# THE ICAC RECORDER

International
Cotton
Advisory
Committee

Discover
Natural
Fibres
Initiative

Technical
Information Section

VOL. XXXV No. 4
DECEMBER 2017

Update on Cotton
Production Research

## Contents

Pages

Editorial ..... 3
Technology Transfer to Enhance Cotton Yield and Fibre Quality in Uganda ..... 4
Transfer of Brazilian Technologies to West Africa ..... 14
Management of Biotic Stress in Cotton ..... 19
Proceedings and Recommendations of the 14th Meeting of the Latin American Association for Cotton Research and Development - ALIDA ..... 26
Proceedings and Recommendations of the 7th Meeting of the Asian Cotton Research and Development Network - ACRDN ..... 33

# Editorial

This issue of *THE ICAC RECORDER* has five articles that include: two articles on transfer of technology (TOT) in Africa authored by teams from Brazil and Uganda; an article on 'constraints in cotton production and possible solutions' written by a team of researchers from Pakistan with specific focus on Asia and two articles that summarize the proceedings and recommendations of the regional (Latin American and Asian) network meetings conducted during August and September 2017 in Maceio, Brazil and Nagpur, India respectively.

The two articles on 'Technology Transfer' are based on the presentations made by eminent lead speakers in the open session of the Technical Seminar' on 'Opportunities and challenges for technology transfer in cotton' at the 76th Plenary Meeting of the ICAC, held in Tashkent, Uzbekistan during 22-27 October, 2017. Mrs. Jolly Sabune and Dr. Lastus Serunjogi describe the Government framework, extension networks and their commendable efforts and experiences in disseminating new technologies for cotton improvement in Uganda. Dr. José Geraldo Di Stefano & Dr. Sebastiao Barbosa share the 'success story' of an elegant participatory extension methodology deployed to transfer Brazilian technologies to Cotton-4 countries in Africa. Both papers describe common objectives of information flow from lab to land; training programmes to improvise skills and knowledge and field demonstrations to show-case new technologies in Africa. Interestingly, the two papers enlist different technologies and present different perspectives and philosophies used in the process of technology transfer. This is what makes the articles unique in their own way.

In the article, "*Management of Biotic Stress in Cotton*" Dr Abdul Qayyum Rao and his team list out biotic constraints in cotton production and outline strategies to combat them. Dr. Rao is the winner of the ICRA-Asia Young Scientist Innovation Medal 2017.

The last two articles capture the essence of the regional network meetings conducted at Brazil and India in August and September 2017. The 14th ALIDA meeting was held at Maceió, Brazil, on August 28th 2017 on the theme 'New technologies for Boll weevil management'. Thirty-six participants from nine countries (Argentina, Brazil, Bolivia, Colombia, Chile, Mexico, Paraguay, Perú and USA) attended the meeting. The 7th ACRDN meeting was held at Nagpur, India during 15-17 September 2017 on the theme '*Production of quality fiber and doubling cotton farmers' income*'. The meeting attracted 239 registered participants. Technical experts from India, Bangladesh, Egypt, Australia and USA led the sessions. Twenty-nine technical sessions were held during the three-day deliberations. The sessions included a plenary session, a valedictory session, panel discussions, an open forum for young researchers, two open sessions, two poster sessions and 24 concurrent sessions. Recommendations and action plans have been listed out in the articles that summarize both meetings.

I hope readers will find the articles interesting and useful.

*The ICAC RECORDER (ISSN 1022-6303) is published four times a year by the Secretariat of the International Cotton Advisory Committee, 1629 K Street, NW, Suite 702, Washington, DC 20006-1636, USA. Editor: Keshav Kranthi <keshav@icac.org>. Subscription rate: $220.00 hard copy, $180.00 electronic version.*
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# Technology Transfer to Enhance Cotton Yield and Fibre Quality in Uganda

**Presentation made at the 6th Open Session, Technical Seminar during the 76th Plenary Meeting of the International Cotton Advisory Committee (ICAC), Tashkent, Uzbekistan, 22nd - 27th October, 2017**

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## Introduction

In the context of this presentation, Technology Transfer, which is also called Transfer of Technology (TOT), refers to the process of transferring or disseminating technology from the Institutions of its origin, to wider distribution among more places and users of the technology (Anon. 2017a). In the case of cotton production in Uganda, the Technology referred to falls into four main categories.

### New Varieties

Category one comprises New Cotton Varieties with improvements over their predecessors on; Host plant resistance to pests and diseases, earliness to maturity, yield and yield components, and on fiber and yarn spinning characteristics. The improvements in the new varieties by the Breeders are based on the various Stakeholders' needs along the cotton value chain (Serunjogi et al, 2001 and 2004).

### Agronomic Practices

Category two of the production technology refers to Agronomical or production practices derived and recommended by Cotton Research Agronomists.

These include *inter alia*;

- Correction of soil nutrient composition on fertility and soil pH for plant nutritional requirements. The technology in this category dwells on; types, rates and timing of application of in-organic or synthetic fertilizers and Farm Yard Manures (FYM); Bio-fertilizers e.g. through intercropping cotton with N-fixing legumes like Soybeans (*Glycine max*) inoculated with appropriate Nitrogen fixing Rhizobium (Serunjogi et al, 2002), or cotton intercropped with beans, *Phaseolus vulgaris* (Elobu et. Al., 1995); use of green manure e.g. digging Mucuna beans or *Tithonia diversifolia* herbs into the soil before planting (subterranean application) or mulching the cotton seed bed with either species' herbs between the rows i.e. surface application (Elobu *et. al*., 2016 and 2017); crop rotations and early seed bed preparation by hand, oxen or by tractor to allow mineralization of the incumbent vegetation before planting.
- Early planting in relation to the rainfall patterns in given production areas and for coinciding flowering and boll development with ample rains, and the time for boll opening and seed cotton picking with a dry spell at the end of the rain season.
- Physical spacing between and within the cotton rows which determine the plant populations in a given area.
- Timing of weed control by hand, oxen or by tractors and by types and rates of herbicide applications.
- Types, rates and timing of application of Plant Growth Regulators (PGR) to control vegetative growth.
- Types and rates of applying defoliants leading to leaf shedding by cotton plants at maturity, for reduction of seed cotton contamination with leaf trash during picking. This is necessary especially under mechanical picking using solar powered hand pickers, like those developed by the Central Institute for Cotton Research (CICR), at Nagpur in India (Anon. 2017b) or while using motorized combine harvesters.

### Integrated Pest Management

Category three of the production technology is in regard with those for the control of insect pests and nematodes in cotton, referred to as entomological technology options.

These include:

- Synthetic or manmade pesticide chemical reagents.
- Derivatives from plant extracts referred to as bio-pesticides.
- Biological agents, which refer to the use of living organisms for the control of pests in cotton. Some of these are on the use of beneficial insects, which predate on cotton pests e.g. the black ants *Lepisiota Spp.,* that were found effective in the control of major insect pests of cotton in Uganda (Ogwal, et al; 2003). Other beneficial insects on cotton include; Ladybird beetles, common wasps, preying mantis and assassin bugs. Biological agents also included beneficial viruses and fungi that infect insect pests of cotton.

For judicious use of the above technologies for control of cotton pests, scientists have recommended the use of Integrated Pest Management (IPM) techniques e.g. insect scouting for assessing Economic Threshold Levels (ETLs) or Action Threshold Levels (ATLs) before deciding whether to apply pesticides or not (Sekamatte et al, 2003).

### Disease Management

Category four of production technology is for the control of diseases in cotton i.e. Pathological Technology options. In addition to search for host plant resistance, by the Cotton Breeders, in conjunction with the pathologists, to the notorious cotton diseases in Uganda, for example Bacterial blight caused by *Xanthomonas axonopodis pv malvacearum,* the pathologists strive for effective protection through the following approaches:

- Evaluate types and rates of chemicals for the control of various diseases in cotton. Chemicals found effective for control of seed borne diseases are recommended for use in dressing all cotton planting seeds for a given season.
- In addition to chemicals, recommendations are made on cultural techniques e.g. having closed seasons after picking coupled with destruction of plant debris (leaves and stems) so as to avoid carryover of diseases to the following cotton seasons.

The balanced use of the four categories of production technologies and technical inputs has important implications on the performance of cotton crops. The genetic makeup (component) of a given cotton variety interacts with any of the technologies or input categories at hand during cotton production to determine the end result on the cotton yield and fiber quality (Serunjogi et al; 2014). This paper dwells more on: Opportunities and Challenges for Technology Transfer for Cotton Production, Productivity and for Fiber quality as experienced in Uganda.

## Sources Of Cotton Production Technology In Uganda And Main Technology Uptake Pathways

The main and official source of the cotton production technology in Uganda is the National Agricultural Research Organisation (NARO) set up by an Act of Parliament (Anon., 2005). The NARO is responsible for research and development of both basic and applied production technologies including those for cotton. The Cotton Research Programme is based at NARO's Semi-Arid Resources Research Institute (NaSARRI), which holds the mandate on cotton Research under NARO's Research Programs. The details on the institutional arrangements on Cotton Research in Uganda are given in Annexure 1.

The Cotton Development Organization (CDO), which was created by an Act of Parliament (Anon. 2000) is the major uptake pathway of cotton production technology developed and perfected by NARO. The CDO works closely with NARO for keeping abreast with new technologies on cotton by participating in NARO's Annual Research Review Workshops and periodic NARO conferences and by having a NARO representative on the CDO's Board of Directors.

## Opportunities On Technology Transfer On Cotton Production In Uganda

Presently, cotton in Uganda is being produced in 62 Local Government (L.G) Districts out of the total of 116 Districts. The Cotton Producing Areas Map below, however, shows that there is wider potential for cotton production in many more Districts with good status on soil fertility and rainfall distribution. All Uganda cotton is currently produced under rain fed conditions.

The opportunities on technology transfer in Uganda include

### Enabling Environment on Policies, Laws, Statutes and Regulations Along the Cotton Value Chain

Policies at a National level outline what the Government plans or desires to be carried out in order to achieve tangible, safe and useful outcomes for the State.

In Uganda, the following major policies cater to the issues of technology transfer in cotton:

- The National Agricultural Policy (Anon. 2013): The policy consolidates the agriculture policy environments, which have been shaped since 1997 by various National level policy frameworks. The issues of technology transfer are addressed in the policy under Section 5. Implementation framework. Sub-section 5.2.1 operates under the core functions of the Ministry of Agriculture, Animal Industries and fisheries (MAAIF). The MAAIF or its agency is required to provide research services for "generating and disseminating appropriate, safe and cost effective agricultural technologies".
- The National Agricultural Extension Policy (Anon. 2016). The NAE Policy was formulated so as to capture reforms recommended by the Cabinet for strengthening the National extension services by;

  1. Transferring the extension function from an off-shoot of MAAIF, the National Agricultural Advisory Services (NAADS) to the Mainstream MAAIF (i.e. eliminating parallel institutional arrangements).

  2. Creation of a Directorate of Agricultural Extension Services (DAES).

  3. Integration of the NAADS program into the Local Governments' (Districts) Production Departments and by,

  4. Separation of agricultural input supply from the extension service delivery system.

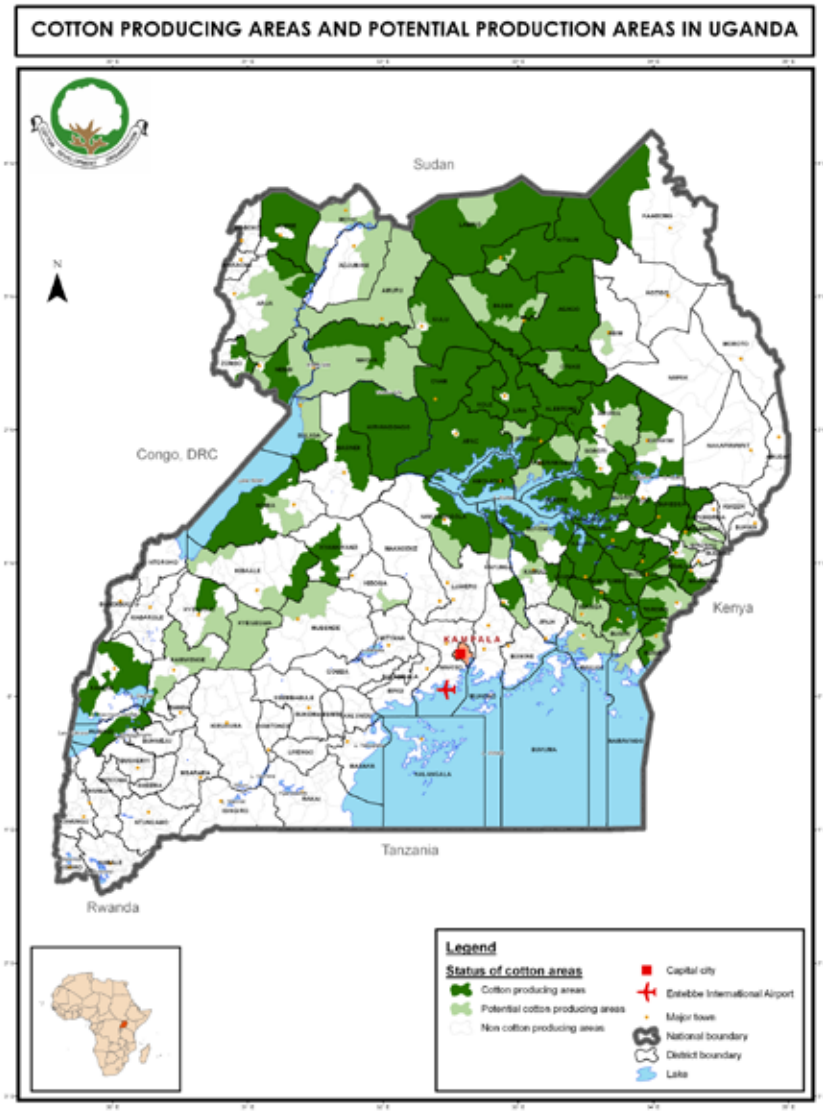
The issues of technology transfer are addressed in the NAEP under Section 5; Implementation Arrangements and Legal Framework. The responsibility for technology transfer relies on MAAIF's Technical Directorates and Agencies, which for

the case of cotton are, NARO and CDO. In collaboration with DAES, the two agencies should; develop and package technical contents; provide technical support and backstopping local Governments and Non-State Actors (NSA), for example UGCEA; develop commodity value chains and define relevant extension requirements and participate in capacity building and in monitoring and evaluation of extension services *inter alia*.

The requirements in given policies are implemented through appropriate Statutes or Acts/Laws. The needs for technology development and transfer on cotton in Uganda are implemented under various laws related to the MAAIF's Technical Directorates and Agencies.

The relevant Acts include;

- The National Agricultural Research Organisation (NARO) Act: The NARO was established in 1993 under the National Agricultural Research Statute Cap205 of 1992 (NARO, 2008a). Following reforms in the National Research Systems (NARS) between 2000 and 2005, a National Agricultural Research Act 2005 was enacted, repealing the 1992 Statute (Anon. 2005). The NARO is responsible for the promotion, guidance and coordination of all agricultural research on crops, livestock, and fisheries and on forestry. It is the Government Agency under MAAIF holding the mandate for Agricultural Research. The National Semi-Arid Resources Research Institute (NaSARRI), based in Serere, 300 km North East of Kampala Capital City (ICAC 2015) holds the mandate on cotton research, under NARO's Research Programmes.
- The Cotton Development (CDO) Act: The CDO was established under the Cotton Development Statute of 1994. This was following the liberalization of the Cotton sub-sector and restructuring of the Lint Marketing Board (LMB). The Statute was repealed and replaced by the Cotton Development Act 2000, which forms chapter (Cap) 30 of the Uganda laws (Anon., 2000). The Act mandates CDO to; promote production, monitor marketing and processing of cotton and represent all aspects of the cotton sub-sector, including inter alia; engaging in technology transfer processes.




Disclaimer: The names and boundaries shown and designations used in the map do not imply official endorsement or acceptance by the CDO.

## Roles Played by the Statutory Agencies in Technology Transfer

The two Agencies under MAAIF i.e. NARO and CDO offer high opportunities for Technology Transfer on cotton while executing their already described statutory responsibilities as follows:

- The NaSARRI through NARO's research programme on cotton plays an upstream role of technology transfer during the Technology Development stages. This is while the researchers are testing technologies in the pipeline off-station at "Technology Verification Centers" (TVCs), located to represent the various cotton production zones, and in "On Farm" Trials' sites. Annexure 1 shows the arrangements and scope of cotton research under NARO's research programmes in Uganda. Farmers get opportunities of getting acquainted with the new technologies in the vicinity of their homes. Further,

in 2000 Agricultural Research and Development Centers (ARDCs) were established under NARO in each of the ten ecological zones in the country. These have been since renamed as "Zonal Agricultural Research and Development Institutes "(ZARDIs). The ZARDIs are responsible for enhancing access to research results by farmers in remote rural areas (Anon. 2008).

- An additional, yet important role played by NARO in technology transfer is the initial multiplication of cotton seeds of newly improved varieties, on-station at NaSARRI, for release into the cotton seed-wave system operated by CDO (Serunjogi et al; 2001). New varieties are constituted as single or multiple pure-lines from the "Breeder's Seed Plots". The Breeders Seed is multiplied out as "Nucleus Seed" during the second season. The Nucleus Seed is multiplied further during the third season on larger acreages still on-station, to give rise to "Foundation Seeds". The Foundation Seeds are released to CDO for farmer's production programmes in gazetted areas in the cotton seed-wave scheme under supervised isolation and ginning of the different generations of a given variety. In subsequent seasons, the Foundation Seeds are used to produce "Certified Seeds" which also give rise to "Registered Seeds" which in turn are used in farmer fields to obtain "Commercial Seeds". Having transcended through the entire production zones, the Commercial seeds can then be crushed by Millers for oil extraction and for formulation of animal feeds. Meanwhile each season, NaSARRI injects fresh Foundation Seeds into the cotton-seed-scheme for either a new variety or re-issue of an already existing variety.
- Under its mandate, CDO in collaboration with the Uganda Ginners and Cotton Exporters' Association (UGCEA), a private sector, undertakes a production technology transfer programme across all cotton production zones (CDO Annual Reports; CDO Website www.cdouga.org). The activities include:

1. Provision of ox-drawn ploughs and tractor hire services for proper land preparation in time before planting of cotton.

2. Formation of Cotton Farmers Groups and special training of volunteers among them as chemical spray teams who assist other farmers on chemical application activities.

3. Setting up demonstration plots every season focusing on recommended crop management practices for; land preparation, spacing (plant populations), use of fertilizers with basal and topping up applications, herbicide application during land preparation for weed management, and for pest management.

*Tractor ploughing in Kasese District in Western Uganda*

*Ox ploughing in Serere District in Eastern Uganda*

*A Chemical Spray Team in Lira District, Northern Uganda*

*Farmer training programme at a Demonstration farm in Rubirizi District in Western Uganda*

4. The Demo plots serve as "class rooms" for hands-on training approaches for the 'cotton farmer groups' established in localities by CDO. A total of 3,780 demos were established during the 2016–17 cotton growing season. The groups are trained by the extension Staff system provided by the same joint venture (Government Agency-Private Sector), on techniques of using appropriate technologies on cotton in a correct manner. The techniques trained include; scouting pest populations to determine the needs for chemical applications through proper pesticide application techniques. Three training sessions are undertaken at each demo site starting from mid to end of the cropping season.

5. The CDO works closely with NARO to learn about new chemical molecules tested on cotton and recommended for entering into the MAAIF's chemical list based on their efficacy. This enables CDO to avoid prolonged use of a particular pesticide, for say more than five seasons, in cotton production zones. This is a precaution against building up of pest resistance to pesticides.

6. Packaging recommended inputs, for a given season, in amounts required for particular cotton crop acreages as a way of; making the inputs affordable by small scale farmers, curbing wastage of inputs and avoiding under-dosing or over-dosing of inputs. Planting-seeds and pesticides are sold to farmers in one-acre packs.

7. The CDO provides High Volume Instrument (HVI) facility for quick testing of lint fiber characteristics. This gives quick feed backs to the researchers on the effects of various technologies (variety breeding stocks, chemical types and rates, cultural practices and timing of applications *inter alia*) on lint. The facility also enables the ginners and lint exporters to determine best destinations for their lint and negotiate appropriate prices with knowledge on the lint quality.

## Use of Various Forms of Information Materials for Technology Transfer

A number of information materials are used in Uganda for the transfer of production technologies on cotton to the farmers. The types of material used include:

- Radio programmes by CDO in both English and vernacular languages explaining; timing of the farm activities for a given season; availability of production implements, seeds and of inputs; production technology and provisions for the marketing season (indicative prices for seed cotton and locations of stores).
- Print media in National and local newspapers on topical issues regarding the cotton sub-sector.
- Simplified and illustrated brochures by CDO and NARO on crop management production technology and post-harvest management of seed cotton and of plant residues for ensuring a closed period between seasons as one method of controlling pests and diseases. The brochures are translated in a number of local languages for ease of assimilation of the messages by the end users of the technology (NARO 2000 and NARO-NaSARRI 2017).
- Technology exhibitions are arranged by CDO and NARO in forms of prints, video films, live plant exhibits (field and potted) types of inputs and cotton by-products during Annual National Agricultural Shows, World Food Day Celebrations and during Trade shows.

## Opportunities under International Collaborations for Technology Synthesis and Transfer

For further support towards faster development of cotton production technologies and their transfer to end users, CDO is engaged in a number of well-planned collaborations between International Institutions, Agencies with the Government of Uganda. The overarching objectives of the collaborations are to learn the basis of successes in the various cotton value chains and adopt the lessons learnt into the Ugandan agriculture. The collaborations have enabled Uganda to become aware of opportunities on technologies which can be synthesized in Uganda, (rather than re-inventing the wheel), under appropriate agreements on the Intellectual Property Rights (IPRs) requirements of the inventors and suppliers of the technology.

The areas of collaboration and participation by CDO include *inter alia;*

- The World Bank funded "Small Holders Cotton Rehabilitation Project (SCRP) which revived cotton research at NaSARRI, restructured the ginning industry and piloted a credit scheme for cotton farmers on cotton production inputs. The NARO's cotton production brochure (NARO 2000) was published under this project.

- The World Bank-IDA funded "Cotton sector Development Project" (CSDP) during 2000 – 2004, supported infrastructure development for research Laboratories and piloting a cotton technology extension programme. Cotton research scientists from NaSARRI trained agriculture extension staff and cotton farmers on advanced technologies of cotton production.

**Table 1: Uganda Cotton Grades and Their Major Characteristics**

| Ugandan Grade Standard | International Equivalent (USDA Standards) | Major characteristics | | |
|---|---|---|---|---|
| | | Micronaire | Strength (g per tex) | Staple Length (mm) |
| Roller ginned cotton: | | | | |
| UCON | Good Middling | 3.8 - 4.0 | 30 - 32 | 29 - 30 |
| UCOB | Strict Middling | 3.8 - 4.0 | 30 - 32 | 28 - 29 |
| UCOP | Middling | 4.0 - 4.2 | 28 - 30 | 28 - 29 |
| UCOA | Strict Low Middling | 4.0 - 4.2 | 29 - 30 | 28 - 29 |
| UCOM | Low Middling | 4.0 - 4.2 | 28 - 29 | 28 - 29 |
| Saw ginned cotton: | | | | |
| UCOSA I | Strict Middling | 4.0 - 4.2 | 29 - 30 | 27 - 29 |
| UCOSA II | Middling | 4.0 - 4.2 | 29 - 30 | 27 - 29 |

- The Cotton Technical Assistance Programme (Cotton-TAP), of 2012 – to date (Anon., 2017b) was developed through the requests made by Governments of six African cotton growing countries to the World Trade Organisation (WTO) for support towards developing their cotton value chains. The Government of India funded the programme under the second India-Africa summit agreements. Uganda has benefited from TAP on the needs of technology transfer through;

  1. Regional trainings in India and under 'in-country' trainings in Uganda for cotton researchers and extension staff on modern production technologies, post-harvest management and value addition to cotton crop residues, farm-field schools approach for technology transfer and organic cotton production techniques. Additionally, Uganda policy makers have been exposed to India's policies, which are underlying the successes of India's cotton value chain.

  2. A laboratory was constructed, supplied with equipment and reagents at NaSARRI for formulation of bio-pesticides and bio-fertilizers for use in cotton production. These bio-reagents are deemed to be safer in protecting the environments, users and livestock, than their counterpart synthetic chemicals. The lab is to be upgraded in phase two of the Cotton-TAP (2017 -2020) programme for commercial production of the bio-agents as a hub for the Africa region.

## Benefits Achieved In The Uganda Cotton Sub-Sector Through The Strategy On Technology Transfer

The efforts put into the processes of technology transfer on cotton production in Uganda have yielded a number of benefits in the cotton sub-sector which includes increase in seed cotton yields and enhanced income.

### Increase in Seed Cotton Yields and Incomes to Cotton Farmers

The adoption of the production technologies by cotton farmers has led to improvements in seed cotton yields to levels of over 2,500 kg of seed cotton per hectare (Annexure 2). The yield increases are attributed to the interactions among the improved genetic backgrounds in the new varieties, the production technologies, inputs, and the environmental factors in the production areas. In addition, the improvements in the yield component of Ginning Out Turn (GOT) i.e. 41% are good incentives to the cotton ginners who are mainly interested in the amounts of lint ginned out of a given lot of seed cotton.

### The Uganda Case of Improved Cotton Quality Due to Technology Transfer and Adoption

The joint and concerted efforts among CDO, NARO and the private sector on transfer of cotton technology on varieties and seeds, agronomical practices including use of appropriate approved chemical inputs at correct rates and at prescribed periods, have led to Uganda producing high quality cotton. This good performance is also attributed to the interaction of the varieties with the crop management regimes, inputs and with the environmental factors in the production areas.

Table 1 shows how Uganda cotton quality falls within the International premium lint grade ranges. Most of the Uganda cotton is roller ginned in comparison to saw ginning. In the roller-ginned group, UCOP is the base group upon which the price for buying Uganda's cotton is set at International markets. It is equivalent to United States Department of Agriculture (USDA) Middling Grade.

Figure 2 shows that over 32% of Uganda cotton falls in the UCOB Grade, which is better than the base Grade, and is equivalent to the USDA Strict Middling Grade. About 3% of the Uganda cotton falls in the UCON superior Grade equivalent to the USDA Good Middling Grade (CDO Annual Reports). Figure 3 shows the trend of Uganda Cotton in the top three grades over the past five seasons.

**Fig 2: Mean Seasonal Grade Performance of Uganda Cotton**

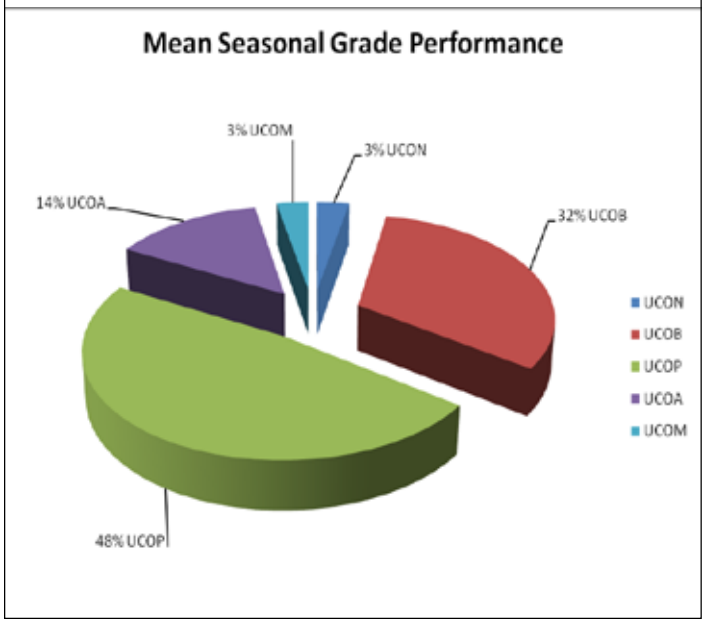
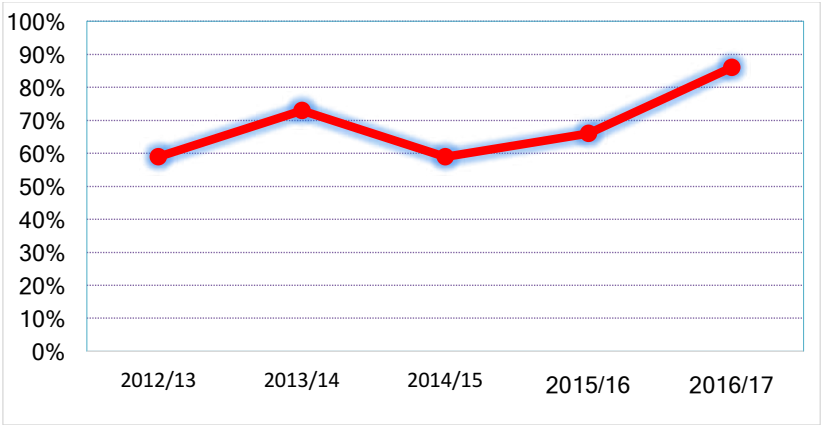



**Fig. 3. Quality performance - percent of total lint classed in the top 3 grades**




## Challenges In Cotton Production Technology Transfer In Uganda

In spite of the efforts made towards technology transfer on cotton production in Uganda, there are still some challenges for attaining an ideal status on the processes. Some of the main challenges are described below.

### Gaps in Enabling Laws on Agriculture and on Neo-Technologies

- The delays in passing of the 'Biotechnology and Biosafety Bill 2012' into law by the Parliament of Uganda until September 2017 have impeded the implementation of the "National Biotechnology and Biosafety Policy" (Anon., 2008b). While Genetically Engineered (GE) events of cotton with *Bt* genes for resistance to cotton bollworms and for tolerances to herbicides were successfully tested during 2009 and 2010 seasons, the bio-technological options could not be commercialized without the enabling law in place.
- There is also need to have a law in place for proper implementation of the new "National Agricultural Extension Policy (NAEP)" (Anon., 2016).

### Effects of Fluctuating International Cotton Prices and Competition with Other Crops

Since Uganda exports most of its cotton as raw lint, fluctuations in the international prices for lint affect the prices for farmers' seed-cotton. The adverse effects come after a low cotton price period, when even trained farmers on cotton production decide to move to production of other seemingly better paying cash and food crops or enterprises. There is therefore need to have in place a strategy for a "Price Stabilizing fund".

### Outbreaks of new Pests and Diseases and Epidemics on Cotton and Food Crops

Outbreaks of new diseases and pests or epidemics of known pests offset the productivity under the existing technology setup. Such epidemics in Uganda include the 2004 cotton bollworm epidemic, which called for innovative emergency actions on using aero insecticides sprays, which were costly to the producers. For example, the destruction of crops due to the 2017 epidemic of the Fall army worm on cereal food crops of maize, millets and sorghum obstructed farmers from managing their cotton crops while they tried to rescue their food crops.

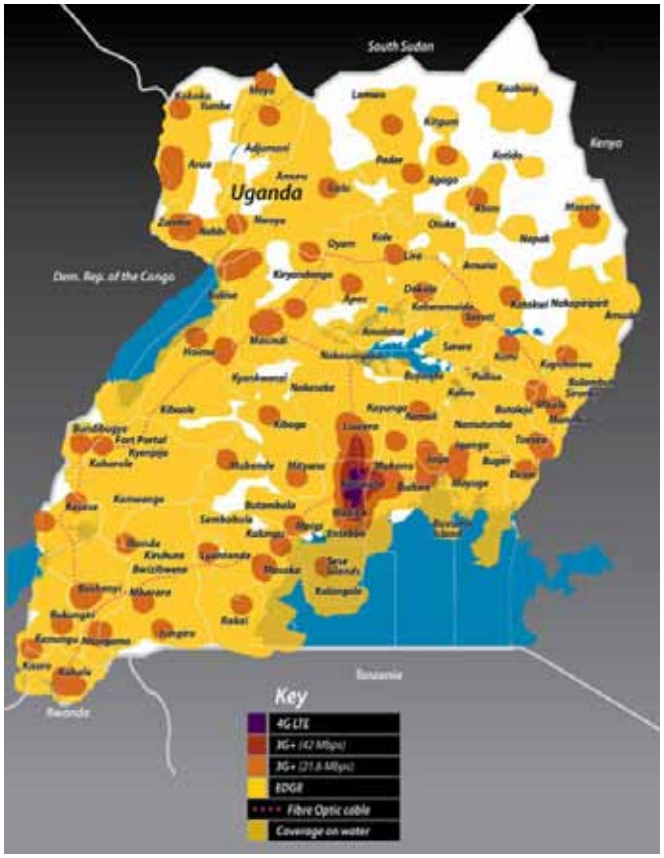
### Effects of Climate Change on Cotton Productivity and Fiber Quality

Uganda is currently experiencing effects of global climatic changes. This is in the form of changes in amounts and periods of rainfall distribution, which are crucial in the case of Uganda, which depends on rain-fed cotton production. Excessive rains or drought conditions adversely affect the seed-cotton yields and the quality of the resultant lint in the cotton crops established under the current production technology guidelines.

## Suggested Approaches For Solving Challenges Of Technology Transfer

Some of the challenges to technology transfer mentioned above can, however, be overcome by innovative approaches through planning and executing new strategies along the cotton value chain. The effects of climate change could, for example, be mitigated through breeding for short duration and drought

**Figure 4: Cellular Telephone (MTN) Coverage in Uganda**

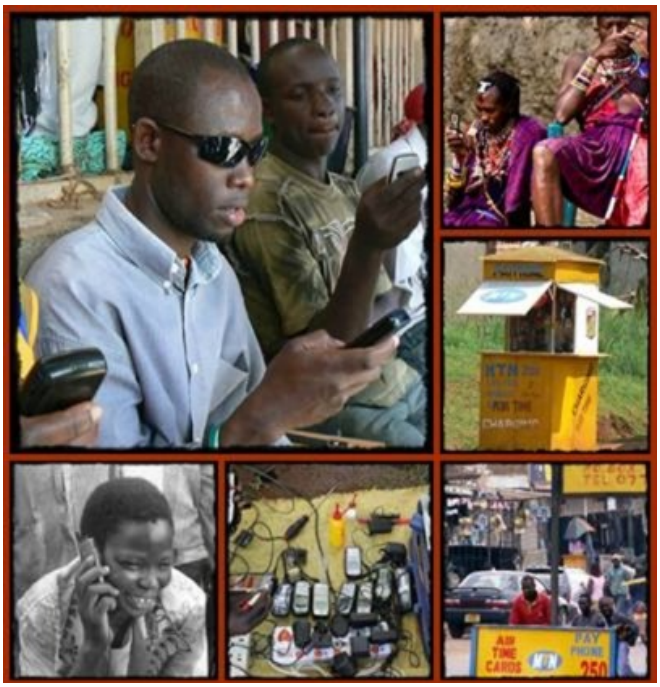



tolerant varieties without affecting the lint quality. Another option is to establish cotton irrigation facilities in production areas through appropriate water harvesting methods during the excessive rain periods, for use during drought periods.

The Uganda Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) in general, and CDO in particular, are aware of the need to embrace new cost-effective methods of technology transfer. Towards this requirement, CDO will continue to strengthen the already effective model of "Public –Private Sector Platforms" for effective and sustainable technology transfer. It is notable that this type of platform initiated by CDO way back in 2011 is now mandatory under the new National Agricultural Extension Policy of 2016. The Government Agencies, like CDO in case of cotton, are required to provide technical support and backstopping to local (District) Governments and to non-state agencies, like UGCEA in case of cotton, for enriching activities of agricultural extension and technology transfer.

Plans are also underway for strengthening the use of electronic media for cotton extension messaging through radios and televisions. It is further envisaged to use ICT based 'pest surveillance techniques' to be provided under the Cotton TAP Africa-India Phase two. Figure 4 shows an example of the already available wide coverage by the Mobile Telephone Network (MTN) Company, a service provider, in all Districts

**Figure 5: Potential of Cellular Phone Usage in Uganda**



in Uganda. Figure 5 shows a cross section of the abundant potential of mobile telephone use in Uganda. Additionally, scaling up of the formulation of bio-pesticides in the TAP facilitated Lab at NaSARRI will pave way for reducing dependence on synthetic pesticides and fertilizers in cotton in Uganda.

## Conclusions

The various Stakeholders along the Uganda cotton value chain appreciate the importance of technology transfer in cotton. The researched, validated and approved technologies, when adopted by the farmers, exert a positive influence on cotton yields and quality. The positive influence of the technologies is due to the interaction of appropriate technologies with the cotton genotypes under proper cotton production environments. The technology's influence is in terms of controlling insect pests, diseases and weeds (manual, pesticides and herbicides); providing nutrients to the cotton plant (fertilizers and cropping rotations); application of growth regulators (PGRs and defoliants) for proper plant growth with respect to appropriate apportioning of nutrients to enhance cotton yield and quality components. Therefore, transfer of technology in cotton production is of paramount importance in increasing productivity and producing high quality cotton.

The experiences for Uganda cited in this paper strongly indicate the large increases in incomes, which cotton producers and processors reaped through proper technology transfer. Adoption of new technologies by the cotton producers resulted in benefits to all the Stakeholders along the Cotton Value Chain.

## Acknowledgements

The Authors thank the ICAC for inviting them to make this presentation. Appreciations also go to the Management of the Cotton Development Organisation and to the National Agricultural Research organization (NARO) for sponsoring the Uganda delegation to attend the 76th Plenary Meeting of ICAC, in the great historical city of Tashkent, Uzbekistan.

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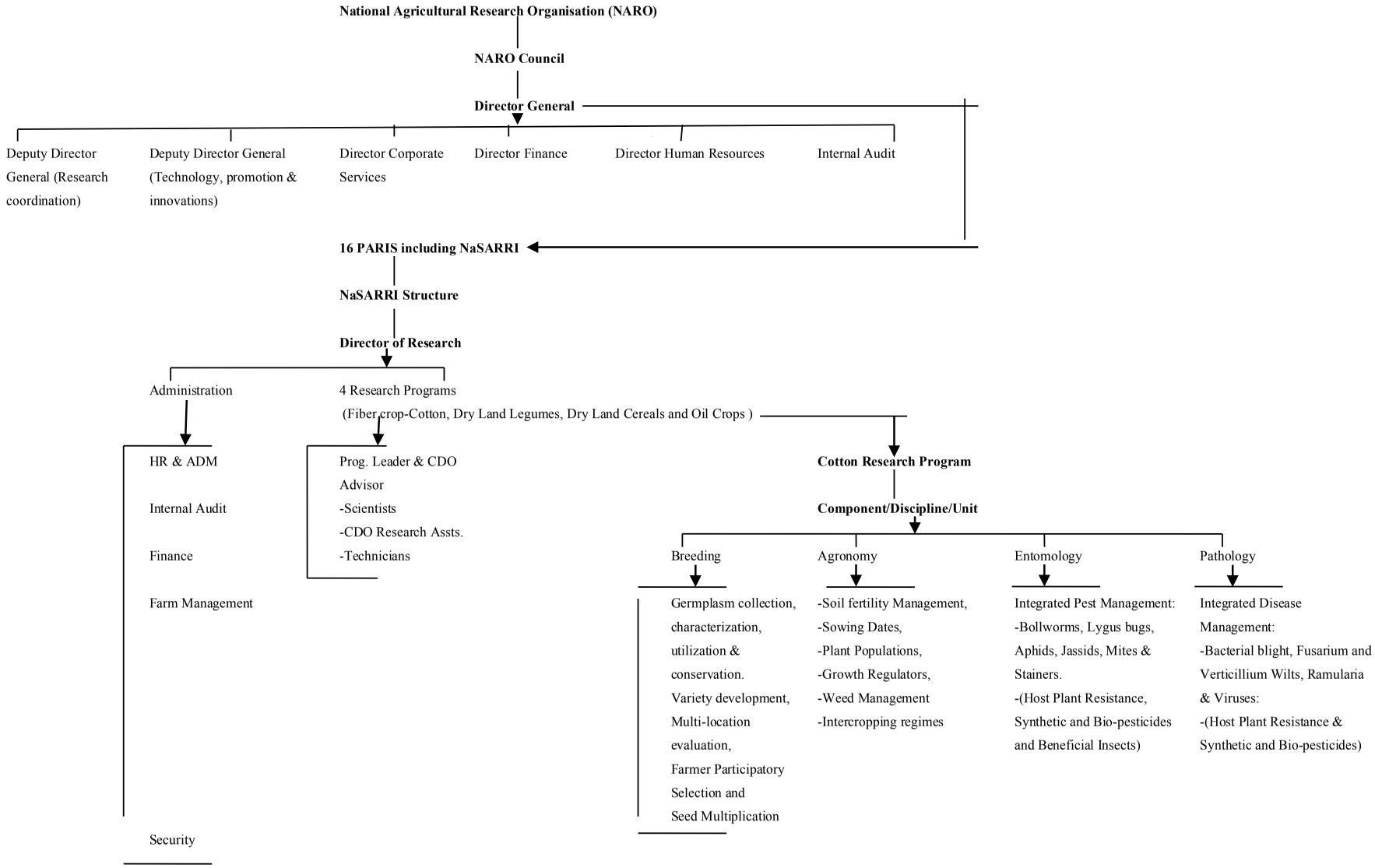
### Annex 2: Cotton Variety BPA 2015A

**ATTRIBUTES**

- **Maturity Period (days): 145**
- **Boll Weight (gms): 6.5**
- **Cotton Yield (kg/ha): >2500**
- **Ginning Out Turn (%GOT): 41**
- **Fiber Length (mm): 30**
- **Fiber Strength (g/tex): 29**
- **Micronnaire Values: 3.9**
- **Lint index: 7.8**

## ANNEX 1: Organogram of Cotton Research System in Uganda



# Transfer of Brazilian Technologies to West Africa

**Paper presented at the Technical Seminar on '*Opportunities and Challenges for Technology Transfer in Cotton*' during the 76th Plenary Meeting of ICAC at Tashkent, Uzbekistan. October 22-27, 2017**

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## Summary

Brazil provided technical assistance to Cotton-4 (C-4) countries in West Africa, namely, Benin, Burkina Faso, Mali and Chad through a project that was implemented during 2009-13. The project was designed and implemented with the purpose of transferring environment-friendly cotton production technologies from Brazil to enhance yields and fibre quality in Africa. The Project was an initiative of the Government of Brazil through the Brazilian Cooperation Agency (ABC). The Brazilian Agricultural Research Corporation (EMBRAPA) was designated as the technical back-stopping agency due to its success in revolutionizing agricultural production technologies in Brazil and establishing novel tropical agricultural paradigms based on science and knowledge. The project was implemented in active collaboration with agricultural research organizations of the recipient Governments, namely: The *L'Institut d'Economie Rurale* (IER, Mali), *L'Institut pour l'Environnement et Recherches Agricoles* (INERA, Burkina Faso), *L'Institut Tchadien De Recherche Agronomique Pour Le Développement* (ITRAD, Chad) and *L'Institut National des Recherches Agricoles du Bénin* (INRAB, Benin). The thematic areas for Project development were: Soil conservation, Integrated pest management (IPM), and cotton varietal development through germ plasm exchange and breeding**.** The project was designed with a philosophy that the traditional top-down approach would not be followed for transfer of technologies. Instead, a participatory approach would govern every single Project activity. There would be no pre-empted solutions to any problems, rather, everyone would work together to find solutions through an over-riding principle throughout the Project, that "a community that learns together grows together". In French, the concept was called "la famille forgeron" or the blacksmiths. Care was taken to ensure that the project met the specific needs and interests of the collaborating partners. As part of the overall management strategy, a Regional Project Coordinator was deputed from EMBRAPA to West Africa and a project steering committee was established with wide representation from the donor and recipient governments. The Project headquarters was established at the Sotuba Experimental Station, of IER, in the outskirts of Bamako, wherein activities related to demonstration plots, training and upgrading of the station facilities were initiated. A very strong training program was set up with EMBRAPA researchers visiting Sotuba and researchers and technicians from the member Countries

Project banner on display in the C-4 countries

The Project team with farmers in a demonstration field

visiting Brazil for intensive training under the 'train-the-trainers' part of the project. The first batches of trained staff went back to their respective countries and shared the newly acquired skills and knowledge learnt either in Brazil or in Sotuba. By the end of the project, Sotuba facilities were up-graded; cadres of researchers and technicians from the four countries were trained locally and in Brazil; and several publications in French were prepared and distributed. The project results on the three thematic areas were disseminated to selected farming communities, thereby resulting in higher productivity. The project was extended into its second phase in 2015, with the inclusion of Togo and funded by the Brazilian Cotton Institute (IBA).

## Background

Cotton is the most important cash crop for agricultural development and poverty reduction in West Africa. It represents 30, 80 and 85% of the total value of agricultural exports of Benin, Burkina Faso and Mali, respectively (FAOSTAT, 2013). It is estimated that more than 10 million people depend directly on the cotton sector in West and Central Africa as source of labour and income (AGRITRADE, 2014). The cotton value chain also brings many other benefits to rural and urban areas in the form of jobs, trade, transport etc., (Theriault and Serra, 2013). Although not always perceived, cotton plays a very important role in the food security throughout the region as source of cooking oil, cotton cake for dairy cows and for the basic food crops produced in rotation with cotton. Thus, cotton supports food-security and livelihood of large populations of West Africa and other countries.

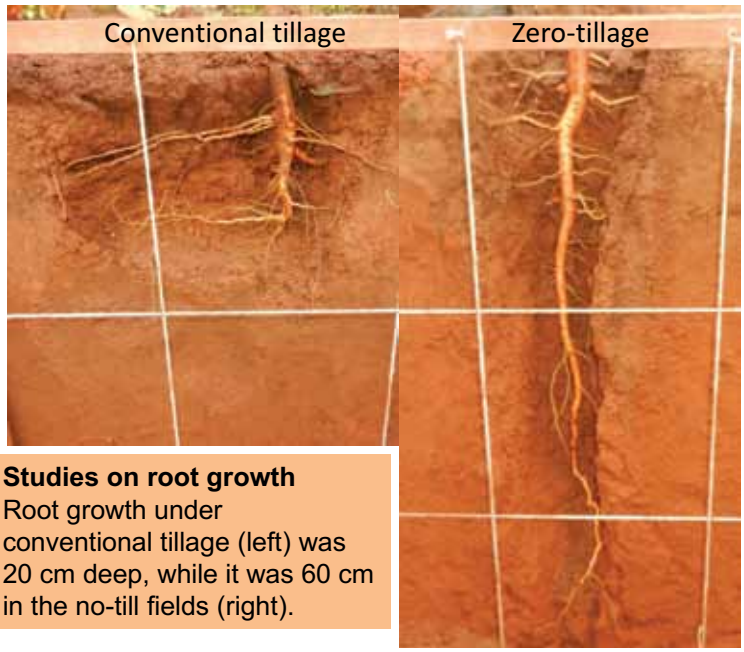
Several cotton growing countries and the C-4 member Governments of Benin, Burkina Faso, Mali and Chad supported Brazil in the 'subsidies case' arbitrated by the World Trade Organization (WTO). In a reciprocal gesture, the Government of the Federative Republic of Brazil offered a project to the C-4 countries, to transfer 'cotton production technologies' developed by EMBRAPA. Created in 1973, EMBRAPA is credited for the development of genuine agricultural technologies for the tropics that revolutionized agriculture in Brazil (Correa and Schmidt, 2014).

A fact-finding mission by the Brazilian Cooperation Agency (ABC) and EMBRAPA, visited Benin, Burkina Faso and Mali during the year of 2006 and interacted with government officials, cotton growers associations and other stakeholders to understand the most important technical constraints in cotton production in West Africa (Pereira and Morello, 2006). The fact-finding mission identified a few key constraints such as degraded soils, inadequate varieties and recurrent pest damage that required attention. Therefore the C-4 project focused its activities in three important thematic areas: 1. Soil conservation and soil health management coupled with

Field training

Root growth studies in the field pits

Laboratory training




**Studies on root growth**
Root growth under conventional tillage (left) was 20 cm deep, while it was 60 cm in the no-till fields (right).

introduction of concepts and practices of zero-tillage, crop rotation and cover crops *2*. Integrated pest management (IPM) with emphasis on biological control and 3. Cotton breeding, involving germplasm exchange and varietal development. The mission also recommended up-gradation of the existing research facilities.

The second author of this paper, (Dr. Barbosa, then retired from EMBRAPA), was hired in 2007 by ABC to draft the project document in consultation with EMBRAPA, ABC officials and representatives of the C-4 countries. After visiting Benin, Burkina Faso and Mali, it was decided to set up the project headquarters at the Sotuba Experimental Station, of the Institute of Rural Economics (IER) of Mali, located outside the capital city, Bamako. Another mission-team comprising of officials from ABC and EMBRAPA visited Bamako and met with representatives of the research organizations of the C-4 countries (Mali-IER, Benin-INRAB, Burkina Faso-INERA and Chad-ITRAD). During this visit, the draft C-4 project document was revised, incorporating suggestions made by all the participants. At the end of this meeting, the project was signed by the Minister of Agriculture of Mali and sent to the ministers of the other C-4 countries for their signatures (ABC, 2009). As Brazil did not have official representation in Ndjamena, a special visit was made to Chad. At the project signature ceremony in Bamako, ten EMBRAPA cotton cultivars were presented to the Minister of Agriculture of Mali, symbolizing the official initiation of Project activities.

## The Project

The project "Support to the Development of the Cotton Sector in the C-4 Countries – Benin, Burkina Faso, Chad and Mali" (or, simply, The C-4 project), was initiated with a total budget of US$ 5 Million for a duration of 5 years (2009-13). The project was designed to focus on adaptive research by transferring Brazilian cotton technologies developed by EMBRAPA to assess their suitability and adaptability to the ecological conditions of the C4 countries with the objective of increasing yields and improving the quality of cotton. Furthermore, the additional income and jobs resulted from cotton yield enhancement and crop rotation with food crops would greatly contribute to mitigating food insecurity in the C-4 region. The Project aimed to address the main constraints of cotton production in the C-4 countries as identified by the fact-finding mission by ABC and EMBRAPA, namely: degrading soil health, pestilence and inadequate varieties. The main objective was to improve competitiveness in the cotton supply chain. Other aims were to transfer knowledge in cotton genetic improvement (new varieties), enhancing soil health, zero-till farming and Integrated Pest Management (IPM). The Project was coordinated by ABC and executed by EMBRAPA.

The project became operational in 2009. As a consultant hired by ABC, the second author initiated the project activities at the Sotuba experimental Station by maintaining contacts with the Brazilian Embassy, the UNDP office, IER management and the Sotuba staff. A field area was identified to validate research findings and to conduct demonstration plots. Mr. Geovando Pereira, of EMBRAPA, was designated as Project Coordinator for the first 6 months of the project activities. Subsequently, the senior author of this paper, Mr. J. G. Di Stefano, succeeded as the Project Coordinator for remainder of project's duration.

The C-4 Project Centre

## Project Philosophy

The C-4 project became the first Brazilian technical cooperation project of a large scale. When he first thought of the project idea, Mr. Olyntho Vieira, of ABC, was keen to develop an infrastructure project with long-lasting impact,

Discussion in class rooms on lessons learnt in the fields

far beyond its duration. However, it was increasingly felt that the project would have to do something for the cotton sector, which would be different from what others had done in Africa before. Therefore the project was designed to have a different attitude by sharing knowledge and experiences with African counterparts to benefit the cotton sector. The project was designed on the principles of knowledge sharing, adaptive research and implemented all through by adhering to the basic philosophy of participatory learning.

The basic guiding principle of the project that the "top down approach should not be accepted" was deeply incorporated into the project functioning, with the arrival of its second coordinator, Mr. Di Stefano. The project soon became 'the community that learn together'. There were no pre-fabricated solutions; it was the birth of the "famille forgeron' or the blacksmiths. Researchers, extension agents, technicians and farmers (men and women and even children) would sit around a table, with a farming tool, a bag of seeds, a plant, an insect etc., and would decide together the next steps to be taken. Banners showing the project guiding principles and results became commonplace; and the field became the school, under the sun or the rain. Knowledge became the main incentive to everyone and the project participants felt empowered to carry out their responsibilities.

## Project Strategy

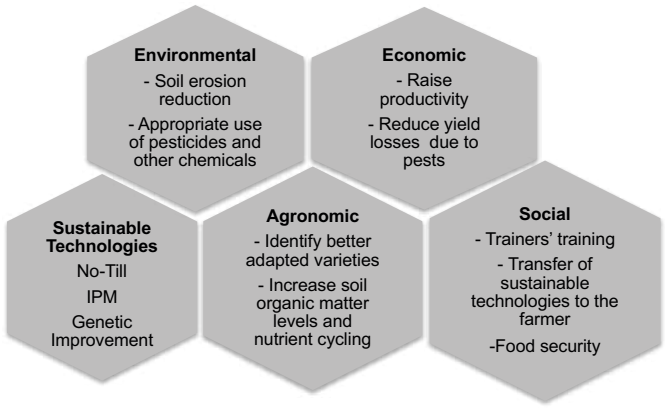
The appointment of a project coordinator from EMBRAPA and the creation of a Steering Committee were two important steps that ensured the success of the project. The project coordinator was responsible for everyday project activities. Additionally, he also liaised with the Brazilian Embassy, the local UNDP office and with government officials to ensure smooth operation of the project. The Steering Committee opened the necessary space for dialogue among the partners and gave the countries an opportunity to either simply proceed with activities as defined in the project document or review them together with the other partners when changes were required. The presence of the Committee gave the project much credibility and differentiated it from other existing projects.

Training was first conducted in Brazil (train the trainers) for researchers and extension agents who, upon returning home, would share the acquired knowledge, skills and experiences with their colleagues in Benin, Burkina Faso, Chad and Mali. In addition, EMBRAPA scientists went to Sotuba to train scientists, extension agents and farmer leaders from the C-4 countries, for which adaptive research was conducted and demonstration plots were set up in farmers' fields. As the project progressed, training and demonstration plots were also organized and conducted away from Sotuba and Mali. As listed in the project document, two representatives of each country were invited to attend the Brazilian Cotton Congress, traditionally held once every two years.

## Project Activities

- Formation of the Project Steering Committee with the nomination of representatives by ABC, EMBRAPA, INRAB, INERA, ITRAD and IER, to conduct meetings and implement recommendations.
- Upgrading the Sotuba experimental Station in Bamako-Mali, including the refurbishing of some of the existing laboratory and field facilities; procurement and purchase of laboratory and field equipment; and building of the C-4 Center and the *Trichogramma* laboratory.
- Organizing the missions by EMBRAPA specialists in the C-4 countries and visits of C-4 researchers, extension agents and farmer leaders to EMBRAPA facilities and cotton growing areas of Brazil, including participation in the Brazilian Cotton Congress.
- Conducting adaptive research and organizing demonstration plots in Sotuba and in other sites of Benin, Burkina Faso, Mali and Chad in Project thematic areas.

**Different Dimensions of the Actions of the C4 Project**



- Intensive training sessions in both classrooms and fields, in cotton genetic improvement (new varieties), soil health management, no-till farming and IPM.
- Design, preparation, revision, production and distribution of manuals and other sources of information on Good Agricultural Practices, in French incorporating the validated and tested technologies in the project's thematic areas in C-4 countries

## Project Results

- The C-4 Project became the first Brazilian technical cooperation project of a large scale. It is highly recognized by the Governments of Benin, Burkina Faso, Chad and Mali for its results and impact. It became a model project and reference for future ABC cooperative programs. Its success motivated IBA to fund a second phase, with the inclusion of Togo.
- The Sotuba Research Station, of IER, was upgraded to function as the main C-4 project pilot unit for adaptive research and to conduct demonstrations on innovative technologies. This included the building of the C-4 Center and the *Trichogramma* laboratory.
- The project contributed to empower researchers, extension agents and farmers with new knowledge, skills and field experience especially on newly introduced technologies such as no-till farming. There were cases in which researchers had their salaries and self-esteem increased because of the project.
- Eight 'training-the-trainer courses' were organized and carried-out in both Brazil and Africa on no-till planting for 166 participants (researchers, technicians, extension agents and farmer leaders).
- Eight 'training-the-trainer courses' were organized and carried-out in both Brazil and Africa on Integrated Pest Management (IPM) for 197 participants (researchers, technicians, extension agents and farmer leaders).
- Five 'training-the-trainer courses' on cotton breeding were organized and carried-out in both Brazil and Africa for 62 researchers and technicians.
- The no-till technology was validated in the C-4 countries and incorporated in selected farmers' fields for demonstration purposes (Sissoko et al., 2015).
- Brazilian experts and their counterparts in the C-4 countries jointly developed a manual on Good Agricultural Practices in French.
- Five Technical Documents on different aspects of Cotton Farming Management were produced in French.
- Notable potential for yield and fiber quality

Effect of cover crops on soil erosion: Laboratory demonstration

Field use of simple instruments for pesticide sprays

Demonstration of simple implements in the field

**Table 1: Agronomic features of some Embrapa cotton varieties in comparison with one standard C-4 variety. Sissoko Research Station-Mali 2009/10 (adapted from Yattara et al., 2011).**

| Varieties | Agronomic features - 2009/10 | | |
|---|---|---|---|
| | kg/ha (Seed cotton) | % of the test | % lint |
| ***STAM 59A (test)*** | **2 217** | **100** | **42.7** |
| BRS 286 | 3 000 | 135 | 42.8 |
| BRS 293 | 2 967 | 132 | 43.1 |
| Araçá | 2 933 | 132 | 41.2 |
| Aroeira | 2 183 | 98 | 39.7 |
| Buruti | 2 217 | 100 | 40.7 |
| Cedro | 2 917 | 132 | 42.7 |
| Safira | 2 433 | 110 | 34.7 |
| Seridó | 2 333 | 105 | 37.2 |
| **Average** | **2 562** | **-** | **40.7** |

enhancement was observed in the progeny of Brazilian and C-4 varieties. Researchers from C-4 countries were provided with access to EMBRAPA's cotton gene bank (Table 1, IER 2010, IER 2011).

- A long-term collaborative research network was established between Brazilian and African scientists.
- The C-4 project created a positive scenario for further cooperation in agricultural research between Brazil and Africa.

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# Management of Biotic Stress in Cotton

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## Introduction

Cotton is a long duration crop and typically takes about 120-160 days to complete its life cycle. Throughout the growth cycle it is exposed to weeds, insect pests and pathogens, which cause economic damage to yields. Cotton yield losses exceed up to 37% due to weeds (Awan *et al.,* 2015) and its long duration as well as slow growing nature (Nalini *et al.,* 2015). Similarly, 50-60% losses are encountered due to insect attacks (Saini *et al*., 2009) and 30% by CLCuV infestation (Khan and Ahmed 2005: Khan *et al*., 2015). Management of nutrients, water, weeds, insect pests and diseases at the critical stage of the crop growth is crucial for obtaining good yields.

## Weeds

The competition offered by different weeds to cotton plants results in loss of nutrition available for growth of the crop plant and results in considerable reduction of seed cotton

**Some of the major weeds of global importance**

| Scientific name | Common name | Scientific name | Common name |
|---|---|---|---|
| *Abutilon spp.* | Velvet weed | *Digera spp.* | Large crabgrass |
| *Acanthospermum hispidum* (DC.) | Bristly starbur | *Eleusine indica* (L.) Gaertner. | Goose-grass |
| *Ageratum conyzoides* (L.) | Goat weed | *Euphorbia spp.* | Asthma herb |
| *Amaranthus spp.* | Slender amaranth | *Ipomea spp.* | Ivy morning glory |
| *Bidens pilosa* (L.) | Spanish needles | *Parthenium hysterophorus* (L.) | Congress grass |
| *Chenopodium album* (L.) | Common lambsquarter | *Portulaca oleracea* (L.) | Common purse-lane |
| *Commelina spp.* | Climbing dayflower | *Sida spp.* | Prickly fan-petals |
| *Convolvulus arvensis* (L.) | Field bindweed | *Solanum nigrum* (L.) | Black nightshade |
| *Conyza spp.* | Canadian horseweed | *Sonchus spp.* | Smooth sow-thistle |
| *Corchorus tridens* (L.) | Wild jute | *Sorghum halapense* (L.) Pers. | johnson grass |
| *Cynodon spp.* | African stargrass | *Trianthema spp.* | horse pulse-lane |
| *Cyperus spp.* | Roadside flatsedge | *Tridax procumbens* (L.) | Coat-buttons |
| *Datura spp.* | Devil's snare | *Xanthium strumarium* (L.) | common cocklebur |

Source: Cotton Production Practices 2017 (ICAC)

yield. Weeds are reported to be a key limiting factor for cotton yield losses. Weeds not only compete for nutrition but also form leaf canopy over cotton and may hinder the growth of crop plant. Weeds are also considered as an alternative host for CLCuV (Rehman *et al.,* 2017) and several insect pests. Weeds serve as source of reservoirs of viruses inoculum as reported in case of TYLCV (Ghanim 2014). Every crop has a critical period of weed control (CPWC), which refers to the short time duration during which the crop must be weed free. In cotton, the CPWC is the first 15 to 60 days. Maximum yield can be derived when there is at least 95% weed control (Ramachandra *et al.,* 2016).

### Effect of weeds on cotton growth

Weeds compete with cotton for nutrients and have the ability to assimilate their biomass much faster than cotton, which results in reduced crop height due to delay in weed removal (Bukun *et al.,* 2004). Number of sympodial branches, fruiting points, boll number and boll weight are badly affected by prolonged delay of weed removal (Velayutham *et al.,* 2002). Significant reduction in boll numbers per plant and boll weight in un-weeded check, was observed by Srinivasan (2003). Un-weeded control produced less no of sympodial branches, boll number plant and boll weight in cotton (Sadangi *et al.,* 2006).

### Weeds affect fiber quality

Fiber quality is severely affected by weed density. Fiber length, uniformity, strength and micronaire are characteristics of cotton fiber, which are affected by weeds. The canopy formed by weeds results in restriction of air movement and increase of moisture level which may cause boll rot and quality losses. The addition of foreign material in cotton at harvest may results in reduction of cotton grade and decrease in price. The interference caused by weeds during harvest may also cause loss of cotton quality (Smith *et al.,* 2000).

### Weeds act as reservoir of insects

A large of number of cotton insect pests except boll weevil, pink bollworm and cotton leafworm, have a wide range of host plants (Fye 1980). Weeds serve as a reservoir of insect and spider mite pests that may invade and damage the crop. The contribution of weeds to pest problems is highly variable, with greatest dependence on climatic conditions during any particular year. Insect pests such as the lygus bugs, false chinch bugs, beet armyworms, stink bugs and spider mites attack cotton crop after their weed hosts are destroyed (Gross and young, 1977).

## Major Pests of Cotton

A large number of insect pests attack the cotton crop. These fauna can be divided in two categories: sucking and chewing insects. Sucking insects mainly include: whiteflies, thrips, aphids, jassids, mealy bugs and mites (Azam *et al*., 2013; Chaudhry *et al*., 2009). Chewing insects are comprised of leafworms, cotton bollworms, pink bollworms and spotted bollworms, which directly damage cotton bolls. It is estimated that about 50-60% losses in cotton yield are caused by sucking and chewing insects (Saini *et al*., 2009). A variety of chemical insecticides have been used to control these insects which have serious threats to environmental and human health (Oerke 2006). The indigenous production of pesticides is on the rise in Asia. In Pakistan pesticides worth US$ 227.88 million were produced in 2013 and annual import value accounted for more than US$ 80.28 million (Economic Survey of Pakistan, 2013-14). The continuous use of these chemical insecticides has resulted in the development of insect resistance to insecticides in almost 500 different species of insect pests (Sanil and Shetty 2011; Schnepf *et al*., 1998).

### Insects with chewing type of mouth parts

The cotton bollworms, *Helicoverpa armigera* (Hub.),

**Insect pests of global importance**

| Sap Sucking Insects | | Insects with chewing mouth parts | |
|---|---|---|---|
| **Scientific name** | **Common name** | **Scientific name** | **Common name** |
| *Amrasca spp.* & *Empoasca spp.* | Jassids & leaf hoppers | *Pectinophora gossypiella* (Saund.) | Pink bollworm |
| *Aphis gossypii* (Glover) | Cotton aphid | *Helicoverpa armigera* (Hubner) | Cotton bollworm |
| *Bemisia spp.* & *Trialeurodes spp.* | Whiteflies | *Helicoverpa punctigera* (Wallen.) | Australian bollworm |
| *Thrips spp., Frankliniella spp.* & *Caliothrips spp.* | Thrips | *Helicoverpa zea* (Boddie) | Corn earworm |
| *Creontiades spp.* & | Mirid bugs | *Heliothis virescens* (F.) | Tobacco budworm |
| *Diparopsis spp.* | Red bollworm & Sudan bollworm | *Earias spp.* | Spotted bollworms |
| *Dysdercus spp.* & *Oxycarenus spp.* | Cotton Stainers & seed bugs | *Spodoptera spp.* | Cotton army worm |
| *Phenacoccus solenopsis* (Tinsley) | Cotton mealy-bug | *Anthonomus grandis* (Boheman) | Boll weevil |

Source: Cotton Production Practices 2017 (ICAC)

*Heliothis virescens* (Fab.) and the other related species *Helicoverpa punctigera* (Wallen.) cause significant damage to cotton across the globe. A single *H. armigera* larva can damage up to 30-40 bolls (Aggarwal et al., 2006). The precise identification of the species is very important because *H. armigera* has evolved resistance to insecticides (Aggarwal *et al*., 2006). *Helicoverpa* adults can produce large number of eggs and because of their mobile nature, populations increase rapidly under favorable environmental conditions (Kurban *et al*., 2005). The pink bollworm *Pectinophora gossypiella* (Saund.) and the spotted bollworm *Earias* spp. are major pests in America, parts of Africa and Asia. The symptoms of the pink bollworm attack include: damaged buds, green bolls with exit holes, rosette flowers, lint discoloration, early boll senescence and burrowed seeds. While the pink bollworm feeds mainly on flowers and young bolls, the cotton bollworms and spotted bollworms can feed on leaves and all other fruiting parts. The spotted bollworms also bore into terminal shoots and stems to cause stunting of plants. Squares, flowers and bolls are damaged completely, thereby resulting in severe economic losses. Early opening is an important symptom when spotted bollworms infest cotton bolls. The presence of predators and other mortality factors influence the survival rate of bollworms. The cotton leafworm, *Spodoptera litura* (Fab.) is an important chewing pest in Pakistan. Eggs are laid in groups. Neonates scrape and feed creating holes in the leaves thereby hindering photosynthesis, which leads to weak bolls and poor productivity. The cotton boll weevil is a major pest in USA and Latin America.

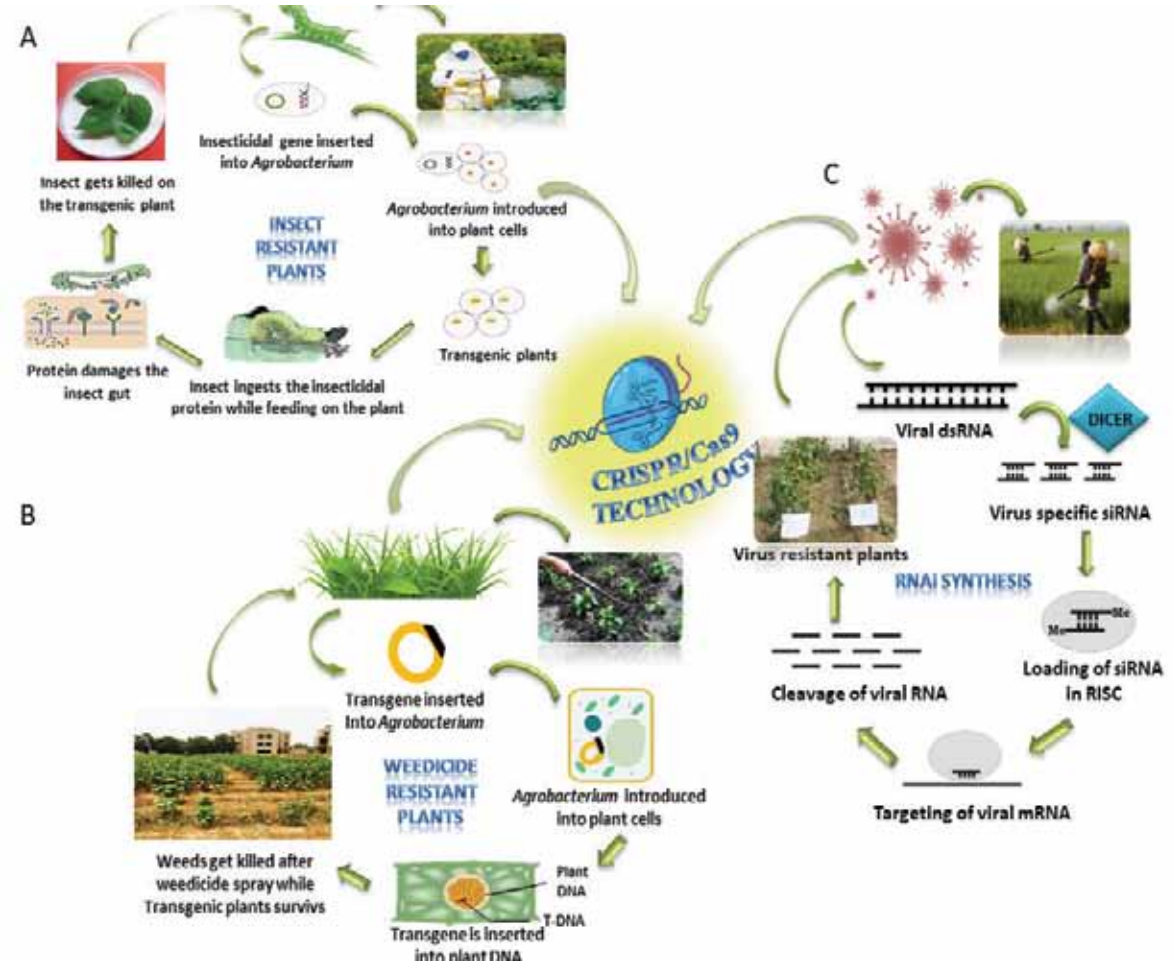
## Sap sucking insects

The whitefly- *Bemisia tabaci* (Genn.) is considered to be the most widespread and the most damaging of all the sap-sucking insect pests of cotton crop across the globe. Aphids cause significant damage in Latin America, Europe and parts of Africa. Jassids and leafhoppers are major pests in Africa and Asia. Thrips are major pests in USA and many parts of the world. About 50% yield loss is due to whitefly among all sucking pests flourishing on cotton plant (Khan *et al*., 2015). Whiteflies feed on phloem sap thereby affecting photosynthesis due to leaf damage, sooty mold and stickiness, which results in low yields and poor fibre quality. Whiteflies also transmit the Cotton Leaf Curl Virus (CLCuV), which is a single stranded DNA (ssDNA) virus that belongs to *Gemini viruses* and causes Cotton Leaf Curl Disease (CLCuD). The virus particles that are ingested through stylets reach the salivary glands through the gut and the hemocoel and finally transmit infection during feeding, about 8–12 h after viral acquisition (Brown *et al.,* 1995). The leaf curl disease is a major problem in India and Pakistan. The first severe epidemic of CLCuV appeared in 1992-93 in Pakistan and caused a loss of 7.9 million bales. It was estimated that during 1992-97, CLCuV caused US $5 billion losses to cotton sector in Pakistan (Maharshi *et al*., 2017).

Amongst other sap sucking pests, the Dusky cotton bug, *Oxycarenus spp.* affect seed quality and lint; thrips lacerate leaves and cause serious damage; jassids cause severe leaf damage and symptoms of hopper burn thereby resulting in low yields; aphids cause damage to foliage and transmit viruses; mealy bugs, *Phenacoccus solenopsis* (Tinsley) feed on leaves and stems to stunt the plants and cause yield losses. Mealy bugs have been reported from Nigeria, Benin and Cameroon in West Africa; India, Pakistan, Thailand and Taiwan in Asia and from New Caledonia in the Pacific (Karar 2008). The first outbreak of mealy bug in Pakistan was reported in 2005 and in 2006-07, it affected the whole cotton belt of Pakistan (Abba et al., 2009). It has been observed in India and Pakistan, naturally occurring biological control keeps mealybug populations under control, if the ecosystems are least disturbed by chemical pesticides.

## Conventional weed management

In past, the only reliable method of removing weeds was manual hoeing but it was not considered beneficial due




**A schematic diagram showing manual and biotechnological approaches to control Insect pests, weeds and viruses in cotton**. (A) Representing manual spray method to control insects in cotton and an alternative biotechnological approach (genetic engineering/ CRISPR/CAS9) to produce genetically modified crop. (B) Showing manual hoeing for weed removal and an alternative approach (genetic engineering/Crispr/Cas9) to produce weedicide resistant cotton. (C) Showing manual spray method and siRNA and CRISPR/CAS9 approach to produce virus resistant cotton.

to time and labor it required. Non-chemical methods are often found not viable because of input required (Latif *et al.,* 2015). A number of different herbicides have been developed to control weeds. Ikram *et al.,* (2012) tested pre-emergence herbicides such as Pyroxasulfone, Pendimethalin, S-metolachlor and reported that excessive nutrients loss was effectively controlled by the application of herbicides along with significant improvement in the cotton yield and growth. The use of early post-emergence or post-emergence as lay-by application of herbicides is also another option for weeds control in cotton (Jabran, 2016).

## Weed Control Using Biotech Herbicide Tolerant (HT) Cotton

Herbicide resistant-cotton became popular in US and other industrialized countries with the development and release of glyphosate-resistant GM cotton by Monsanto in 1995. Considering the tedious methods of manual weeding or tractor based inter-culture, weed management through broad-spectrum potential of certain herbicides on HT-GM-crops gained popularity soon. Glyphosate resistant HT cotton (Round-up Ready Flex) was developed using '*cp4-5-enolpyruvulshikimate-3-phosphate synthase'* (*epsps*) gene. A '*bialaphos resistance (bar) gene*' was used to develop glufosinate resistant HT-cotton. Extensive use of glyphosate resulted in resistance development in weeds notably in *Amaranthus palmeri* in many countries including the US (*THE ICAC RECORDER*, 2006). This prompted the stacking of genetically engineered events to confer multiple-resistance to dicamba, glufosinate and glyphosate in transgenic cotton varieties. The 'three-genes' based herbicide tolerant cotton varieties have been approved for commercial use in the USA. For dicamba resistance, dicamba monooxygenase *DMO* gene from *Pseudomonas maltophilia* (a soil-bacterium) was utilized (Behrens *et al.,* 2007). The application of registered formulation of 2,4-D + glyphosate and dicamba on 2,4-D and dicamba-resistant soybean respectively, sufficiently controlled susceptible and glyphosate resistant pigweeds (Palmer amaranth and tall waterhemp) and common ragweed

(Inman *et al.,* 2016). These formulations did not significantly disturb soil microbial activities related to nutrient cycling in the soybean rhizosphere and confirm their effectiveness to control glyphosate resistant and other herbicide resistant weeds without disturbing beneficial activities of soil microorganisms (Figure 2B). (Nandula *et al.,* 2016). Currently, an estimated 915,000 metric tons of herbicide active ingredients valued at $15.5 billion are used each year to control weeds worldwide and more than 485 biotypes from 252 weed species are resistant to 163 of 281 different herbicides (Fabian Menalled., 2017).

## Conventional methods of insect pest management

Integrated pest management (IPM) is the intelligent selection and use of all pest control actions to ensure effective pest control with least negative effects on the ecology and environment (Kranthi, ICAC). Farmers across the globe rely on chemical pesticides that cause problems on several fronts. Thus far 14,644 cases of insect resistance to insecticides have been reported in 597 insect species to 336 insecticide compounds (IRAC., 2016). Out of the twenty insect species that have the greatest propensity for resistance, six of them are cotton pests. Insecticide Resistance Management (IRM) and IPM form the basis for sustainable pest management in cotton. Integrated pest management methods include all strategies that are expected to support ecosystems for a healthier environment. Biological control and cultural methods are preferred to fulfill such an objective. The OECD (Organization for Economic Cooperation and Development) has predicted that the biopesticide share may grow to 20% of the world's pesticide market by 2020 (Whalon and Wingerd, 2003). Genetically engineered cotton must be considered as one of the strategies in IPM to enable long term sustainability and effectiveness of the technology.

## Insect pest management using genetically engineered insect resistant (IR) cotton

Plant transformation provides an effective platform for cultivar improvement as well as for studying gene function in plants (Rao *et al.,* 2009, 2011a, 2011b). *Bt*-cotton expresses proteins encoded by crystal (*cry*) and vegetative insecticidal protein (*vip*) genes derived from the soil bacterium *Bacillus thuringiensis* (*Bt*). The *Bt* proteins deployed in *Bt*-cotton are considered to be toxic to Lepidopteran insects and safer to human beings and other non-target organisms. After integration into plant genome, these genes are inherited and expressed like other plant genes and have shown good control efficacy on bollworms. Two main approaches have been used to express insecticidal proteins (Jouanin *et al.,* 1998), which targets the digestive system of insect pests (Schuler *et al.,* 1998). Using plant-derived genes, is an important approach, e.g. the genetic information that code for enzymes like proteinase inhibitors, amylase inhibitors, cholesterol oxidase or lectins (e.g. the snowdrop lectin (GNA) of *Galanthus nivalis* L.; Amaryllidaceae). The second approach uses genes from *B. thuringiensis* that express insect-toxic proteins – mostly the *cry* (Schuler *et al.,* 1998) and *vip* genes. Cowpea trypsin inhibitors and Cry toxins were jointly expressed in biotech-cotton varieties commercialized in China. However, majority of the insect resistant GE cotton events are based on *Bt* toxins.

## RNAi approaches to combat insect pests and virus attack

Ribonuclei acid interference **(**RNAi) for gene silencing, is one of the largely used approaches against some insects like whitefly and pathogenic viruses like CLCuV (Yasmeen *et al.,* 2016). RNAi technology has been used to developed GE cotton for resistance against *Geminiviruses* (Zha *et al.,* 2011; Shepherd *et al.,* 2009) and insect pests. Recently, resistance through RNAi has successfully been applied against Bean golden mosaic virus in Brazil (Aragao *et al.,* 2013). Similarly, control of CLCuV through application of RNAi against different genomic regions of the virus has also been reported (Ahmad *et al.,* 2017, Yasmeen *et al.,* 2016). However, in case of RNAi silencing 'knocks-down' occurs in a gene but the cells might still have some gene expression and contain the transcripts. It is also reported in case of CLCuV that the virus takes over the cotton plant in subsequent generations.

## CRISPR/Cas9 based insect, virus resistance and weed control in Cotton

Clustered Regularly Interspaced Short Palindromic Repeats CRISPR RNA (crRNA) can help guide the CRISPR associated Cas9 endonuclease to scan the invading DNA and cleave the target sequence. CRISPR/Cas9 is one of the most widely adapted genome engineering systems and has been successfully used in several species ranging from simple microbes to complex plants and animals. The *begomoviruses* (family *Geminiviridae*) associated with cotton leaf curl disease (CLCuD) pose major threats to cotton production in India, Pakistan, and other parts of the Asia. Methods to control these viruses depend not only on controlling production of the circular, ssDNA genome but also two satellite DNAs, alphasatellite and betasatellite. Recently, CRISPR/Cas9 has successfully been used as a tool to engineer virus resistance in plants in general and cotton leaf curl virus (CLCuV) in particular, either by directly targeting and cleaving the viral genome, or by modifying the host plant genome to introduce viral immunity.

Four recent studies confirmed that the CRISPR/Cas9 system could efficiently confer resistance to *Geminiviruses* in plants. *Nicotiana benthamiana* plants expressing the CRISPR/Cas9 machinery exhibited resistance against TYLCV, Beet curly top virus (BCTV), and *Merremia* mosaic virus (MeMV). All of these studies demonstrated that *N. benthamiana* plants expressing the CRISPR/Cas9 system showed reduced viral titers, which ultimately eradicated or significantly reduced disease symptoms (Iqbal *et al.,* 2016). Herbicide resistant rice was developed through discrete point mutations in the

rice ALS gene using CRISPR/Cas9-mediated homologous recombination (Sun *et al.,* 2016).

## Conclusion

Cotton plants encounter a range of biotic stress factors throughout the season. Insect pests, diseases and weeds are the major constraints in crop production. The recent discovery of RNAi and CRISPR CAS9 offers great opportunities to develop multipronged strategies to mitigate biotic stress factors in an effective manner to ensure sustainable control of insect pests, diseases and weeds in a sustainable and eco-friendly manner.

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# Proceedings and Recommendations of the 14th Meeting of the 'Latin American Association for Cotton Research and Development' (ALIDA)

Keshav R. Kranthi & Lorena Ruiz, International Cotton Advisory Committee, Washington DC.- USA

The 14th ALIDA meeting was held at Maceió, Brazil, on August 28th 2017 on the theme *'New technologies for Boll weevil management'*. The meeting was organized jointly by the International Cotton Advisory Committee (ICAC), the Food and Agriculture Organization of the United Nations (FAO), the Brazilian Agricultural Research Corporation (EMBRAPA), Brazil and the Brazilian Cooperation Agency (ABC / MRE).

## Background

The Latin American Association for Cotton Research and Development (ALIDA) was formed in 1986. Thus far 14 network meetings were held in various countries of the region in Argentina (1986, 1997, 2010 and 2011), Bolivia (1999), Brazil (1991, 2003 and 2017), Colombia (1993, 2005 and 2013) Nicaragua (1995), Paraguay (2001) and Peru (1988). The primary objective of ALIDA is to facilitate active interactions amongst researchers of Latin America and also with experts of other countries to discuss challenges, share experiences and knowledge with an aim to strengthen the Latin American cotton sector.

## Inaugural Session

In her opening remarks, Mrs. Cecilia Malaguti (ABC/MRE) described IBA and ABC initiatives under the Trilateral South-South Cooperation to strengthen the cotton sector in Africa, Latin America and the Caribbean. Ms. Adriana Gregolin (FAO) welcomed the participants and emphasized the need for combined efforts of ALIDA and FAO projects for the progress of cotton sector in Latin America. In his presidential address, Dr. Sebastião Barbosa (EMRAPA) described ALIDA as a platform for effective exchange of knowledge and research findings for the progress of cotton research in the region. He said that the boll weevil and bollworm are of serious concern to the major cotton growing countries in Latin America and ALIDA can address these problems effectively. Dr. Keshav Kranthi (ICAC) highlighted the rapid strides made by the Brazilian cotton for yield enhancement and the experiences of USA and Mexico in boll weevil eradication which he said could be considered as brilliant case studies to prepare developmental plans for the benefit of Latin America. Ms. Lorena Ruiz (ICAC) reiterated the importance of cotton in the world economy and enlisted the challenges facing Latin America. Engineer Eduardo Román facilitated and compered the meeting.

### Participants

Thirty-six participants from nine countries (Argentina, Brazil, Bolivia, Colombia, Chile, Mexico, Paraguay, Perú and USA) attended the meeting.

Sebastião Barbosa - EMBRAPA, Brazil;
Liv Soares – EMBRAPA, Brazil;
Joao Henrique Zonta - EMBRAPA, Brazil;
Fatima Grossi, EMBRAPA, Brazil;
Raimundo Braga - EMBRAPA, Brazil;
Odilon Reny - EMBRAPA, Brazil;
Franklin Suarez – MINAGRI, Perú;
Marité Nieves – INIA, Perú;
Jose Arturo Távara – INIA, Perú;
Eduardo Barragan – CORPOICA, Colombia;
Sofia Ortiz – MARD, Colombia;
Jairo Palma – CONALGODON, Colombia;
Juan Campero – FEDEPA, Bolivia;
Juan Carlos Cousiño – IPTA, Paraguay;
Moisés Santiago Bertoni – IPTA, Paraguay;
Mario Mondino – INTA, Argentina;
Guillermo Carrera – Ministry of Production, Argentina;
Carlos Oscar Mitre – A.P.A.Z IV, Argentina;
Silvia Navarro – UTALCA, Chile;
Jesús García – SENASICA, Mexico;
Stacy Plato – Plato Industries, USA;
Scott Plato – Plato Industries, USA;
Adriana Gregolin – FAO-RLC;
América González – FAO-PY, Paraguay;
Eduardo Román – FAO-CO, Colombia;
Gonzalo Tejada – FAO-PE, Perú;
Ronald Franz Quispe – FAO-BO;
Joelcio Carvalho – FAO-RLC, Chile;
Emmanuel Salgado – FAO-RLC;
Palova Souza – FAO-BR, Brazil;
Eliane Faria – FAO-BR, Brazil;
Aurelie Duray – FAO-RLC;
Cecilia Malaguti do Prado – ABC;
Ana Elisa Larrarte – ABC;
Lorena Ruiz – ICAC, Washington DC
Keshav R. Kranthi – ICAC, Washington DC.

Participants of the ALIDA Meeting

## Session-1

*Sustainable Cotton Development in Latin America: The Role of ALIDA*

Dr. Sebastião Barbosa, EMBRAPA, Brazil

ALIDA needs to set up an action plan with specific focus on pest management. Boll weevil is a major problem in Latin America. After its arrival in Brazil, the cotton scenario changed. Though the area declined from 4.0 million to 1.0 million hectares, new technologies were used to enhance the yields from 300 kg to 1800 kg per hectare. Even under rainfed conditions, yields reached 2000 kg/ha in Mato Grosso. High productivity and premium quality have become the hallmarks of Brazilian cotton. The Brazilian Cotton Growers Association (ABRAPA) is very strong with capabilities to strengthen the cotton sector. Boll weevil can be menacing. For effective boll weevil eradication in Latin America, there is a need to develop simple science-based strategies that must be disseminated through participatory training programs and implemented vide area-wide-community network programs in an organized manner across countries. There is a need for trained people, laboratories, experimental fields and R&D programs. Some of the key components of the management strategies are 1. Short-season varieties 2. Destruction of stubbles 3. Uniform planting dates 4. Regular monitoring 5. Need based appropriate chemical sprays and clean cultivation. Organic cotton cultivation can be risky due to boll weevil infestation. ALIDA should play a major role in exchange of information, sharing of experiences, organizing participatory training at the field level and coordinating activities between Government agencies, NGOs, producer organizations and farmers.

EMBRAPA is introducing three new transgenic varieties, one which produces long fibres. EMBRAPA and ABRAPA are collaborating to develop cotton tolerant to herbicides, diseases and nematodes. The program is also focusing on production practices and soil management. Some of the challenges are related to development of machinery for small scale farming systems, weed management, reducing cost of production and sustainability especially in dryland farms. The ICAC, FAO and ABC must facilitate cooperation between Latin American countries to enhance yields with reduction in manual drudgery and cost of production.

## Session-2

*Overview of the Cotton Sector in Latin America*

Mr. Joelcio Carvalho, FAO-RLC

There is a need to develop strategies for crop rotations especially in small-scale farming systems to ensure subsistence of food crops and improvements in soil health and ecology. The major problems in the region are related

to limited access to finance, market information, technical assistance and inadequate knowledge. A good farmer is not the one who produces the most, he is the one who best knows how to sell and in the best condition. The FAO together with ICAC developed indicators to measure social, environmental and economic performance (SEEP) of cotton production systems. Attempts are being made to collect and collate baseline data on SEEP indicators on a regional basis so as to ensure proper interventions involving Governments and institutions to work towards sustainable farming systems.

Dissemination of information and transfer of technologies depend greatly on the basic level of education in the rural sector and participation of women. Though decisions are made together in the family, the participation of women is 7% Bolivia, 5% in Paraguay and only 3% in Peru.

In Latin America there is limited interaction among the different actors of the cotton value chain and limited access to cotton varieties adapted to each agro-ecological zone. In Bolivia, Colombia, Paraguay, and Peru many producers manage the crop without access to financing; most of the times producers seek finances from private banks, stockholders with stipulated conditions and fixed prices. Producer associations can make a difference in decision making, planning of the production and sale. Several other initiatives include proposals for productive models, training camps, adaptation of technologies for certification and regional events for institutions, technicians and farmers.

## Discussion

- Ms. Adriana Gregolin: The yields in Brazil are high and low in other countries of Latin America. Can there be a paradigm shift to enhance yields in the region based on lessons from the success story of Brazil?
- Dr. Keshav Kranthi: Lessons from Brazil are very important, not only for Latin America, but for the rest of the world. High yields can be obtained through a combination of short season variety + compact plant architecture + planting pattern and good agronomic management. Great care must be exercised in optimising chemical inputs and GM cotton. Organic farming is possible; but, it must be based on robust scientific strategies using varieties that are developed to sustain organic practices.
- Dr. Sebastião Barbosa: A new paradigm would mean different things for different people. Technological development, modernization and access to information will be the key elements in the present and the future.
- Dr. Eduardo Barragán: Innovation unites research and development. Innovations generate knowledge and money. Linking producers with knowledge and markets is very important.
- Dr. Juan Campero: ALIDA can play an important role in transfer of technologies with active participation of member and non-member countries of the ICAC.

# Panel Discussion On 'Boll Weevil'

Chair: Dr. Sebastião Barbosa, EMBRAPA

Dr. Raimundo Braga Sobrinho: Boll weevil arrived and spread across Brazil after 1983, thereby changing the cotton scenario in the country. The ideal conditions of high temperatures and high humidity favoured establishment and rapid dispersal. From being a major exporter, within a decade of boll weevil damage, Brazil became the world's largest cotton importer. But EMBRAPA and other institutions reversed this soon through new technologies, to revive the cotton sector in Brazil, to make it into a major cotton exporter again. The boll weevil damages fruiting parts all through the season. It has about seven generations per year and reaches menacing proportions. After cotton harvest, the weevil seeks refuge in stubbles and ratoon plants thus obtaining food all round the year. Apart from ideal weather and availability of continuous source of food, lack of regional monitoring, low participation of producer organizations and low adoption of IPM contribute to higher levels of incidence. Management strategies short-season varieties, regular monitoring, use of pheromone traps and appropriate chemical control. It would be important to implement the IPM programs on area-wide scale though collective actions of producer groups across Latin America.

Dr. Keshav Kranthi: A few recent research publications have proposed new arsenal for boll weevil eradication. Two papers from EMBRAPA describe the development of new generation transgenic cotton varieties using cry10Aa genes and identification of double stranded RNA (dsRNA) for gene silencing of chitin synthase-2. Expression of Cry10Aa in transgenic plants was found to cause 100% mortality. Ribonucleic acid interference (RNAi) using chitin synthase dsRNA also resulted in 100% mortality. Therefore, a combination of both events could be expected to be not only highly effective but also sustainable in delaying development of insect resistance to the combination of the two events, mainly because the two approaches have different modes of action. Deployment of the two event-stack combined with the existing boll weevil eradication strategies would immensely strengthen IPM in Latin America. The CpTi (cowpea trypsin inhibitor) based transgenic cotton may be tested for possible efficacy on the boll weevils to explore additional arsenal for control.

Mr. Jesús García Feria: In Mexico, The National Service for Agro-Alimentary Public Health Safety and Quality (SENASICA) regulates management of boll weevil, pink bollworm and the bollworm complex. The producer is obliged to follow a specified planting date, destruction of stubbles within 10 days of harvest and is obliged to have a technician to control these regulatory pests. The binational program which began in 2002, involves the Mexican government, the USDA, state governments, auxiliary plant health agencies, authorized phytosanitary professionals and producer organizations. SENASICA, Government and farmers contribute a third each towards pest control. The Government

institutions, SENASICA, USDA and the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) monitor the program, evaluate results and analyze them for later execution, supervision and follow-up. The main boll weevil eradication strategies include regular monitoring and net-working through weevil-expert, uniform planting dates, destruction of stubbles, pheromone based trapping and four spray applications: two in spring and two to kill diapausing insects. The participation of plant health auxiliaries and producers is vital for control of the weevil. Despite initial apprehensions, the program was implemented on an area-wide basis with active involvement of the Government and all stakeholders thereby achieving successful results. Since 2016, 85% of the cotton area in Mexico is purported to be free of the boll weevil.

Dr. Mario Mondino: In Argentina, the major aim is to reduce the incidence and thereafter eradicate the boll weevil. About 82% of the cotton area is rainfed. This entire area is under the threat of the boll weevil. The objectives are to generate validated models of institutional and technical management for boll weevil control and develop action plans to be organized by a council of cotton farmers, managers and technical assistants, and a technical committee for joint implementation of control measures by farmers. Some of the important management measures are, uniform sowing dates in a narrow-window period, regulating optimum plant density, timely defoliation, destruction of stubbles immediately after harvest, prevention of ratoon emergence, regular monitoring and selective application of insecticides according to damage at specific phenological stage based on economic thresholds. INTA would actively consider developing transgenic technologies using Cry10Aa and the CpTi from China. The Provincial Plant Health Committee (COPROSAVE) designs an annual operational plan as individual farmer based 'property framework' and a 'zonal framework' that is jointly coordinated by a group of technicians using latest technologies including satellite imagery. Registered cotton producers are mandated to implement pest control actions based on the precise locations and extent of infestation. Small producers with less than 10 hectares are required to set up physical barrier called 'boll weevil attract and control tube' 30 days prior to planting to prevent weevils from entering the fields and subsequent to harvest to prevent weevils going to refuges.

Dr. Maria Fatima Grossi de Sá: As of now, boll weevil resistant cotton varieties are unavailable, thereby waranting the need for 18-25 insecticide applications per season accounting for 25% of the production cost. Alternative strategies include rigorous IPM and transgenic varieties. The biotechnological approaches include plant defense proteins, exploring the genome and transcriptome in the boll weevil to search for unique targets for gene silencing, search for new regulatory sequences and promoters. Ribonucleic acid interference (RNAi) for gene silencing is being used to target house-keeping genes that are unique to the insect species. Gene silencing is being attempted by using double stranded (dsRNA) through nano-particle sprays. Transgenic plants developed at EMBRAPA express 12-18 ppm of Cry10Aa leading to 90-100% mortality of the weevils. Field trials will be conducted at Mato Grosso. Micro-injection dsRNA of *chitin synthase-2* caused gene silencing and a decrease in haemolymoph proteins thereby causing 100% mortality of boll weevils. At lower doses of dsRNA of chitin synthase-2 and a neuropeptide, infertile eggs were laid by the treated females.

## Discussion

- Dr. Liv Soares Severino: Do Africa and Asia have the boll weevil?
- Dr. Kranthi: As of now there are no records of the cotton boll weevil in Asia and Africa.
- Ms. Adriana Gregolin: In Mexico, how do producers adopt practices and what role do technicians play? In Argentina, what are the main difficulties in the field?
- Mr. Jesús Garcia: in Mexico implementation is voluntary, but the farmer pays only one-third of the cost, which encourages them to participate. The companies interact with farmers. The technician is dedicated to the sampling of pests and complements our information; traps are used extensively.
- Dr. Mario Mondino: In Argentina, the main constraint is for the small producer with less than 1 hectare farm. They are provided with seed, machinery and technical assistance to help them get organized.
- Ms. Adriana Gregolin: What was the investment in the Cry10Aa transgenic project and how many researchers work in the program?
- Dr. Fatima Grossi: The team has eight researchers and a few technical assistants.
- Dr. Sebastião Barbosa: The research program has a few graduate students. Investment is actually less for a problem of this kind. Some farmers resort to 40 insecticide applications per season. Expenditure for boll weevil control could reach US$300 in some years.
- Dr. Marité Nieves: How is compliance of planting date and removal of stubbles ensured in Mexico and Argentina? In Peru, though stubble clearance is mandatory, there is very less compliance.
- Dr. Mario Mondino: though it takes time, fines are imposed on producers for non-compliance.
- Mr. Jesús Garcia: In Mexico, the producer signs that if he does not destroy the stubble he pays more money. Though, it is difficult to comply with the legal norm, one mechanism is to regulate the irrigation dam based on compliance.
- Mr. Jairo Palma: The Colombian Agricultural Institute – ICA in conjunction with cotton cooperatives, exercise control by retaining 8% of the value of the seed cotton. Once the farmer certifies that the destruction of the stubble

was completed, the farmer can get the retained value back, if it doesn't it is used as a fine for non-compliance.

- Dr. Sofía Ortiz: Colombia has a strict regulation with the sale of seed, sowing time, for each of the producing areas. However, some farmers are imposed fines while some find ways to evade it.
- Mr. Eduardo Roman: *Bacillus thuringiensis* (*Bt*) is being used by EMBRAPA in Brazil and Argentina. Biological control should also be considered by farmers as in some cases it could be cheaper and the only management option.
- Dr. Fatima: *Bt* strains have a large toxin repository and many of them are different from each other in their modes of action.
- Dr. Sebastião Barbosa: Investment in science and research is most important for all countries if they are serious in finding robust solutions to intractable problems.

## Panel Recommendations

Chair: Dr. Sebastião Barbosa

Dr. Sebastião Barbosa

- ALIDA should work towards optimizing and maximizing resources.
- There is a need to develop precisely focused collaborative programs and for a specific meeting in relation to the science and the weevil.
- Success stories and experiences must be shared among countries.

Dr. Raimundo Braga

- ALIDA will need more support from the ICAC to enhance communication amongst researchers through ICT.
- Each country needs to review their strategies against the boll weevil. Protocols that are feasible should be disseimated to farmers.
- Trainings needs must be harmonized for technicians.
- Weekly reporting of production practices will be needed to synchronize planting dates.

Mr. Franklin Suarez & Mr. Gonzalo Tejada

- In Peru the boll weevil is *Anthonomus vestitus*. Due the variable weather conditions, the boll weevil is problematic only in some years. In Senasa, the weevil network has detection points, using pheromone traps, in the port of Callao and on the border with Bolivia. Insecticide sprays in Peru do not exceed 6-7 applications per season for all pests.

Mr. Juan Campero

- Though farmers in Bolivia resort to control the boll weevil, there is doubt on whether it is *Anthonomus grandis* or *A. vestitus*. The cotton varieties are being changed now as part of boll weevil management.

Mr. Santiago Bertoni

- In Paraguay, the cotton area declined from 600,000 hectares to 10,000 hectares, thereby leading to reduction in boll weevil populations. Bollworm *Heliothis* species is a major problem for which farmers spend about US$100 on control methods. First generation Bt-cotton is being used now.

Ms. Adriana Gregolin

- A discussion page on the boll weevil may be initiated by the ICAC/ALIDA/ICRA, with updated information on the boll weevil.
- Each country must organize awareness meetings and training of producers and technicians to control the weevil.
- There is a need to raise concepts of training and biotechnology for boll weevil management.
- Online courses on cotton production technologies must be initiated.

Dr. Fatima Grossi

- Symposia with specific focus on boll weevil management and biotechnological approaches will be conducted within the cotton congress 2018 to facilitate interaction amongst researchers of the Latin American countries

Ms. Silvia Navarro & Dr. Gonzalo Tejada

- Collaboration between institutions can enlarge the scale to make projects more efficient.

# Session-3

*ICAC perspectives - Status and Challenges of Cotton in Latin America*

Ms. Lorena Ruiz, ICAC

The cotton area in Latin America was 5.3 million hectares in 1985, but, declined to 1.3 million hecatres in 2001-02. Currently the area is about 1.5 million hectares with majority of the area in Brazil. Other profitable crops have replaced cotton. There is a correlation between Cotllok-A index and the cotton area. The historical average of production in Latin America is 1.6 million tons, but 2.5 million tonnes were produced in 2010-11. Brazil accounted for 55% of the total cotton produced in Latin America in 1986-87, but the contribution increased to nearly 80%% in 2016-17. The average yield of Latin America increased from 330 kg/ha during the mid 1980s to an impressive 1,170 kg/ha that remained stable over the past 9 years after 2007. Much of this progress must be attributed to the technological progress in Brazil. It is important to compare Latin America with the rest of the world, to understand how far we can go.

A baseline is drawn 98-99 to show how yields in Latin America exceeded the rest of the world with a difference of 420 kg of fiber per ha. The yields vary significantly among countries in the region, with Brazil and Mexico as the largest

producers, followed by Colombia, Peru and Argentina. Until 2001, Brazil imported cotton, but became a net exporter after 2003. Brazil is currently, the fifth largest cotton producer, 4th largest cotton exporter and 8th largest consumer. It occupies the 3rd global rank in yields with 1700 kg fiber per ha. Mexico produces cotton that caters to 50-70% of the domestic consumption with rest of the cotton imported from the US. Argentin aproduces cotton that is in excess of its domestic consumption, and exports the surplus to other countries such as Indonesia, Colombia and Turkey.

The national consumption has been stable for the past 6 years. Colombia produced 128,000 to 159,000 tonnes of cotton in 1990-92, which was 20-30% higher than its domestic consumption. However, production levels declined to 8000 tonnes by 2016. Consumption was 110,000 to 112,000 tonnes during 2003 to 2010, but declined by 50% by 2016 due to competition from Asia. Cotton is now imported from USA and Argentina. Cotton consumption in Peru declined by 55% over the past 10 years, from 125,000 tonnes in 2006 to 57,000 tonnes in 2016. Production declined from 80,000 tonnes in 2006 to 20,000 tonnes in 2016. Production in Paraguay declined from 264,000 metric tonnes in 1990 to 5000 tonnes in 2016. Paraguay was a major exporter in the 1990s. Production in Bolivia declined from 28,000 tonnes in 1995 to 1000 tonnes in 2001. Consumption also declined by 70% from 10,000 tonnes in 2007 to 3000 tonnes in 2016. Thus cotton production underwent radical changes over the past 2-3 decades. Due to the reduction in area, many of the local varieties were lost and cost of production increased due to introduction of less adapted varieties.

The main challenges are, the scale of planning dwindled and sectoral planning became unsustainable, mainly due to frequent changes in policies as influenced by change in Governments. Though much is spoken about the importance and consumption of cotton, synthetic textiles are commonly used. Cotton must be promoted because it is a natural product and provides livelihood to millions of producers across the globe. Synthetic fibres are unnatural and cause environmnetal contamination through micro-fibres. World consumption of cotton has been increasing; but cotton's market share is forecast to continue to decrease from 68% in 1960 to an estimated 23.0% by 2025. Though majority of the world's cotton is being produced using technologies that are common to agriculture, cotton is singled out by vested interests to malign its reputation. The ICAC is focusing its efforts towards enhancing the sustainbility of cotton production systems.

### Discussion

- Dr. Sebastião Barbosa: Brazil has shown that integrated farming can conserve and save water. By increasing yields more cotton can be produced from less area and degraded pasture lands can be reclaimed for agriculture.
- Ms. Silvia Navarro: Digital communication with economies of scale must be used to promote natural fibres.
- Mr. Jairo Palma: the cost of production in Colombia has been on an upward trend. The cost of the seed, especially GMO, is very high. There is only one distributor of cotton seed. This has created a huge problem to farmers as they have to accept the conditions imposed and the varieties offered by the seller.
- Ms. Lorena Ruiz: the ICAC publishes cost of cotton production once every three years. The information is part of ICAC's Technical Section and the report includes information by country in USD dollars. It is important to make cotton more profitable by reducing the cost of production, which in turn would make it more competitive to synthetic textiles.
- Mr. Eduardo Roman: Cotton is now associated more with surgical products as synthetic textiles are gaining ground.

## Session-4

*FAO Perspectives for Sustainable Cotton in Latin America*

Ms. Adriana Gregolin, FAO

The South-South Cooperation for sustainable cotton in Latin America is an innovative intiative. Sustainable cotton production using GMO or conventional varieties through optimization of resources should be based on equitable social aspects for profitable income generation. It is important to work on the issue of efficient marketing with a perspective of inclusive territorial development and poverty reduction. The reality is that about 80% of the Latin America and Carribean sector are family farmers, with farm size of less than 3 ha. The regional FAO - ABC - IBCS project addresses this perspective. The public-private technical institutions in the project countries develop institutional capacities to strengthen the cotton sector by working closely with farmers. The project is framed within the strategic objectives of FAO to reduce poverty, promote integrated agricultural systems, and make agriculture more productive and sustainable using four main concepts of strategic alliances, social innovation, sustainable technologies and inclusive markets. The main challenges for the Latin American countries relate to production constraints, soil health, conservation practices, crop management, density of planting, pest control, financing, low access to credit, production of seeds that has decreased and limitations for a quality seed, machinery for small areas and technical assistance not specialized in cotton. In Paraguay, there is collaboration with EMBRAPA to develop sustainable technologies, production of cotton seeds and associated crops and to conduct training of technicians and professionals of the sector. In Peru, efforts are being made to strengthen producer organizations, support research, produce quality seeds and promote machinery for small farming systems. In Colombia, there is emphasis on producer organizations, strengthening research, professional training, commodity competitiveness and facilitation of access to credit. The overall challenges for actions relate to strategic alliances to strengthen institutional capacities, sustainable technologies for better research

and obtaining quality varieties, crop management, social innovation to increase associativity, facilitating dialogues between producers wherein the private sector must be involved. Additionally, inclusive markets are important for the advancement of regulation of marketing conditions and ease of access to differentiated and niche markets. ALIDA is important to strengthen the capacities in the field as an autonomous group of researchers.

### Discussion

- Mr. Jesús Garcia: You need a different strategy to work with small producers, it is not the same to work with large producers.
- Dr. Raimundo Braga: Prevention of damage by the weevil is very important. Monitoring the cotton fields is as important as monitoring the refuges. The damages of boll weevil are not only reflected in higher cost of production, but also in lower yields.
- Dr. Sebastião Barbosa: While several International organizations believe that small farmers will not have the capacity to compete in the market, it is pertinent to understand that small farmer groups can make good profits through organized marketing. Migration of farmers to cities can be curtailed by giving them access to advanced information and technologies. Farmers should have the right to get the best available technology, including transgenic cotton.
- Dr. Juan Campero: Small farmers are becoming smaller over the years. They need assistance.
- Dr. Keshav Kranthi: About 10 million farmers cultivate 12 million hectares of cotton in India. Majority of them are small farmers. Though the average farm size is 1.2 hectares, the crop means annual livelihood for the family. With the recent advancement in communication through mobile phones, the small farmers also have access to technologies and market information even in the remotest of areas. They assimilate and adopt whatever adds value to their farming.
- Dr. Eduardo Barragán: Participatory research must be inclusive and effective. Rural extension goes beyond technical assistance and there is a need to work on territory perspectives. Information delivery is different for different sections of farmers. Despite whatever is disseminated, the farmer is very practical and takes what is useful for him.

## Session-5

Working Groups: Actions to be Prioritized by ALIDA for 2017/2018

### Group-1

Three recommendations were finalized:

1. Technological innovation, with focus on exchange of genetic material, accessibility to quality seeds and integrated management programs such as the weevil.
2. Transfer and technological adaptation: Scientific knowledge that is generated must reach the farmers.
3. Promotion of cotton consumption: This is a priority issue due to the reduction of production areas in Latin America.

ALIDA activities can be made sustainable by working on common actions, to generate impact, to have a focal point in each country, to raise awareness of activities and work in coordination with other institutions such as ICRA to promote synergies. ALIDA will remain in force as long as it has resources, and that goes in the capacity to generate projects and thus give it visibility.

### Group-2

Eight recommendations were finalized:

1. The ICAC must issue advisories to members on market information for producers.
2. Opportunities to exchange seeds through societies and facilitate access to quality seed.
3. Harmonize regulatory criteria for new investigations of molecules for weevil control.
4. Standardize technical and scientific concepts.
5. Support technological innovation for the mechanization of small-scale farming.
6. Seek support from the IBA - FAO for funding for participation in future congresses.
7. Create the role of technical secretaries to coordinate national actions.
8. Strengthen collective actions for boll weevil management.

## Election of a New ALIDA Team

- Dr. Raimondo Braga, Brazil: Chair
- Dr. Mario Mondino, Argentina: Vice-Chair
- Dr. Eduardo Barragán, Colombia: member
- Dr. Santiago Bertoni, Paraguay: member
- Mr. Jesús Garcia, Mexico: member
- Dr. Marité Nieves Peru: member
- Dr. José Arturo Távara, Perú: member
- Dr. Juan Campero, Bolivia: member

## Closing Session

Mrs. Cecilia Malaguti, Dr. Sebastião Barbosa, Ms. Adriana Gregolin, Dr. Keshav Kranthi and Ms. Lorena Ruiz acknowledged the contribution of Dr. Diana Piedra, ex-Chair of the ALIDA, welcomed Dr. Raimondo Braga as the new chair, the new team-ALIDA members and thanked all the participants for the useful interactive sessions.

# Proceedings and Recommendations of the Seventh Meeting of the 'Asian Cotton Research and Development Network' (ACRDN)

M. V. Venugopalan (ICAR-Central institute for Cotton Research, Nagpur, India),
A. J. Shaikh (ICAR-Central institute for Research on Cotton Technology, Mumbai, India), &
K. R. Kranthi (International Cotton Advisory Committee, Washington DC.)

The 7th ACRDN meeting was held at Nagpur, India on 15-17 September 2017 on the theme *'Production of quality fiber and doubling cotton farmers' income'*. The meeting was organized jointly by the International Cotton Advisory Committee (ICAC), the Indian Society for Cotton Improvement (ISCI), ICAR-Central Institute for Cotton Research (ICAR-CICR) and ICAR-Central Institute for Research on Cotton Technology (ICAR-CIRCOT).

## Background

The first ACRDN meeting was conducted in June 1999 as a regional consultation on insecticide resistance management in cotton at the Central Cotton Research Institute, Multan, Pakistan. The second meeting on the theme "New Genetic Approaches to Crop Improvement" was held in Tashkent, Uzbekistan, on November 14-16, 2002. The third meeting was held at Nagpur, India on June 27-29, 2005. The Chinese Cotton Research Institute hosted the fourth meeting in Anyang, Henan, China, on September 23-26, 2008. The fifth meeting of the Network was held in Lahore, Pakistan in February 2011. The FAO Sub-regional Office for Central Asia and CABI continued providing their support. The Cotton Development Board hosted the sixth meeting in Dhaka, Bangladesh from June 18-20, 2014.

## Inaugural Session

Dr. Terry Townsend, Former Executive Director, International Cotton Advisory Committee (ICAC), Washington DC inaugurated the 7th ACRDN meeting on 15 Sept. 2017. Dr. Townsend conveyed the greetings of Mr. Kai Hughes, Executive Director of the ICAC and emphasized the relevance of cotton research and technologies for the economic development in the Asian region. Dr. AK Singh, Deputy Director General (Crop Science), Indian Council of Agricultural Research delivered the presidential address.

### Participants

Two hundred and thirty nine participants registered for the meeting. Technical experts from India, Bangladesh, Egypt, Australia and USA led the sessions. Participants comprised of farmers, researchers from the public and private institutions, Government officials and experts from trade and industry.

## Sessions

Twenty-nine technical sessions were held during the three-days meeting. The sessions included one plenary session with two speakers, valedictory session with three speakers, one panel discussion, one open forum for young researchers, two open sessions, one poster session and 24 concurrent sessions. A total number of 126 abstracts were received, 40 of them were presented in poster session and 72 as oral presentations. The main thematic areas of the meeting focused on 'doubling farmers income', 'production of quality fiber' and development of sustainable management strategies for whiteflies, leaf curl virus and bollworms. The sessions included better management practices (BMPs) for high yield, cotton mechanization, germplasm exchange, breeding for yield and quality, climate change and abiotic stress, management of viral diseases, whiteflies and bollworms, transfer of technology, application of nanotechnology, nutrient management, CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) and CRISPR Associated System-9 (CRISPER–CAS-9), Ribo-Nucleic-Acid interference (RNAi) techniques, high density planting systems (HDPS), promotion of *Gossypium arboreum* cotton, and contamination and quality evaluation.

### Plenary Sessions

Dr. Terry Townsend, former Executive Director, ICAC delivered a plenary talk on "The role of research in cotton

Dr Terry Townsend inaugurating the meeting

Inaugural Session

development in Asia" and emphasized the need to develop technologies to enhance yields and reduce cost of production to make cotton competitive with synthetic fibers.

Mr. Suresh Kotak, Chairman, ISCI, delivered a plenary talk on the topic "King cotton - Future for Asia" and said that cotton will remain to be the king of fibers because of its excellent qualities that enable it to be used independently as well as in blends with synthetic fibers.

### Valedictory Session

Dr. Md. Fariduddin, Chairman, ACRDN, in his valedictory address spoke on the importance of cotton sector in Bangladesh and the imperative need for cooperative networks in progress of research, development and trade in Asian countries.

Dr C. D. Mayee, President, ISCI, delivered his plenary address on "Novel Technologies: Today and Tomorrow" and reiterated the importance of biotechnology as a game changer in the progress of cotton research and development.

Dr. Mrs. Kavita Gupta, Textile Commissioner, Government of India, delivered the valedictory plenary address and chaired the valedictory session. She spoke on the rich heritage of cotton in Asia and the current relevance of cotton production and utilization to the development of the region. Dr. Kavita Gupta emphasized on the need for doubling farm income and suggested a pathway for doing so through a combination of low cost yield enhancement technologies.

## Recommendations

### Plenary and valedictory sessions

- There is a need to explore new uses of cotton to expand the market share of cotton.
- Genetic engineering and nanotechnology have the potential to impart unique properties to cotton fibers to make it more competitive with synthetic fibers.
- There is a need to develop technologies that can enhance yields and reduce cost of production to make cotton more competitive with synthetic fibers.
- The negative propaganda regarding the high ecological footprint in the cultivation and processing of cotton needs to be effectively countered using scientific studies and data. (Action: The ICAC panel on Social, Economic and Environmental Performance (SEEP) may be requested to address the issue).
- Bangladesh has immense potential for cotton production and mill use. New efforts should be intensified to develop short season varieties for Bangladesh and strengthen crop production technologies in the country (Action: Bilateral agreements between Bangladesh, India and Pakistan may be developed through South Asian Association for Regional Cooperation (SAARC) for germplasm sharing to develop short season varieties).

### Open Session 1

#### Global best practices for high yields

- Best Management Practices (BMPs) for high yield of cotton in Australia, Egypt, Bangladesh and India were discussed. Australian agriculture deploys scientific findings to develop and constantly upgrade BMPs. Publications on sustainable practices are provided to cotton growers every year. Employing good management practices is the only option to improve yields, reduce production costs and make cotton more competitive. Although BMPs are available, there is a need to strategize and prioritize them. Also it is necessary to strengthen the extension system in the Asian region to hasten the diffusion and uptake of BMPs.

### Concurrent Session-2

#### Cotton Mechanization

- Labor shortages and high wages in India, Pakistan and China are prompting the need for mechanization in cotton cultivation in the Asian region. Mechanization makes production systems more efficient and improves the farmers' income significantly by reducing the cost of cultivation particularly the cost of picking. Asian countries must develop region specific machinery suitable for operations in small-scale farms for planting, crop care and harvesting operations.
- Cotton breeders, agronomists, tractor & harvester manufacturers, ginning machinery manufactures, trade and industry and government must work together to achieve mechanization in cotton crop. In view of small size land holdings in Asian region, the low cost machinery developed by Argentina for cotton mechanization may be examined and modified.

## Concurrent Session-3

### Panel discussion germplasm exchange among SAARC countries

- Germplasm resources must be enriched, exchanged and utilized to broaden the genetic based of cultivated cotton cultivars. For effective exchange of cotton germplasm between countries of the South Asian Association for Regional Cooperation (SAARC) region, memoranda of understanding (MoU) and bilateral agreements need to be worked out within the purview of the National Biodiversity Act in respective countries. Sound and systematic benefit sharing protocols have to be established for exchange of cotton germplasm among the private and public institutions after discussion with all the concerned stakeholders.

## Concurrent Sessions

### 4A: Cotton Viral Diseases

- Cotton leaf curl disease (CLCuD) is caused by a complex of whitefly (*Bemisiatabaci*) transmitted Begomoviruses. The disease is a serious threat to American cotton in north India and Pakistan. Recent reports suggest that CLCuD was detected in China and could pose problems to cotton in future. Speakers resolved that quarantine measures need to be strengthened to contain movement of recombinant viruses and whitefly vectors of the leaf curl disease. There is a need to develop and utilize good diagnostic tools to identify, restrict and manage the viruses.
- Plant breeders must give impetus to breeding genotypes for resistance to viral diseases by stacking multiple mechanisms of resistance for durable resistance. The resistant genetic stocks for different strains of viruses may be identified, pyramided and strengthened with transgenes for Ribo-Nucleic-Acid interference (RNAi) based gene silencing so as to ensure sustainable management.
- lant protection scientists must develop integrated strategies for the management of different strains of viruses and different species of the whitefly vector. Monitoring of whitefly vector populations and disease occurrence is crucial for efficient and effective management of whitefly and the leaf curl disease.

### 4B: Breeding for quality & high yields

- Improvement of harvest index is of critical importance in cotton breeding programme especially under rain-fed conditions. New germplasm lines and genotypes with good harvest index have been identified in India, Pakistan and China. These can be used for the development of compact varieties required for High Density planting Systems (HDPS). Work on this aspect needs to be intensified in Asian countries especially India, Pakistan and Bangladesh.

### 4C: Abiotic stress and Climate change

- Climate change is a crucial factor that poses immense risk to cotton cultivation. Research on developing genotypes with specific plasticity to abiotic stress, water logging, salinity and drought has to be intensified to minimize yield losses in the Asian region. Germplasm lines with definite tolerance to abiotic stresses need to be shortlisted and utilized.
- There is a need for systematic studies on the architecture of root system by using modern imaging tools. The variability in rooting pattern in relation to the adaptation mechanisms of cotton varieties to different abiotic stresses needs to be studied.

### 5A: Whiteflies

- The cotton whitefly, *Bemisia tabaci* (Gennadius) is a serious polyphagous pest that causes damage to cultivated crops throughout the world. Different species of whiteflies have been found to occur periodically in an epidemic form in the cotton growing regions of Asia. Hence, an in-depth basic research must be undertaken to understand the factors triggering their periodic epidemics. There is an immediate need to develop effective proactive and pre-emptive strategies to prevent further recurrences of whitefly outbreaks.
- There is a need to strengthen various components of integrated pest management (IPM) for the management of whitefly. Insecticide resistance monitoring and eco-system management are vital to whitefly management programs and hence there is a need to strengthen these aspects of research in India and Pakistan.

### 5B: Socio-economics and technology transfer

- Both customary and contemporary information and communications technology (ICT)-based extension methodologies have certain merits and limitations. There is a need to develop and validate a 'transfer of technology module' integrating all available extension tools so as to accelerate the diffusion and uptake of best management practices (BMPs) in Asia.

### 5C: Nanotechnology and its applications in Cotton

- A networking project on "Application of Nanotechnology in Cotton" may be initiated among the cotton growing countries to tap the potential of nanotechnology across the cotton value chain.
- Biotechnology and nanotechnology tools must be used to develop novel methods of traceability to detect the fiber genetic and molecular identity through the cotton value chain.

### 6A: Bollworms- Integrated Pest Management (IPM) and Insecticide Resistance Management (IRM).

- Pink bollworm has been reported to develop resistance to Bt-cotton. The pest is causing serious damage to Bt-

cotton in India and Pakistan. There is an imminent need to fine-tune management strategies based on genotypes that express Bt genes in homozygous condition, deployment of short season varieties, identification of appropriate sowing time for different regions, pheromone based mass trapping and mating disruption techniques, sterile insect release techniques and cultural practices that ensure disruption of diapausing insects.

- There is a need for basic studies that are essential to understand the biology of key pests of cotton so that eco-friendly protection technologies could be developed without the need to resort to repeated use of insecticides.
- The use of synthetic pyrethroids on cotton may be discouraged especially during the early stages of the crop as overuse or misuse of these insecticides induces resurgence of whiteflies as well as the cotton bollworms. In addition, excessive use of synthetic pyrethroids disrupts the cotton crop ecosystems, the crop cycle and reproductive phase of the crop, which could necessitate additional sprays.
- Management of insect resistance to insecticides and Bt toxins is extremely important to ensure sustainable efficacy of insecticides and Bt cotton. Continuous monitoring of resistance of *Helicoverpa armigera* &*Pectinophora gossypiella* to new insecticides and the two Bt proteins, Cry1Ac and Cry2Ab needs to be done on priority. Pest management recommendations must emphasize the need for refugia compliance and also to avoid overuse and misuse of pesticides and Bt-cotton.

### 6B: Nutrient management technologies

- There is a narrow genetic variability in the working collection of germplasm across the Asian region. Hence, improved management technologies like manipulating plant geometry, use of foliar nutrition to supplement soil application and plant growth regulators for canopy management must be developed to harness high yields. These technologies should be standardized, validated, refined and deployed as components of best management practices (BMPs).
- There is a need for extensive testing of *Trichoderma* and *Azotobacter* bio-films to establish their role in altering soil nutrient dynamics and enhancing plant growth. If consistent benefits are obtained, these biological products can serve as cost-effective and environment-friendly inputs for yield improvement in cotton.

### 6C: Bio-reviews

- Multi-parental Advanced Generation Inter Cross (MAGIC) populations help in shuffling of genes across different parents enabling novel rearrangement of alleles. This method also brings in greater genetic variability and enhanced chances to get best combination of desirable genes and phenotypic selection in advanced generations thereby reducing the frequency of deleterious/undesirable alleles from donors. MAGIC populations may be used for precise quantitative trait loci (QTL) mapping and breeding of multi-trait varieties.
- The phyllosphere of cotton harbors significant populations of *Beijerinckia* sp., *Enterobacter* sp. and *Klebsiella*sp. Incidentally, all these belong to Gram –ve type perhaps due to the presence of gossypol in cotton, which inhibits Gram +ve bacteria. These could be used to explore for the presence of novel insecticidal toxins. The toxin genes cloned from *Xenorhabdus* and *Photorhabdus* elicit insecticidal activity and may have the potential for use to strengthen Bt cotton.

### 7A CRISPER-CAS-9 and biotech ideas for cotton

- CRISPER-CAS-9 system is a new potential tool for genome editing and should be exploited for resistance to CLCuD and for knocking down delta-cadinene synthase genes in seeds of cotton to get gossypol free cotton seeds.
- New events of biotech cotton available with the Universities, public sector institutions and private sector organizations may be pyramided for effective and long-term management of cotton pests.

### 7B: Field experiments for high yields

- In the era of changing climate, a re-establishment of optimum sowing window may be attempted for obtaining higher yields. Alternative weed control method of stale-seed bed with cover crop can be encouraged to reduce cost of weed management.
- Plant breeding methods for the selection of novel traits following the creation of new variability are integral components of crop improvement programs. Efficient individual plant selections per progeny in each of the early and segregating generations can reduce cost of plant breeding in terms of time, labor and other resources without compromising on efficiency.

Field visit of the Asian net-work group

### 7C: High density planting system in cotton

- Recently, early maturing compact short season genotypes with high yield potential, possessing good fiber quality, have been developed in India, Pakistan and China. These can be validated for their performance under high density planting systems (HDPS) to harness high yield potential. A SWOT analysis of HDPS can be done to identify specific recommendations. The success of HDPS experiments documented in India can be suitably refined and adapted using locally available compact and semi compact genotypes in other Asian countries to enhance cotton yields and farmers income.

### 8A: Sustainable technologies for high yields

- In Bangladesh, *Rabi* planting of cotton with sustainable intercrops is found promising and should be validated, reaffirmed and recommended.
- Short duration varieties should be developed with good fiber quality attributes suitable for different production systems in Bangladesh.

### 8B: Breeding for *G. arboreum* cotton improvement

- Diploid cotton species *Gossypium arboreum* and *Gossypium herbaceum* are ideally suited for organic cotton production because of their environmental robustness in tolerating biotic and abiotic stress factors. There is a need to intensify both research and promotional activity of *G. arboreum* cotton in all the cotton growing countries of Asia. There is a need to intensify efforts of introgression Breeding to develop new varieties possessing desirable traits such as abiotic stress, pest resistance and fiber quality.

### 8C: Ginning and quality evaluation

- There is a need to reduce the cost of ginning per bale to make cotton more competitive.

## Special Session: Young Scientists Open Forum –New Ideas

Nineteen young scientists presented their ideas and vision for research and development.

The priority areas suggested were as follows:

- Dr. Milia Binte Momtaz: There is a need to strengthen networks amongst researchers for effective exchange of ideas and research methods.
- Dr. Santosh (Dr PDKV): Ensure compliance of IRM strategies for sustainability.
- Dr. A. Arputraj & Dr. P. K. Mandhyan: Develop traceability methods using fluorescent particle based nanotechnologies coupled with bale tagging so as to create a new brand 'Indian cotton'.
- Dr. H. B. Santosh (ICAR-CICR): Breeder and farmer rights must receive top priority in germplasm exchange.
- Dr. Manoj Kumar, Dr. A. Manikandan & Dr. V. Mageswaran: Cotton seed is a valuable source of oil and Protein. Removing gossypol through microbial, biochemical and biotechnological tools can provide excellent proteins as food and feed supplements.
- Dr. Upender Mahesh: Network projects must be developed to use 'Single Nucleotide Polymorphisms (SNPs)' for the development of new varieties with high yield potential.
- Dr. Archana Mahapatra: Nano-cellulose technology provides opportunity for paint and coatings
- Dr. S. Gangadhar: Water management and irrigation can greatly enhance cotton yields
- Dr. J. Joshi & Dr. Rajendra Akhani: Price forecasting protects farmers from risks. Policies should be framed to provide right price for right quality. Digital agriculture will make a huge difference in technology transfer and capacity building.
- Dr. M. Saravanan: Several varieties of *Gossypium arboreum* (Desi) cotton species are amenable for organic farming, which in turn would be an ideal option to combat climate change.
- Dr. R. Raja: Zonation of varieties will solve several intractable problems. Separate conferences should be organized for similar categories of farmers such as small-scale, marginal and progressive farmers.
- Dr. G. Balasubramani and Dr. Rakesh Kumar: Cotton fiber quality can be tremendously improved through biotechnology. Molecular engineering tools should be used to develop bullet proof cotton and fire resistant cotton
- Dr. B. K. Patel: Judicious use of insecticides and monitoring of pesticide quality hold the key for effective and sustainable pest management in the Asian region.
- Dr. V. N. Chinchane: There is an imminent need to reduce cost of production by promoting long linted Desi cotton in HDPS

## Special Session: Taking ICRA forward

Dr. Md. Negm, Vice-Chair of ICRA conveyed the greetings of Dr. Michel Fok, Chairman ICRA. He said that The International Cotton Researchers Association (ICRA) was created in 2012 to compensate the lack of a specifically dedicated international cotton research institute or program. ICRA is an independent organization, open to the membership of any individual researcher working substantially on cotton production research in the world. Researchers from the public and private sectors, retired or in service, can become members of ICRA. ICRA is governed by an Executive Committee comprising of 15 members representing different countries such as 4 from Asia, 3 from Africa, 2 from North America, 2 from South America, 1 from Australia, and 2 from international organizations which are ICAC and

CIRAD). The primary objectives of ICRA are to promote and strengthen networking among cotton researchers mainly through interactions on the ICRA web-site, deliberations at WCRC (World Cotton Research Conferences), information dissemination, management of a database on cotton research activities, facilitating training and sharing of problems hampering cotton production to find solutions. ICRA has updated its web-site integrating wiki function and also to facilitate uploading of user profiles, publications and forum discussions. ICRA is expecting researchers to share new ideas, methods and innovative findings through the network forums on the ICRA website. The 'Pakistan Central Cotton Committee' will soon host the ICRA secretariat. The largest numbers of researchers are concentrated in the Asian region. They have the greatest potential to make a significant impact on ICRA's activity and visibility. ICRA is expecting the Asian researchers to take up the leadership role to initiate a vibrant interactive scientific forum. Recently in June 2017, ICRA initiated the ICRA Young Scientist Innovation Medal within the purview of each of the four regional network meetings in Asia, Africa, Mediterranean and Latin America. The first medal was announced for Asia in August 2017.

## ICRA-Asia Young Scientist Innovation Medal 2017

The International Cotton Researcher Association (ICRA) launched a new medal for young scientists (<40 yrs), in the framework of the four regional cotton research networks in Asia, Mediterranean, Africa and Latin America. Applications for the ICRA-ASIA Young Scientist Innovation Medal 2017 were invited in July with the following criteria:

- The most innovative research work published in a research paper as first author on a subject strictly related to cotton
- The most innovative granted patent as first author on a subject strictly related to cotton
- The total number of citations (Google scholar) from five best papers as first author on a subject strictly related to cotton
- Total number of citations (Google scholar) from all publications all through scientific career, *h*-index
- i10 index and Research Gate (RG) score.

ICRA received 8 applications from Pakistan, China, India and Iran. A committee comprising of six judges from six countries evaluated the applications and arrived at the decision to declare Dr. Abdul Qayyum Rao as the winner of the 'ICRA-ASIA Young Scientist Innovation Medal 2017'.

Dr. Rao works as Assistant Professor at the Centre of Excellence in Molecular Biology (CEMB), University of Punjab, Lahore, Pakistan. He is also a guest professor Humboldt Fellow, Germany. Dr. Rao has a commendable publication record in reputed international journals. His citation records are equally impressive. In addition to his citations, his paper on "*Over-expression of Phytochrome B gene from Arabidopsis thaliana increases plant growth and yield of cotton (Gossypium hirsutum)*" and his patent "*Novel transgenic approach to decrease cost of production in Pakistan*" were considered by the Panel of judges to merit his selection for the Medal.

## Election of New Chair of ACRDN

Dr. P.G. Patil, Director, ICAR-Central Institute for Research on Cotton Technology was elected as the new Chairman of the Network until the next ACRDN meeting. Dr. Md. Fariduddin, Chairman ACRDN and Executive Director Cotton Development Board, Bangladesh, congratulated the new chairman and handed over the charge to Dr. Patil in the valedictory session.

# ADVERTISEMENT

## ICAC -13th Meeting of the Inter-Regional Cooperative Research Network on Cotton for the Mediterranean and Middle East Regions
## Luxor, EGYPT, February 02-06, 2018

### Meeting Venue:

The 13th Interregional meeting will be held at:
SONESTA St. GEORGE HOTEL-LUXOR
Distance from the Airport : 17 minutes, 10.3Km
Distance from railway station : 7 minutes, 2.0 Km
Address : Corniche El Nile Street, East Bank, Luxor-Egypt

Website: www.sonesta.com

### Invitation for participation

The organizing Committee cordially invites researchers and extension functionaries from private and public sector to participate in the interactive sessions. The organizing committee will identify lead speakers. The ICAC shall provide partial sponsorship to researchers of the public sector institutions.

**Language: English**

## Technical Sessions:

- Breeding for yield and fiber quality
- Genetic engineering and biotechnology
- Crop production, protection, economics and extension
- Fiber quality assessment
- Ginning, spinning and weaving

## Visits:

- Valley of Kings –'The Gateway to afterlife',
- Valley of queens and
- Nile Felucca light Lunch

**Gala Dinner at the Temple of Luxor**

For Details: https://www.icac.org/getattachment/tech/Overview/Mediterranean-Meeting-2-6-Feb-2017-E-brochure.pdf