



Boosting Yields in Africa, What Technologies Work?

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Introduction

The ICAC estimates for the 2018/19 cotton season show that out of the 75 cotton-growing countries, lint yields ranged between 118 kg/ha in Chad to 1,848 kg/ha in Australia. The top eight countries (in descending order) with the highest yields in the world in 2018 were, Australia, Israel, Turkey, China, Russia, Mexico, Brazil and Greece (Figure 1). The average yield of these countries was 1,562 kg/ha. In 2018, 20 countries in sub-Saharan Africa produced 1.44 million tonnes of lint from 4.43 million hectares at an average yield of 324 kg/ha. However, 68%

of the production came from 60% of Africa's area that is concentrated in five countries in West Africa: Benin, Mali, Burkina Faso, Cote d'Ivoire and Cameroon. In sub-Saharan Africa, South Africa topped the list in yields with 955 kg/ha followed by Ethiopia at 657 kg/ha, Cameroon at 473 kg/ha, Cote d'Ivoire at 452 kg/ha and Benin at 418 kg/ha. All other countries in Africa harvested less than 350 kg/ha.

However, the estimates on lint yields for Uganda, as of November 2018, were 363 kg/Ha, while the actual yield in the 2017 season was 340 kg/Ha, (CDO Annual Reports and www.cdouga.org).

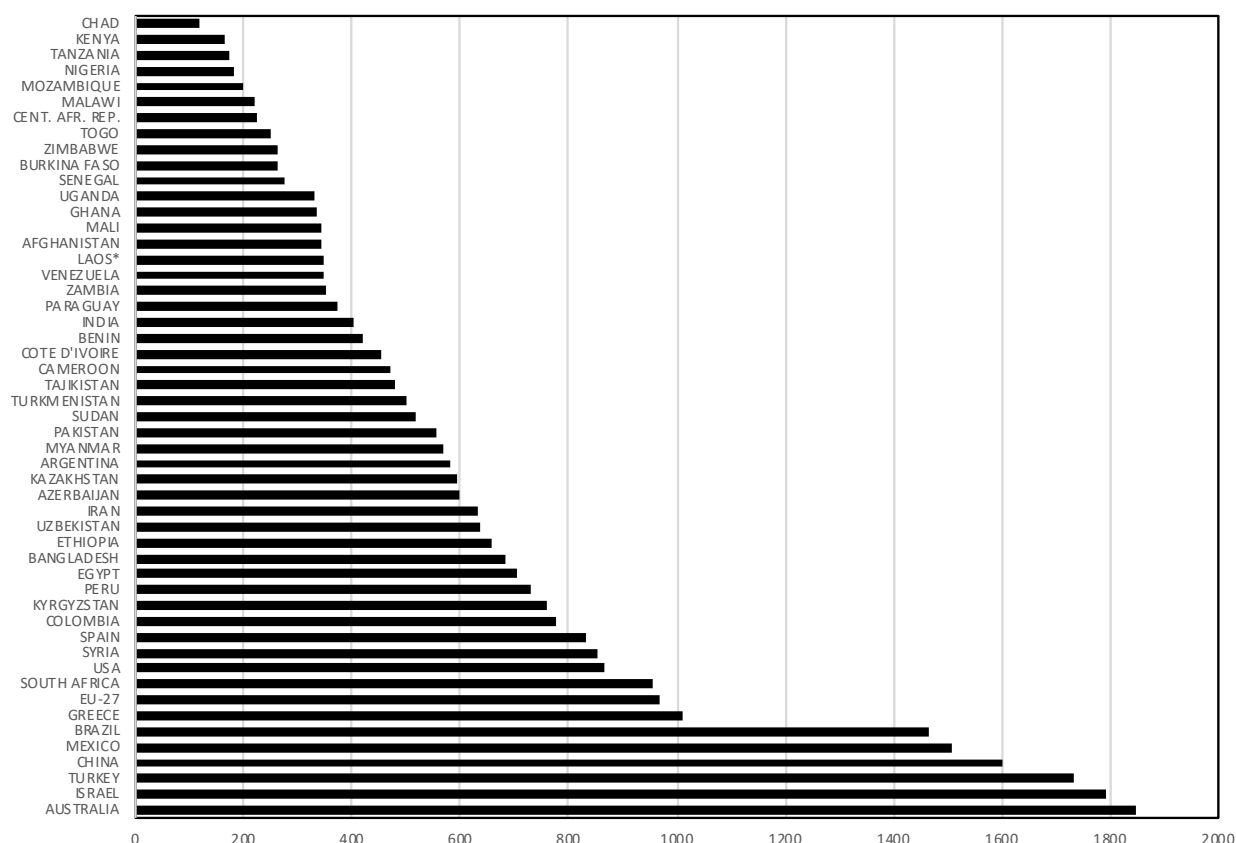


Figure 1. Yield (Kg/ha) in main cotton growing countries 2018

In 2018, the lowest cotton yields in the world (range 118 kg/ha to 274 kg/ha; average 222 kg/ha) were realised from eleven countries in Africa — Burkina Faso, Tanzania, Nigeria, Zimbabwe, Togo, Mozambique, Malawi, Chad, Central African Republic, Kenya and Senegal — which cultivated cotton in a total area of 2.1 million hectares to produce only 465,310 tonnes of lint. Thus, It is clear that the cotton yields in Africa are dismally low compared to any other part of the world.

The ICAC, (2018c), state: ‘The average lint yields in Africa have been about 350kg/ha for more than three decades, and this must change’. While attributing the low African cotton production to low yields, CIRAD (2018) stated that ‘African cotton yields are among the lowest in the world, yet the continent has huge production potential’.

Cotton, which is by far the most important renewable raw material in the global textile industry, is predominantly grown by more than 3.5 million smallholder farmers in Africa. Also, the cotton sector is cited as one of the most important sources of rural employment and cash income in Africa (CHA, 2018).

The importance of cotton in African countries’ economies was further elaborated upon by CIRAD 2018, as ‘more than two million rural households in Sub-Saharan Africa rely on cotton production to earn their livings. Overall, 37 out of 55 African countries produce cotton (Figure 2), where in many of those countries, cotton is a critical crop which accounts for significant proportions of GDP or total exports. However, taken as a whole, Africa is relatively a small global producer; it contributes only 6.0% to the global cotton production by using 13.5% of the global



Figure 2. Cotton Growing Countries in Africa

cotton acreage. Clearly, the main reason for low African cotton production is low yields’.

It is therefore important to identify the factors responsible for low cotton yields and identify means and strategies to increase the yields in Africa. High yields from optimised input usage can enhance sustainability of the cotton supply chains, contribute to the welfare of African populations in the cotton sectors and have the potential to improve African economies in general. This paper examines the practical technological options to boost yields in Africa. Needless to emphasise, increasing cotton yields in Africa is invariably expected to go hand in hand with increases in fibre lint quality.

Determinants of Cotton Yields

Genetic, agronomic and environment components and their interactions play an important role in yields. There is a need to diagnose the critical factors responsible for low yields in Africa to identify pragmatic solutions that can lead to yield enhancement.

The main factors that determine cotton yields are;

- The genetic potential of a variety used in cotton production,
- Genetics and the environment (GXE) interaction, and
- Production technologies or agronomic practices that can actualise the genetic potential of the variety.

A Variety’s genetic potential for higher yield and for any other economically important traits such as plant protection or drought-resistance or herbicide-tolerance or input-use-efficiency can be improved either through conventional breeding or through bio-tech based technologies. There is, however, a group of comparatively contemporary or new and or innovative types referred in this paper as ‘neo-technologies’.

The environmental components on the other hand, include; rainfall amounts and patterns, soil fertility, temperature regimes, insect pests, diseases, nematodes and their epidemics; inter alia.

Diagnosis of the precise interaction effects between production technologies and the environments on yields and likely causes of low yields could serve as the basis to design effective strategies to enhance yields.

Low yields in Africa are most likely due to the following two factors:

- Failure of the cotton sector to develop appropriate technologies suitable for facilitating high performances of the cotton crops under the prevailing environments, and
- Failure in ensuring formidable adoption and appropriate application of the technologies by the cotton farmers.

The desirable increases in cotton yields and fibre quality through interaction effects between the cotton genotypes and production inputs were described by Serunjogi *et al*; (2014) with emphasis on the need for balanced input use in cotton production. Proper use of inputs during the critical stages of cotton crop production, as recommended by the research and development (R&D) sector, would play a crucial role in achieving desired magnitudes of lint yields and fibre quality. Sabune and Serunjogi, (2017) described increases in yields as benefits realised under facilitated Cotton production technology transfer regimes in Uganda. Production technologies should not remain closeted in R&D shelves; there is an urgent need for developing comprehensive but simple technology transfer mechanisms in Africa.

Boosting Cotton Yields in Africa -What Technologies Can Work?

Cotton production conditions in Africa

While the cotton yields have been stagnant and low for decades in Africa, observations have been made on the existence of suitable production technology and conducive environments for high yields in the same production domain.

The ICAC in 2018 perceived this coexistence of low yields, despite favourable conditions as a 'paradox', since African cotton production conditions comprise of the following factors:

Highly suitable weather for cotton, with good sunshine and rainfall;

Good soils and probably better than many other parts of the world where cotton is grown;

New technologies which have been developed in Africa that reach many farms; and

Hardworking farmers applying their best management skills for higher production.

Therefore, it would be pertinent to ask; 'What are the prohibitive constraints responsible for the prevalent low cotton yields in Africa despite the existing favourable opportunities? How can these constraints be solved?' and 'for boosting yields in Africa-what technologies could work?'

British Cotton Growing Corporation (BCGC)

The prevailing conducive cotton production conditions listed by the ICAC (2018) which are expected to favour high cotton yields in Africa date back to the early cotton research which was supported in some African countries by the erstwhile rulers, for example, the activities of the British Cotton Empire in Africa (Figure 3). These were succeeded later by the British Cotton Growing Corporation (BCGC) activities (Anon. 2018, b) that contributed substantially in

shaping the present-day production technologies in most cotton growing countries in Africa. A few examples are listed below:

- The Namulonge Cotton Research Station was established by the BCGC in 1949 in Uganda. The research station which was first set up as Kawanda Research Station, was later transferred to Bukalasa, (now an Agricultural College), and then eventually to Namulonge. All the three sites were located in the Central Region of Uganda. Namulonge eventually became the Headquarters of BCGC activities in Africa, until 1972, when the corporation staff left in a hurry under the difficult law-less rule which prevailed in Uganda then. Other Cotton research programmes were started earlier in the 1930's, at Serere in North Eastern Uganda, (Serunjogi *et al*; 2001), to cater to the cotton production technology requirements of the semi-arid Northern and Eastern regions.



Figure 3. The British's Cotton Corporation's Director of Research Station, Dr. Hutchinson, with workers examining cotton plants for signs of diseases at Namulonge, Uganda in the 1950s (www.iwm.org.uk).

- The successes of the production technology then, in effecting high cotton yields, are attributable to exchanges of; information on production technologies, breeding materials, and of germplasm stocks, between the African countries under the auspices of BCGC. For example, the Albar cotton Stocks which were desired for their resistance to the then notorious Bacterial Blight disease caused by *Xanthomonas axonopodis malvacearum* in East Africa then, are known to have originated from selections made out of a variety called 'Allen' obtained from Nigeria. The Nigerian Allen in turn had been imported from Uganda in 1912. It is, however, believed that while in Nigeria, Allen had naturally out crossed with a perennial cotton species,

Gossypium hirsutum race *punctatum*, which conferred to Allen the genes for resistance to bacterial blight. The resultant resistant accessions became to be known as 'Albar', where 'Al' stands for 'Allen' and 'bar' for 'blackarm/bacterial blight resistance' (Serunjogi *et al*; 2001 and Orawu *et al*; 2017). The Albar stocks laid the foundation of the current breeding programs for the development of cotton varieties in Africa, especially in Uganda and continue to play a crucial role in breeding programmes mainly, because of their resistance to Bacterial blight disease, coupled with adaptability to wide ranges of environmental variations in production areas, and good fibre quality.

- In essence, the efforts in the current African cotton research programmes continue to build upon the achievements that were made under the times of BCGC and its affiliated Institutions on cotton research, which operated elsewhere in non-BCGC benefitting African countries then. Some 'schools of thought', however believe that there is a need to renew and revamp African cotton research at the technical level (Seine and Bachelier, 2017, a & b) to achieve a breakthrough. This is to enable African cotton growing countries to gear up to the new global requirements on yields and fibre qualities under competitive cotton value chains, a scenario which is different from the one which existed during the times of BCGC.

The current cotton production technologies in Africa

The prevailing cotton production technologies in vogue are similar in many of the African countries, that inherited a common research structure of the BCGC. The technologies are categorised under:

Varietal improvement

The varieties developed in Africa were developed, tested and selected across intended production areas, for characteristics of; early maturity periods, improved seed cotton and lint yields (complemented by high Ginning Out-turn, GOT), high quality fibres, resistance to pests e.g. selecting for high density plant hairiness which confers resistance to sucking pests like the jassids (*Empoasca* sp), resistance to diseases and for tolerance to drought.

Seed multiplication and processing

Varietal development and seed production are based on organised procedures standardised by the ICAC. During the 72nd ICAC plenary meeting held in Cartagena,

Colombia in 2013, the ICAC member countries approved the standardisation of nomenclature of cotton planting seeds for adoption by member governments. The nomenclature comprises the following levels: Breeders', Foundation, Certified, Registered and Commercial seeds (ICAC 2013). The seeds are processed, de-linted, treated with chemicals for pest and disease resistance, packed and labelled to indicate varietal name, targeted season of planting, agronomical packages on spacing for desired plant populations and on pest management.

Agronomic packages

Crop production practices include details on land preparation, seed bed preparation, proper sowing date, soil moisture management, planting geometry, soil fertility management, weed management, regulating plant growth and picking. Crop residue management is followed to ensure that residues are incorporated into the soil in a timely manner to provide nutrients to the ensuing crop. Sowing dates are decided based on the monsoon predictions to ensure adequate soil moisture for seedlings and at least 500 mm of rainfall for the crop (Serunjogi *et al*, 2001). Land preparation, seed bed preparation, sowing and weeding operations are carried out using minimal mechanisation using oxen drawn implements, (Figure 4).



Figure 4. Using Animal Draft Power for Cotton Seed Bed Preparations in Uganda

Integrated Pest Management (IPM)

Insect pests and diseases are managed using IPM strategies. These approaches include, *inter alia*, the use of biological control, biopesticides and chemical insecticides based on economic threshold levels to ensure that the pest control actions have least disruptive effects on the naturally occurring biological control organisms (Sekamatte *et*

al, 2003). The IPM options also expect farmers to follow recommendations of proper pesticide dilution, follow safety precautions, use appropriate spray technologies of knapsack, motorised and or tractor mounted sprayers with appropriate nozzle types.

Biotech cotton

Several African countries have streamlined the official biosafety procedures to regulate the assessment and approval of bio-tech cotton for economically important traits such as resistance to insect pests, diseases and herbicides.

In August 2018, Nigeria became the seventh African country to officially grant approval of production of bio-tech cotton. Thus, Nigeria followed the six African countries — South Africa, Sudan, Swaziland, Kenya, Malawi and Ethiopia — that approved bio-tech cotton production under their national laws before (ISAAA, 2018).

Kranthi (2018a), described the status on government approvals on use of bio-tech cotton in African countries on trait basis. So far, insect-resistant biotech Bt-cotton had been approved in six countries in Africa — South Africa, Burkina-Faso, Sudan, Nigeria, Swaziland and Ethiopia. In addition, herbicide tolerant trait was also approved in South Africa. Malawi, Kenya and Cameroon were conducting multi-location trials of Bt-cotton while Cameroon was considering herbicide tolerant traits for approval.

In Uganda, the 'National Biotechnology and Biosafety Bill 2012' was tabled in the Parliament in October 2017. It was referred back to the Parliamentary Committee on Science, Technology and Innovation for refining. The refined Bill was re-tabled and passed by the Parliament in November 2018. It had been renamed as 'Genetic Engineering Regulatory Bill, 2018' and was mandated to provide a regulatory framework for safe development and application of biotechnology and release of Genetically Modified Organisms (GMOs), Anon (2018a). The new Act had to be assented to by the President of Uganda by the end of February 2019 before being fully operationalised under the Uganda Laws, Anon 2019.

ICAC Perspectives to Boost Yields in Africa

- In 2018 and 2019, the ICAC released three special issues of 'The ICAC Recorder' which contain views and ideas of various stakeholders in the global cotton fraternity on how to increase cotton yields in Africa, (ICAC 2018b, ICAC 2018c, ICAC 2019). In the September, 2018 issue (ICAC 2018b), the Editorial gave an excellent summary on the low yields which had marred the African cotton production. The yields had stagnated at 350kg/ha in the last three decades,

in comparison to over 1,500 kg/ha of lint in five high cotton yielding countries: Australia, China, Mexico, Brazil and Turkey.

- The editorial emphasised the need for a change in plant architecture and planting geometry for high plant density in Africa and India, as an idea that could lead to a break-through in yields. The proposed planting geometry could enable the crop to enhance its utilisation efficiency of sunlight, water and inputs and produce high yields in a short time with less inputs and low cost. These ideas were based on the proofs derived from success stories Australia, China, Mexico, Brazil, Turkey and USA.
- The editorial brought out the need to identify the basic principles which underpin the required technological changes towards increasing the yields. The principles would then be assimilated and used in the development of concepts, strategies and technologies which had to be tested and validated in the local environments of adoption in Africa.
- Some of the above observations were also captured in an article titled 'Perspectives on Cotton Research and Ideas for Africa-Proceedings & Recommendations of the XIV Meeting of Southern & Eastern Africa Cotton Forum (SEACF)' that represented the views expressed in the SEACF Meeting held at Harare, Zimbabwe during 4-6 July 2018, with a theme 'Global best practices for cotton yield enhancement in Africa' (ICAC 2018b).
- Following is an abridged list of the recommendation that emanated from the SEACF meeting:
 - Breeding cotton varieties 'efficient' on the use of nutrients and water and with compact architecture to enable mechanisation of production operations.
 - More support to cotton research and strengthening cotton research institutions.
 - Formulation of demand driven production technologies, with farmers' participation for increasing their uptake.
 - Design farmer-participatory strategies to protect the cotton crop from weather vagaries and climate changes.
 - Government and private agencies facilitation of farmers' access to crop protection technology against pests and diseases.
 - Organised production and availability of good quality certified planting seeds.
 - Support schemes for sustainable availability of inputs such as fertilisers, pesticides and machinery.
 - Sustainable cotton brands under the rain-dependent systems to fetch higher prices in global markets.

- Promotion of conservation agriculture to enhance soil health vis-à-vis the existing conventional tillage systems which are in operation in Africa and responsible for soil degradation.
- Technology transfer training programmes for farmers' education and awareness.
- Among the other comprehensive and 'must-read' papers related to ideas for increasing cotton yields in Africa published in the September 2018 ICAC Recorder (ICAC 2018b), include the ones authored by Farid Uddin *et al*, and Sabesh.
- Furthermore, in the same issue of the September 2018 ICAC Recorder (ICAC 2018b), Kranthi (2018b) gave invaluable insights into how compact cotton plant architectures and canopy management would lead to increased yields in cotton in Africa. He explained the merits of scenarios in Australia, Brazil and USA wherein breeders aim to develop compact architecture cultivars that retain an optimum of 15 to 20 bolls per plant but with a planting density of 80,000 to 110,000 plants hectare. High yields of 1,000 to 2,500 kg/ha of lint are obtained in such cases. Kranthi advocated for the need of adopting compact cotton architecture and canopy management for increasing cotton yields in Eastern and Southern African countries (Section on the Authors' Views to Boost Cotton Yields in Africa, of this Paper). He described the different scenarios in Africa and India where plant breeders have been developing plant types that produce high number of bolls of up to 80 to 150 bolls per plant. Such plants need wide spacing for their tall and wide plant growth habits. While they produce many bolls, such cotton cultivars take longer time to maturity and if terminated prematurely, they result in low yields. Their 'critical windows' (flowering to boll formation stages) range from 80 to 120 days in comparison to the high-density short duration crops of 40 to 80 days. Thus, the cotton crop in Africa or India needs more water and nutrients during the long critical windows to provide high yields.
- In the December 2018, 'Special Issue' of 'The ICAC Recorder' Hezhong Dong and Michel Fok (2018) described how Light and Simplified Cultivation (LSC) techniques could lead to increased yields in small-scale farming systems in Africa. The technique includes use of small-scale agricultural machinery, materials and equipment designed to reduce or replace manual operations but simplified in comparison to heavy machinery used in intensive cultivation technologies, such as those deployed in China. The techniques include single-seed precision sowing machines, control of vegetative branches without pruning, one-time fertilisation, fertigation and maturity grouping for unique harvests.
- In the December 2018 issue of the ICAC Recorder (ICAC 2018c), Blaise Desouza gave a comprehensive description on how adoption of the 'Best Management Practices (BMPs)', under small-holding and limited resources category of farming, could increase cotton yields in Africa. Conservation Agriculture (CA) is one of the major components of BMP which holds the key to improving productivity. CA revolves around three basic principles namely; minimising tillage, including a permanent cover and crop rotation. It was emphasised that achievement of merits of CA need testing of the technologies on a regional basis i.e. successful CA technologies in a given country may not directly or necessarily work in another country without confirming their suitability in the new environment. There is need to understand the local situation (including soils and climate), and tailor the CA practices to suit the local conditions.

Authors' Views to Boost Cotton Yields in Africa

Since the conventional technologies and existing production systems have not been successful in obtaining high yields in Africa (ICAC, 2018b), it is proposed that efforts be made towards promotion of neo or innovative technologies, that have been developed and found effective in African research stations. There is a need to use appropriate technology transfer mechanisms to take innovations from the labs into the land. These new approaches should be backed by appropriate legal and institutional arrangements and supplemented by collaborations across research and initiatives' programmes in Africa. Efforts should also be made periodically to review the effectiveness of the technologies that are currently in use, and also propose new strategies for cotton research in Africa wherever appropriate.

Use of 'Neo-innovative' and Affordable Technologies

Biopesticides

Formulation of affordable, safe and effective bio-pesticide extracts from locally available plant materials like trees' and herbs'; leaves, barks, fruits and kernels or seeds has been attempted in Uganda. A Bio-pesticide Laboratory was constructed and inaugurated in August 2017, www.cdouga.org, (Figure 5). It is strategically located at the National Semi-arid Resources Research Institute (NaSARRI). The NaSARRI (www.nasarri.go.ug) holds the mandate for cotton research under the broad research programmes of the National Agricultural Research Organisation (NARO), (www.naro.go.ug). The Bio-pesticides Lab was constructed under the auspices of the Cotton 'Technical Assistance Programme' Cotton-TAP-Africa -India, with the support of the Government



Figure 5. Training of scientists in the Bio-pesticide Lab at NaSARRI Serere, Uganda in August 2017

of India towards strengthening the cotton supply chains, (www.cottontapafrika.org), in African countries. The TAP phase-1 was operational from March 2012 to 2017 in Seven African cotton growing countries, namely Benin, Burkina Faso, Chad, Mali, Nigeria, Uganda and Malawi.

The Bio-pesticide Lab at NaSARRI is already formulating bio-pesticides from Uganda native trees and shrubs such as *Lantana camara*, Neem (*Azadirachata indica*), Mahogany sp, *Khaya senegalensis* and *Moringa olifera* tree species. The laboratory has also a facility for testing soil samples to determine fertiliser requirements for cotton production in the different production zones. The Bio-pesticide laboratory is expected to be upgraded to commercial production level of the bio-pesticides so as to serve other cotton producing countries in the region.

Gayi *et al*, (2016) showed that bio-pesticides such as 'Nimbecidine', which are extracts from Neem tree; leaves, bark, fruits, roots and from seeds kernels, and Khaya extracts from seeds and barks, provided better control of cotton bollworms and significantly higher yields of seed cotton than their counterpart synthetic pesticides in Uganda. These bio-pesticides were recommended in Uganda for the control of cotton bollworms, namely, American bollworm (*Helicoverpa armigera*), Spiny bollworm (*Earias insulana* and *Earias biplaga*) and Pink bollworm (*Pectinophora gossypiella*), (Gayi, *et al*; 2017).

Isolates of a fungus *Metarhizium anisopliae* have been derived at the NaSARRI Bio pesticide Laboratory. The fungus is known to be effective in the control of major pests, especially the Lepidopteran insects, which include: Fall army worms, Cotton Bollworms and Maize Stem borers. Pure cultures of the fungus have been obtained at the Lab. The cultures are being tested in the lab and

field conditions to identify the most potent strains that can be multiplied and released for use in cotton crops in Uganda, (Gayi, 2019. *Pers com*).

Biological control

The use of biological control refers to the use of living organisms for the control of insect pests and harmful pathogens in cotton. Some of these techniques include the use of beneficial insects or natural enemies, which predate on cotton pests e.g. the Black Ants *Lepisiota spp.*, which were found effective in the control of major insect pests of cotton in Uganda (Ogwal, *et al*; 2003). Other beneficial insects on cotton include; Ladybird beetles, common wasps, praying mantis, assassin bugs (*Pristhesancus sp.*), wasps (*Trichogramma* and *Telenomus sp.*) and spiders. Biological agents also include the Nuclear polyhedrosis viruses, *Metarhizium*

anisopliae, *Beauveria bassiana*, *Isaria sp.*, and *Verticillium lecanii* that infect insect pests of cotton (Gayi, *et al*; 2017). Modalities for mass rearing of such biological agents should be developed to enhance sustainability of crop protection through low cost and environmentally friendly approaches.

Bio-fertilisers

The use of biofertilisers greatly enhances soil health in the eco-friendliest manner. Many species micro-organisms such as *Rhizobium*, *Azotobacter* and phosphate solubilising bacteria (PSB) such as *Pantoea agglomerans* or *Pseudomonas putida* have been commonly used in cotton ecosystems either as inoculants for leguminous crops, or application to seeds and soils to enhance soil fertility. Intercropping cotton with nitrogen fixing legumes like Soybeans (*Glycine max L.*) (Serunjogi *et al*; 2002), or common beans *Phaseolus vulgaris* (Elobu *et al*; 1995) inoculated with nitrogen fixing *Bradyrhizobium japonicum* or appropriate *Rhizobium* species greatly enriches the soil with nitrogen. Several strategies have been used to design crop-legume intercropping systems to ensure significant nitrogen fixation without any competition of the legume crop with cotton. While enhancing the soil health, many such legume crops provide food security and additional income. Apart from intercrops, cover crops and green manure crops are grown before the crop is sown or between cotton rows and incorporated into the soil later to enhance fertility. Those tested and recommended for use in cotton in Uganda include; digging Macuna beans *Macuna pruriens*, Wild or Mexican sunflower, *Tithonia diversifolia*, (Figure 6), herbs into the soil before planting (subterranean application) or mulching the cotton seed



Figure 6. Plants of *Tithonia* sp, (left), and leaves applied in trenches between Cotton Rows, (right) to be incorporated into the soil



Figure 7. *Tithonia* treated cotton crop at flowering (left) and at boll opening stages (right)

bed with either species' herbs between the rows i.e. surface application (Elobu *et al*; 2016). Increased seed cotton yields were realised with application of *Tithonia* leaves in trenches 5-10 cm from the cotton rows and about 10 cm deep, where the *Tithonia* leaves were buried at a rate of 1000 kg/ha of leaves (Figure 6). *Tithonia* sp leaves are known to be rich in Nitrogen, Phosphorous, Potassium, Calcium and Magnesium nutrients which contribute to the growth of cotton plants. Plots treated with *Tithonia* gave up to 2,245 kg/ha of seed cotton compared to 1,796 kg/ha of the controls without *Tithonia*. This represented a 25% increase in yield over control (Figure 7) with improvements in fibre quality (staple length and strength) which would thus fetch better prices for the lint especially in International markets. Additionally, there were increased residual soil nutrients such as Phosphorous and Potassium which could benefit the subsequent crops like; Finger Millet (*Eleusine coracana* (L) Gaertn), Maize (*Zea mays*), and Groundnut (*Arachis hypogaea* L.) in the crop rotations (Elobu *et al*; 2017).

Growth regulators

A few growth-regulating chemicals have been tested and some were found to be useful in boosting plant growth and for insect pest management. In Uganda a chemical called 'Vitazyme' was tested on cotton for three seasons. Vitazyme is known to be a cotton root vigour inducing chemical. It contains highly active bio-stimulating agents from natural plant sources that lead to luxuriant plant growth. Its active ingredients include B-vitamins, folic acid and other un-quantified growth regulators (Syltie, 1985). Vitazyme was tested in combination with the already approved commercial seed dressing chemical 'Cruiser Extra Cotton' used for control of seed borne diseases, like bacterial blight, and known for enhancement of root vigour. Vitazyme was found to be effective in boosting vigor of cotton roots which enabled deeper penetration and wider coverage of soils for tapping of water and nutrients by the cotton crops. In addition to improving plant vigor in the study, Vitazyme led to enhanced seed cotton yields and

fibre characteristics compared to the controls. The best results were from the 5% Vitazyme concentration for seed dressing, coupled with one foliar spray on cotton plants using 1 l/ha of Vitazyme at full bloom (Elobu *et al*; 2018). Chemicals with novel modes of actions were tested in IPM programmes. In Uganda, a product known as 'Celite 610' (trade name: 'Deadzone') is being tested on cotton (Figure 8). Celite 610 is a 'Mechanical Insecticide', that adheres to the insect cuticle and adsorbs to their lipid layers or cuticular wax. It thereby creates pores in



Figure 8. Pest control with a Novel Mechanical Pesticide, "Deadzone". Chemical residues on the sprayed leaves (left) and the resultant healthy crop (right)



Image: Keshav Kranthi, ICAC

Figure 9. Canopy Management

the cuticles which leads to desiccation and death of the pest. It is manufactured from Diatomaceous Earth which consists of Diatoms, a type of hard-shelled algae deposited on prehistoric fresh water lakes and marine estuaries. Deadzone was found to be very effective in control of pests such as Lygus, Leafminers, Mealy Bugs, Pink bollworms and Tobacco Thrips *Frankliniella fusca*, (Jiwei Zhu *et al*; 2016).

Canopy management

The use of cotton vegetative growth through canopy management techniques by reducing vegetative branching leads to effective 'source-sink' channeling of nutrients and photosynthates into fruiting branches, fruiting points, flowers and into developing cotton bolls thereby enhancing the harvest index (ratio of seed cotton versus

a) Mechanical Plant canopy management;

Restricting height to 60-90cm by manual clipping of apical nodes and a short season of 140 days, giving 15-20 bolls per plant with removal of vegetative branches and leaving only 9-10 fruiting branches: (b) Application of PGR; for a cut-out on apical growth at 4-5 fruiting branches above white flower. The PGR application also restricts internode length to 4-5 cm and offers retention of 80% of the flower squares and 60-70% of the bolls.

plant biomass). Some of the techniques include application of Plant Growth Regulator (PGR) such as 'Pix', (Mepiquat Chloride) on the cotton crop to arrest further vegetative growth of the cotton terminal points (Elobu *et al*; 1997). Similar effects can also be achieved by mechanically de-topping the main stem apical or terminal buds. The above treatments are applied after boll setting stages, so as to divert photosynthates and nutrients to the developing fruiting points and cotton bolls. Canopy management techniques which were described by Kranthi, (2018b, 2018c), include; breeding for short season varieties of about 150 days or less to maturity, restricting plant heights to 60 – 90 cm by manual de-topping or by use of PGR and/or removal of non-productive (vegetative) or monopodial branches (Figure 9). Canopy management is considered as an important technique for high yields in

high density planting of over 111,000 plants/ha as in top cotton yielding countries, as opposed to less than 16,000 plants/ha with tall and wide and bushy cotton plants in African cotton farms. Breeding cotton varieties with reduced vegetative branches has been successful in some breeding programmes for example in Uzbekistan. These compact varietal architectures, which are generally referred as 'zero monopodial plants' enable



Figure 10. Cotton Plant Varietal Architecture: (Left) Vegetative Wide Branched and (Right) Zero or Compact Branchless Types.

high plant population. For example, with 'zero monopedal plants', close cotton plant spacings of 76.5 x 8cm have been attained in Australia. This is in comparison with spacings of 90 x 60 cm which are in use in India and Africa. In addition, compact cotton plants make it easy for mechanisation of operations (Figure 10) of weeding, chemical applications and picking (Kranthi, 2018b).

Institutional Support

A few institutions have been active in Africa offering alternative technological approaches, dissemination strategies and to enhance the sustainability of cotton value chains. Some institutions and programmes on Initiatives have come up with objectives of developing new approaches and insights into cotton production and entire cotton value chains in Africa. Their main priority is to obtain high cotton yields in sustainable manners. The Cotton Expert House Africa (CHA), is a private sector-driven non-profit organisation (www.cotton-house-africa.org) aimed at supporting sustainability in the African cotton and textile sectors under the changing market environments. The CHA supports production of cotton under certification 'standards' like, Cotton made in Africa (CmiA), Better Cotton Initiative (BCI), and Fairtrade cotton. These standards are recognised by major textile manufacturers, brands and retailers of cotton by-products. Certified African cotton is bought at premium prices, part of which is ploughed back to cotton farmers' gate prices for seed cotton, thereby leading to sustainability in production and to increased yields at farm levels. Among other initiatives in the CHA programme is the plan to run the 'Cotton Seed Improvement Program' aimed at improving African cotton planting seed quality. The cotton seed quality in Africa is perceived to be poor and identified as one of the main causes of low cotton yields. The first phase of the program will comprise a study on the state of cotton seeds in four African cotton producing countries: Zambia, Tanzania, Ivory Coast and Burkina Faso (Anon. 2018c). The CHA in collaboration with Cotton Development Organisation (CDO) of Uganda organised the 2nd Pan-African Cotton conference 1-2 November 2018 in Kampala Uganda. The conference attracted a total of 168 delegates drawn from 20 different countries. The objective of the conference was to 'provide a platform for actors in the African cotton sector to network, share sector information and experience with sustainable cotton production'. The theme of the conference was 'Standard and certification in relation to sustainable cotton production in Africa'. The Conference formed a platform for technology transfer. The proceedings of the conference are available on; 'www.cotton-house-africa.org'.

A study was sponsored by the European Union under the auspices of Africa-Caribbean Pacific (ACP) Cotton, on 'Diagnosis and recommendations for the elaboration of a

proposal for revamping strategy of Africa cotton research'. Two reports were produced:

- Seiny B.L and Bachelier B. (2017a). Final Report 'Diagnosis and recommendations for the Elaboration of a proposal for a Revamping Strategy of African Cotton Research'. ACP COTTON, January 2017.
- Seiny B.L and Bachelier B. (2017b). Final Report 'Proposal of a detailed strategy for revamping African Cotton Research at the Technical level', ACP COTTON June 2017.

The reports focused on four strategic objectives that envision:

- Reinforcement of research capabilities on human/scientific capacities, finance and on tools' capacities.
- The adoption of research themes and tools for sustainable production.
- The need for streamlining of research efficiency in the cotton value chain i.e. stressing relevancy of research to the needs of Africa for achieving the aims of research objectives.
- The integration of African cotton research in the worldwide scientific community so African cotton scientists do not work in isolation or 'scientific cocoons'.

Enabling Policies to Boost Yields

Further in addition to the above proposals, suggestions and recommendations, there is need to have in place effective mechanisms for supporting sustainable use of the suggested technologies, human skills and scientific capacity for increasing and sustaining cotton yields in Africa. The required mechanisms include formulating policies, legal frameworks and regulations in place for supporting various activities such as increasing public and private sector funding of Research for development of the production technologies including step-wise multiplication of quality planting seeds and enabling germplasm exchanges between various research programmes, but, in conformity with required Intellectual Property Rights (IPRs).

During the 77th Plenary Meeting of ICAC in Abidjan Ivory Coast in December 2018 the Committee stressed the imminent need for 'Inter-Governmental Policies on Seed-Exchange' (ICAC 2018a). It was emphasised that the exchange of seeds (germplasm) between countries would facilitate progress in cotton production. The narrow genetic base available for cotton improvement in cotton producing countries (including Africa), and the ever-changing market demands for specific fibre qualities, along with the need to improve yields made seed exchange important across countries.

Clearly, access to new germplasm holds the key to genetic improvement, enhancement of genetic diversity, and expanding genetic variability for useful traits. The Speakers (ICAC, 2018a) recommended that Governments develop a roadmap for creating a global platform that operates as a smooth and trustworthy channel of seed exchanges amongst countries across borders. The ICAC Member Governments were also urged to create an International Cotton Research Institute under the CGIAR system, which could act as a research and educational institute and a 'Global Repository' of germplasm sources that could be freely shared.

The CGIAR System is currently comprised of 15 Global Agricultural Research Centers, which are independent and non-profit making, conducting innovative research. These include; Africa Rice Center (AfricaRice), Biodiversity International, Center for International Forestry Research (CIFOR), International Center for Agricultural Research in Dry Areas (ICARDA), International Center for Tropical Agriculture (CIAT), International Crops Research Institute for Semi-Arid Tropics (ICRISAT), International Food Policy Research Institute (IFPRI), International Institute of Tropical Agriculture (IITA), International Livestock Research Institute (ILRI), International Maize and Wheat Improvement Center (CIMMYT), International Potato Center (CIP), International Rice Research Institute (IRRI), International Water Management Institute (IWMI), World Agroforestry Research Institute (ICRAF) and WorldFish; (www.cgiar.org/research/research-center).

- The policy frameworks need to formulate structures and contents of the research programmes in tandem with the requirements or and preferences of all operators along the cotton value chains and comprehensive technology transfer systems from research to the cotton farmers including requirements

for extension services and training of farmers as described and recommended by Sabune and Serunjogi (2017) (Figure 11).

- There is a need to Streamline marketing, under commensurate and stable prices for seed cotton, and processing of the increased cotton volumes produced by the Farmers.
- Periodic reviews by the Cotton sector on catalysts required for sustaining the attained high cotton yields. The reviews should assess, *inter alia*; the ease with which farmers continue accessing standard and true to label, or type, production inputs. This is to safe-guard farmers against infiltration into the cotton production systems of 'fake' and adulterated or sub-standard inputs, a factor which has been identified as one of the causes of low cotton yields in Africa.
- Inclusion of the cotton sector in the 'National Strategic Commodities', under the periodic 'National Strategic Plans', as is the case in Uganda (Anon., 2016).

Recommendations

The above inputs on the required changes for improvement of cotton yields in Africa have been based on literature search of records on what has transpired in Africa at the continent level and on real life observations in the cotton Industry in Uganda. Some information has come from tested or piloted new approaches at public research levels and from private sector initiatives that are yet to be passed to farmers. As a way forward for increasing cotton yields in Africa, the following strategies and activities are recommended;

- Direct more support towards conclusion of ongoing diagnostic and piloting initiatives aimed at increasing cotton yields and find means of implementing the recommendations arising thereof at farm production levels.
- Conduct inventory surveys on all available production technologies and new innovations in the 27 African cotton producing countries. Through literature search and analyses, assess comparative effectiveness of the current and neo-technologies on station and on-farm in countries where they are being used or tested. Ascertain their suitability, through adaptive trials in the 'new' countries, so as to recommend the viable ones for use in other or new African cotton producing countries at farm levels.
- There is a need to identify all available global technologies that can be validated in Africa's cotton research programmes for ease of adoption or domesticating



Figure 11. Technology Transfer: Farmers' Training in a Cotton Demonstration Plot in Uganda.

the suitable ones rather than starting from scratch the exploration for new technology development, a situation which translates into unnecessary and expensive 're-invention of the wheel'. Such approaches should, however, be in conformity with requirements of the 'Intellectual Property Rights' (IPR) in recognition of the inputs of the 'originators/inventors' of the new technology.

- Assess, recommend and support the required collaborations between the activities and approaches of Institutions which are forging towards increasing cotton yields and quality in Africa.
- Assess requirements for the sustainability of those new approved and recommended initiatives and approaches along the entire African cotton value chains.
- Develop technology transfer strategies especially for the new technologies and implement them across the African cotton producing countries.
- Creation of a Cotton CGIAR Research Center as recommended by the ICAC 77th Plenary Meeting (ICAC 2018a).

Conclusions

For achieving the above objectives toward increasing cotton yields in Africa, there is need for the coordinating bodies — ICAC, CHA, and others — in these initiatives, to forge means of having the member governments and the private sectors working in tandem. This is to ensure conformity for amicable legal environments and financial aspects to support the new developments in the respective countries towards sustainable increases in yields of high fibre quality cottons in Africa. One way towards this goal is to create a cotton CGIAR Research Center. The new CGIAR will play roles pertinent to cotton but similar to the already existing 15 CGIARs on other commodities which are in place alongside cotton in the various farming systems and in National economies.

References

- Anon. 2019. The 'Uganda New Vision Daily Newspaper', February 6th, 2019. Vol.034 No.027 pp6. 'GMO Bill: Scientists Want Strict Liability Clause Dropped'.
- Anon. 2018a. The 'Uganda Observer Weekly Newspaper', November 29th, 2018. 'Parliament Passes GMO Bill'.
- Anon. 2018b. www.iwm.org.uk. The British Empire Cotton-Growing Corporation's Research Station at Namulonge, Uganda (CIRCA 1950S).
- Anon. 2018c. Cotton Seed Improvement Program. A Flier by: Cotton Expert House Africa (CHA) and CIRAD.
- Anon. 2016. Cotton: In 'Agriculture Sector Strategic Plan 2015/16-2019/20'. The Republic of Uganda. Ministry of Agriculture, Animal Industry and Fisheries (MAAIF).
- Bachelier B. 2018. Cotton Research in Africa: a Diagnostic Study and Proposal for a relaunch. Cotton Outlook. Abidjan 2018. ICAC 77th Plenary Meeting pp 20 – 25.
- CDO Annual Report 2017-18 Season
- CDO website: www.cdouga.org
- CHA 2018: Cotton Expert House Africa, <http://www.cotton-house-Africa.org/vision>.
- CIRAD 2018. Agricultural Research for Development 2018. Cotton seed Improvement Programme in sub-Saharan Africa.
- Desouza B. 2018. Conservation Agriculture for Sustainable Cotton Production in Africa. In. The ICAC Recorder, December 2018 Volume XXXVI, No. 4. Special Issue (Volume 2). Pp 23 – 28.
- Dong, H and Fok, M. 2018. Light and Simplified Cultivation (LSC) Techniques and Their Relevancy for Africa. In. ICAC Recorder, December 2018. Volume XXXVI, No.4. Special Issue (Volume 2). Pp. 15 – 21
- Elobu P, Orwanga J.F, Ocan J. R, and Opolot G.W. 1995. Recovery of cotton (*Gossypium hirsutum*) from intercropping Suppression by Beans (*Phaseolus vulgaris*). In Proceedings of the World Cotton Conference 1: Challenging the Future: pp. 206 – 209. (Ed.) Constable G.A. and Forrester, N.W.
- Elobu P, Kabanyoro R, Orwangga J.R, Ocan J.R, and Mukalazi W. 1997. Response of Cotton to 'Pix' Application in Uganda. African Crop Science Conference 3, Proceedings; pp 657 – 663. African Crop Science Society.
- Elobu P, Ocan J.R, Olinga J, and Ogabe P, 2016. Use of *Tithonia diversifolia* to improve cotton productivity under marginal soils in Uganda: In Proceedings of the World Cotton Research Conference VI. Goiana Brazil, May 2016.
- Elobu P, Ocan J.R, Ogabe P, and Olinga J. 2017. A Technology Dissemination Flier, NARO-NaSARRI. *Tithonia diversifolia*- An Organic Means to improve Cotton production Potential in Uganda.
- Elobu P, Ocan J.R, Ogabe P, and Olinga J. 2018. A Final Report on Testing Vitazyme on Cotton in Uganda during 2015 – 2018. NARO Annual Report for 2018. In Press.
- Farid Uddin, Fakhre Alam Ibne Tabib, Kamrul Islam, Washington Mubvekeri, M. Sabesh and Usha Rani Joshua. 2018. Novel Ideas to Enhance Cotton Production and Value of By-products in Africa. (A compilation of six concept notes on novel ideas proposed by six authors). In: ICAC Recorder; September 2018 Volume XXXVI, No.3; Special Issue (Volume 1), pp 13 – 17.
- Gayi D, Ocen D, Lubadde G and Serunjogi L.K, 2016. Efficacy of Bio and synthetic Pesticides against the American Bollworm and their natural Enemies on cotton. Uganda Journal of Agricultural Sciences: 17 (1) pp 55 – 69.
- Gayi D, Orawu M, Biruma M, Ocen D, Ejiet E.I, Echaku S, and Kyeeyune U, 2017. Management of Bollworms in Cotton. A brochure published by NaSARRI and NARO.
- ICAC 2018a. www.icac.org/Events, Plenary Meetings. The Final Statement of the 77th Plenary Meeting, Abidjan-Ivory Coast-December 2018.
- ICAC 2018b. The 'ICAC Recorder', December 2018 Volume XXXVI, No.4

- ICAC 2018c. The 'ICAC Recorder', September 2018 Volume XXXVI, No.3.
- ICAC 2013. [www.icac.org/Press-Release/2013/PR-42-Standardization of Nomenclature in Cotton Planting Seed](http://www.icac.org/Press-Release/2013/PR-42-Standardization%20of%20Nomenclature%20in%20Cotton%20Planting%20Seed).
- ISAAA. 2018. Crop Biotech Update, August 2018. Nigeria registers Biotech Cotton Varieties for Access to Farmers. International Services for the Acquisition of Agri-biotech Applications (ISAAA).
- Jiwei Z, Dhammi A, Roe R.M, Stewart D, and Roswell G.A. 2016. Novel mechanical Pesticides for Tobacco Thrips, *Frankliniella fusca*, Control in Cotton. Beltwide Cotton Conference, New Orleans, LA January 5-7, 2016. pp 704 – 712.
- Kranthi K.R. 2018a. Biotech Cotton-Relevance for Africa. In: ICAC Recorder; December 2018 Volume XXXVI, No. 4; Special Issue (Volume 2). Pp 29 – 34.
- Kranthi K.R. 2018b. A Change in Plant Architecture Can Break Yield Barriers in Africa. In: ICAC Recorder; September 2018 Volume XXXVI, No.3; Special Issue (Volume 1), pp 13 – 17.
- Kranthi K.R. 2018c. Uganda, Can Cotton Yields be Doubled? In: 'Proceedings of the; United Nations Conference on Trade and Development (UNCTAD), National Workshop held in Kampala Uganda 14 – 16 March, 2018'. UNCTAD Project on 'Promoting Cotton By-products in Eastern and Southern Africa i.e. Tanzania, Uganda, Zambia and Zimbabwe'.
- Ogwal S, Epieru G, Barwogeza M, and Acom, V. 2003. Effect of Inter-cropping Systems on establishment and biological Control Efficacy of the *Lepisiota Spp.* Predator Ant on Major Insect Pests. Uganda Journal of Agricultural Sciences 8, pp. 67 - 74
- Orawu M, Amoding G, Serunjogi L.K, Ogwang G and Ogwang C.O. 2017. Yield Stability of Cotton Genotypes at Three Diverse Agro-Ecologies of Uganda. Journal of Plant Breeding and Genetics 05 (03)2017, pp 101-114.
- Sabesh, M. 2018. Hope and Scope for Enhancing Cotton Production in Africa. In: ICAC Recorder; September 2018 Volume XXXVI, No.3; Special Issue (Volume 1), pp 18 – 24.
- Sabune, Jolly K. and Serunjogi L.K. 2017. Technology Transfer to Enhance Cotton Yield and Fiber Quality in Uganda. ICAC Recorder VOL XXXV No 4, December 2017, pp 4 – 13. International Cotton Advisory Committee.
- Seiny B.L and Bachelier B. 2017 (a). Final Report 'Proposal of a detailed strategy for revamping African Cotton Research at the Technical level', ACP COTTON June 2017.
- Seiny B.L and Bachelier B. 2017 (b). Final Report 'Diagnosis and recommendations for the Elaboration of a proposal for a Revamping Strategy of African Cotton Research'. ACP COTTON, January 2017.
- Sekamatte, M.B, Serunjogi, L.K, El-Heneidy, A.K. 2003. Gaining Confidence in Farmer Participatory Pest Management in Uganda. NARO's Experience in Improving Uptake of Crop Protection Technologies for Cotton. In: Proceedings of the World Cotton Conference-3. Cotton Production for the New Millennium pp. 697 – 974. (Ed.) Swanepoel, A.
- Serunjogi L.K, Sabune, J.K. and Akello, B. 2014. Balancing input Use: Mechanisms and Impact on Quality of Cotton. In: Proceedings of the 6th Session/Technical Seminar of the 73rd Plenary Meeting of ICAC, Thessaloniki Greece (www.icac.org/Meetings).
- Serunjogi L.K, Martin S.K, and Bauer W.D. 2002. Effects of Genotype x *Bradyrhizobium* Inoculation x Fertilizer interactions on Genetic Gain While Selecting in Soya bean. Uganda Journal of Agricultural sciences 7. Pp 1-6.
- Serunjogi L.K, P. Elobu, G. Epieru, V.A.O Okoth, M.B Sekamatte, J.P Takan and J.O.E Oryokot. 2001. Cotton (*Gossypium Sp*) in Agriculture in Uganda Vol II (Ed) J.K. Mukiibi, Fountain Publishers/CTA/NARO pp322-375.
- Syltie P.W 1985. Effect of Very Small Amounts of Highly Active Biological Substances on Plant growth. Bio. Agric. Hort.2: pp 245 – 269.
- USDA November2018: www.indexmundi.com-Agriculture-cotton-Yield.