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The ICAC Recorder

International Cotton Advisory Committee

Photo credit: Mr Lawrence Malinga

Special issue (Volume 1):

Cotton High Yields - This Time for Africa

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Editorial

Why are cotton yields so low in Africa, and why have they been so stagnant over the past 30 to 35 years? These two queries lead to many more questions. Are the soils infertile? Is the weather unsuitable for cotton? Is there inadequate water? Are there no technologies for high yields? Is there a problem with technology transfer? Are farmers unable to provide necessary inputs due to poverty?

Paradoxically, low yields in Africa persist despite many favourable conditions for cotton production. Experts would agree that:

- The weather in Africa is highly suitable for cotton, with good sunshine and rainfall;
- The soils are as good as, and probably better than, many other parts of the world where cotton is grown;
- New technologies have been developed in Africa that reach many farms; and
- Farmers are hardworking and apply their best management skills for higher production.

But nothing seems to be working, at least on the yield front. There have been innumerable attempts, made by reputable international agencies over the past several decades, to introduce new cotton-technologies into Africa — mostly related to varietal development, integrated pest management and soil and water conservation — in efforts to enhance yields. Projects with many ideas were formulated by these international agencies; implemented with huge funding and completed as planned, but none of them seem to have resulted in yield enhancement.

This is intriguing, indeed. Are there ideas that haven't been explored in Africa as yet? This September 2018 issue and the forthcoming December 2018 issues of the ICAC RECORDER attempt to explore the ideas for yield enhancement in Africa. This issue has articles that briefly look at the perspectives on African cotton research and ideas from across the world to enhance the cotton yields in Africa. While some ideas are related to the need for new government policies to streamline the market, some deal with 'researchable' problems, and others address the issue of technology transfer. Many ideas were inspired by success stories from the developed world. Will they be relevant for Africa?

In recent years, Australia, China, Mexico, Brazil and Turkey have been harvesting more than 1,500 kg of lint per hectare, with Australia touching a record 2,680 kg/ha in 2014. Interestingly, Turkey harvests 1,800 kg/ha without using biotech cotton. USA has been harvesting about 1,000 kg of lint per hectare. Cotton yields in these countries have been on a significant positive growth curve over the years. A critical analysis shows that the ascent in this growth curve was due to consistent improvements in plant breeding, agronomy and integrated pest management (IPM).

Improvements are happening every year and yields are constantly on the rise. The strategies appear to be based mainly on interlinked elements, such as new varieties that were specifically developed to suit mechanised conditions that demand a particular type of agronomy. The new varieties were designed for a plant architecture that suits spindle-type machine pickers. The plants were of a short stature at less than 100 cm, with a narrow width of 60 to 70 cm, having 10 to 15 productive sympodial branches that bearing 15 to 20 bolls per plant, in a high-density planting system (more than 110,000 plants per hectare). Although Australia, Mexico, Brazil, USA and Turkey were compelled to change the plant architecture and follow canopy management with plant-growth-regulating (PGR) chemicals due to mechanisation, China adopted these strategies only to increase yields. Scientists soon realised that the short-statured plants were more efficient in utilising sunshine, water and nutrients because they could bear adequate number of bolls in a shorter time by expending less energy with more efficiency.

Can such strategies be applied in Africa to break the yield jinx? It is true that no alien technology can simply be replicated, adopted or relocated from one country to another. It is unlikely that technologies developed for a condition in a specific environment for a particular country would be suited for other conditions a different environment in another country. But inspiration can strike, and lessons can always be learned.

The basic principles that underpin the technological change must be elucidated, assimilated and used for the development of concepts, strategies and technologies that must be tested and validated in the local environment of adaptation. It would be a mistake to simply assume that technologies from the developed world would not be relevant for an underdeveloped or developing world. The average lint yield in Africa has been about 350 kg/ha for more than three decades, and this must change. But a change is possible only when someone dares to dream. And dreams can come true when scientists dare to dream and move forward through experimentation.

With this as a backdrop, and with a bank of ideas proposed by cotton scientists from developing and underdeveloped countries, the special September and December 2018 issues on 'Cotton High Yields -This Time For Africa' of the ICAC RECORDER should be seen as the torch bearers for a new tomorrow for the cotton sector in Africa. I earnestly hope that the ideas proposed by cotton researchers soon become the harbingers of hope for Africa.

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The ICAC Recorder

Perspectives on Cotton Research and Ideas for Africa- Proceedings & Recommendations of the XIV Meeting of the Southern & Eastern Africa Cotton Forum (SEACF)

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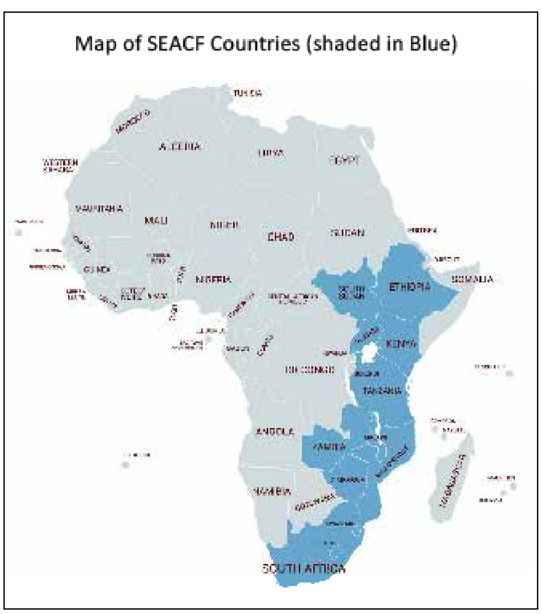
Lawrence Malinga, ARC – Industrial Crops, South Africa
Washington Mubvekeri, Cotton Research Institute, Zimbabwe

The XIV Meeting of the Southern and Eastern Africa Cotton Forum (SEACF) was held at Harare, Zimbabwe, during 4 – 6 July 2018, with a theme "Global best practices for cotton yield enhancement in Africa". Seventy-seven researchers from seven countries (Kenya, Mozambique, South Africa, Zimbabwe, India, Bangladesh and China) attended the SEACF meeting. Dr. Dumisani Kutywayo, chaired the local Organizing Committee and guided Mr. Lawrence Malinga, ARC – Industrial Crops, South Africa and Mr. Washington Mubvekeri in organizing the meeting.

Background

The SEACF was founded 20 years ago. Prior to the formation of SEACF in 1997, the ICAC supported three African regional meetings; the first in 1982 in Sudan, the second in 1984 in Tanzania and third as African Cotton Conference in 1989 in Togo. Subsequently during the first World Cotton Research Conference in February 1994 in Australia, researchers from the Southern and Eastern African countries met and proposed to set up the 'African Cotton Research Network' under the aegis of the ICAC. Dr. Joe Kabissa, Tanzania was elected as the Chairman. The network was merged into SEACF in 1997 to focus more on production research instead of trade issues. So far fourteen meetings have taken place. The past six meetings were held in Tanzania (2008), Zambia (2010), Kenya (2012), Mozambique (2014), Brazil (2016) and



Hon. Ringson Chitsiko and Kai Hughes

Zimbabwe (2018). Dr. Graham Thompson of South Africa served as the SEACF coordinator for more than 10 years. Mr. Adalberto Banze was the SEACF Chairperson of the X1Vth meeting in Harare.

Inaugural Session

Dr. Dumisani Kutywayo, chair of the local organizing committee, Mr. Adalberto Banze, SEACF Chairperson, and Mr. Kai Hughes, Executive Director, ICAC, delivered key note addresses. The Permanent Secretary Mr. Ringson Chitsiko represented the Minister of Lands, Agriculture and Rural Resettlement, Zimbabwe to inaugurate the meeting.

Members of the organizing committee: Mr Kai Hughes, Mr. Lawrence Malinga, Dr Keshav Kranthi, Mr Washington Mubvekeri and Dr Graham Thompson

Session1: Policy Perspectives

Mrs. Nancy Zitsanza, Agricultural Marketing Authority (AMA), Zimbabwe, presented perspectives on the cotton sector governance in Zimbabwe: policy, regulation, and national strategies. Cotton crop is grown by more than 200,000 smallholder farmers in Zimbabwe. It is a major source of livelihood for approximately 600,000 people, including farmers, farm workers, their families and industrial workers. Three farmer unions namely, ZFU, ZCFU and ZNFU are actively involved in cotton production. Independent farmer groups also get involved in cotton production and marketing. The AMA has a regulatory function. Other service providers are the Cotton Research Institute, Research Services Division, Agritex, Ministry of Lands and Agriculture, Ministry of Industry & Commerce and input suppliers. The key players in the cotton value addition are Cottco – countrywide, ETG Parrogate – Masvingo, Manicaland, China Africa – Gokwe, Alliance - Gokwe, Sanyati, Kadoma, Southern Cotton – Mbire, Muzarabani, Rushinga, Makonde and Gokwe. The National ginning capacity is 600,000 metric tonnes. The average ginning out-turn is 41% lint. Over the past seven years, area, production and yields have declined, with a slight recovery in 2017. The key issues affecting the cotton sector are; 1. Low viability of cotton production due to international prices being affected by subsidies; 2. International price volatility; 3. Low yield per hectare – Average national yield is 700kgs/ha of seed cotton despite high yield potential of local varieties; 4. High input costs; 5. Weak sustainability of contract schemes and 6. Recurrent droughts. The National strategies include comprehensive cotton production & marketing framework, cotton input support schemes and cotton to clothing strategy. There is a need to improve productivity through research and development by strengthening support to the Cotton Research Institute and Quton. Farmer training programmes can improve seed cotton yields. There are ample opportunities in the Zimbabwe's cotton industry. There is conducive climate for cotton production. Contractors could increase investment in cotton production. About 70% of cotton is exported as raw lint, though the sector yearns for increased investment in spinning, weaving and textile industry to utilize the lint that is produced. The AMA remains committed to foster the sector's growth by providing a level playing field for all the players in the cotton industry in Zimbabwe.

Mr. Michael Jenrich focused on the importance of one variety, one zone, one gin concept. He said that 10% of the world's cotton is grown in Sub-Saharan Africa (world's fourth largest cotton exporter following the USA, India and Uzbekistan). The Sahel states along the southern belt of the Sahara alone generate $1.5 billion each year by exporting raw cotton, which accounts for up to 35-75% of the agricultural export earnings in this region. In southern and eastern Africa, cotton is cultivated exclusively by smallholder farmers (3 million in number). 18 million people in Sub-Saharan Africa (SSA) depend either directly or indirectly on cotton farming. Mr. Jenrich emphasized that companies investing in production need to be certain to receive cotton, through contract compliance and also by ensuring that companies that do not support farmers can't get cotton procurement licence. A central procurement system needs to be set up so that companies get their investment back. Additionally, concessions are provided for one zone, one gin concept where only a single ginner would be allowed (accredited) to operate in defined

areas. Mozambique cotton production is unique in the region, that is entirely based on a concession system. The ginning companies are granted concession and rights as exclusive buyers of seedcotton in their respective areas of concession. The overall set up is controlled and monitored by the Government. The companies get exclusive right to purchase all cotton grown within the concession area. There is support in organizing district and village task forces and farmer business groups to buyers in recovering loans. Extension package is provided to all registered cotton farmers. Extension training support is offered as a mandatory requirement to get concession. Minimum price is set up to ensure that farmers receive “fair” market price. Procurement of cotton is done at the minimum support price. Seeds, fertilizers, herbicides, improved tools etc., are supplied to farmers. Tanzania is investigating district concession, as districts are easier to manage from an administrative point of view. Single district is easier to monitor and control trade thereby reducing leakage during marketing. This makes the concession more attractive to bidders, thereby potentially getting better offers. Technical and input provision for cotton production is essential to ensure productivity and viability to producers and buyers. Individual control set ups (contract supervision and enforcement) are costly and complex. Controlled systems from field to gin can ensure investment and viability for producers and buyers. Price and service monitoring systems would need to ensure fair trading. Tendered and monitored concession set ups with exclusive production and purchasing based on investment (Gin, infrastructure and support) would need investment in production and productivity. Finally, transparent and effective monitoring of rules and guidelines are pivotal for the sector to progress.

Mr. Fungayi Simbi, Bayer Crop Sciences, proposed public & private sector interventions to improve cotton productivity in the southern & eastern African region. He highlighted the following constraints in the region: Low cotton yields and poor quality seed cotton production; lack of access to credit for key inputs in cotton production; poor funding for national agricultural extension services; lack of investment into the cotton industry; poor compliance of contract integrity by smallholder farmers; side marketing to dodge repaying cotton input advances; use of chemicals that are not recommended; repeated use of the chemicals from same group that accelerates insect resistance; lack of high yielding cotton cultivars; selling of free inputs provided by the Government and use of obsolete technology. He concluded that the collective efforts of private and public partnership resulted in increase of lint production from 25,000 bales in 2013 to 180,000 bales in 2017, investment in 3 ginneries, investment in harvesting machines to consolidate picking and baling, creation of 5,500 jobs from farm to retail and provision of funding support for 1,000 small farmers (4,500ha).

Mr. Jeremiah Tevera, Federation of Farmers’ Unions (FoFU), spoke on the cotton grower’s roles, challenges and expectations in the cotton sector. The cost of production has been on the rise mainly due to the increase in input cost and labour wages. Depletion of draft power due to cattle deaths, diseases and droughts esp. during the 2015/16 season were the main production constraints. Technology adoption is slow because of which the yields were low at 710 kg seed-cotton /ha during the 2016/17 season. Climate change has been causing monsoon anomalies. Input-use is as per blanket recommendations and not based on soil analysis or any diagnostic studies. He said that the Government’s proposal to revive cotton is a good move, but this would be successful only when an enabling environment for private sector participation becomes operational. Further there are issues that need immediate attention. Family labour is taken for granted and includes exploitation of children and women. Exposure to harmful chemicals is detrimental to human health. There is a need for proper education and awareness programmes on compliance with labour rules and proper chemical usage. Businesses operating in cotton growing regions usually manipulate prices of inputs and other products during the marketing season to the disadvantage of producers and consumers. Government interventions would be necessary to prevent such manipulations. Extension service provision should be complementary between Government and the private sector. There are several expectations that include better yields and better prices, reasonably priced inputs available at the farm gate, private sector participation in cotton production funding, prompt payments and access to supplementary irrigation in case of dry spell. There is a need to encourage investment by supporting value chain players. Other expectations are; access to effective management practices for weed, pest and disease control; rebates on duty; import bans via improved producer prices; employment creation; reduced input costs; improvements in farmer education and production system advancements in line with regional and global trends; and export Incentive to capacitate local investment in the sector.

Session 2: Technology Transfer

Dr. Usha Rani Joshua, Central Institute for Cotton Research, India, described front-line demonstration (FLD) experience as a time-tested and successful 'transfer of technology (TOT)' practice in India and its relevance for Africa. The performance of the cotton sector in India has been quite impressive in terms of its achievements in area and production over the years. This is due to the introduction of promising genotypes and efficient production and protection technologies. FLD is based on properly defined and streamlined technology dissemination arrangements. It is a proven cotton extension mechanism with the objectives of demonstrating the usefulness of the latest improved crop production and protection technologies to the farmers as well as extension workers, with an objective to reduce the time lag between technology generation and its adoption. It also enables scientists to obtain direct feedback from cotton farmers, which facilitates reorientation of research programmes to develop appropriate need-based technology packages. FLD is generally implemented in low productivity areas. Farmers are selected by rural institutions in consultation with local leaders and agricultural officers. These officials form part of the FLD team. Bench mark surveys are conducted before taking up the demonstrations which includes information on the crops and cropping system of the area, inter cropping, average yields of cotton, local practices adopted and information on cost of cultivation. Technological interventions are planned and demonstrated by the scientists in selected farmers' fields based on problems identified. Critical inputs needed for the technological interventions are supplied and frequent field monitoring visits are made. A total of 19500 FLDs were conducted during 1996 to 2017 in eleven cotton growing states of India by sixteen participating centres with a budget outlay of US$ 1.6 Million. The FLD results were compared with yields of farms under regular practices with respect to yields, insecticide use and reduction in cost of cultivation. Results showed an average of 18.0% increase in yield. The interventions recommended to improve the status of cotton growers in Africa mainly comprise of 'farmer to farmer' technology dissemination, empowerment and capacity building of farmers, gender mainstreaming, public-private partnerships and promoting information and communication technology in technology transfer. The FLD format is most likely to suit Africa because of the identical nature of challenges in small-scale farming systems in Africa and India.

Mr. Nkosilathi Nkomo, National University of Science and Technology, Zimbabwe, enlisted technologies for the development of value-added products from cotton stalks. Cotton is cultivated primarily for fibres, and little use is made of the cotton stalks which are considered as farm-waste. Approximately two to three tonnes of cotton stalk are generated per hectare in cotton farms. Approximately a million tonnes of cotton stalks are produced in Zimbabwe every season. During the off-season, cotton stalks provide shelter to pathogens and insect pests such as mealybugs and pink bollworms. Generally, stalks are burnt thereby causing environmental pollution. Approximately 0.85 million metric tonnes of CO_2 is produced per million metric tonnes of cotton stalk burnt. Cotton stalks can be used to manufacture particle boards, preparation of pulp and paper, hard boards, corrugated boards & boxes, microcrystalline cellulose, cellulose derivatives as substrates for growing edible mushrooms, organic fertilizers for soil amendment and soil incorporation to improve micro-organism activity and increase seedling growth. These different uses can add value thereby increasing profit margins of farmers to enhance the viability of cotton farming in Zimbabwe.

Dr. Richard Musebe, CABI, Kenya, described initiatives on integrated crop management, pest management, technology transfer and capacity building in smallholder cotton production systems in Kenya. Agriculture contributes 24% to the GDP and 80% of the rural population relies on agriculture as the primary source of livelihood. Eighty per cent (80%) of the land mass in Kenya is dry land; hence only 20% that is arable land is used to feed a population projected to increase to approximately 60 million by 2030. Cotton thrives well in the arid and semi-arid dry land (ASAL) thereby enabling effective use of land that would otherwise be unsuitable for some crops. Cotton provides raw material for multiple industries and thus holds the key for employment, incomes and poverty alleviation. The seed-cotton productivity is low at 488 kg/ha due to poor quality seeds, poor land preparation and declining soil fertility. Pest control is grossly inadequate, though pests account for 20-30% of the total production costs. Farmers have limited knowledge and inadequate technical support that lead to low adoption of technologies. Improving capacity of farmers is critical for better cotton production. It is also necessary to strengthen linkages between the actors in the cotton value chain. Dr. Musebe discussed the transfer of integrated crop and pest management strategies, and suggested measures that would most likely meet the needs of target farmers. He underscored that institutional learning and associated changes are vital elements for successful technology dissemination. He observed that aligning technology attributes with end-user preferences can accelerate uptake. It is important to enhance farmer participation so that farmers are part of the solution rather than just being passive recipients of knowledge that can improve uptake of technologies. This can be facilitated by improving access to capital and finances by linkages with financial institutions. He concluded that efforts aimed at increasing ownership of technologies by farmers in the initial instance can enhance uptake thereby leading to improved cotton productivity.

Session 3: Plant Breeding

Mr. Manuel Maleia, Centro de Investigação e Multiplicação de Sementes de Algodão de Namialo, Mozambique, examined stability and adaptability of cotton genotypes under multi-environmental conditions in Mozambique. He tested the adaptability and performance of 15 new genotypes in comparison with three checks. Maleia concluded that the seed cotton yield is highly affected by environment complex than genotype itself. Among the new genotypes, IMACD 06-6798, IMA1 08-3917 and BA919, were found to have an acceptable adaptability and potential stability.

Mr. Maco Mare, Cotton Research Institute, Zimbabwe, presented results on determining adaptability of medium staple *G. hirsutum* genotypes to the agro-ecological conditions of the Lowveld in Zimbabwe. Cotton variety development in Zimbabwe requires that test genotypes undergo multi-environment evaluation and selection in marginal growing conditions such as the ones in Lowveld. Superior cotton varieties for the Lowveld were identified through field experiments conducted for four seasons from 2013-17. Eight genotypes were code-named 830-01-3, 89-01-2, 85-01-1, 831-01-3, 820-01-1, 812-01-3, 830-01-7 and 83-01-4, to be compared with three standards namely SZ9314, CRI-MS-1 and CRI-MS-2. Seed cotton yield, lint yield, ginning out-turn, boll weight, seed weight, earliness, staple length using the upper half mean length (UHML), micronaire, length uniformity, strength, elongation and fibre maturity were measured. Results revealed no significant 'genotype x environment' interaction for all traits. Genotypic differences were observed on boll weight, seed cotton yield, lint yield and seed weight whilst the other field parameters had no significant differences. Genotypes 83-01-4 and 89-01-2 had the highest seed cotton yields of 1896kg/ha and 1888kg/ha respectively. These also had the highest lint yields of 690.50kg/ha and 694.50kg/ha respectively. No significant differences were observed on all fibre characteristics. All the varieties were within the range of global standards on staple length, micronaire and elongation although 812-01-3 performed poorly with 5.9% elongation. The varieties had good fibre strength which was above the standard of 30g/tex and good maturity above 0.85. Stability analysis using genotype and genotype by environment interaction (GGE) revealed that 83-01-4, 89-01-2 and 830-01-3 were more stable and adaptable in all environments. In conclusion, two genotypes, 83-01-4 and 89-01-2 were identified which were suitable for the lowveld conditions based on the field performance and fibre qualities.

Mr. Kudzai Mandiveyi, Mahyco seed company, presented results of field trials conducted with new Mahyco cotton hybrids for Zimbabwe and Africa. He proposed commercialisation of 6 new hybrids based on their yield superiority over checks by 12-24%.

Dr. Ye Wuwei, State Key Laboratory of Cotton Biology, China, described cloning and expression of drought & salt-tolerant genes in cotton. Abiotic stress (water deficiency and soil salinity) has become a serious global problem affecting the agricultural development and the ecological environment. Salinity is one of the most important abiotic stresses in the world, that severely limits the production of crop. Salt-tolerant cotton cultivars can play a vital role in combating the problem of salinity. The conventional methods of screening cotton genotypes for abiotic-tolerance are laborious and time-consuming. Identification of genes can accelerate the development of salt-tolerant cultivars. Seven salt-tolerance related genes, H^+-pyrophosphatase gene and S-adenosylmethionine synthetase gene and others, were cloned from salt-tolerant varieties of *Gossypium hirsutum*, which were named *GhVP, GhSOS1* and *GhSAMS,* respectively. These genes are being utilized to develop salinity resistant cultivars.

Session 4: Agronomy

Dr. Blaise Desouza, Central Institute for Cotton Research, India, emphasized the importance of conservation agriculture for sustainable cotton production in Africa, based on Indian experiences. Cotton is a commercial crop supporting the livelihoods of millions of farmers in Africa. However, productivity levels are low. Low soil fertility, soil degradation, rain dependence and biotic stresses are some of the key factors responsible for low crop productivity. Furthermore, majority of the farmers belong to the small holding category with limited resources. In such situations, adopting the Best Management Practices (BMP's) can help address this challenge. Conservation Agriculture (CA) is one of the major components of the BMP that holds the key to improving productivity. CA revolves around three basic principles: (i) minimizing tillage, (ii) including a permanent cover and (iii) Crop rotation. Experiences in India indicate that CA is more sustainable and has a wider adaptation because it improves soil quality and crop productivity. Thus, CA systems are best suited to the African countries since soil and water is conserved and improves livelihoods. The results of the CA systems in cotton in India and those of other parts and Africa were summarized. Although, most of the studies indicate synergism when the three technologies are used in combination; there are instances where the CA systems were inappropriate. For instance, in southern Zambia, CA systems had poor yield levels compared to the conventional farmers practice. On the other hand, in Cameroon, CA systems were found to have a positive impact. It is important to understand that a CA technology developed in a region cannot be directly used elsewhere. We need to understand the local situation (soil, climate) and tailor the CA practices to suit the local conditions. Therefore, it is important to learn and adapt to the local conditions by innovating technologies to make it acceptable to the farmer. Full paper by Dr. Blaise on the subject will appear in the December 2018 issue of the ICAC Recorder.

Dr. Matilda van der Westhuizen, ARC-Institute for Industrial Crops, South Africa, evaluated cotton cultivars under irrigation in the southern region. The cultivars DP1240 B2RF, DP1531 B2RF, DP1541 B2RF, Delta 12 BRF, Candia BGRF and Carla were tested during the 2016/2017 growing season in Loskop (Mpumalanga province), Vaalharts and Upington (Northern Cape). Fibre yields differed significantly at different locations and with different cultivars. At Loskop, the highest fibre yield was obtained with DP1541 B2RF (1175 kg ha^{-1}), followed by DP1240 B2RF with 1101 kg ha^{-1}. Yields at Loskop were below average as there was a very high infestation of Cotton stainers. At Vaalharts, fibre yields differed significantly. The highest fibre yield was obtained with Candia BGRF (2141 kg ha^{-1}), followed by DP1240 B2RF with 2074 kg ha^{-1}. Although fibre yield did not differ significantly at Upington, the two best performers were DP 1240 B2RF (2887 kg/ha) and DP 1531 B2RF (2842 kg/ha). The lowest fibre yield was obtained with Delta 12 BRF (2414 kg/ha).

Dr. Md. Farid Uddin, Cotton Development Board, Bangladesh, described cotton seedling transplantation techniques for adaptation to climate change. Bangladesh is one of the wettest countries of the world where a long duration of heavy rainfall is very common. The mean annual rainfall over the country ranges between 2320-6000 mm. June-August is the peak period of rainfall which coincides with the sowing period of upland cotton. As a consequence, fields remain unsuitable and unmanageable for cotton sowing. To overcome this barrier, cotton seedlings were grown in seedbeds covered with polythene mulch and transported to the main field during favourable conditions for transplanting. In 2017-2018, on-farm trials were conducted to identify the most suitable age of seedlings for transplantation. The effect of 4 different seedling ages at transplantation viz. 10, 15, 21 and 28 days on seedling survival rate, yield contributing characters, seed cotton yield and farmers net income was evaluated. Results revealed that seedling age at transplantation significantly affected the seedling survival rate, cotton yield, yield contributing characters and farmers net income. The highest seedling survival rate (98.4%) and the highest seed cotton yield 5.75 t ha^{-1} was obtained when 10-day old seedlings were transplanted, that also gave the highest net income (US$ 2707 ha^{-1}). Thus, the study showed that the optimum age for cotton seedling transplantation was 10 days and with the increase in the age of seedlings used for transplantation, seed cotton yield and farmers net income reduced significantly.

Ms. Cheidza Gwiranenzara, Cotton Research Institute, Zimbabwe, described the impact of conservation agriculture on cotton productivity. Cotton is traditionally cultivated on conventional tillage systems in Zimbabwe which exposes the soil to degradation on a wide scale due to the slow growing nature of the crop during the first six weeks (Cotton handbook, 1998). Unless concerted measures are undertaken to address soil degradation resulting from overworking of the soil in conventional tillage systems, arable land shortages will seriously become a problem in the major cotton growing areas in the near immediate future. In recent years, technologies such as development of drought tolerant crops, conservation agriculture and moisture conservation techniques have been developed as remedial measures to mitigate the impact of climate variability. In Zimbabwean cotton, conservation agriculture is in its infancy. A study was therefore carried out to determine the benefits of conservation tillage technologies on seed cotton yield under Zimbabwean conditions. Experiments were carried out at Cotton Research Institute, Umguza, Wozhele, Shamva and Dande communal areas for three seasons during 2015 to 2017 in a randomised complete block design with five replications under conventional tillage practice, basins, ripped rows and dibbler made holes. Results showed that the highest seed cotton yield of 3002 kg/ha was achieved under basins in 2016 season. This yield was comparable to the yields obtained under ripped rows and dibble made holes at the same site and during the same season. Thus, conservation agriculture practice was identified as a promising technology that can be used in cotton production in Zimbabwe with benefits being apparent with time.

Session 5: Crop Protection

Prof. Yuan Youlu, State Key Laboratory of Cotton Biology, China, presented results on genome wide quantitative trait loci (QTL) mapping for resistance to *Verticillium* wilt (VW), fibre quality and yield traits in cotton chromosome segment substitution lines. The development of Chromosome Segment Substitution Lines (CSSLs) from *Gossypium barbadense* in *G. hirsutum* background provided ideal mapping populations for further genome research and crop improvement through marker assisted selection (MAS). Back-cross-Filial $BC_5F_{3:5}$ population with the donor parent Hai1 and the recurrent parent CCRI36 were developed. 300 CSSLs and their two parents were planted in a randomized complete block design with 2 replications in two different ecological locations (Anyang and Xinjiang) in 2015 and 2016, respectively. Phenotypic evaluation included *Verticillium* wilt resistance (disease index), fibre yield (plant height, boll weight, lint percentage and seed index) and fibre quality (fibre length, fibre strength, micronaire, fibre uniformity and fibre elongation) parameters. *Verticillium* wilt resistant materials were collected during July and August in the field. A total of 597 pairs of simple sequence repeats (SSR) markers screened from 2292 pairs of markers in the high-density map from a BC_2F_1 population of *G. hirsutum*×*G. barbadense* were used to identify polymorphisms among the $BC_5F_{3:5}$ lines. A total of 56 QTLs for *Verticillium* wilt resistance were detected; 30 of which were stable and 38 QTLs (68%) had negative additives effects; which indicates that the *G. barbadense* alleles increased *Verticillium* wilt resistance and decreased disease index (DI) by about 2.64 to 13.23. By meta-analysis, 30 QTL hotspot regions for VW resistance were identified and 13 of them were new hotspot regions. A total of 191 QTLs were detected for fibre yield and fibre quality, of which 98 were for fibre quality traits and 93 for yield related traits. 54 of these QTLs were stable. Three chromosomes, Chr05, Chr10 and Chr20 contained more QTLs. 30 clusters with disease index and fibre related traits were identified on 16 chromosomes. Most of the fibre traits were clustered with the disease index stable QTLs. We found 6 clusters namely, C01-cluster-1, C05-cluster-4, C07-cluster-1, C19-cluster-2, C22-cluster-1 and C22-cluster-2, which had positive correlation between VW resistance and fibre quality traits. Two clusters, C10-cluster-1 and C25-cluster-1 had also positive correlation between VW resistance and yield related traits (boll weight and lint percentage). One cluster, C20-cluster-1 is important for VW resistance, fibre quality and fibre yield. It is concluded that these clusters and related QTLs are very important for breeding improvement of fibre quality, yield and Verticillium wilt disease resistance.

Mr Fredy Musiniwa, Cotton Research Institute, Zimbabwe, measured tolerance levels of pre-released *Gossypium hirsutum* L. genotypes to a soil borne fungal pathogen *Verticillium dahliae* Kleb. *Verticillium* wilt is one of the most important diseases of cotton which affects yield and fibre quality in cotton across the world. The pathogen is capable of infecting plant roots throughout the growing season and persists in the soil for long periods of up to 10 years. Once *Verticillium* wilt is introduced into the field, it is difficult to eradicate because of its saprophytic ability. There is no chemical control for the disease. The disease can best be controlled by planting tolerant varieties. Experiments were conducted at Cotton Research Institute for three seasons to screen promising cotton genotypes for natural defence against *Verticillium* wilt in a field with a long history of infection by the pathogen. The experiments were laid down in Randomized Complete Block Design (RCBD) with 12 treatments replicated 3 times. Disease incidence, disease severity and

seed cotton yield were measured. Disease severity was scored using a scale of 1-5, while incidence was scored using percentage infection. The results showed that the promising genotypes had different tolerance level to the pathogen. Genotypes: 931-05-1, GN96(b)-05-8, 919-05-2, 932-00-3, 648-01-4 and 562-00-9 showed high tolerance levels to the disease and are therefore suitable for further breeding advancement.

Session 6: Best Practices for Yield Enhancement in Africa

Papers are presented as separate chapters in this issue.

Dr Isaiah Mharapara conducting an interactive session

Session 7: Biotech Cotton Practical Workshop & Interactive Session

Dr Keshav R Kranthi conducted participatory practical sessions on *Bt*-detection using immuno-chromatographic strips and *Bt*-quantification through Enzyme Linked Immuno-sorbent Assay (ELISA).

Dr Keshav R Kranthi, ICAC, presented two talks. The first talk titled 'Secrets of high yields' dealt with the main principles of best practices that are used by the top 5 cotton productive countries. The second talk 'Biotech cotton -Africa' dealt with the details of biotech cotton products available across the world and the relevance for the major cotton producing countries of Africa.

Recommendations

- Yield enhancing strategies: Cotton yields in Africa are low and have been stagnant for about three decades. Plant breeding and agronomy efforts must be oriented towards breeding of 'efficient' plants with compact architecture, short duration that possess capacities for higher 'nutrient-use efficiency' and 'water-use-efficiency' due to a much shorter critical window of boll formation compared to the current 'inefficient' long duration cotton production systems in Africa. Research across the world has shown that short season, early maturing, compact plant types when planted under high density result in higher yields in a shorter time and have the potential to escape biotic (pests and diseases) and abiotic stress (drought).
- Support for Research: There is a need to strengthen cotton research institutions by improving infrastructure facilities and human resource development through consolidation of local expertise, knowledge and also overseas training in advanced technologies.
- Demand driven technologies: African farmers need comprehensive cotton production packages that protect them from weather vagaries. Research institutions in the respective countries must strive to develop climate resilient, sustainable, environment friendly, demand driven, locally adaptable technologies. Technology adoption is easiest when they are demand-driven. However, the adoption of many agricultural technologies is slow either because they are expensive or are not designed to solve the local problems. Aligning technology attributes with end-user preferences can greatly enhance uptake. In this process, it is important to enhance farmer participation so that farmers are part of the solution rather than just being passive recipients of knowledge that can improve uptake of technologies. Efforts aimed at increasing ownership of technologies by farmers in the initial instance can enhance uptake thereby leading to improved cotton productivity.
- Crop protection: Insect pests and diseases cause significant economic losses thereby resulting in low yields in Africa. In many cases poor access to pest control technologies or inputs or lack of access to credit for key inputs in crop protection leads to crop damage. There is a need for Governments and private agencies to facilitate timely and affordable access to effective weed, pest and disease management practices according to the principles of integrated pest management and Insecticide resistance management.
- Seed quality: Yields can be greatly enhanced with good seed quality. Organised production of good quality certified seed has the potential to transform cotton production in Africa.
- Sustainable inputs: In many African countries, technological inputs such as fertilisers, pesticides and farm machinery are scarce. To ensure environment

friendly farming and sustainability, farmers must be provided with access to biological inputs for pest and nutrient management under cotton input support schemes that incorporate components of integrated pest management and integrated nutrient management.

- Sustainable brand: Cotton is completely rain dependent in Africa (Except in South Africa, Egypt and Sudan and some parts of Ethiopia, Kenya and Nigeria). In all other countries where cotton is 100% rainfed, opportunities must be explored to develop organic cotton or sustainable cotton production systems that create 'sustainability brands' to fetch higher prices in the global market.
- Conservation agriculture (CA): Cotton cultivation in Africa is based on conventional tillage systems, which lead to soil degradation. Conservation agriculture is best suited to the African countries, since the technology is not input intensive and results in the conservation of soil and water through inexpensive approaches, which improves yields and livelihoods in small-scale farming systems. It is important to understand that a CA technology developed in a region cannot be directly used elsewhere and that the CA practices must be tailored to suit the local situations based on the soil type and climate. By innovating locally relevant CA technologies, it will be possible to gain farmer acceptance.
- Fibre to fabric: Cotton generates enormous employment opportunities. There is a need to encourage private investment and Government support for the textile industry. It is estimated that one tonne of cotton provides annual employment to at least 5-6 persons. About 80% of the raw cotton produced in Africa is exported. The raw cotton produced in Africa has the potential to employ 8-10 million persons all through the year in the textile value chain. Cotton producing countries in African must seriously contemplate on setting up textile mills, which would not only generate employment but can enhance revenues by 8-fold to 20-fold or more depending on the type of value-added products produced such as yarn, fabrics, textiles and apparel.
- Wealth from waste: Value addition to cotton farm waste can improve the status of cotton growers in Africa. Instead of being burnt, cotton stalks can be used to manufacture particle boards, preparation of pulp and paper, hard boards, corrugated boards & boxes, microcrystalline cellulose, cellulose derivatives as a substrate for growing edible mushrooms, organic fertilizers for soil amendment and soil incorporation to improve micro-organism activity and increase seedling growth. These different uses can add value thereby increasing profit margins of farmers to enhance the viability of cotton farming in Africa.
- Technology transfer: Farmer training programmes can improve seed cotton yields. There is a need for proper farmer education and technology awareness programmes. Extension services become confusing when there are conflicting messages from the private input providing companies and public sector agencies. It is important that a standard technology curriculum is developed for the country and technology transfer is made complementary between Government and the private sector. Novel methods such as 'farmer to farmer' technology dissemination, empowerment and capacity building of farmers, gender mainstreaming, public-private partnerships and promoting information and communication technology in technology transfer should be initiated in Africa. The front-line demonstration format which has been highly successful in India, is most likely to suit Africa because of the identical nature of challenges in small-scale farming systems in Africa and India. Funding for national agricultural extension services would result in effective technology transfer.
- Business opportunities: Currently chemical inputs such as fertilizers and pesticides are imported into Africa and become more expensive due to additional transport costs. Non-chemical technologies for pest management and nutrient management have been developed across the world. Technologies such as biological control, biopesticides, biofertilizers, production of biochar etc., can be generated in the public sector and private sector research institutes and these biological products can be manufactured locally, to create business, employment opportunities and revenue. Contractors could increase investment in cotton production based on the local technologies.
- Marketing support: African farmers need robust marketing support policies that shield them from price fluctuations and market uncertainties. Poor compliance of contract integrity by smallholder farmers is a common phenomenon in Africa and other developing countries, wherein farmers resort to side marketing to dodge repayment of cotton input credit. Contractors need to be insured against side marketing by farmers. Private companies operating in cotton growing regions usually manipulate prices of inputs and other products during marketing season to the disadvantage of producers and consumers. Therefore, it is important to ensure fair trading practices to protect farmers from being exploited by traders and middle-men. Price prediction and trade monitoring systems would be needed to ensure fair trading. Transparent implementation of rules and guidelines will greatly enhance credibility and trust in transactions and trade.

The ICAC Recorder

Novel Ideas to Enhance Cotton Production and Value of By-products in Africa

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This chapter is a compilation of the six concept notes on novel ideas proposed by the six authors

Ideas Proposed By Dr. Md. Farid Uddin

Cotton is the main tradable commodity of West and Central African countries, representing the main exported agricultural product for some countries. Cotton is a major concern since it represents an important source of income, accounting for more than a tenth of total exports. Moreover, the subsector as a whole is essential for rural poverty reduction. Cotton in Africa is mainly produced in rainfed conditions with relatively few financial resources. Climate plays an important role in the variability of cotton yields over the course of years.

The most common challenges to cotton production in Africa are as follows:

- Smaller scale of production,
- Limited access to good quality seeds,
- Heavy reliance on insecticides,
- Decreasing soil fertility,
- Increasing production costs, and
- Volatile markets.

The following strategies can help in the development of the cotton sector in Africa:

1) **Upscaling:** There is a need to increase the scale of production. Large-scale projects and a better support by national services and policies will definitively increase productivity and will bring down production costs,
2) **Good quality seed:** Good agriculture results from good seeds. Improving access to good quality seeds will play a major role in yield enhancement. Seed production units in the public sector research institutes need to be strengthened to produce sufficient quantity of good quality seeds.
3) **Integrated pest management (IPM):** Effective pest management can efficiently prevent yield losses. Therefore, there is a need to actively promote IPM practices. A practical, country-specific training curriculum for smallholders and export-oriented farmers needs to be developed. The focus for smallholders should be first on good agricultural practices (GAP) coupled with the basic principles of IPM, whereas the focus for export-oriented farmers can be fully based on IPM.
4) **Soil health:** Adoption of Integrated soil fertility management practices holds the key for good crop health. Integrated Nutrient Management (INM) practices need to be promoted, combining agronomic practices relating to intercrops, mineral fertilisers, organic inputs and other amendments that are tailored for different cotton-based cropping systems, with objectives to enhance soil fertility status and increase socioeconomic profiles of farmers.
5) **Profitability:** Improving income from cotton is important to sustain farmers' interest in the crop. Profitability can be enhanced by optimising the usage of water and agrochemicals to prevent wastage of resources and investment. Cotton production cost should be rationalised by increasing productivity as well as adding value to cotton fibres and by-products derived from the cotton farm.
6) **Subsidies:** Subsidies in farm inputs and cotton prices will help farmers to cope with the uncertainties of volatile markets.

Cotton is one of the most important cash crops in Africa and has had an important role in job creation, poverty reduction and foreign exchange generation. African cotton exporters face three interconnected challenges:

- How to increase yields and quality to achieve higher incomes in the context of small holder farming?
- How to deal with volatile international prices and to be shielded from external vulnerability?
- How to increase value addition through local processing of cotton lint and seed.

An integrated effort to address these issues will increase the sustainability of African cotton sector.

Ideas Proposed By Dr. Md Fakhre Alam Ibne Tabib

Research

Problem-based coordinated research activities in African countries should operate through SEACF under the aegis of the ICAC. Research should be focused on fibre quality improvement, efficient water use, agronomic practices for conservation agriculture, high-density planting systems, insect pest management, heat tolerance, and crop management. Research should also be oriented toward the development of the cotton value chain and cotton by-products. There should be continuous socio-economic surveys and research on cotton production and marketing. Government support for cotton research and development plays a pivotal role in development of the cotton sector.

Extension services

Coordinated government extension services should be developed for cotton growers by forming a Common Interest Group (CIG) and provide cotton production technologies to CIG members through training, ICT-based information sharing, booklets, leaflets, posters and other extension tools. Introduction and dissemination of good extension practices that are practiced in other ICAC member countries. Formation of a central cotton extension/extension advisory service body under ICAC, involving government and non-governmental organisations that deal with cotton production, research and marketing in African countries. Easy access to the cotton market information by the cotton growers and farmers group (CIG) and other stakeholders of cotton. Creation of a central database to strengthen coordinating activities and information sharing for the stakeholders involved in cotton production and marketing.

Contract farming

Asian countries that import cotton can get involved in cotton production and marketing in African countries through contact-farming. Asian investors can establish ginning and processing factories and import cotton fibre from African countries for their textile industries.

Ideas Proposed By Dr. Kamrul Islam

Improving soil fertility for sustainable cotton production

Cotton (*Gossypium spp.*) is a very important fibre crop and plays a major role in the economies of several African countries. Many cotton farms are in a crisis due to decreasing soil fertility. The cost of chemical fertilisers is high. Many farmers prefer to use chemical fertilisers for cereal crops instead of cotton. Nevertheless, fertiliser use practices in cotton production systems are reported to be inappropriate and are leading to soil nutrient depletion, rapid land degradation and low fertiliser-use-efficiency.

The problems related to soil fertility include:

1. Constrained ability of the soil to supply nutrients to the crops.
2. Constrained ability of the soil to retain nutrients.
3. Asynchrony of nutrient availability as per demand of the cotton crop.

The following practices could be used to address these problems:

- **Appropriate use of chemical fertilisers:** Use of chemical fertilisers that offer an instant solution to the issue of limited nutrient supply, considering the fact that their injudicious use might lead to negative effects on the soil as well as loss of applied nutrient elements particularly of nitrogen (N).
- **Organic fertilisers:** Use of organic fertilisers such as animal manures, green manures or cover crops not only provide nutrition to the crop but also enhance soil health. However, there are two major shortcomings associated with organic fertilisers: 1) The nutrient-release pattern of organic resources does not match with crop requirement phases, and 2) The nutrient contents of most of these organic inputs tend to be very low, and as result, very large quantities (up to 20 tons/ha) are required to meet the nutrient demand. The large quantities required creates logistical challenges of transporting these resources, incorporating them and sourcing for sufficient quantities.
- **Cropping systems:** Intercropping with crops that do not compete with cotton for water and nutrients due to different plant morphology and root architecture, and have a different requirement window for nutrients, water and sunlight. Leguminous intercrops can benefit cotton through nitrogen fixation and integrated pest management. Intercropping also helps to break the cycles of diseases, weeds and pests.

To ensure synchronisation of nutrient availability as per demand of the cotton crop as well as preventing the nutrient loss, a combination of chemical and organic fertilisers is the best option for enhancing the nutrient supply to crops. All the shortcomings associated with the sole use of either chemical fertilisers or organic inputs are addressed by combining the two practices.

The following strategies help in integrated nutrient management:

1) Split application of chemical fertilisers.
2) Replacement of chemical fertilisers with organic manures as much as possible, the quantity of which is determined by location specific field trials and

local availability. For example, in Bangladesh 30% to 40% nitrogen of chemical fertiliser (urea) could be replaced by organic fertiliser (poultry manure).

Ideas Proposed By Mr. Washington Mubvekeri

- **Suitable agro-ecology:** Grow cotton in a suitable agro-ecology.
- **Adaptation and validation:** Avoid using imported technologies before testing them for adaptability.
- **Certified seeds:** Grow certified seeds of adaptable cotton varieties. Zimbabwe has a strong seed-certifying institution.
- **Nutrition management:** Provision of adequate levels of nutrition is critical for both free-input or contract grower schemes. Adequate nutrition promotes crop vigour, desirable and potentially productive vegetative framework, boll retention, and viable boll weights.
- **Early sowing:** Plant early in the season. Ensure that recommended plant populations for particular cotton varieties are achieved and maintained throughout the growing season.
- **Effective weed management:** Sustain an effective and efficient weed-management regime.
- **Effective pest management:** Initiate an effective and efficient pest-management regime that minimises boll loss. In Zimbabwe, pest management tools include the Pyrethroid Window, Acaricide Rotation Scheme, Closed Season, Use of Economic Thresholds
- **Timely harvesting:** Pick only fully mature bolls early enough to preserve colour and avoid unnecessary boll weight loss.
- **Avoid contamination:** Rid the seed cotton of contaminants during harvesting and storage.
- **Contract integrity:** Grow a culture of honesty and accountability among cotton growers. These qualities are critical for dealing with 'side-marketing syndrome'.
- **Fair marketing:** Sustain fair, win-win grower schemes by setting viable input prices and motivating the growers through fair prices.
- **Eco-friendly, farmer-adaptable technologies:** Knowledge and technology generation must be ecologically and environmentally compatible and must be affordable to benefit the cotton sector.
- **Farmer participatory training:** Knowledge and technology transfer should reach the grower in a practical and realistic way rather than in a superficial manner. Most of it ends with the training of trainers.
- **Fibre to fabric:** Value addition enriches the downstream cotton sector.
- **Value addition to cotton by-products:** Economic usefulness of cotton by-products depends on the specific circumstances of countries. Utilisation of cotton stalks for fuel purpose requires 'patriotic' consideration because ecological conditions in most SEACF member countries are favourable for forestry.

Ideas Proposed By Dr. M. Sabesh

Although many countries in Africa attained independence during the 1960s, the living standards, nutrition, health care and education have not progressed significantly even after six decades. Comprehensive reforms with the support of local governance in basic health care, education, nutrition, labour welfare, and a strong legal framework are required in many African countries. The recent World Bank report mentioned that six of the 10 fastest-growing economies in the world are in Africa. About 60% of the world's unused arable land is in Africa. There is a lot of scope for growth in the agricultural sector in Africa, with ample investment by donors in fertilisers, machinery, water and irrigation systems. African countries would be the world's major destination for the agricultural sector in the years to come, provided proper policies are formulated and implemented effectively.

- **Varietal development programmes should be farmer-participatory.** Farmer opinion on socio-economic and agro-ecological constraints should be considered during adaptive field trials.
- **Germplasm introduction:** Brazilian varieties (BRS 286 and BRS 293) have adapted well in Mali, Burkina Faso and Benin. These varieties yield better under irrigation. Germplasm introduction into Africa will strengthen genetic diversity for varietal improvement.
- **Conservation agricultural techniques:** Zero-tillage, especially with organic mulching, was found to enhance cotton productivity and soil fertility in many countries in Africa. The technique involves dry season land preparation, early planting, early weeding, precise field layout, and careful input application. The technique requires experimentation in Africa and further fine tuning for large-scale adoption with adequate training.
- **Topping and pruning of sympodial branches:** Manual trimming of cotton plants has been adopted successfully in China to greatly enhance yields. Such operations are possible with the availability of sufficient man power. This technique is ideally suited for African countries, where labour is inexpensive.
- **Early sowing is crucial:** Farmers must be inculcated with the technical know-how on early planting with the onset of the monsoon to ensure moisture retention during the critical crop-growth period. Since cotton

cultivation in Africa occurs predominantly under rainfed conditions, early sowing would enable the crop to get adequate soil moisture at a critical phase of the crop to enhance cotton productivity.

- **Investment in water conservation:** Ethiopia, Kenya, Tanzania and Uganda have good rainfall and abundant resources of water, whose potential has not yet been fully tapped, and requires investment.
- **Organic fertilisers:** Most of the African cotton farmers are smallholders with minimal access to financial resources. Chemical-input-intensive agriculture is unlikely to be sustainable for Africa. There is a need for research on developing crop production technologies and pest management strategies using the abundantly available natural resources that can be used as for profitable cotton farming. Crop residue recycling, organic manures and fertilisers can be cost effective and sustainable.
- **Rejuvenating ecosystems for efficient INM and IPM:** African ecosystems are comparatively less disrupted by chemical-intensive agriculture. Thus, there is a great opportunity to rejuvenate the agricultural ecosystems through natural resources, which would in turn allow integrated nutrient management (INM) and integrated pest management (IPM) to function effectively under the prevailing agro-ecological conditions for the benefit of the resource-poor smallholders in Africa. There is a need for strong research institutions across potential cotton growing countries in Africa to strengthen biological control-based pest management. Efficient non-chemical approaches for pest and disease management must to be developed, such as development of resistant varieties, cultural controls, agronomic practices and biological control for the prevailing agro-ecological conditions.
- **Wasteland reclamation:** There are large tracts of lands in Africa that have immense potential for farming. There is a need to identify the resources available in the vicinity of such wastelands for further augmentation. A comprehensive wasteland-development programme needs to be created and implemented with the help of appropriate investment from governments and private agencies. Brazil has converted large tracts of unfertile lands in the Cerrado region in central Brazil and reclaimed them. The region become agriculturally more productive.
- **Decentralised ginning units:** Establishment of small-scale ginning units, as is done in Brazil, can enable farmers to get additional remuneration by value addition to their produce. Farmers would be able to trade cotton lint directly without being exploited by middlemen to get more profits.
- **Fibre processing in eastern and southern Africa:** Textile processing generates significant employment. Data from Asia show that one tonne of lint is known to provide year-long employment to at least five persons (Kranthi, ICAC Recorder, Sept. 2018). The shift in cotton production domain from Eastern and Southern Africa to Western and Central Africa triggered the need for a few processing units in Western and Central Africa. However, 80% of raw cotton is exported from Africa. Establishment of full-scale textile manufacturing factories in Africa can greatly change the fortunes of countries and their farmers.
- **Diligent breeding:** The case of *Bt*-cotton in Burkina Faso presents a case-study on how things can falter if local sensitivities are taken for granted. Beyond a doubt, *Bt*-cotton as a pest management technology was successful. Cotton produced in Burkina Faso was known all across the world for its excellent fibre quality. Cotton harvested from the *Bt*-cotton varieties was inferior in quality compared to conventional non-*Bt* cotton. The problem was basically poor selection and incomplete cycles of back-crossing conducted with the local cultivars. The issue highlights the need for diligent breeding to ensure that the locally adapted varieties are reconstituted properly to their original state at the end of back-cross cycles.
- **Good crop management v/s Bt-cotton:** The current yields in Africa are low mainly because of poor practices. Many of the soil, nutrient, water, and pest and disease management practices, if followed precisely without any compromises in agro-input supply, have the potential to enhance the cotton yields and offer best returns to farmers in a manner that is equivalent to the adoption of *Bt*-cotton technology (Valerie 2011). Crop production technologies, if followed properly, have immense potential to enhance yields.
- **Yield gaps due to socio-economic constraints:** Many African farmers achieve lower yields because they cannot afford to apply proper inputs due to socio-economic constraints. Many African cotton varieties have high yield potential, but poor management leads to poor yields. There is a need to strengthen research that can empower the farmers in Africa to manage their crops with locally available natural resources for profitable farming, and also to sell their produce at competitive prices.

Ideas Proposed By Dr. Usha Rani Joshua

Africa is an important cotton producer with a significant role in the value chain of cotton. Cotton is one of the most widely cultivated cash crops by small and marginal farmers in Africa. Despite its economic potential, the cotton sector in Africa is subject to many risks with respect to weather conditions, price fluctuations and pest attacks, all of which threaten the sustainability of cotton production in Africa. A reform to sustain and foster cotton production in Africa is imperative since millions of smallholder farmers depend on cotton for their livelihood. This concept suggests seven strategies to enhance the cotton production and value of by-products in Africa:

- **Diagnose the constraints.** First of all, there is a pressing need to diagnose constraints in cotton cultivation and identify the needs of cotton stakeholders in Africa. This can be attempted by using standard interactive tools such as participatory rural appraisal, brainstorming, stakeholder interface meetings, and focused group discussions at the micro and macro levels. The results would shed light on researchable issues, policy perspectives, and the obvious and unrecognised needs in cotton sector at micro and macro levels.
- **African cotton mission.** Devise an 'African Cotton Mission' with best production practices, efficient techniques for transfer of technology, policy and regulatory interventions to solve the constraints and enhance productivity in small-scale farms. The nationwide mission mode approaches under 'African Cotton Mission' should include technological, extension, capacity building, policy and regulatory interventions involving the line departments and all stakeholders in a Public Private Partnership (PPP) mode.
- **Global best practices.** As part of the 'African Cotton Mission', researchers must develop the best integrated crop management package of practices for cotton in Africa, based on global best cultivation practices in cotton. Such best practices include short duration varieties, soil health management, planting system alterations, precision farming, use of mulching, conservation agriculture, canopy management, good harvesting practices, and integrated management of pests, diseases, weeds, nutrients and water.
- **Transfer of technology:** To disseminate the best management practices in farmers' fields, technology translators should devise mechanisms that combine both conventional and contemporary good extension practices such as: field demonstrations, training for trainers, Farmers Field Schools (FFS), soil health cards, printed materials, short videos, personal field visits, exposure visits, radio broadcasts, Television, mobile-phone-based voice texting, mobile apps, Web-based advisories, decision support systems (DSS), usage of social media, WhatsApp, Facebook and blogs, expert systems, market intelligence, organising Farmers Interest Groups (FIGs), Commodity Interest Groups (CIGs), producer organisations, and contract farming.
- **Capacity building:** Design and implement a country-wide, massive-capacity building program through training, field camps and study tours within the country and abroad for all stakeholders, including government officials, bureaucrats, researchers, extension functionaries, private partners, and farmers. To strengthen and support both the technology developers as well as translators, governments should drive training programmes at all levels — from top policy makers to para extension workers at field level — including visits to far-away cotton growing countries and even to successful local farmers' fields.
- **Supportive policies:** Create supportive policies that attract and involve women and rural youth in cotton cultivation through government-aided supportive policies such as smart credit, micro financing, and price support mechanisms that will reinforce and strengthen the mission.
- **Right regulatory interventions:** Aim to double the cotton yield and reduce the cost of cultivation by optimising inputs to prevent waste of water and agrochemicals, thereby executing the mission with the proper regulatory interventions.

The ICAC Recorder

Hope and Scope for Enhancing Cotton Production in Africa

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Introduction

Africa's agriculture is dominated by a variety of staple food crops (maize, rice, sorghum, millet, cassava, yam, sweet potato, etc.) and a few traditional cash crops (coffee, cotton, cocoa, palm oil, sugar, tea, and tobacco). Cotton has been depicted in some studies as "the mother of poverty" (Isaacman, 1980). In contrast, other studies have described cotton as "the white gold" (Tefft, 2010; Kranthi, 2015).

Cotton is a major source of foreign exchange earnings in more than 15 African countries and a vital source of cash income for millions of rural people. Cotton plays a significant role in the fight against rural poverty in Africa. Of the 30 leading cotton-growing countries in the world, 12 are from Africa (ICAC). Cotton production has been a major economic component in terms of export earnings in several African countries over the past few decades. The cotton production and marketing sectors are considered as paradigms for agricultural commercialisation and industrialisation in African cotton-producing countries, especially in Benin, Burkina Faso, Chad and Mali, often called the 'cotton four' or 'C4' countries (Badiane *et al.,* 2002; Gergely and Poulton, 2009).

Stagnant yields and increasing input costs have made cotton cultivation less sustainable in Africa over the past three decades. This could be due to many factors related to the ecological conditions where cotton is cultivated, or the socio-economic conditions of small-scale farmers. But by and large, policy decisions over the period across African countries appear to have been ineffective in enhancing the profitability and sustainability of cotton production.

A review of various dossiers related to cotton in Africa shows that there is commonality in constraints connected with a financial crunch in production, poor crop management, weak extension systems, disorganised cotton procurement, and amorphous marketing and export. Cotton farmers in Africa face three main constraints:

- Low yields,
- Non-remunerative prices, and
- Cotton area replacement by food crops.

Several projects on reforms and technological interventions in cotton production were implemented by different global agencies in different countries of Africa during the past 3 to 4 decades. However, there has hardly been any perceptible change in the cotton fibre quality or yields. Despite external aid and support and innumerable internal policy interventions in major cotton-producing countries, cotton-production systems do not seem to have benefitted much.

Over the years the farming community in Africa has been in a precarious state in which their income doesn't match with the increasing inflation, which affects their standard of living. Although the African countries produce excellent-quality raw cotton fibre for the improved lifestyle of the most modern and civilised societies across the world, many in Africa continue to be deprived of basic clothing. In most of the African countries, farmers still do not earn enough to support basic education, nutritious food and good health care.

Over the past five decades, cotton farming underwent several turbulent phases in almost all cotton-growing countries in Africa. Low yields and low profitability have rendered cotton farming unsustainable in Africa in recent times. This paper analyses the core issues and recommends best practices that were drawn from successful examples across the globe. It describes the hope and scope to improve the cotton production systems in Africa.

Cotton Scenario in Africa

Cotton is grown in small-scale farming systems, predominantly under rainfed conditions, where it is grown along-with food crops mainly sorghum or maize. Traditionally, due to colonization by foreign rulers, cotton production systems have been based on contractual basis. Coordination between cotton cultivators and cotton companies has evolved into contractual arrangements wherein, the cotton companies provide inputs in the form of seed, pesticides, fertilisers, and extension services and purchase all cotton produced by cultivators at agreed prices (Badiane et al., 2002; Silvie et al, 2001).

The cotton scenario in African countries underwent formidable changes in the past decades. There was a significant shift in the cotton cultivation scenario in Africa after 1960. Over the past 4-5 decades, cotton area in Francophone Africa increased three-fold whereas the area in north Africa plus eastern and southern Africa reduced to less than half. During the 1960s, the Eastern African countries occupied an average area of 75% of the total cotton area in Africa, but the share decreased to

37% between 2010 and 2017 (Table 1), whereas during the same period the WCA (Francophone) countries enhanced the area under cotton from 24% to 62%. In the early 1960s Egypt cultivated cotton in about 0.8 million hectares (ha.) and in the early 1970s Uganda was a major cotton cultivator, with an area of 1.0 million ha (ICAC data). From 1964 to 1987, the average cotton area in southern and eastern Africa was 1.52 million hectares, whereas the average area in Francophone countries, including the C-4 countries (Burkina, Mali, Benin and Chad) was 0.67 million hectares. For the period between 1964 and 1987, north Africa and southern and eastern Africa together had an average area of 2.52 million hectares under cotton. In 2017, the average cotton area in Francophone countries was 2.80 million hectares while the combined average cotton area in north Africa and southern and eastern Africa was 1.19 million hectares.

Notably after 1980, cotton cultivation shifted predominantly from Eastern and Southern Africa (ESA) to Western and Central Africa (WCA). In the 1980s and thereafter the area under cotton was drastically reduced in Uganda and Egypt. The C4 countries consolidated their position as the leading cotton cultivating countries in Africa, especially between 2010 and 2017. Currently, Francophone countries including C4 countries occupy 66% of the total cotton area in the continent, but contribute to 72% of the cotton production. Due to the predominant shift in cotton cultivation domains in Africa (Figure 1), the pattern of cotton production also got relatively transformed. ESA countries reduced their average cotton production from 85% in 1960s to 34% between 2010 and 2017, in contrast, the WCA countries increased the share of their cotton production basket in Africa from 15% to 66% during the period.

Export of cotton from ESA countries decreased from 85% in 1960s to 28% over the recent past. Traditionally, due to the lack of cotton processing and value addition, the WCA countries also export their raw cotton. In 1960 these countries cotton exports increased from 15% to 71% of the total export from Africa in last decade. In 2017, the WCA countries increased their export share to 10.05 lakh tonnes, which is equivalent to 80% of the total exports from Africa.

Among African countries, Egypt, South Africa, Nigeria, Kenya, Tanzania and Ethiopia have been the major consumers of raw cotton. About 70% to 90% of the cotton produced in these countries is utilised by the domestic textile industry. As the present research and environment conditions are improving in WCA countries, cotton productivity is also proving to be superior compared to the ESA countries. Apart from Egypt, where the agroecological conditions are totally different from other cotton growing countries of Africa, the productivity in WCA countries has been comparatively good, especially in the past 20 years.

Varietal Improvement and Seed Technologies

Seed is a commodity that is both an input and an output of the agricultural production system, and whose quality and quantity depends on management technologies. Providing seeds of adapted cultivars and good-quality seeds to farmers is essential to ensure productive and remunerative returns to farmers, traders and other stakeholders. It is appropriate to expand seed development and distribution processes — including fostering public-private partnerships — in order to make high-quality cotton seeds available to diversified agro-ecosystems, with strict quality control measures by government agencies (Charles *et al.,* 2012).

The introduction of an upland variety called Allen Long Staple from the USA to Africa in the beginning of the 1900s proved to be a highly significant event. Since then, numerous genetic materials or varieties have been derived from the genetic background of Allen. Early in the 1960s, a well-coordinated parastatal cotton industry model in WCA promoted cotton

Table 1: Decadal percent share to total African cotton

	1965-70	1971-80	1981-90	1991-2000	2001-10	2010-17
Area						
Western and Central Africa[1]	24.82	31.25	36.00	51.60	55.09	62.37
Eastern and Southern Africa[2]	75.18	68.75	64.00	48.40	44.91	37.63
Production						
Western and Central Africa	14.69	19.66	30.64	52.50	57.48	65.84
Eastern and Southern Africa	85.31	80.34	69.36	47.50	42.52	34.16
Export						
Western and Central Africa	15.21	21.90	41.92	69.38	66.57	71.89
Eastern and Southern Africa	84.79	78.10	58.08	30.62	33.43	28.11
Domestic consumption						
Western and Central Africa	10.69	15.95	15.58	19.79	19.41	12.44
Eastern and Southern Africa	89.31	84.05	84.42	80.21	80.59	87.56
Average Yield (kg/ha)						
Western and Central Africa	243	274	387	405	376	348
Eastern and Southern Africa	270	298	307	315	378	391

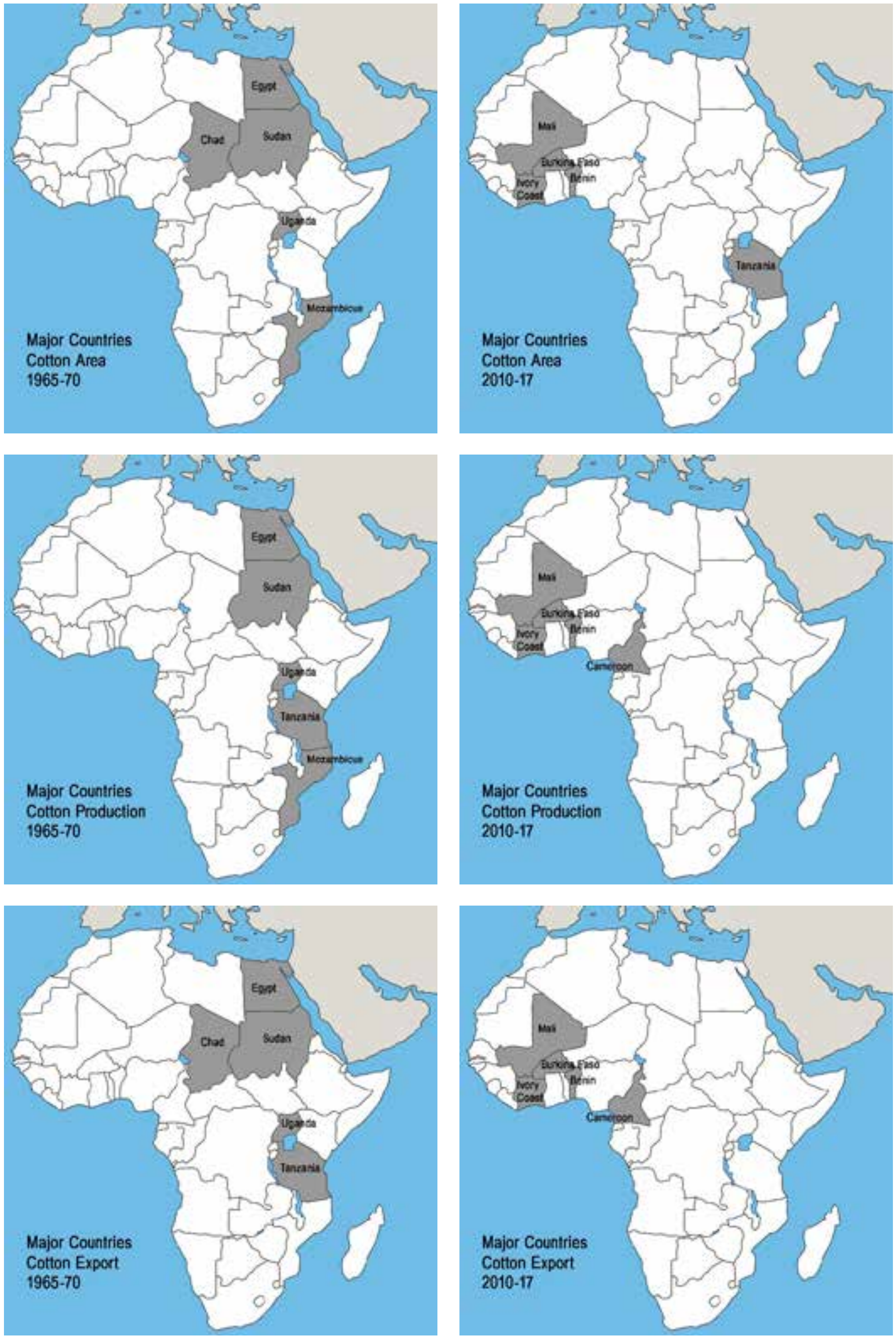
Source: Compiled by author; Data source: ICAC, 2018

[1]Western and Central Africa major cotton growing countries: Burkina Faso, Mali, Benin, Cameroon, Chad, Nigeria, Togo, Senegal and Cote d'Ivoire

[2]Eastern and Southern Africa major cotton growing countries: Zimbabwe, Zambia, Mozambique, Tanzania, Malawi, Uganda, Kenya, Sudan Egypt, South Africa and Ethiopia.

Figure 1. Change in African cotton scenario

1965-70 2010-17



cultivation and facilitated the sector's growth (Baffes, 2007). The model clearly contributed to the organisational stability of cotton research when compared with ESA, in addition to providing farmers with equipment and extension advice, thereby enabling them to adopt research recommendations (Tschirley *et al.,* 2009).

A review of different studies indicates that there has been less focus on cotton breeding or improved varieties being introduced in Africa. This is perhaps due to reduced investment by governments and private cotton companies in varietal research (Tschirley *et al.,* 2009). The African countries mostly depend on other countries outside of Africa for cotton varietal improvement programme or improved varieties. The Brazilian Government introduced nine Brazilian varieties developed by *Embrapa* into C4 countries.

In Mali, the varieties BRS 286, BRS 293, BRS Araca, BRS Aroeira, BRS Buriti, BRS Cedro, BRS Jatoba, BRS Safira and BRS Serido were introduced. The variety BRS 286 performed well with an average yield of 3,000 kg/ha in 2009 compared to 1,000 kg/ha of local varieties (WTO, 2011). The variety BRS 293 proved to be fairly good and productive. It was popularised in different names in Burkina Faso (FK37), Mali (NTAL 100) and Benin (H279-1) (Bourgou and sanfo, 2012). In the early 2000s in Burkina Faso, *Bt*-cotton varieties that were developed elsewhere, were evaluated under Burkina Faso's growing environment. Adoption of *Bt*-cotton reduced insecticide applications from 6 to 7 per season to 1 to 2, apart from resulting in yield enhancement of 15% to 35% (Baghdadli *et al.,* 2007).

However, in the recent past, it was found that the fibre quality of *Bt*-cotton varieties was inferior to traditional non-*Bt* varieties. Though the *Bt* technology in cotton was *per se* efficient in controlling bollworms, incomplete introgression and improper selection in breeding methods are presumed to have caused problems with fibre quality. Many studies and reviews mentioned that *Bt*-cotton technology is more input oriented and is therefore ideally suited for irrigated conditions (Narayanamoorthy., 2006, Ashok Gulati 2011, and Sabesh *et al.,* 2014). This may also be one of the reasons for yield stagnation in Burkina Faso, where cotton is completely rainfed.

Varietal development programmes in Africa should consider socio-economic and agro-ecological conditions of the farmers, while governments should devise policies that ensure good prices based on high-quality fibre. For example, in Mali, a new cotton variety was introduced with an increased ratio of fibre to seed. Such varieties are most preferred by ginners, but farmers complained that the weight of their seed cotton production, on which their cotton earnings depend, was less with the new variety (Valerie *et al.,* 2011).

Agronomic Practices

Many agronomic practices and nutrient- and water-management technologies have been developed and tried in African countries. Fertilisers and manures are beneficial not only to cotton but also to the food crops that are part of the cropping pattern (Quola, 2008). Inorganic fertilisers have been advocated in order to counterbalance losses of mineral elements necessary for crops included in the traditional cropping pattern. However, due to high costs, the application of chemical fertilisers is rarely followed. Ripoche *et al.,* (2015) found that a combination of inorganic and organic fertilisers is the best option to rebuild and maintain the sustainable productivity of some countries in West Africa, which have low levels of organic matter. The study also concluded that inorganic fertilisers applied to rotations of cotton with food crops help improve and maintain soil fertility.

Numerous studies have shown that pruning of sympodial branches and mechanical topping of the main stem have been practiced to control excessive growth, increase earliness, and improve yields. This technique facilitates increased supply of nutrients to reproductive parts of the plant. China has been adopting this technique extensively to increase yields (Dai and Dong, 2014). The topping technique could be ideal for African countries due to small farm holdings and abundant labour availability. In contrast, Renou *et al.,* (2011) mentioned that cotton topping in Mali had no significant effect on cotton yields, but reported that the infestation of *H. armigera*, *Earias* spp., and *D. watersi* bollworms was significantly reduced. However, it must be remembered that canopy management is an art that emanates from diligent science. The beneficial effects from pruning or topping will depend on many critical factors, such as the proper stage of the crop and the methods followed.

Conservation tillage, which involves ploughing before planting, with a no-till plus mulch method used after planting, was introduced a few years ago in Mozambique, Malawi, Ghana and other African countries. It resulted in high yield gains in maize and is spreading to cotton areas with the promise of reducing labour costs while decreasing soil erosion and increasing fertility (Ito *et al.,* 2007). Conservation agriculture in cotton is well suited in African conditions and involves dry-season land preparation, early planting, early weeding, precise field layout, and careful input application that coincide with best management practices in cotton production.

In Mali, smallholders are more likely to use no-till practices, while resource-rich farmers — who have better access to land, animal traction, equipment and fertilisers — have largely discarded the no-tillage method. In Benin, farmers use organic fertilisers mixed with inorganic fertilisers in differing proportions, often combining this with ridging and mounding (Saidou *et al.,* 2004). In

Burkina Faso, in maize-cotton crop rotations, farmers have used minimum tillage with a combination of organic and inorganic fertilisers (Ouattara *et al.*, 2006). Conservation agriculture practice in Zambia involves a package of several key practices including minimum tillage; crop residue retention; nitrogen-fixing crop rotations; and application of reduced (but precise) doses of mineral fertilisers (Grabowski *et al.,* 2014). Conservation farming in Zambia resulted in yield increases ranging from 25% to 50%. Econometric analysis separating the impact of the tillage method from other practices indicates average yield increases to 1,650 kg/ha, of which 750 kg/ha could be attributed to tillage methods alone (Haggblade *et al.,* 2010; Tschirley, Zulu, and Shaffer 2004).

Organic fertilisers (animal manure, crop residues, and green manure) have been promoted as essential complements to inorganic fertilisers because of their capacity to build soil organic carbon, especially for smallholders who have less access to chemical inputs (Bationo *et al.,* 2007; Saidou *et al.,* 2004). Improved fallows using agroforestry methods have improved soil organic carbon, contributing to better yields in many African countries (Vagen, Lal, and Singh 2005). Fallows in Zambia and Kenya, using fast growing, nitrogen-fixing leguminous trees, have improved soil moisture capacity.

Cotton cultivation in African countries is predominantly under rainfed conditions, as no irrigation schemes exist in many countries. Early sowing is highly recommended in order to avoid soil moisture stress during the cotton plant's reproductive growth stage, which would cause a decline in productivity. Many African countries have good rainfall but few water-harvesting and conservation systems that could enable supplemental irrigation for yield enhancement. The lack of development of irrigation potential has contributed to the low productivity of agricultural systems, food insecurity and high poverty rates (Nakawuka, 2017).

Cotton is a long-cycle crop in Africa. Early planting and retention of moisture during the critical crop growth period is vital for enhanced yields. Cotton extension specialists in Zambia estimate that cotton yields increased by about 100 kg/ha for each early week of planting (Grabowski *et al.,* 2014). Naudin *et al.,* (2010) conducted experiments on conservation agriculture techniques during 2001 and 2006 in Cameroon with no-tillage, and no-tillage combined with organic mulch. They concluded that no-tillage with organic mulching decreased yield by 16 kg/ha, with delays in sowing for each day. The reduction is less than that reported from 20 to 50 kg/ha per day when sowing was delayed under conventional tillage techniques. The same study also concluded that conservation agriculture experiments at field level showed potential benefits for smallholders.

Pest and Disease Management

Insects are a major threat to cotton. About 15% of the world cotton production is lost due to insect attacks every year (Oerke, 2005). In West Africa, the numbers are higher, with about 23% of cotton production lost to insects (Magicson *et al.,* 2013., Vognan *et al.,* 2002). The cotton bollworm complex causes significant damage to cotton in Africa. Amongst bollworms, the cotton Bollworm *Helicoverpa armigera* is the most damaging to cotton yields all across Africa. A greater proportion of insecticides used in cotton goes towards bollworm control.

For the past few decades, even after the introduction of GM crops, the pesticide consumption for crops has not decreased significantly in the developing world. Oerke (2005) mentioned that despite an increase in pesticide use all over the world, crop losses have not significantly decreased during the last 40 years. There is a great opportunity to promote IPM more effectively among resource-poor smallholders in Africa. Most crop protection research programmes are not oriented towards IPM but continue to focus primarily on chemical control (Agnes and Merman, 1991) or toward the need for *Bt*-cotton. Way and Van Emden (2000) conducted surveys and confirmed that there exists a vacuum in the area of IPM in the African region that needs to be filled with appropriate research in order to develop an effective, low-input, environmentally feasible and acceptable pest management approach that is appropriate for the resource-poor farmers and fits well within their practices of mixed cropping. Since smallholder cotton production is part of a mixed cropping system in Africa, IPM approaches in Africa require strong research that considers local cropping systems and institutional capacity-building programs and extension methods that educate farmers on the mixed-crop interaction effects.

The development of economic threshold-based pesticide interventions in several countries, particularly Mali and Cameroon, following the development of targeted pest and disease control programmes in Benin, demonstrates that it is possible to reduce the quantities of pesticides needed for effective crop production. A threshold-based insecticide spraying decision programme has been an important option in integrated pest management in cotton in Africa. The calendar-based programmes followed traditionally in Africa can circumvent the problems of any mistakes in pest identification or operation of the sampling procedures followed by farmers (Silvie *et al.,* 2001).

Under calendar-based intervention, cotton plants are protected during the entire period — from the start of flowering until the majority of bolls reach maturity — through insecticide applications that are scheduled on specified dates. But this method seldom worked because of the mismatch between pest infestation and the time when insecticides are sprayed. In the west African countries, though, threshold-based pesticide application has been initiated; adoption and expansion of this method remains slow due to insufficient knowledge of the growers, especially in identification of pests and natural enemies and assessing the level of economic threshold levels of the pest.

Several non-chemical methods of pest control have been tried in Africa including the development of resistant varieties, cultural control, agronomic practices and biological control. The hairy varieties developed for the control of jassids and aphids were found to be susceptible to whiteflies, which have been the major cotton pests in the West African region since the 1990s. The hairy cotton varieties greatly encouraged whitefly infestations, as the hairiness sheltered them against their natural enemies and insecticides (Ouola, 2008). Research on varietal development should need to focus on strategies that can enable the cultivars to tolerate all the major pests in the region.

Combining improved pest and soil fertility management practices shows promise for increasing yields in several countries of West Africa, apart from reducing the incidence of pests (Valerie *et al.,* 2011). Several studies found that:

- Deep ploughing destroys bollworm pupae;
- Hoeing helps to eliminate weeds that are potential host for pests,
- Early harvesting reduces sticky cotton, which is due to sugars produced by aphids and whiteflies; and
- Destruction of stubbles and crop-residues prevents pest carry-over.

Discussion

Research reviews point out that extensive socio-economic research is needed to understand the yield gap between the genetic potential of African cultivars and the low yields realised. In reality, it is unlikely that all the technologies would always succeed in all agro-ecological, socio-economic and political situations. However, many studies show that lack of political will and poor socio-economic conditions of farmers could be mainly responsible for low yields in Africa.

Since the colonial period and after independence, most African countries strived to improve the living standards of their people. The efforts may not have succeeded in alleviating poverty due to inefficient institutional setup along with exploitative nature of parastatal investors in the cotton sector. The lack of institutional support — either from government or from the private investors — in technology-transfer and adequate financial resources for research and technology adoption play a major role in yield stagnation.

There is no dearth of technologies developed locally in Africa or adoptable from other countries. However, most cotton technologies developed elsewhere in the world are input oriented and may not necessarily be suitable for the small-scale production systems of Africa. Many technologies that deal with nutrient management, water management, pest and disease management, or post-harvest management, require financial resources, which are scant in Africa. Cotton farming is less profitable in Africa mainly due to low yields and high input costs. The low yields and low income generated from cotton farming supports their bare minimum standards of living and does not enable farmers to invest more into agriculture.

Bt-cotton may be useful for effective bollworm control and insecticide reduction. But *Bt*-seeds would be expensive and farmers will have to invest more on seeds and supporting inputs for high yields. *Bt* cotton technology was adopted in Burkina Faso, South Africa and Sudan, as these countries have a well-established credit system for cotton. In eastern and southern Africa, where the cotton sector provides little credit to farmers, high seed costs may deter speedier adoption of *Bt*-cotton.

Valerie (2011) notes that given the constraints to widespread promotion of the *Bt*-cotton technology in Africa in the near future, it is encouraging to note that many of the soil, nutrient, water, and pest and disease management practices followed without any compromise in input applications, were found to have the potential to enhance the conventional cotton yields equivalent to *Bt*-cotton.

Since 2000, at least half of the world's fastest-growing economies have been in Africa, and as of 2012, the African countries with the highest agricultural value-addition (in terms of annual growth) included Burkina Faso, Ethiopia, Nigeria, Mali, Mozambique, Rwanda, and Tanzania (Landry Signe, 2018). With about 60% of the world's unused arable land, there is a lot of room for growth in Africa. Ample investment opportunities in agri-technologies such as fertilisers, machinery and irrigation systems could make Africa the major investment destination in the world.

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A Change in Plant Architecture Can Break Yield Barriers in Africa

Keshav R. Kranthi, International Cotton Advisory Committee, Washington DC

Over the past 30 years, cotton yields in Africa have been stagnant at an average of 350 kg of lint per hectare (ha). Cotton in Africa is grown mainly in the tropical regions, where abundant sunlight, adequate rainfall and fertile soils (in many countries) should have resulted in high yields and good crop growth. A critical analysis shows that it is paradoxical that the unabated crop growth could be the main factor that is responsible for low yields.

It would be possible to enhance yields by breeding 'compact-architecture' cultivars coupled with 'canopy management' in which excessive vegetative plant growth is curtailed at a critical stage — either through mechanical methods or with the use of plant growth regulators — to ensure a proper nutrient source-sink relationship. Apart from compact architecture, yield improvement in Africa requires best practices for plant mapping, canopy management, soil reclamation, soil conservation, cropping systems, conservation tillage, water-use efficiency, nutrient-use efficiency, pest management, and weed management.

In developed countries such as USA, Australia and Brazil, plant breeders aim to develop cultivars that retain an optimum number of bolls, generally at 15 to 20 bolls per plant, with a population of 80,000 to 110,000 plants per hectare. However, in Africa and Asia, plant breeders traditionally have been developing plant types that produced the highest number of bolls (80 to 150) per plant. Agronomists recommended wider spacing for such varieties to cater to their potential for tall, wide growth.

Producing more bolls per plant takes a longer time for higher yields, and if terminated prematurely, result in low yields. Cotton plants need about 80% water and nutrients during the flowering and boll-formation stage, which is referred as 'the critical window'. Incidentally, the critical window is the period most vulnerable to bollworms. Any stress during this time adversely affects the yields depending on the level of stress. The critical window is about 40 to 50 days in a short-duration, high-density crop, whereas it ranges from 80 to 120 days in a long-duration crop like those in Africa or India.

If the plants have to be kept in the field for longer than six to eight months to obtain high yields, the crop would need adequate water, nutrients during the longer (80 to 120 day) critical window of 'flowering and fruiting' to obtain higher yields. A long-duration crop becomes vulnerable not only to stresses from water and nutrients but also from insect pests and diseases, thereby warranting proper management.

In all other countries that harvest high yields of 1,000 to 2,500 kg/ha, emphasis is placed on high-density planting (more than 75,000 plants per hectare) coupled with canopy management to terminate the crop at four or five sympodial nodes (fruiting branches) above the white flower (generally at a total of 12 to 16 sympodial nodes per plant below the white flower). Care is taken to ensure 80% square retention, and/or retention of 60% to 70% of the bolls formed, to obtain high yields in a short season.

To achieve a breakthrough in yields and to increase input-use efficiency of water and nutrients, Africa needs to seriously consider the development and evaluation of the following systems:

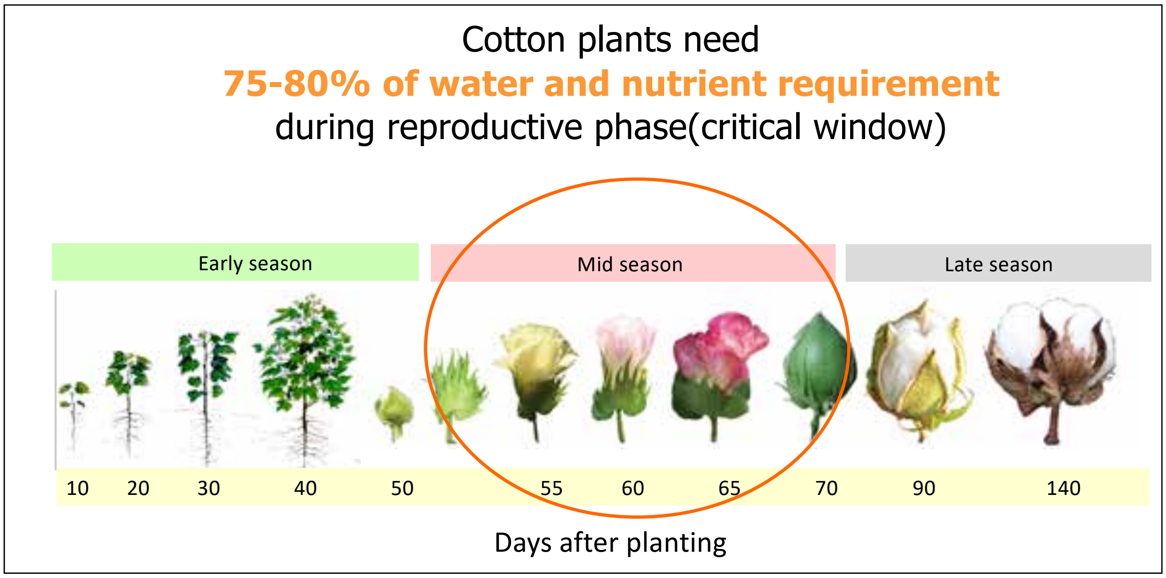
- A new system of plant architecture;
- New planting geometry;
- Canopy management;
- Soil health management; and
- Ecological engineering for pest management.

Development of Efficient Cultivars

Plant breeders must seriously consider developing cultivars with the following plant features: 1. Compact, short-statured; 2. Zero-monopodial; 3. Short season (140 to 150 days); 4. Resistant to sap-sucking insects and local pathogens; 5. High initial shoot and root vigour; and 6. High ginning out-turn and good quality fibre.

Compact statured plants with short internodal length are known to be more efficient in channeling water and nutrients to fruiting parts such as flowers and bolls. Canopy management becomes easier with plants that are genetically designed to be compact.

Zero-monopodial plants have a single main stem that bears sympodial branches with short internodes, which makes it very efficient in energy dynamics for boll development, thereby resulting in higher harvest index (ratio of seed cotton to plant biomass). A higher number of monopodial branches with longer internodes will require more energy in the form of nutrients and water for their growth and development.



Short-season, compact cotton cultivars planted in a high density of >110,000 plants per hectare are expected to retain at least 14 to 15 bolls per plant for high yields, which needs less time for development, maturation and opening. In a short-season crop, the critical window of squaring, flowering and early green boll formation extends for about 50 to 60 days. This critical window is most vulnerable for bollworm attack and is also most vulnerable to water and nutrient stresses. High yields depend on how well the critical window is managed. Effective pest management, weed management, water and nutrient management during this crucial phase determines yield levels. With timely sowing, a short-season crop escapes water stress and bollworms to a great extent, thereby significantly easing management stress. Currently, Africa has a very long critical window of 100 to 120 days during which the cotton crop is highly vulnerable to insect pests, water, nutrients and abiotic stress for a longer period of time. A short, critical window of boll formation makes it easier for management even for illiterate farmers, if trained properly, whereas a long critical window is a nightmare — even for experts and resource-rich producers.

Sap-sucking pests infest the crop in the early vegetative stage. Naturally occurring biological control consolidates itself in the early stages of the crop. Cultivars that are resistant to sap-sucking insects will not warrant the need for chemical insecticides for management, which results in the conservation of generalist natural enemies that protect the crop against bollworms later in the season. Biopesticides and biological control strategies work well under ecosystems that are minimally disrupted by chemical pesticides.

Cultivars with high initial shoot and root vigour have competitive advantage over weeds and will also be able to produce adequate number of sympodial branches in a short time to synchronise the critical fruiting window with available soil moisture. They could also have the ability to withstand abiotic stress and possess capabilities to compensate early damage by pathogens, nematodes and insect pests.

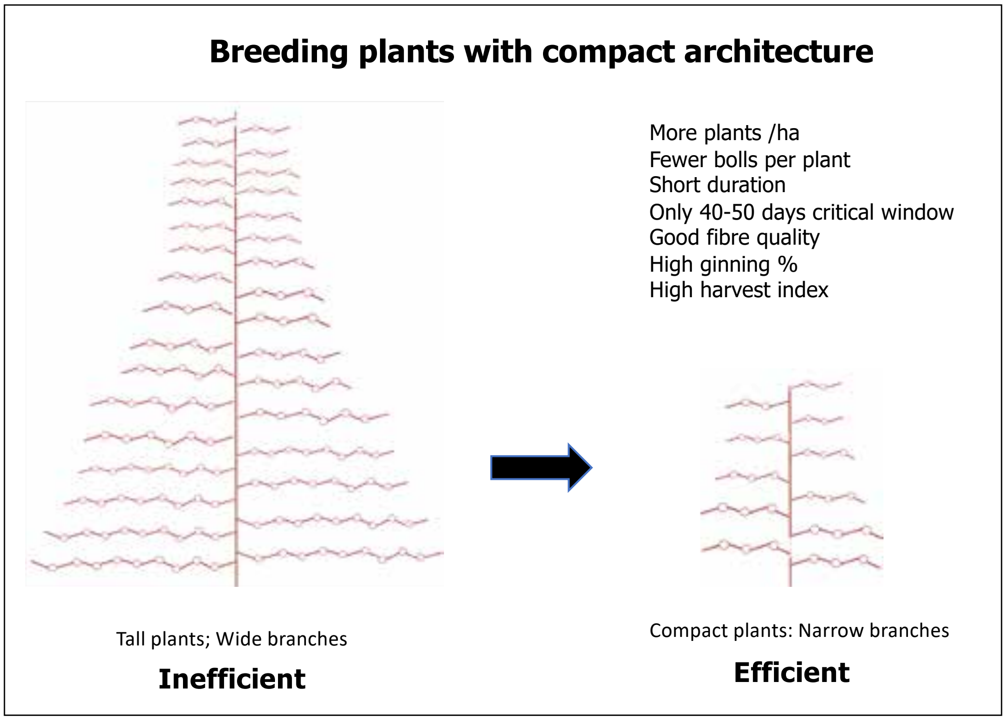
High ginning out-turn results in higher lint yields. High-quality fibre fetches higher prices and thereby produces better profits.

Planting Geometry

Agronomists should seriously consider standardising optimum plant spacing and try a geometry of 8 to 10 cm between plants in a row, with row-to-row spacing at 30 cm, 45 cm, 60 cm, 75 cm or 90 cm, depending on plant architecture, soil type and environment. High yields can be obtained with precision seeding at 1 to 4 cm depth at a spacing of 8 to 10 cm within rows, and 43 to 76 cm between rows, to get 8 to 10 plants per metre and more than 100,000 plants per hectare. The time of sowing must be adjusted to synchronise the boll formation phase with the monsoon. Cotton is highly sensitive to waterlogging and leads to low yields in poorly drained soils. Therefore, planting on ridges or raised beds protects the crop against water-logging. Planting on raised beds improves drainage and enhances soil warmth to minimise seedling pathogens. Gaps between plants must be strictly avoided. Wide spacing causes delayed maturity as more bolls are formed on the outer position and on the higher nodes.

Canopy Management

Agronomists must explore plant growth regulators and mechanical techniques of canopy management to ensure optimum plant growth and to avoid unproductive vegetative growth. Removal of unproductive branches and biomass facilitates proper 'source to sink' channelling of nutrients into fruiting parts, without any wastage into unproductive plant biomass.



Crop monitoring is crucial prior to canopy management. Initially, plant population must be monitored to ensure good plant stand. At the squaring stage from first square to first bloom, it is important to record plant height, number of nodes and node of first fruiting branch, and fruit retention at first position. At flowering stage, there is a need to monitor the plant height, number of nodes above the first position white flower (NAWF), when 25% of plants have their first position flower. At cut-out stage, when 4 to 5 nodes are present above the white flower, it is important to ensure that the number of fruiting parts below the white flower are adequate for high yields. Protecting squares from insect damage and stress contribute significantly to high yields. Retention of 80% of the first position bolls and 9 to 10 nodes above first position white flower is crucial for good yields. Less than 80% retention delays maturity and reverts back to excessive vegetative growth. High retention of fruiting parts plus good plant structure results in high yields. Determining a proper cut-out stage, when all input supplies are stopped, ensures proper source to sinking of nutrients.

Canopy management is done by restricting plant height to 70 to 80 cm by using growth-regulating chemicals coupled with proper management of water and nutrients. Vegetative branches are removed manually after the appearance of the first fruiting branch. This is known to reduce boll shedding, increase boll size, increase the number of fruiting nodes, enhance the dry mass of fruiting parts, and increase seed-cotton yields. This practice is followed in 50% to 70% of the farms in China. Growth tips on the main stem are clipped when an adequate number of fruiting branches are produced, depending on the plant density. Early fruiting branches, generally the lowermost 2 to 3 fruiting branches of the main stem, are removed at peak squaring stage. Apical points of vegetative branches are removed after peak flowering, and those of fruiting branches are removed at peak boll-setting. Removing apical buds of vegetative and fruiting branches is known to enhance root growth, reduce premature senescence, limit horizontal growth of branches and canopy closure/shading and to improve yield, lint percentage and earliness. Empty fruiting branches, and old and yellow diseased leaves, are removed after full flowering for improvement in ventilation and light penetration, as well as a reduction in soil humidity and boll rotting.

It is possible to inhibit lateral growth of vegetative branches by high-density planting, growth regulators and manual clipping to achieve a balance between vegetative and reproductive growth without decreasing yield and fibre quality. The plant height and architecture are generally controlled through timely application of chemical growth regulators. Growth regulation starts from squaring. Apply growth regulators (mepiquat chloride) to restrict vegetative growth or curb excessive growth, after the growth curve when the top third inter-node length is more than 7.5 cm or the length of the top five inter-nodes is more than 18 to 23 cm. Multiple, low-rate applications of growth regulators reduce risks. Do not apply growth regulators when the crop is under stress. Plant height must be maintained equivalent (±10%) to the row width. About 70% to 80% of squares and harvestable bolls across 10 to 14 nodes must be retained. About 80% of the bolls

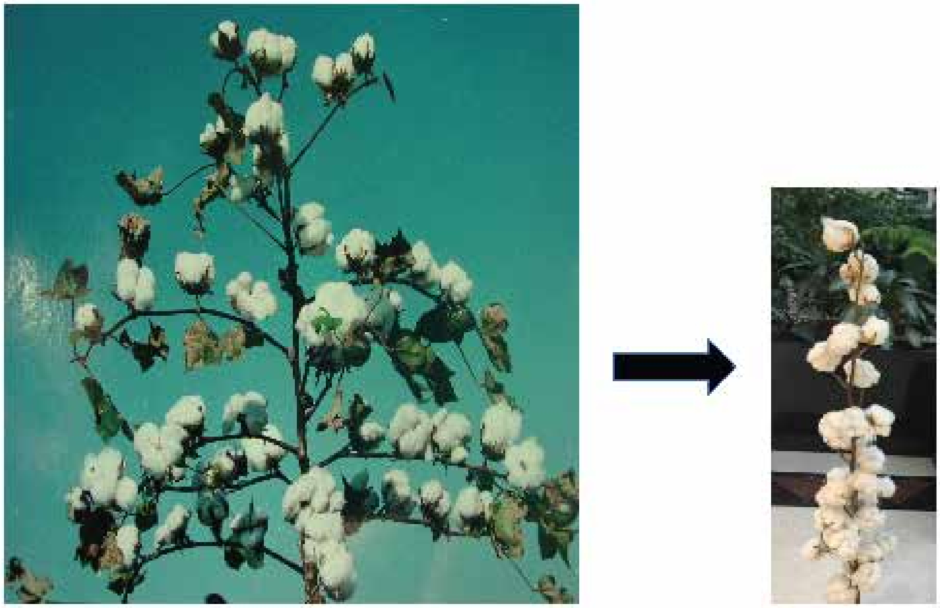


Photo courtesy: Mr. Mubvekeri

must be in the first position. The flowering period is best restricted to 30 to 40 days.

Soil Health Management

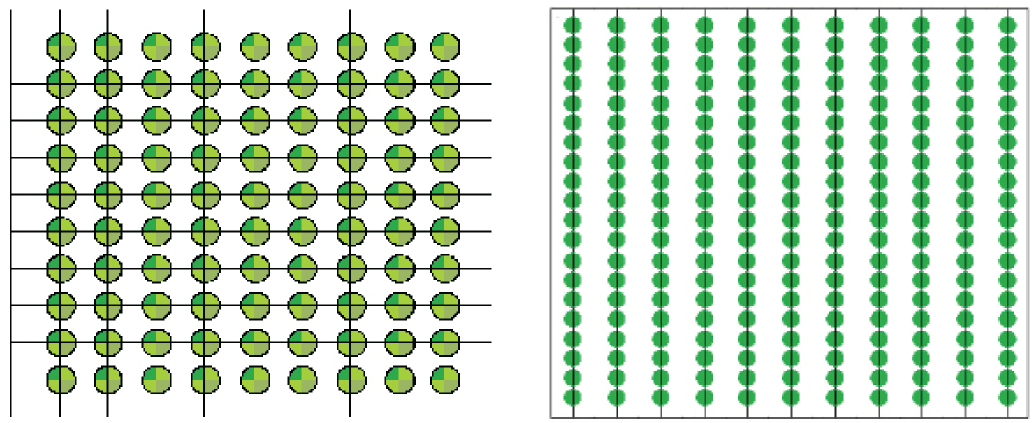
Water and nutrients play a crucial role in plant growth and yields. Uptake of available NPK (nitrogen, phosphorus and potash), secondary and micronutrients in the soil depends on soil health that is based on organic carbon content and the microbial environment. Soil health is mostly a function of good soil management practices that include cropping systems, soil management, nutrient management, soil-moisture management, minimising chemical toxicants, nitrogen fixation by plants, and organic matter that is returned back to the soil as crop residue biomass — which, in turn, is microbially converted to organic manure. Improvement of soil health is crucial for good yields.

Agronomists must conduct experiments to identify the best conservation tillage options for local conditions. Minimum tillage or zero tillage, crop residue management, and choice of appropriate cover crops and crop rotation would play a crucial role in conservation agriculture. Cover crops with legumes such as (*Trifolium incarnatum*) and hairy vetch (*Vicia cillosa*) can provide up to 70 kg N/ha to the subsequent cotton crop. Cover crops improve soil texture, increase soil organic matter, reduce erosion and provide weed control. Crop rotation with legumes such as beans or vetch was found to be profitable in Africa. Mulching with crop residues of cover crops and post-harvest shredding and mulching enhances soil health.

If tillage is required to solve the problem of soil compaction, in-row subsoiling (40 to 45 cm depth) or para ploughing and planting into old crop residue of winter crop can be done to reduce soil compaction. Inter-culture at 15 to 20 days after sowing (DAS) and 40 to 50 DAS can be combined with weeding, earthing up and top dressing of fertiliser.

Ideal soil pH for cotton is 5.8 to 8.0 and adjustments are critical for good yields. Soils in many African countries are slightly acidic and may need reclamation with dolomite lime. Acidic soils do not facilitate proper nutrient uptake, which results in an unhealthy crop that does not have proper capabilities to combat insects and pathogens. Soil reclamation can also be done with biochar that can easily be produced by using cotton stalks and residues obtained from cotton fields. For best effects, amendments with gypsum or lime should be done 5 to 6 months before sowing, which also take care of Ca and Mg requirements.

A significant portion of the chemical fertilisers applied in Africa and elsewhere in the world are lost due to improper application. Precision usage is crucial in resource-poor countries like those in Africa. Soil sampling must be done for less mobile nutrients such as P, K, Ca, Mg and pH. Boron is a key element and should be applied based on soil tests. Optical sensors (such as those form GreenSeeker) that emit light of a specific wavelength to estimate leaf nitrogen may be used for precision N application. Neem-coated urea can be used in Africa for slow release and reduction of losses. Placement of fertilisers, split application, foliar application during blooming, use of growth regulators, use of urease inhibitors and nitrification inhibitors have the potential to prevent nutrient losses. Nitrogen deficiency can be detected by petiole nitrate estimation and visual symptoms. Nitrate content in soil should not be below 25 ppm. Apply N when nitrate is below 50 ppm. Nitrogen and water demands are highest during squaring to the green



Low density planting (Eg: 90x60cm; India and Africa) with bushy type plants

High density planting (Eg: 76.5x8 cm; Australia, China, Turkey etc.,) with compact type plants

boll formation stage. Avoid excessive N in the early stages of the crop (before squaring) to prevent excess vegetative growth and a delay in maturity. The crop needs potash (K) during boll formation stage. Initial soil application and foliar sprays of K during boll formation stage are beneficial. Phosphorus is relatively immobile and should be broadcasted and incorporated so that roots can get a chance to absorb the nutrient. *Arbuscular mycorrhiza* (AM) is important for P absorption. It improves solubilisation of soil-bound P to enhance its uptake through efficient interception. Frequent tillage destroys AM. Yields are always higher due to improved soil structure. The presence of an active soil microbial biomass coupled with restoration of *arbuscular mycorrhiza* (AM) improves nutrient availability, uptake and efficiency.

Ecological Engineering for Pest Management

Integrated pest management (IPM) depends largely on cultivars that are resistant to sap-sucking pests. Seed treatment protects seedlings from pests and diseases. Avoidance of chemical insecticides to control sap-sucking insects prevents disruption in the stabilisation of naturally occurring biological control in the cotton ecosystems. Concomitant with sap-sucking pest infestations, naturally occurring biological control of insect pests starts early in the season and gets consolidated as the season progresses. Populations of insect parasites such as *Eretmocerus* spp., *Trichogramma* spp., and predators such as green lace wing bugs, syrphids, spiders, ladybird beetles, etc., start building up early in the season and survive by feeding on sap-sucking insects and multiply at the expense of a few caterpillars such as semi-loopers, leaf rollers and hairy caterpillars that cause less economic damage. Most of these predators and parasitoids continue to survive and multiply throughout the season. These are detrimental to bollworms and keep them under check. Cultivars that are tolerant to sap-sucking insects do not warrant broad-spectrum insecticides. Botanicals and bio-pesticides or vegetable oils would be adequate for management of sap-sucking pests with minimal harm to biological controls. Cultivars that are susceptible to sap-sucking insects would require application of broad-spectrum insecticides such as those belonging to the organophosphate group, carbamate group, chlorinated hydrocarbons, etc. Just a few applications of these insecticides disrupt ecosystems significantly by destroying naturally occurring biological control that can tilt the ecological balance in favour of insect pests that rebound easily, whereas biological controls takes a much longer time to recuperate.

Intercropping with cowpea or beans helps to attract predatory insects that feed on aphids that occur on the leguminous (nitrogen fixing) intercrops. There are several leguminous crops that do not compete with cotton and can be experimented under ecological engineering as intercrops with cotton to assess the pest-parasite predator ratios under different combinations. Bollworm management becomes easier with biopesticides, if naturally occurring biological control is conserved by avoidance of chemical insecticides early in the season. Marigold serves as an effective trap crop for cotton bollworm. However, if bollworm populations reach economic threshold levels of 5% to 10% damage to fruiting parts, one or two applications of any of insecticides such as spinosad, emamectin benzoate or chlorantraniliprole could be used for effective control. Terminating the crop in 5 to 6 months will provide a closed season for pink bollworm, mealybugs and a few other pests, thereby reducing their infestation significantly in the subsequent season.

It would be worthwhile for researchers in Africa to examine the above-mentioned suggestions to formulate research projects for the development of new cultivars and supporting crop production systems that are most efficient in water use and nutrient use. These efforts will need strong multi-disciplinary research involving good teamwork especially among plant breeders, agronomists, entomologists and extension scientists. Changing the mindset of researchers and farmers for such new approaches, such as compact plants with fewer bolls per plant, would be a great challenge in itself. But these ideas are worth exploring because they have succeeded in countries such as Australia, Brazil, China, Mexico, Turkey and USA, which are placed in divergently different geographical areas, different agro-ecological zones, and with a very different socio-economic and cultural structures. These suggestions are based on success stories and standard practices being followed in developed countries.

It should be remembered that a success story from a developed country may not find resonance in developing or underdeveloped countries, which are located in completely different geographical domains and have very different socio-economic profiles. However, lessons can always be learned from anywhere and adapted to local conditions through rigorous experimentation and validation.

Good scientists never shy away from experimenting with new ideas. If the yield-stagnation jinx is to be broken, new ideas must be tried and tested so effective alternatives can be developed. Success will eventually depend on how determined researchers are to try new things and make a change.

HIGH YIELDS: BASIC CONCEPTS AND TECHNOLOGIES

$$\text{Seed cotton yield (Kg per hectare)} = \frac{\text{No. of bolls per hectare X average boll weight in grams}}{1000}$$

High cotton lint yields can be obtained with a combination of a good cultivar and good management at the mercy of good weather.

The Basics

- Cotton plants are most vulnerable to insects and nutrient stress. Vulnerability increases with the crop duration.
- Flowering and fruiting period (reproductive phase) is most sensitive to bollworms, drought and nutrient stress.
- Cotton plants need about 70-80% of water and nutrient requirements during reproductive phase.
- Longer the reproductive phase, the crop becomes more prone to biotic and abiotic stress.
- A long season crop is a management nightmare.

Good cultivar

High genetic potential:

- The genetic potential for fruiting part formation and boll retention should be high.
- Plants with higher initial shoot and root vigour escape stress.

Sympodial-compact architecture:

- Sympodial short statured plants with short-internodal length and compact architecture are more efficient in ‘nutrient-use’ and ‘water-use’.
- Plants with compact architecture are amenable for high density without compromising on light availability.

High harvest index:

- Breeding for high harvest index enhances water and nutrient use efficiency.

Short duration:

- Plants with a short reproductive window can be efficiently managed for bollworms, water and nutrients.

Resistance to sucking pests:

- Cultivars that are resistant to sap-sucking pests and the major disease of the region, should be preferred. Avoiding insecticide application in early vegetative stage (sucking pest vulnerable stage) helps naturally occurring biological control to establish in the ecosystem.

Good fibre quality plus high ginning out-turn:

- High ginning % (out turn) gives higher lint yield.

Good management

Timely sowing:

- Cotton plants are sensitive to sowing time and degree-day regimens.
- Sowing time in rain-fed regions should coincide with the reproductive phase of peak water need of the crop.

Soil health:

- Nitrogen fixing intercrops, cover crops and rotation crops plus manure or compost enables proper soil health so that plants get a complete complement balanced diet that they need.
- Initial fertilizer dose prior to sowing or at sowing time should be based on soil nutrient analysis to ensure that the plants produce 8-9 sympodial branches in 65-70 days after sowing -before the first flower appears on the first sympodial branch.
- The next split of fertilizer should be applied so that the plants get nutrients during the peak reproductive phase.

Canopy management:

- Plant architecture is managed with plant growth regulating chemicals or physical trimming to ensure proper source-sink flow of water and photosynthates into fruiting parts and also for efficient light penetration into the lower parts of the plant.
- Unproductive branches and vegetative plant parts must be curtailed manually.
- Good boll retention on the first point of the sympodial branches results in high yields.

Water management:

- In rainfed regions, water conservation methods such as water harvesting, ridge planting, mulching, conservation tillage, draining excess water, cover crops etc., are very important to provide adequate soil moisture to the crop, especially during the reproductive phase.

Weed management:

- Creation of a stale seed bed by destroying weeds that emerge in early rains helps cotton seedlings to consolidate initial vigour.
- Appropriate inter-crops, cover-crops and conservation agriculture assist long term weed management.

Pest management:

- Good pest management starts with a cultivar that can tolerate sucking pests and diseases that occur early in the season during vegetative phase.
- Timely sowing helps the crop to escape many insect pests and diseases.
- Timely harvest and residue management practices prevent survival and proliferation of residual pest and pathogen populations.
- A healthy soil greatly enhances crop health thereby enabling the innate crop defenses effectively. Imbalanced nutrient application such as excessive nitrogen and indiscriminate application of broad-spectrum insecticides cause insect pest resurgence.
- Ecosystems get consolidated with naturally occurring biological control organisms, with least application of chemical insecticides on cultivars that are tolerant to sap-sucking insects.
- Implementation of IPM becomes easier and the need for insecticide applications for bollworms gets greatly reduced in ecosystems that contain biocontrol organisms and that are least disrupted with chemicals.

ICAC 77th Plenary Meeting

Abidjan, Côte d'Ivoire 2 - 6 December 2018

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- Mechanisation, Drones and Robotics for Small-Scale Farms: Opportunities and Issues
- Organic Cotton Challenges and Policy Perspectives
- Intergovernmental Policies on Seed Exchange
- Combating Pest Resistance to Biotech Cotton and Pesticides

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