3 (1561 kg/ha).

From the study, it is inferred that soil moisture conservation measures *viz.* mulching with paddy straw or planting on ridge-furrow system along with 100 kg N/ha may be adopted cotton under HDPS for rainfed conditions of south Gujarat.

Abstract No. Oral: 47

INFLUENCE OF FOLIAR APPLICATION OF POTASSIUM AND MEPIQUAT CHLORIDE ON YIELD, QUALITY AND UPTAKE OF MICRONUTRIENT IN COTTON

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Plant growth regulators and balanced nutrient management are of utmost importance for maximizing cotton yield. Foliar applications of potassium offer the opportunity of correcting deficiencies quickly and efficiently, especially late in the season when soil application of K may not be effective or possible. Plant growth regulator helps to maintain sufficient plant structure to fit maximum boll in cotton. Field experiments were conducted during the crop growing season in 2012 and 2013 at Cotton Research, Training and Seed Multiplication Farm, Jessore, Bangladesh to study the influence of foliar application of potassium additional to basal K @ 0.0, 0.75, 1.5 and 2.25% K at 60 and 90 days after planting (DAP) and the plant growth regulator mepiquat chloride (MC) sprayed twice at 40 and 70 DAP @ 0.0, 5, 10, 15, 20 and 25 g *au/k.* per ha on yield, quality and uptake of micro-nutrient of cotton. Shorter plant height and higher boll number, seed cotton yield, lint index and fiber length in cotton were the characteristics of present investigation using foliar K and MC. Seed cotton yield was increased significantly by 29% and 25% compared to the control in 2012 and 2013 respectively with combined application of 1.5% K and 10 g ha^{-1} MC. The fiber length was increased 1.5 mm with 0.75% K and 15 g ha^{-1} MC in 2012 and it was increased 0.6 mm with 1.5% K and 15 g ha^{-1} MC application in 2013. Combined use of K and MC affected significantly on micronaire. Zinc concentration in leaf (highest 21.47 µg g^{-1}) was increased consistently with higher level of K and MC in the second growing season. The finding infers that combination of K and MC might have enhanced effect on yield and quality of cotton and uptake of micro nutrient in the study area.

Abstract No. Oral: 48

PRECISION NUTRIENT MANAGEMENT TO ACHIEVE TARGET YIELD IN BT COTTON (*Gossypium hirsutum* L.) THROUGH SITE SPECIFIC NUTRIENT MANAGEMENT

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The field experiment was conducted to study the "Precision nutrient management in Bt cotton through Site specific nutrient management and target yield approach" during *kharif* 2014-15 under rainfed condition. The

experiment was laid out in a randomized block design with four replications. Grid-wise soil samples were analysed to know the soil spatial variability. A uniform management zone was selected for pilot plot experimentation. The pilot study area was low in available N, high in P and medium in K. The treatments comprised of nutrients applied precisely through site specific nutrient management (SSNM) to achieve the target seed cotton yields of 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 t/ha, RDF, modified RDF (As per soil test) and absolute control. In the present study, seed cotton yield (3.91 t/ha), Yield parameters [(number of bolls plant^{-1} (61.3), mean boll weight (6.2 g) and seed cotton yield plant^{-1} (217.7 g)], total dry matter production (462.7 g plant^{-1}), nutrient uptake (159.9, 47 and 178.6 kg N- P- K /ha, respectively) and nutrient availability (270.2, 35.09 and 400.8 kg N- P- K /ha, respectively) differed significantly due to precise application of nutrients required for target yield of 4.5 t/ha over other target yields (2.0, 2.5, 3.0 t/ha), and other treatments. However, nutrients applied to achieve 3.5 and 4.0 t/ha target yields were on par with target yield of 4.5 t/ha. The target yield achieved with application of nutrients required for 3.5 t/ha was 3.6 t/ha. Further, increase in the level of fertilizer to achieve 4.0 or 4.5 t/ha does not help in increasing the yield to achieve the targeted cotton yield.

Abstract No. Oral: 49

TRICHODERMA-AZOTOBACTER BIOFILM AS A PROMISING INOCULANT FOR ENHANCING PLANT GROWTH AND SOIL NUTRIENT DYNAMICS IN COTTON

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Microbial inoculants are an important component of integrated soil and crop management practices in agriculture, which is slowly leading to a reduction in the dependence on chemical fertilizers. For deriving maximum benefits from inoculation using microorganisms, effective colonization of roots and rhizosphere is an essential step. As several biotic and abiotic factors reduce the survival and proliferation of the applied bioinoculants in the rhizosphere, a novel concept of microbial biofilms was introduced. Biofilms are commonly observed on different parts of the plant, on soil/water surfaces and represent assemblages of microbial cells, irreversibly associated with a surface and enclosed in a self-produced matrix of extracellular polymeric substance. The aim of the present investigation was to illustrate that the developed fungus-bacterial biofilm *Trichoderma viride - Azotobacter chroococcum* may colonize the root and rhizosphere better and enhance plant growth and soil nutrient availability more effectively, as compared to individual inoculation.

In the present investigation, the effect of single inoculation of *Azotobacter chroococcum (Az) and Trichoderma viride (Tv),* their biofilm *(T. viride – A. chroococcum (Tv-Az)* and treatments involving recommended dose of fertilizer treatment/control (RDF) and 75% N + Full dose of P and K fertilizers were compared in cotton. Tv-Az biofilm proved superior to all the other treatments in terms of enhancing the available macro- and micronutrient content in soil and plant growth attributes by 10-40%, over RDF; particularly leading to 25% N savings. Effective root colonisation and biofilm formation was confirmed through scanning electron microscopy and confocal laser scanning microscopy, which were supported by the increments of one to several folds, in soil polysaccharide content, soil proteins and soil dehydrogenase activity. Significant enhancement, upto one-two fold increase in the elicitation of defense and antioxidant enzymes in shoot and roots of cotton was also recorded. Principal component analysis illustrated the positive influence of Tv-Az biofilm inoculation on cotton growth parameters, soil macro- and micronutrients, and the activity of plant defense enzymes. Time course studies indicated that the population of both the partners was significantly higher (0.1-0.3 log cfu increase) in biofilm-inoculated treatment, in both the rhizoplane and rhizosphere of cotton. The dual species biofilm interacted synergistically in terms of its functionality, leading to

enhanced growth and nutrient availability and uptake, indicative of its better survival in the crop rhizosphere. In the future scenario, the implications of these improvements on cotton productivity, quality and biocontrol potential against insects and fungal/bacterial pathogens need to be investigated, for its potential use as an environment-friendly input in cotton farming.

Abstract No. Oral: 50

PROBLEMS AND PROSPECTS OF COTTON CULTIVATION IN GUJARAT

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Cotton is one of the most important cash crop for Gujarat covering about 2.5 million ha area of the state with the production of 9.5 million bales and 633 kg/ha productivity. After approval of *Bt* cotton hybrids for cultivation and seed production in 2002, Gujarat, being the hub of seed production, had adopted the technology on a very large scale doubling the area and production in 15 years. About 80% area of cotton cultivation is covered by *Bt* cotton hybrids. The production and productivity of cotton in the state were boosted due to favorable seasons and introduction of Bt hybrids, which changed the socio economic status of the cotton growers. The situation is different in recent years as some of the biotic, abiotic and legal issues affected cotton cultivation by the growers.

Mealybug infestations created havoc amongst cotton growers during 2006. Pink bollworm posed serious threat to Bt cotton cultivation from 2010 onwards. Besides, leaf reddening, parawilt, spurious seeds and low price posed serious threat to Bt cotton cultivation. Area under cotton cultivation in Gujarat declined from 3.0 to 2.5 million ha and replaced by groundnut, castor and pigeon pea cultivation in Saurashatra, north Gujarat and south Gujarat, respectively. However, timely interventions and directives of Central and State Government, Awareness and training programme with FLDs on technology dissemination by the ICAR, SAUs, line department and private sector helped to a great extent to contain mealybug and pink bollworm menace. Management technology through research for control of mealybug, pink bollworm, parawilt and leaf reddening were developed and popularized. The Government also intervened to provide attractive prices. At present, it seems that cotton cultivation will be in rhythm in future and the same glory of cotton will be back again. Area specific cotton cultivation with suitable technology (irrigated, rain fed and organic) and effective price seem prospective for cotton cultivation in Gujarat.

Abstract No. Oral: 51

MAGIC: A NEW GENETIC RESOURCE FOR MULTIPLE TRAIT IMPROVEMENT AND QTL IDENTIFICATION IN COTTON (*G. hirsutum)*

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So far plant breeders have mostly used populations derived from bi-parental crosses to develop varieties and mapping QTLs for the traits of their interest. Breeders have also exploited multi-parental crosses e.g. three-way cross involving three parents or double crosses involving four parents to maximize genetic variability in breeding population, however extensive use of these crosses has been restricted because of the high labour

requirement for crossing and large population required to be maintained for recovering maximum variability through recombination of desirable traits.

Complex scheme of crossing involving six, eight way and diallel selective mating for use in breeding had been proposed many years ago but have rarely been used in development programmes. MAGIC (Multi-parental Advance Generation Intercross) population helps in shuffling of genes across different parents enabling novel rearrangements of alleles, greater genetic variability; chances to get best combination of desirable genes and phenotypic selection in advance generation reduce the frequency of deleterious/undesirable alleles from donors. MAGIC population will be a permanent mapping population for precise QTL mapping and direct or indirect use in varietal development.

With these benefits, recently MAGIC strategy/approach was initiated to utilize multiple alleles and to provide increased recombination and mapping resolution in *G. hirsutum*. We aim to develop inbred lines (3000) to grab the largest/broadest variability through crossing of six, eight and ten parents of selected lines. Selections of parents were totally based on its relevance to breeding. Single plants selections were effected in crosses showing high drought tolerant efficiency, good yield and fibre quality.

Abstract No. Oral: 52

DEVELOPMENTAL BREEDING FOR JASSID TOLERANCE WITH HIGH PRODUCTIVITY AND SUPERIOR FIBRE QUALITY IN *G. hirsutum*

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A study was initiated in 2002 to develop in-built resistance for jassid tolerance in elite cultivars of *G.hirsutum.* The donors used as male parents were Deltapine-66 (hairy), JBWR-JK-54 and CIHS-97-9 (early maturing, jassid tolerant line). The elite parents *viz*. G.Cot 10, LRA-5166, PKV- 081 were used as female parents. The methodology adopted was pre-breeding or developmental breeding. Single pair-wise crosses involving these parents and donors resulted in the development of 55 jassid tolerant lines, after rigorous selections for tolerance. The crop was grown in an unprotected condition over the years. These 55 identified improved jassid tolerant lines were evaluated in two seasons and highly tolerant lines were identified based on the phenotypic scoring (grade 1 in the scale of 1-4). Out of these, 18 select highly tolerant lines associated with superior values for other traits *viz*., boll weight, fibre quality and productivity were further evaluated in a replicated trial in 2016-17 at CICR, Nagpur research farm with three checks *viz.* Suraj, NH-615 and LRA-5166 (susceptible check). The improved jassid tolerant lines *viz*., CNH-2053 (3148 kg/ha) and CNH-2067 (3055 kg/ha) followed by CNH-2067 (3055 kg/ha), CNH-2064 (2870 kg/ha) and CNH-2049 (2870 kg/ha) recorded higher yields which were statistically and significantly superior to the three checks *viz*. Suraj (2222 kg/ha), NH-615 (2200 kg/ha) and LRA-5166 (2500 kg/ha). These lines had a high level of tolerance. For boll weight, CNH-2055 (4.6 g) followed by CNH-2058 (4.4 g) and CNH-2063 (4.4 g) were found superior and at par to checks *viz*. Suraj (4.4 g) and NH-615 (3.9 g). Two jassid tolerant lines *viz*., CNH-2044 (fibre length - 29.2 mm and fibre strength - 31.g/tex) and CNH-2045 (fibre length - 29.31 mm, fibre strength - 29.4 g/tex) were identified as superior fibre quality lines which were comparable to checks *viz*., Suraj (fibre length - 29.8 mm, fibre strength -28.9 g/tex) and NH-615 (fibre length - 32.2 mm and fibre strength - 32.0 g /tex). These developed lines with a marked level of high tolerance to jassids will serve as potential donors and productive lines in further breeding programmes.

Abstract No. Oral: 53

DIVERSE BACTERIA ASSOCIATED WITH ENTOMOPATHOGENIC NEMATODE SPECIES-POTENTIAL SOURCES OF INSECTICIDAL TOXINS

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Development of resistance in bollworm to insecticidal transgenic cotton has emerged as a major cause of concern worldwide. Although *Bt* (*Bacillus thuringiensis*) cotton now occupies more than 90% acreage under cotton in India, few other *Bt* proteins are being utilized for insect control. Development of resistance against insecticidal proteins expressed in transgenic cotton can be avoided by deployment of insecticidal proteins from other alternative toxin sources. Entomopathogenic nematodes (EPN) and their bacterial symbiont offer a potent source of insecticidal molecules against insect pests of cotton. Apart from *Photorhabdus luminescens subsp. Akhurstii and Xenorhabdus indica* bacterial symbiont of Entomopathogenic nematodes *Heterorhabditis indica and Steiner nemathermophilum* respectively, many other bacterial species have been recorded to be associated with Entomopathogenic nematodes and found to elicit insecticidalactivity. Bacteria belonging to genera *Bacillus, Paenibacillus, Cellulomonas, Acinetobacter, Micrococcus, Enterobacter* and *Enterococcus* belonging to 16 phylogenetic group affiliated with lactobacillales, actinobacteria, proteobacteria and cytophaga-Flavobacterium, Bacteroides, Enterociccyus have been isolated from *Helicoverpa armigera* and *Sprodoptera litura* infected with entomopathogenic nematodes. These bacteria were identified based on morphological and biochemical characteristics as well as molecular characterization based on 16sRNA. Primers were designed based on sequences of toxin genes available in public database. Amplicons similar to Tcc1b andTxp40 were amplified from *Providencia sp.*BB isolate, Tcc1b from *Klebsiella variicola* BW isolate,Tca C, Tcc1a, Tcc1b and Txp40 from *Xenorhabdus indica*, Tcac, TccC and TcaA from *Paenibacillus sp.* Out of these toxin genes cloned TcaC, *Xenorhabdus* Xpt1 and TccC are known to have oral toxicity and thus have potential for their use as alternate to Bt toxin in development of transgenic cotton.

Abstract No. Oral: 54

COTTON PESTS SCENARIO DURING LAST DECADE IN INDIA

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Area under Bt-cotton rose to current >95% from merely 42% of the total cultivated area in 2006. Two gene (Cry1Ac+Cry2Ab) Bt-cotton, Bollgard II was approved during 2006. It occupied only 4% area in 2006 but today 100% of the area is BG II, replacing single gene Bt-cotton (Cry1AC), Bollgard that was introduced during 2002. Pest scenario also witnessed outright transformation. Bt cotton was able to keep bollworm complex *viz.*, American bollworm (*Helicoverpa armigera* (*Hubner)); Spotted bollworm (Earias vittella* (Fabricius)), Pink bollworm (*Pectinophora gossypiella* (Saunders)) under check until 2009.The first report of resistance development by pink bollworm to Bollgard came during 2010 and subsequently to Bollgard II during 2014. This development was an eye opener to farmers, researchers, seed industry, policy makers and technology developer as Bt-cotton was the first and sole genetically engineered technology approved in India

that got broken down to pink bollworm. Beside other reasons, non-compliance of the refuge planting, long duration hybrids, segregating seeds in F_2 plants were significant contributor for this development. At present major cotton producing states like Gujarat, Maharashtra, Telangana, Andhra Pradesh, Karnataka and Maharashtra are under grip of pink bollworm damage. However, American bollworm and spotted bollworm are showing negligible resistance against Bt-cotton. Bt-cotton came along with hybrids (at present >2000) which are inherently susceptible to sucking pests. These Bt hybrids and also non Bt-cotton fell prey to cotton mealybug (*Phenacoccus solenopsis* Tinsley) across India and papaya mealybug (*Paracoccus marginatus* Williams and Granara de Willink) in south Indian cotton growing states during 2007-08 onwards. These mealybugs caused severe losses to cotton production varying from 20-50%. The infestation of mealybugs receded from 2010. During 2015, whitefly (*Bemisia tabaci* (Gennadius)) outbreak in north Indian cotton growing states of Punjab, Haryana and Rajasthan shattered the economy of farmers of these states by reducing yield significantly which compelled to phase out whitefly susceptible genotypes from the cultivation. Whitefly happens to be carrier of Cotton leaf curl Virus disease (CLCuD), a dreaded disease of cotton in those areas. Mirid (*Creonteades biseratnse* (Distant)), T Mosquito bug (*Heliopeltis bradyi* Waterhouse), Flower bud maggot (*Dasineura gossypii* Fletcher) were seen to damage cotton crop in South India. Five mealybug species of mealybugs viz., pink hibiscus mealybug *(Maconellicoccus hirsutus* (Green)), *sp*herical mealybug *(Nipaecoccus viridis* (Newstead)), *striped mealybug (Ferrisia virgata* Cockrell) in central zone; *mango mealybug (Rastrococcus iceryoides (Green)) in central and south zone* while ber mealybug *(Perissopneumon tamarindus* (Green)) were recorded in north zone in traces. Tobacco caterpillars (*Spodopteralitura* Fabricius and *S. exigua* (Hubner)) were seen to cause negligible damage to both Bt as well as non Bt-cotton. Recently, chafer beetle (*Oxycetonia versicolor* (Fabricius)) was seen to damage cotton flowers in Gujarat and Maharashtra. Infestation of regular sucking pests viz. leaf hoppers/ jassid (*Amrasca biguttula biguttula* (Ishida)), aphids (*Aphis gossypii* Glover), thrips (*Thripstabaci* Lind.) contributed to significant yield losses in absence of timely interventions. Though cotton production faced pest burden but timely interventions using improved and updated IPM/IRM strategies, introduction of new molecules, effective use of bioagents (*Aenasius arizonensis* (Girault) and *Acerophagous papayae* Noyes and Schauff against mealybugs and *Bracon lefroyi* Dudgeon & Gough against pink bollworm), taking advantage of information and computer technologies like disseminating real time pest advisories through CROPSAP, voice messages through e-Kapas, weekly advisories in local languages uploaded on CICR website, mobile calls, Scientists' field visits helped cotton crop protection to mitigate the challenges due to insect pests faced by the cotton growers.

Abstract No. Oral: 55

RECENT ADVANCES IN FERMENTATION TECHNOLOGY FOR VALUE-ADDITION TO COTTON STALKS AND COTTONSEED

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The two major by-products generated during cotton cultivation and processing are cotton stalks and cottonseed. In India, thirty and twelve million tonnes of cotton stalks and cottonseed, respectively are generated annually. The value-addition to cotton by-products increases the value of cotton crop and thus brings additional revenue to the farmers. The fermentation technology employs industrial microorganisms and enzymes for conversion of any agricultural wastes into 4F's (Food, Feed, Fertilizer and Fuel). The

fermentation technology is gaining importance in agro wastes processing due to its low energy cost and zero effluent discharge. This paper discusses on recent developments in application of fermentation technology for value-addition to cotton stalks and cottonseed. Cotton stalks contain about 50-55% Cellulose, 15-20% Hemicellulose, 22-25% lignin and 5-6% ash content. The lignocellulosic nature of cotton stalks makes them amenable for value addition by fermentation.The possible value-additions to cotton stalks by fermentation technology are mass multiplication of compost culture and preparation of bio-enriched cotton stalks compost, oyster mushroom spawn production and its cultivation in cotton stalks and biorefinery of stalks for generation of bio-ethanol and chemicals. The on-farm utilization of cotton stalks by fermentation process offers a solution for environmental problems that arise due to burning of cotton stalks in the field. The linters, hulls, oil and meal are the four major products generated during the scientific processing of cottonseed. Fermentation technology adds value to the cottonseed products and makes scientific processing more economical, especially for small and medium level cottonseed processing industries. The possible value-additions to cottonseed by fermentation technology are efficient recovery of linters, bio-enrichment of cottonseed hulls, enhanced oil recovery and degossypolization and nutritive quality improvement of cottonseed meal.