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African cotton has tremendous scope to produce high yields in a sustainable manner with low input costs and fewer inputs of water and agrochemicals. Effective farm welfare policies, good agricultural research, efficient transfer of technologies to farms, fair market practices, and establishment of textile value chains will eventually determine the future of African cotton. Following a July 2018 network meeting in Harare, Zimbabwe, three consecutive special volumes of the ICAC RECORDER on the theme ‘This time for Africa’ were planned. This volume is the third in the special series on Africa. I realise that there is still more that remains to be said on the efforts made so far, and some new efforts that need to be initiated. Therefore, the June 2019 ICAC RECORDER will carry the final set of articles to complete the four-volume special series on ‘This Time for Africa’.

This volume has three articles that address some core issues. At the ICAC Plenary Meeting held in Abidjan, Côte d’Ivoire, in December 2018, Dr. Joe Kabissa made an impressive and impactful presentation on ‘Insecticide Management: Progress and Prospects in Africa’. His article in this volume documents his views. Dr. Kabissa examines the issues related to insecticide management in Africa and emphasises the need for stakeholders to have a clear understanding of the implications related to the externalities associated with insecticide use, and how they should be minimised in the interest of sustainable cotton production. In their lucidly written article ‘Extension Methods Relevant to Africa’, Dr. Usha Rani and Dr. Prakash describe the state-of-the-art extension technologies that could be suitable for small-scale production systems in remote regions of Africa. The third article, by ICAC Economist Ms. Lorena Ruiz and myself, explores the employment potential in the textile-apparel industry in sub-Saharan Africa, which could be a game-changer for the continent.

The articles in the three Africa-focussed volumes of the ICAC RECORDER create confidence that Africa could easily double its cotton yields in the next few years. Needless to say, ‘Where there is a will, there will be a way’. With great natural resources of sunlight, adequate heat, good soils and good rains, African cotton has all the factors required for good growth and high yields. Global scientific research has shown that for high yields, the natural resource energies — sunlight, water, heat and nutrients — must be used more for the production of economically important fruiting parts rather than for the production of low-value plant biomass. These principles of ‘source to sink’ for a higher ‘harvest index’ have been applied in Australia, Brazil, China, Mexico, Turkey and the USA, and the result is that these countries harvest 1,000 to 2,500 kg lint per hectare (kg/ha), compared to 160-450 kg/ha in African countries.

One of the arguments has been that cotton is grown in Africa under rainfed conditions, and therefore yields will not increase. But the cotton yields in Brazil are high — more than 1500 kg/ha, despite being completely rainfed. The lessons learnt from the six countries mentioned above show that high yields are not be necessarily due to irrigation, high agrochemical inputs, and complex management practices. A combination of plant architecture, planting geometry, canopy management, and synchronization of the crop’s water, nutrient and light requirements, helped many countries achieve high yields with or without biotech cotton and costly inputs. These simple technologies could help Africa go a long way toward achieving high yields and enhancing profitability.

Africa needs self-confidence. It needs good, local cotton scientists who understand the domestic terrain and challenges — and whose research can knit together simple strategies that are tailored to fit the local African context and suit the local agricultural socio-economic dynamics of small-scale producers. With the existing large network of mobile phones and apps, technology transfer is no longer the nightmare that it used to be — as it was in prior years. With a combination of good research, good agri-extension services, and a good value chain, Africa will be poised for a breakthrough in yields, profitability and sustainability. To surmise, it would not be wrong to state that Africa has all the natural resources and talent; but Africa is a giant in slumber. The time has now arrived to arise, wake up, and show Africa’s mettle to the world.
Insecticide Management in Cotton: Progress and Prospects

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Abstract

Chemical insecticides continue to be a necessary input for profitable cotton production. Recently, cotton’s share of the global insecticide market declined from 24% in 1994 to 14.8% in 2010. Such a decline did correspond with the increased adoption of transgenic cotton during that period. Prior to the introduction of Bt cotton in 1996, bollworms had accounted for at least 50% of all chemical insecticides used on the crop annually. Bt cotton is toxic to bollworms and generally does not warrant any supplemental need for insecticide use, except when bollworms develop resistance to Bt cotton. Estimates show that extensive cultivation of Bt cotton resulted in the reduction of insecticide usage by 268.6 million kilograms (kg) from 1996 to 2015 (Brookes and Barfoot, 2017). However, the recent increasing trends in the use of insecticides have been necessitated by the need to suppress a global resurgence of sucking pests, as well as the pink bollworm, which has recently developed resistance to Bt cotton. On conventional cotton, the rise in insecticide use has been in response to the growing need to deal with the increased spread of some major cotton pests across continents, and the advent of insecticide resistance. In low-income countries, increased use of insecticides is also being fuelled by increased informal trade in pesticides due to rampant market failures. In this paper, I discuss these developments together with some of the steps that are needed for more sustainable insecticide use in cotton.

Key words: cotton, insecticides, IPM, externalities, sustainability, market failures

Introduction

Cotton is the world’s most important natural fibre. It is grown on up to 3% of the world’s arable land in many countries located between 37 and 32 degrees north and south of the equator respectively (ITC, 2011). Cotton is thus one of the few crops of major economic importance worldwide that is produced in both developed and developing economies. In the latter, cotton is often regarded as the answer to poverty alleviation and export-income generation. To date, up to 80% of cotton’s annual global output is produced by smallholder farmers living in Asia, China and sub-Saharan Africa (SSA). The remainder is produced by large farmers in developed countries (Kranthi, 2018).

On the global fibre market, cotton’s share in textile production has dropped from 68% in 1960 to just 26.5% in 2018 (ICAC, 2019). Due to rising cost of production, cotton has been losing its market share to synthetic fibres, whose share currently stands at 66.1%. The major driver for cotton’s rising production cost has been the worldwide upsurge in the use of agrochemicals, mainly insecticides. In 2006, crop protection accounted for up to 45% of variable costs in cotton production in low-income countries (Russell and Kranthi, 2006). Due to emerging pest problems, the use of insecticides worldwide has risen, resulting in cotton’s market share climbing from 14.8% to 16.1% between 2010 and 2014 (Ferrigno et al., 2017; Kranthi, 2018). Paradoxically, this is happening at a time when average yields in low-income countries are still well below the global average yield of 772 kg lint/ha (Kranthi, 2018).

Because the bulk of cotton is grown in tropical and sub-tropical areas — where pest pressure tends to be severe — greater use of insecticides in such countries is perhaps a reflection of that fact. However, the use of insecticides in low-income countries often tends to be inappropriate and not based on rational and carefully considered criteria (Russell and Kranthi, 2006). George Santayana had earlier warned through his prophecy that ‘those who cannot remember the past are doomed to repeat it’. In light of what happened on cotton last century (see Smith, 1969) and its bearing on what is happening now, we may already be heading towards a precipice — unless and until cotton stakeholders urgently revisit their current production and protection strategies. We need to reduce and optimise insecticide use and thus make cotton productive, profitable and sustainable in the long term.

Smallholders Vis-a-Vis Large Farmers

Smallholders are best described as farmers practicing a mix of commercial and subsistence production, in which the family provides the majority of labour and the farm provides the principal source of income (Narayan & Gulati, 2002). They tend to prioritise food-crop production and often allocate land to cotton and other crops on the basis of considerations such as available labour, land, input requirements and selling prices. Furthermore,
because cotton is often sown after food crops, it tends to be not well-looked-after, agronomically. These and other considerations tend to have a strong bearing on the types of yields that smallholders get from their cotton.

In developed economies, farmers often adopt a high-input, high-output approach to cotton production on large plots of land. However, due to increased adoption and use of integrated pest management (IPM) practices and other tools, their overall insecticide use patterns tend to be far more organised than in the case of smallholders in low-income countries. Furthermore, due to strong concerns on resistance, environmental pollution and other health-related issues, the use of insecticides in developed economies often tends to be subject to more stringent legal and regulatory controls (Matteson, 1995) than in low-income countries, where proper regulatory controls are lacking and many governments have failed to support independent research on pesticides.

**Insecticide Use Trends in Cotton**

There are reportedly 1,326 species of insects and other arthropods associated with cultivated cotton worldwide (Hargreaves, 1948). Many of the insects recorded in a cotton field just happened to be there when collected, but were not pests. Nevertheless, a complex of lepidoptera comprising of *Helicoverpa armigera*, *Helicoverpa zea*, *Helicoverpa punctigera*, *Heliothis virescens*, *Earias spp*, *Diparopsis spp* and *Pectinophora gossypiella* are frequently the most damaging to cotton. They tend to be collectively referred to as bollworms because their larvae have a propensity to preferentially feed on cotton's bolls as well as other fruiting points, thus affecting yield directly. For prevention of such damage, bollworms as a group account for well over 50% of all insecticides used on cotton globally (Fitt, 1989; Shelton et al., 2002). To date, most of the sucking pests that were previously categorized as secondary pests have now assumed full economic status on transgenic cotton and are being targeted for insecticidal control (Ferrigno et al., 2017; Kranthi, 2018). This is currently a big issue because those supporting Bt cotton failed to clearly emphasize that Bt toxins only killed lepidopteran larvae.

Prior to 1960, the bulk of the cotton in SSA was grown without the use of insecticides (Matthews, 2014). The use of cultural practices such as early planting was encouraged in order to allow the crop to mature and be picked before late pests such as *Dysdercus spp*, *Oxyacarus spp*, and others moved onto the crop. Although early-sown cotton is more likely to recover or even escape attack from *H. armigera* than late-sown cotton, farmers' tendency to sow food crops first often tends to make this recommendation impractical. To circumvent such problem, the use of varieties that flower rapidly over a relatively long period of time and, consequently, being capable of compensatory flowering in the event of early season bollworm attack was advocated (Reed, 1965). To control *P. gossypiella*, farmers were compelled to destroy crop residues after harvest and to observe a mandatory three-month closed season thereafter. The closed season was mandatory after about 1938 (Matthews, personal communication). In SSA, plant leafhoppers that are commonly referred to as jassids, *Jacobiasca lybica* — which tended to kill the cotton crop during its vegetative stage — have, over time, tended to be controlled by mere selection for increased leaf hairiness in cotton genotypes, a morphological trait which confers resistance to cotton varieties. Although work on this pest began in the early 1920s it remained unpublished until 1949 (Parnell et al., 1949).

Following the advent of chemical insecticides, farmers have tended to prefer them to non-chemical methods and such attitude tends to be promoted by agrochemical companies. There is a conspicuous paucity of data on insecticide use on cotton in most countries. Available information indicates that cotton’s share of the global insecticide market declined from 24% in 1994 (Myers & Stolton, 1999) to 19% and 14.8% in 2000 and 2010 respectively (Ferrigno et al., 2017). However, by 2014 cotton’s market share had risen to 16.1% (Ferrigno et al., 2017). The decline in insecticide use between 1994 and 2010 corresponds with a period of increased adoption of transgenic cotton and use of IPM practice. The surge in insecticide use from 2014 onwards occurred worldwide on both transgenic and conventional cotton.

**Drivers for Increased Insecticide Use on Cotton**

*H. armigera* and white flies have become resistant to chemical insecticides: The case of SSA

In West and Central Africa (WCA), the institutional set up has for many years promoted a high-input cotton production (Tschrley et al., 2009). As a result, farmers there have been getting higher average yields per ha than farmers in Eastern and Southern Africa (ESA). However, statistics from WCA have shown declining cotton yields and increased pesticide use (Zepeda et al., 2007). Because cotton in WCA has tended to be sprayed more frequently than cotton in the ESA (up to 15 times for the former, as opposed to just 6 to 8 times for the latter), *H. armigera* and *Bemisia tabaci* became resistant to pyrethroid insecticides in WCA but not in ECA — despite having been introduced for use on cotton at about the same time in the early 1980s (Kabissa, 1997; Martin et al., 2005). Furthermore, because sucking pests in WCA move into cotton from vegetable crops and vice versa, spraying both host plants with insecticides with the same mode of action inevitably speeds up resistance.
Technological responses to pest problems do not last forever: The case of Bt cotton

It is a truism that where transgenic cotton became commercialised, most bollworms became quickly relegated to non-economic status. In such countries, insecticide spray frequencies as well as overall quantities of insecticides used on cotton declined significantly (Shelton et al., 2002). However, other insects — notably white flies, mirids, stink bugs and mealy bugs, which were previously regarded as secondary pests prior to the introduction of transgenic cotton — have now become de facto economic pests in most countries wherever transgenic cotton is being grown (Ferrigno et al., 2017; Kranthi, 2018). The change in pest status of sucking pests following widespread adoption of transgenic cotton has necessitated the increased use of insecticides in order to control them.

In some countries, most notably India, severe damage by insect pests has continued to occur even on Bt cotton, thus necessitating a resumption of insecticide sprays against it. Such situations are being blamed on weak regulatory and legal controls on systems for the production, multiplication, distribution and sale of Bt seed resulting in rampant parallel markets for the sale of recycled seed as well as cheap but fake Bt seed (Ferrigno et al., 2017; Kranthi, 2018). Due to lack of proper agronomic controls on the release of cotton varieties in India, more than 800 new Bt cotton hybrids were approved during 2006 to 2011, most of which were susceptible to sap-sucking insects, which resulted in doubling of insecticide use on cotton during the period (Kranthi, 2013). Insecticide use increased further after 2011 in India due to the development of insecticide resistance in jassid and whiteflies, and resistance of pink bollworms to Cry1Ac in 2009, and to Cry1Ac+Cry2Ab in 2014. In China and Pakistan, the continued use of varieties containing the single Cry1Ac gene has resulted in populations of the pink bollworm, Pectinophora gossypiella becoming resistant to Bt toxins, thus compelling farmers in these countries to use insecticides on Bt cotton (Kranthi, 2018). These developments serve to further confirm the fact that technological responses to insect pest problems do not last forever.

Increased globalisation of cotton pests

Cotton has recently witnessed an increased expansion in the range of some well-established pests into new areas across the globe. To minimise crop losses due to such ‘new pests’, farmers have had to spray their crops more than would normally be the case. Some of the recently introduced pests include the boll weevil Anthonomus grandis grandis into several South American countries including Argentina, Brazil, Colombia and Paraguay (Showler, 2009). In Africa, the fall armyworm, Spodoptera frugiperda was first spotted in Benin and subsequently reported in Nigeria in 2016. It has now spread to India and 44 countries in SSA where it has been causing extensive damage to several crops, maize in particular (Rwomushana et al., 2018). In 2018, the fall...
armyworm caused severe damage to maize and cotton in Tanzania. For cotton, none of the synthetic pyrethroids that are normally used for control of *H. armigera* were able to suppress it. In Brazil, the entry of *H. armigera* after 2012 necessitated an increased use of insecticides on cotton and on its non-transgenic host plants. Entry of the boll weevil has also tended to complicate the use of refugia in insecticide resistance management programs for Bt cotton (Barbosa, 2016). A new mega-pest due to hybridisation of Helicoverpa armigera and Helicoverpa zea was discovered in Brazil in 2017 (Li et al., 2017; Anderson et al., 2018). This hybrid pest poses a huge threat to cotton and many other crops in Brazil and rest of South America. Due to the lack of institutional capacities to deal with the spread of invasive pest species, low-income countries will continue to depend to use fire-brigade-type approaches to dealing with new pests.

**Market failures in low-income countries**

The trend toward increased use of insecticides on cotton in many low-income countries is partly an outcome of market policy reforms that started in the early 1990s. Cotton farmers in SSA were previously dependent on marketing cooperatives, marketing boards or state-owned companies for their supply of seasonal inputs. Colonial and post-independence administrations had opted to use such institutions because they had long realised that for the reasons of geography and poverty, smallholders are the most difficult group for private traders or even the government to reach (Dorward et al., 1998). Furthermore, the presence of relatively few key actors on the cotton market tended to facilitate an easy regulation and control of some relative sensitive inputs, insecticides in particular. After liberalisation, the proliferation of informal trading resulted in all kinds of insecticides becoming available to farmers, who increasingly made their own decisions on which insecticides to buy and use. This was further helped by insecticide retail prices becoming cheaper as patent protection for most insecticides expired and their sale as generics took effect (Shepard and Farolfi, 1999). In Tanzania for example, the number of pesticide outlets between 1995 and 2001 increased by 30% (Williamson, 2003). More recently, Kabissa (2016) found out that although cotton farmers sourced up to 30% of their insecticide needs from retailers and open markets, 40% of such insecticides had an expired ‘use by’ date. As a result of informal trading, counterfeit agrochemicals in Kenya accounted for up 15% of the pesticide market and caused between 40% and 60% yield losses where they were used (Williamson, 2003). Due to weak enforcement of pesticide legislation in low-income countries, informal trade coupled with aggressive marketing of insecticides has resulted in some highly hazardous pesticides continuing to be widely available to predominantly illiterate farming communities. In 2017, the use of monocrotophos and other highly hazardous insecticides on late cotton in India caused the deaths of 63 farmers in the central Indian state of Maharashtra (Matthews, personal communication).

In many ESA countries, some attempts were made to deal with the seasonal input supply problems in a post-liberalisation era by introducing some form of contract-farming arrangements (Minot & Sawyer, 2014). To date, such attempts have been met with mixed results. The ability and willingness of ginners to provide services such as input credit, extension services and market outlets for farmers’ seed cotton has tended to be undermined where the number of ginners operating in the country is quite large, and hence contract farming agreements are becoming plagued by rampant malpractices involving side-selling by farmers on one part, and side-buying by ginners on the other. Such tendencies have quite often proven disruptive to contract sanctity, and no doubt contract-farming arrangements are not as widespread as they were expected to become (Tschirley et al., 2009; Minot & Sawyer, 2014). In WCA — where an alternative model involves the use of semi-privatized cotton companies such as SONAPRA, SOFITEX, SODECOTTON, CMDT and SODEFITEX in the provision of input credit and other key services to cotton farmers — there are indications that it is also susceptible to several malpractices, notably the diversion of insecticides destined for cotton to food crops, as well as their sale across national borders (Ferrigno et al., 2017).

**Impacts of Increased Insecticide Use on Cotton**

An accepted fact about chemical insecticides is that they do not permanently resolve any of the pest problems facing society. However, what is not apparent to most smallholder farmers is the fact that while chemical insecticides may be relatively cheap to individual users, they tend to impose negative consequences on the larger community of farmers because of their side effects. Insecticides are known to have a cost beyond their purchase price when overused, improperly handled, and poorly applied, resulting in their up-front purchase price being often more than doubled by hidden costs to society in relation to dealing with insecticide-induced resistance, suppression of natural enemies, and environmental pollution (Knipling, 1979; Regev, 1984; Wilson & Tisdell, 2001).

Cotton's production history has tended to be characterised by narratives largely pertaining to the negative impacts associated with the over-exploitation of chemical insecticides. The stories of cotton in the Canete Valley of Peru in the 1960s, Rio Grande Texas in the 1970s, Ord River Valley in Australia in the 1980s, and the Gezira Scheme in Sudan in the 1960s (among many others) vividly confirm that the use of chemical insecticides in cropping systems is analogous to using a double-edged...
sword (Wilson & Tisdell, 2001). What happened in Sudan — where the use of insecticides against jassids, Sudan's then key economic pest in the early 1960s, helped to elevate *H. armigera* from a secondary pest to an economic pest — has a strong bearing on what is happening on Bt cotton today. The elevation of *H. armigera* from a minor cotton pest to a major cotton pest after 1981 subsequent to the introduction of synthetic pyrethroids in India is yet another pointer to indicate the double-edged nature of insecticides. The current upsurge in sucking pests on cotton worldwide is a significant testimony of how agroecosystem disruption, by either introduction of new varieties or chemical insecticides *per se* or by *Bt* toxins, can bring about the resurgence of previously innocuous pests on crops.

Apart from resistance and resurgence, indiscriminate use of chemical insecticides has had other impacts relating to the environment in general and human health in particular. In India, users of a knapsack sprayer often hold the nozzle on the lance in front of their bodies, resulting in poor pesticide distribution in the crop — and greater exposure to the operator, causing more deaths when using highly hazardous insecticides (Matthews, personal communication). In spite of the paucity of published data on insecticide-related cases of poisoning, deaths and chronic ailments, it is obvious that low-income countries tend to incur high pesticide-related health costs (Wilson & Tisdell, 2001; Ferrigno *et al.*, 2017).

**The Need for Insecticide Management**

Insects and their allies will continue to be our principal competitors for a limited food and fibre supply (Winston, 1998). In order to minimise their impacts, we have to adopt insecticide management programs that seek to use insecticides more rationally than in the past. Because the use of chemical insecticides may pose risks to human health, non-target species and to the environment — and because insecticides have a tendency to be freely disseminated into the environment and to become ineffective through over-use — our approach to using them should rigorously take these aspects into consideration ((NAS, 2000).

**1st Step: Changing the mindset**

Mankind has tended to regard insect pests as a problem to be controlled rather than an integral part of nature that should be managed in effective and environmentally responsible ways (Winston, 1998). This mindset has to change because, for every action contemplated against them, insects have always found ways of countering or circumventing our actions. The idea that insects, too, have a right to life can perhaps be best illustrated by what happened to the Christian Apostle Paul in Turkey. During one of the nights that he spent on a missionary trip, he realised that the guest house where he was due to spend a night was heavily infested by bedbugs. Rather than calling for divine power to kill them, he merely commanded them to exit the house and to stay outdoors. The next morning, he simply allowed them back in (Cimok, 2012). The need to exercise restraint prior to dealing with insect pests on crops is one of the underlying principles of IPM. The latter clearly and emphatically advocates for tolerance of insect damage up to some threshold level beyond which corrective action is to be taken against them. In other words, IPM calls for our qualified coexistence with arthropods. More importantly, building up and conserving beneficial fauna in the cotton ecosystems by carefully considered human interventions would go a long way toward ensuring sustainable eco-friendly pest management. Such interventions are mainly related to introduction of new varieties, pesticides and cropping practices.

**2nd Step: Switching from preventive to ‘as-needed’ spray programs**

Until recently, insecticide use on cotton has tended to be based on the age-old norm of either weekly or bi-weekly sprays of designated insecticides, starting either at the start of flowering or a designated number of days after planting. To date, the need for a paradigm shift from such prophylactic or preventive calendar-based ‘rain of death’ regimes to ‘as-needed’ spray programs is being...
necessitated by the fact that insect pests neither occur on cotton regularly, nor do they always cause economic damage when present. However, if the switch is to be successful, farmers need to be trained on how to use practical and research-based action thresholds, based either on pest-infestation or crop-damage levels, and how to correctly identify the pest species in question — as well as the natural enemies that occur on cotton from time to time. Ideally, farmers will base their decisions on whether to spray or not on some combination of these parameters (Matthews, 2014). Further, following proper pesticide-application technologies also strengthens IPM approaches. Since the early 1970s, farmer in Zimbabwe have been coached on how to rationalise insecticide use on cotton against *H. armigera* and *D. castanea* through the institutionalisation of scouting and threshold spraying using the peg board (Matthews, 2014). Similarly, farmers in Egypt have for ages been using spray windows in order to optimize the control of *P. gossypiella* and *Spodoptera littoralis* by insecticides (Sawicki et al., 1989). In the aftermath of massive pesticide control failures in Burkina Faso, Ivory Coast and Benin in the 1990s, farmers in most WCA countries have increasingly adopted a practise called ‘targeted spraying’, which requires them to scout their cotton fields for pests on 40 plants on a weekly basis, and to use designated fixed-action thresholds for the main cotton pests — and to spray only if those thresholds are attained. Deployment of such approach was facilitated by adoption of the Farmer Field School approach to train farmers; significant reductions in pesticide applications were achieved (Martin et al., 2005; Settle et al., 2014).

**3rd Step: Switch from generality to selectivity**

To date, pressure from scientific advances, societal concerns and regulatory demands have necessitated the withdrawal of some well-known but old and hazardous insecticides, has resulted in the development new insecticides with lower impacts on human health and non-target organisms; new modes of action (hence with lower pest-resistance potential), and a high compatibility with on-going IPM programs (NAS, 2000). In short, there has been a gradual shift from the use of 1st generation neuroactive insecticides — which were effective, inexpensive and persistent — to newer, selective and relatively safer products such as avermectins, neonicotinoids and anthranilic diamides, among others. On cotton, the most widely used chemical insecticides belong to just three major insecticide categories; synthetic pyrethroids, organophosphates and neonicotinoids (Kranthi, 2018). In order to deal with some of cotton’s new and emerging pest problems, a shift towards newer chemistry and other tactics, such as the use of seed treatment with systemic insecticides, should be investigated. Such approaches may provide answers to resurgent early-season sucking pests.

**4th Step: Promote increased use of multiple tactics (Integrated Pest Management)**

In SSA, the use of a combination of crop-management practices and use of designated varieties to deal with specific pests such as jassids allowed for the successful commercialisation of cotton prior to the introduction of chemical insecticides. Even after the introduction of insecticides, their use remains limited largely because most farmers could not afford to use them as frequently as recommended by R&D institutions on sheer cost considerations. Scouting was thus introduced in order to help them economise insecticide use and optimise production costs. However, as their use on cotton has intensified — particularly in WCA — resistance finally appeared. Insecticide resistance is unknown elsewhere in SSA where a low-input/low-output approach to cotton production still holds (Matthews, 2014).

In other cotton-growing countries outside SSA, IPM became the logical answer to problems arising as a result of the over-exploitation of chemical insecticides (Smith, 1969). Australia is perhaps one country where IPM was of tremendous assistance. Between 1960 and 1990, Australian cotton farmers relied so much on the unilateral use of chemical insecticides that eventually *H. armigera* became resistant to almost all recommended insecticides.
However, following a country-wide adoption of transgenic cotton, new production practices and the adoption of IPM practices, the country managed to significantly reduce insecticide use on cotton from 1,000 tonnes of active ingredient from 1998-2003 to just 50 tonnes from 2008-2013, while raising average yields of irrigated cotton from 1,200 kg/ha in the 1970s to 2,270 kg/ha today (Sustainability Report, 2014).

IPM has traditionally entailed using a combination of four tactics to manage pests:
- Cultural methods,
- Host plant resistance,
- Biocontrol agents, and
- Chemical insecticides.

This ‘IPM toolbox’ is currently undergoing a rapid evolution in tandem with an emerging need for new options that provide effective, economical and environmentally sound management as necessitated by a re-registration of existing insecticides; advent of new insecticides with novel modes of action; emergence of new pest species on cotton; the development and emergence of new technologies based on genetic engineering; and new tools such as drones and geographical information systems among others that may help farmers to more efficiently deal with pests (NAS, 2000). Much more could be done with ‘genetic male-sterile’ technologies and pheromones, but this might only be feasible on an area-wide basis, not on individual smallholder farms.

**Walking the Talk on IPM**

Attempts to replace the insecticide-dependent control paradigm with other methods that allow for more sustainable use of insecticides have so far achieved limited success, especially in low-income countries. Parsa et al., (2014) have identified 51 potential reasons on why this has been the case. Some of the key reasons include the farmers’ needs for simple solutions to apparently complex problems, while R&D institutions have not yet done enough to make them practical and efficient. Other factors include IPM’s requirements for larger inputs of time and knowledge than conventional control, and the lack of adequate collaboration between governments and other institutions — notably R&D, extension services, and NGOs — on the promotion of IPM practices. Agrochemical companies have, quite naturally, not been in a position to support IPM, which seeks to minimise insecticide usage. In spite of many challenges, IPM has at least helped to promote the drive toward a more enlightened approach to pest control by encouraging the routine monitoring of pests on crops, as well as an increased consideration of multiple factors such as damage levels, pest infestation levels, and the presence or absence of natural enemies prior to making the decision to spray.

**Government Policies to Increasingly Focus on Reducing Insecticide Use on Cotton**

In pest-management practice, farmers will continue to overuse insecticides on cotton because there exists a basic gap between their viewpoint and that of society. While farmers tend to consider only the direct monetary costs of insecticides, society tends to add to such cost the impact of future damages from resistance and the suppression of natural enemies, as well as the cost of environmental pollution. The difference in costs has led to insecticide overuse because users of insecticides often see the cost of insecticides as being much lower than what it should be, in terms of long-term damage and pollution (Regev, 1984; Wilson & Tisdell, 2001).

Because it is virtually impossible to control the harmful effects of insecticides once they have been applied, the goal of government policies should be to significantly reduce the usage of insecticides in the first place. To that end, governments must use their influence, statutory and other powers to make the public in general and farmers in particular aware of the negative impacts of the unenlightened use of insecticides. The need by governments to re-regulate pesticide markets after the liberalisation mess cannot be over-emphasised, in light of the fact that enforcement of previous laws was ineffective and not restrictive enough on pesticide use, which allowed for increased use of unsafe, ineffective and unsustainable pest management practices.

One option that is being promoted for ensuring safe and effective use of insecticides on cotton involves the deployment of schemes that emphasize ‘insecticide use exclusively by prescription’. In the USA, where a few states have adopted such schemes, it is mandatory for insecticides to be applied only after a licensed prescriber or professional pest manager has evaluated the pest problem and established that an insecticide application is indeed warranted (Whitaker, 1998). Such practices, which in the case of pharmaceuticals for human use requires designated drugs to be dispensed on a prescription basis, has helped to curb drug misuse in low-income countries. Adoption of insecticide use by prescription may hopefully help to limit some of the malpractices that are generally associated with insecticide use. However, if the introduction and ultimate adoption of these schemes in such countries is to be successful, an institutional overhaul of current systems for the provision of farmers’ support services by extension, non-governmental organisations and R&D institutions will be needed.

The other option for managing insecticide use entails governments using economic instruments to deliberately minimise insecticide use and thus promote the development and uptake of alternative pest control
methods. For example, in 1995, Sweden, Denmark and the Netherlands collectively passed legislation that mandated reductions of 50% or more of agricultural pesticide use in their countries by 2000. Such reductions, which were in response to public outcry about environmental pollution and the need to keep agriculture competitive, were achieved without significantly affecting crop yields (Matteson, 1995). Recently, researchers from France (Lechenet et al., 2017) demonstrated that low pesticide use rarely decreases productivity and profitability in arable farms. They did not detect any conflict between low pesticide use and both high productivity and high profitability in 77% of the 946 farms examined. In many low-income cotton-producing countries where abuse of insecticides is rampant, governments can similarly adopt mandatory reductions in pesticide use by imposing taxes on pesticide imports. Such interventions would increase retail prices of chemical insecticides and hence encourage greater use of alternative non-chemical methods for pest control. Government subsidies on biological inputs for pest management would also strengthen non-chemical approaches. Cotton farmers in particular would feel compelled to spray their fields on an as-needed basis, thus exploiting cotton’s ability to produce an optimal crop even after having lost some of its fruiting points, either to bollworms or through natural shedding through compensatory growth (Reed, 1965). The use of regulatory instruments such as environmental taxes or tax rebates as incentives has the potential to bring about similar outcomes (Whitaker, 1998).

Conclusion

In view of the critical importance of cotton to the agriculture-led economies in most low-income countries, the need to make cotton production sustainable and profitable cannot be over-emphasised. Because pest management is crucial for the optimisation of cotton yields, cotton stakeholders need to have a clear understanding of the implications of externalities associated with insecticide use, and how it should be minimised in the interest of the sustainability of cotton production.

To that end, cotton stakeholders in general and farmers in particular, should be given an understanding of how cotton agro-ecosystems function, as well as how interventions such as the use of insecticides can bring about resistance, resurgence, and other side effects to both mankind and the environment. Cotton R&D institutions will need to increasingly take up training roles to ensure cotton stakeholders need to have a clear understanding of the implications of externalities associated with insecticide use, and how it should be minimised in the interest of the sustainability of cotton production.

Because the agrochemical industry has tended to prioritise the sale of their products rather than ways their products could be safely applied, farmers have invariably ended up being unduly exposed to pesticides. For lack of facilities needed to specifically deal with pesticide poisoning, many of the ill effects associated with exposure to highly toxic and hazardous insecticides pesticides tend to be wrongly attributed to other causes. This fact — coupled with high illiteracy rates, prevailing information asymmetries, and weak regulatory institutions — tends to worsen the situation. The need for primary health care services in order to deal with the prevention, recognition and treatment of pesticide poisoning cannot therefore be over-emphasised.

Acknowledgements

I am very grateful to the International Cotton Advisory Committee and the Tanzania Cotton Board for their financial support. I owe special thanks to Professor G. A. Matthews, not only for his valuable comments on my paper, but also for sharing with me some of his experiences on cotton pests and the use and application of pesticides in SSA and other countries.

Literature cited


Cotton is grown commercially in more than 70 different countries, mostly under arid and semi-arid environments. It is either grown rain-fed or through irrigation in the longitudinal band between 37° N and 32°S (ITC, 2011). It is a major agricultural and industrial crop that provides employment and income for about 250 million persons involved in its production, processing and marketing across the globe (Kranthi, 2017). It is cultivated on 30-36 million hectares across the world by 26.0 million cotton growers mostly from Asian countries (85.0%) and African countries (13.8%). In Africa alone, cotton is cultivated by 3.61 million farmers on 4.2 million hectares in 19 countries (Kranthi, 2018). African cotton growers primarily encounter challenges of poor access to agricultural inputs and technologies; low cotton yields; and low remunerative prices. To increase the yield of cotton in Africa, many reforms have been implemented during the 1990s both by the public and private sectors. Irrespective of these reforms and approval of biotech cotton in six countries of Africa, the yields are low and stagnant (Sabesh and Prakash, 2018). Among the various causes for the low yields, the slow diffusion of both locally developed cotton technologies and know-how adapted from other countries to the end users appears to be the most critical. Several researchers argue that without access to technological inputs, cotton yields in Africa cannot increase (ICAC, 2018). This paper explores the relevance of modern tools of technology transfer that may improve the diffusion of technologies for a desirable change in the cultivation behaviour of cotton growers in Africa and thereby enhance cotton productivity.

**Key Issues Related to Cotton in Africa**

Agriculture is generally referred to as the mainstay of the African economy — the real driver of economic growth — because it contributes substantially to the Gross Domestic Product (GDP) and export earnings of many African countries (Msuya et al., 2017). African agriculture is dominated by a variety of food crops and a few traditional cash crops including cotton (Sabesh and Prakash, 2018). Most of the cotton grown in African countries — including Burkina Faso, Cameroon, Chad, Côte d’Ivoire, Kenya (western), Mali, Malawi, Mozambique, Tanzania, Togo, Uganda, Zambia, and Zimbabwe — is almost completely dependent (95-100%) on rainfall (Kranthi, 2018). From 2000-2017, cotton production in different African countries varied from 15,000 MT in South Africa to 215,000 MT in Burkina Faso; exports varied from 4,000 MT from Ethiopia to 205,000 MT from Burkina Faso and cotton consumption varied from 1000 MT in Chad and Senegal to 162,000 MT in Egypt (ICAC, 2018; Sabesh and Prakash, 2018).

Cotton yields in Africa are the lowest in the world. The 10-year average yield from 2008 to 2017 are:
- 162-202 kg/ha in Kenya, Central African Republic, Chad, Mozambique, Nigeria and Tanzania;
- 246 to 300 kg/ha in Zimbabwe, Malawi, Zambia, Uganda and Togo; and
- 343-424 Kg/ha in Ghana, Senegal, Ethiopia, Benin, Mali, Burkina and Cote d’Ivoire.

Yields are relatively higher in Sudan, South Africa and Egypt, where cotton is mostly irrigated. The challenge of low yields in Africa is historical. It appears to reflect a combination of neglect in agricultural research and technology transfer. Either investment in agricultural research and commitment to farming was so low that there was hardly any scope of inventions or discoveries that may have enabled a breakthrough in agriculture or the possibilities of any of the few innovations to move beyond the gates of research institutions. There has been a long stagnation in research investment in Africa over several years (Poulton, 2009). Some national agricultural research systems in sub-Saharan Africa have only ‘notional’ budgets (less than US$20 million per year) and many employ fewer than 50 research scientists (Evenson and Gollin, 2007). More than half of sub-Saharan countries have fewer than 100 regular staff employed in agricultural research, with the private sector accounting for only 2.0% of the total investment in agricultural research (Beintema and Stads, 2004). A total of 292 studies that were published from 1953 to 2000 were reviewed to report a total of 1,886 estimates of return that showed mean rates of return on investment of 100% for agricultural research, 85% for extension, and 48% for combined investments in both research and extension (Alston et al., 2000). Such studies highlight the need for increased investment in agricultural research and extension services in Africa.
Small farmers receive on average US$0.21 per kg seed-cotton in Zimbabwe and about US$0.33 per kg in Burkina Faso. The gross revenue per hectare was US$ 103.91 in Mozambique and US$345.53 in Cameroon, but the net profits were US$2.37 in Mozambique (Poulton et al., 2009) and a net loss of US$72.34 in Zambia. The cotton produced in Africa is mainly exported to Asia to process into yarn. The domestic value addition of fibre in Africa is generally low. About 2.0% of the cotton produced is used in the local textile mills in the major cotton-growing countries of West Africa such as Burkina Faso, Mali, Benin, Chad, Côte d’Ivoire, Cameroon and Togo. Similarly, only 7.7% of the cotton produced in Zambia, Zimbabwe, Mozambique, Uganda is used by the domestic mills in the respective southern and eastern African countries. In Africa, reasonably sized textile mills exist only in Nigeria, Egypt, Ethiopia, Sudan, South Africa and Tanzania.

Low yields in Africa are a function of biotic, abiotic and management factors. Insect pests and diseases constitute the major biotic factors that exert a significant impact on cotton production in Africa. The hot tropical and semi-arid climatic conditions of the major cotton-growing countries in Africa favour multiple pest generations and heavy pest densities every year (Oerke, 2006). Although widespread use of chemical pesticides for cotton pest management throughout the world has helped farmers to overcome yield losses, it is also the source of many problems in Africa. On an average the cotton producers in Africa, spray about six times per year, although as many as ten sprays are not uncommon. About 14-15% of the global insecticide use is devoted to cotton and almost half of the insecticides in Africa and a significant proportion in other developing countries are used on cotton. Several of those insecticides are classified by the World Health Organization as ‘highly hazardous’ (Kooistra et al., 2006). Moreover, the availability and promotion of cheap, low-quality insecticides combined with sub-optimal agricultural practices have led to the emergence of insecticide resistance in a number of pests coupled with the decline or disappearance of natural enemies of cotton pests that formerly helped in maintaining an ecological balance (Tabashnik et al., 2013). By far the most visible issue related to cotton cultivation, particularly in African countries, has been the relationship between low international prices and domestic support for cotton production (VIB, 2018). A study in Benin estimated that a 40% drop in cotton prices caused an 8% rise in rural poverty, where cotton accounted for 22% of the gross value of crop production in Benin (Minot and Daniels, 2005).

**African Extension System & African Cotton Extension System**

Different types of agricultural extension approaches are being practiced in various parts of the world to facilitate the transfer of technologies from laboratories to the land with an aim to make farming systems economically profitable and environmentally sustainable. Each approach reflects a particular set of objectives, aims, clients and socio-cultural setting. Over the years, Africa has practiced a mix of extension approaches, starting with colonial commodity approach that marked the connection of scientific agriculture in Africa to the Training and Visit (T & V) system (Akinola et al., 2011). Under the commodity based approach, Compagnie Francaise pour le Développement des Textiles (French Company for Development of Textiles), provided extension services for cotton growers in a number of francophone West African countries. Similarly, the cotton parastatals in Côte d’Ivoire, Mali, and Togo have extended their crop coverage during the commodity approach period (Roberts, 1989). ‘Community development cum extension approach’, which is the successor of the commodity-based approach worldwide, had operated to a limited extent in Africa. The latter innovation-centred approach could not succeed in Africa because of the inadequacy of technical information being extended. From the 1940s to the 1980s, the Food and Agriculture Organization of the United Nations (FAO) provided global leadership in extension by drawing on its worldwide field experience and offering counsel to member states on a range of extension models. The farmer–focused approaches of FAO were challenged by the World Bank’s initiative ‘training and visit (T&V) system’ in late 1970s and 1980s in Africa (Eicher, 2007). Some of the African countries such as Mali are currently using a modified version of T&V called ‘Block Extension’ (Dembele, 2007). Simultaneously, in many cotton-growing African countries, the cooperative movement spread rapidly, and several hundred primary societies had sprung up. In 1990s, many non-governmental organisations (NGOs) emerged as ‘agents of development’ in Africa. In the 1990s and 2000s, governments and their development partners started reforming traditional extension services to address their major weaknesses (Roling, 2006; Rivera and Alex, 2004). In 2000, an important institutional arrangement called ‘Famer Field School (FFS)’ network emerged as the most preferred extension method to empower farmers. Currently many reforms have been taken place in the African extension system; for example, the farmer-to-farmer extension (diffusion) approach developed by farmer innovators in Burkina Faso includes the ‘Market Day’, the ‘Teacher-Student’ approach and the ‘Zaï Field School’ (Akinola et al., 2011). Examples of SSA countries that are implementing some form of demand-driven extension models (pluralistic, participatory, FFS, SG-2000; modified T&V, etc.) include: Benin, Ethiopia, Ghana, Mali, Mozambique, Nigeria, Rwanda, Senegal, Uganda and Zambia (Davis, 2008).

As for the evolution of an extension system exclusively for cotton in Africa, there were stages viz., introduction
of cotton into Africa, integration of cotton extension with other activities, development of CPDT (Compagnie Française pour le Développement des Fibres Textiles) derived extension system, cotton extension through community development, T&V, modified T&V, FFS and Information and Communication Technology (ICT)-based cotton extension interventions. During the introduction stage, the companies used highly trained extension personnel to provide techniques to farmers for achieving high yields when cotton crop was newly introduced. In the integration stage, the supply of inputs, provision of equipment, and management of both seasonal and investment credit were added to the agent’s extension and marketing tasks. Added to this, the extension workers were made responsible for the distribution of seeds and the dissemination of improved techniques for all farm activities. Currently, many countries in Africa are benefitting from the FFS approaches and ICT based Extension services.

Constraints in African Cotton Extension System

The present extension system in Africa is facing many constraints in disseminating agricultural technologies to farmers. The high cost of reaching large sections of smallholders who are geographically dispersed in remote areas is a major constraint. The problem gets compounded due to the high levels of illiteracy, limited access to mass media, and high transportation costs. Similarly, the outcome of extension efforts depends on policies related to input and output prices, credit policies, input supplies, marketing and infrastructure system, etc., over which the extension system has little influence. Other major constraints include:

- Weak political commitment and low level of support for agricultural extension budget and expenditure;
- Weak accountability which reflects in low-quality and repetitive advice given to farmers; and
- Meagre efforts of extension agencies to interact with farmers and learn from their experiences.

Agricultural extension systems also become weak due to extraneous duties assigned to government extension staff. Such extra duties other than knowledge transfer include collection of statistics, distribution of subsidised inputs, assisting and collecting loan applications, and election campaign work on behalf of local or national ruling parties (Feder, Willett and Zijp, 2001). Moreover, the traditional approaches of extension in Africa were seldom inclusive. They did not take advantage of farmers’ indigenous knowledge and provided limited scope for participation of women farmers. Many extension programs of Africa could not reach the farmers in the remote areas. The private extension efforts in many African countries are poorly regulated and hence likely to mislead farmers, mostly in favour of promoting agrochemicals. Very few women have been employed as extension managers and frontline extension agents in Africa. These factors led to cotton lagging behind other crops since the increase of yields in cotton has been slower than in food crops such as rice and wheat; which is also one of the reasons for the less attractiveness of cotton to public extension systems in Africa. Modern extension approaches in Africa face several other challenges such as weak implementation of Intellectual Property Rights, limited capacity to regulate and coordinate multiple providers of advisory services that lead to multiple and conflicting messages targeting same end users and lack of market led extension.

Extension Methods Relevant for Africa

Extension services are amongst the most important rural services in developing countries. Evidences from many countries show that agricultural extension is a pro-poor public investment that is most relevant for African countries. Studies state that one agricultural extension visit reduced poverty by 9.8% and increased consumption growth by 7.1% in Ethiopia (Dercon, et al., 2008). Therefore, it is important to introduce a few novel extension methods such as field demonstrations, cotton schools, web- and mobile-based cotton advisory services, ‘farmer to farmer’ technology dissemination tools, mainstreaming methods, public-private partnerships, and information and communication technologies (ICTs) for technology transfer in Africa (Kranthi, 2018).

Field demonstrations

‘Show me how’ is the mantra of the demonstration concept. It started during the birth of Cooperative Extension (1896-1905) of the Land Grant Commission of the United States of America. The father of the ‘demonstration concept’, Seaman A. Knapp, the special agent with the United States Department of Agriculture, established the first demonstration farm in 1903 at Walter C. Porter farm, near Terrell, in Kaufman County, Texas. Interestingly, the first-ever field demonstration farm had a cotton crop (Martin, 1921).

The front-line demonstration (FLD) format which was adapted from the ‘demonstration concept’ has been highly successful in India. The FLD approach is most likely to suit Africa because of the identical nature of challenges in small-scale farming systems in Africa and India (Kranthi, 2018). Since 1996, India has been conducting field demonstrations on cotton under the close supervision of cotton scientists. In the FLD format, the implementing centres are given the challenge of enhancing production in low productivity areas in their respective states. A baseline
survey using participatory rural appraisal methods is conducted to understand the resource endowments of the farmers and the level of cotton productivity in the region. Benchmark 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. For selecting the beneficiaries and identifying the priority areas, rural agencies are actively utilised. A list of beneficiaries and their plot numbers are notified in the local Block Development Office. Farmers are selected in consultation with local leaders and Agricultural Officers. These officials form part of the FLD team. Technological interventions are planned and demonstrated by the scientists in selected farmers’ fields based on the problems identified. Critical inputs needed for the technological interventions are supplied and frequent field monitoring visits are made. The results of FLDs are compared with yields of farmers’ regular practices. An impact analysis after the harvest is carried out to assess the extent of reduction in insecticide use, yield enhancement, reduction in cost of cultivation, awareness of modern technologies etc.

Until 2017, a total of 19500 demonstrations were conducted in eleven cotton growing states of India with a budget outlay of 102.8 million rupees (about US$ 1.45 Million) by sixteen participating centres. Analysis on yield parameters over twenty years revealed an 18.0% increase in yield in FLDs when compared to farmers’ regular practices. Considering the similarities in the profiles of cotton growers in India and Africa, the FLD format appears to be a preferred transfer of technology (TOT) practice for improving the socio economic status of cotton growers in Africa (ICAC, 2018).

**The Cotton Farmer Field School (FFS)**

The Farmer Field School (FFS) approach is yet another successful extension method that could be used for the dissemination of cotton technologies in Africa. The FFS approach was first developed by FAO and its partners about 25 years ago in Southeast Asia as an alternative to the prevailing top-down extension method of the Green revolution. In a typical FFS, a group of 20-25 farmers meets once a week in a local field setting and under the guidance of a trained facilitator. In groups of five, farmers observe and compare two plots over the course of an entire cropping season. One plot follows local conventional methods while the other is used to experiment with what are considered as ‘best practices’. Farmers conduct simple experiments by observing key elements of the agro-ecosystem by measuring plant development, taking samples of insects, weeds and diseased plants, and conducting simple cage experiments or comparing characteristics of different soils. At the end of the weekly meeting, they present their findings in a plenary session, followed by discussion and planning for the coming weeks (FAO, 2018). Studies showed that the adoption of IPM by FFS had significantly reduced the overuse of pesticides and is expected to mitigate the serious consequences that the heavy use of pesticides has been causing on human health, biodiversity and water quality in India, Africa and other developing countries. The strong correlation between knowledge levels and reduction in pesticide use proved that a skill-oriented, knowledge intensive and hands-on education approach — as used during the FFS — is an efficient system to deliver the complex IPM principles to farmers. The FFS approach focuses on the importance to judge the necessity for plant protection interventions on the basis of agro-ecology and actual field needs, which provides a good road map to sustainable agriculture. Substituting pesticides with bio-control agents or other technologies such as biotech cotton are unlikely to emerge as definitive solutions to sustain agricultural productivity, if these new technologies are not paired with appropriate educational programs (Usharani, 2007).

**ICT-Based extension services**

The recent advances in ICT have changed the way knowledge is produced, processed, stored, retrieved and disseminated to different stakeholders in agriculture (Ansari et al., 2013). Africa has a huge potential of harnessing ICT for cotton development. Expert Systems – Information system, Crop
Doctor-Decision Support System, Video Conferencing, Interactive Multimedia, Web Search Tools, Social Media, Pedia, Video Streaming and Databases are the major tools ICT uses for disseminating cotton information across the globe (Usharani, 2014). The ICT initiatives in Indian cotton extension system were web portals – Knowledge Repository based online advisories and market services, Village Knowledge Centres (VKCs), Village Resource Centres (VRCs), mobile-based advisory services and hybrid initiatives.

Web- and mobile-phone-based advisory services
The majority of African farmers own mobile phones, thus facilitating an easier connection to farmers in remote areas. The availability and accessibility of mobile phones among the farmers is higher than any other ICT tools in Africa. Mobile phones have the advantages of having many ancillary services in addition to the standard voice function, such as SMS for text messaging, email, packet switching for access to the Internet, gaming, Bluetooth, infrared, camera with a video recorder, and MMS for sending and receiving photos and videos. Viewing the modern advancements in ICT and advantages in mobile phone technology, the Central Institute for Cotton Research (CICR) in India has been executing a novel extension mechanism called ‘e-Kapas network’ (‘e’ represents electronic and ‘Kapas’ means cotton) since 2012 for effective knowledge transfer among Indian cotton growers. ‘e-Kapas’ is a novel web-based weekly advisory service exclusively for cotton. It effectively utilises mobile phones for delivering cotton technologies to farmers, extension workers and other development workers engaged in cotton sector. Farmers interested in e-Kapas network register with their local state centres by registering their mobile numbers. Centres send regular voice SMS about cotton genotypes, production and protection technologies in their local languages to the registered growers (Usharani, 2014). Automated recorded voice advisories are relayed to registered farmers on a particular day of the week. The voice advisories tell ‘what to do’ and ‘what not to do’ in cotton cultivation on a weekly basis in nine different vernacular Indian languages. The ‘e-Kapas’ project is currently being funded under the Technology Mission on Cotton by the Government of India, to increase the productivity of cotton in the country. The project has been functioning in 17 university centres across the 10 cotton-growing states of the country under the leadership of CICR, Nagpur. The service became very popular, with a high demand in farmer registrations. e-kapas was found to have a strong impact on farmers and extension workers mainly because it enables technology transfer even to illiterate farmers. The initiative had great impact in intensive pest monitoring, overcoming pest epidemic situation through awareness and quick advisories provided directly to farmers in vernacular languages (Wasnik and Kranthi, 2014). The impact created by this advisory service was highly visible when India had to combat the whitefly menace in 2015, and pink bollworms in the past few years. Replicating the success of this novel mobile phone-based cotton extension model in Africa could pave the way for profitable and sustainable cotton farming in the coming years. Similarly, mobile apps play a major role in advisory services. CICR has also developed mobile apps for pest management in cotton in vernacular languages. Harnessing social media for cotton development can also be explored in Africa.

Cotton capacity-building programs
Farmer training programs can improve seed cotton yields. There is a need for proper farmer education and technology awareness programs. The programs must include the private input dealers also since majority of the farmers in Africa seek extension service from them. In India, the cotton research and development institutes conduct regular ‘on farm and off farm training programs’ for all stakeholders in cotton and there are exclusive training programs for women and the resource poor tribal cotton growers.

In India and Africa, agri-input dealers are the prime source of information to the farming community besides the supply of inputs and credit. There are about 282,000 practicing agri input dealers in India. However, the majority of these dealers do not have a formal agricultural education. The
National Institute of Agricultural Extension Management (MANAGE) in India offers a one year ‘Diploma in Agricultural Extension Service for Input Dealers’ (DAESI) program that is aimed to build their competence in agriculture thereby enabling them to serve the farmers better and to act as para-extension professionals (www.manage.gov.in). Such a diploma course, if used by the pesticide dealers of Africa or if replicated in Africa, has the potential to create a major impact in agriculture.

**Market information system**

The public and private extension systems in Africa have traditionally focused their attention on diffusion of technologies and agricultural inputs. The majority of the cotton growers desperately search for information on cotton markets and prevalent prices, but in Africa and many other less-developed countries, information on cotton markets is often imperfect, incomplete and inaccessible. India has established a few successful agricultural market information services such as AGMARKNET, Krishi Marata Vahini, Reuters market light, IFFCO Kisan sanchar limited, etc., which cover cotton market information too. These approaches on diffusing market information using ICT tools may be replicated in Africa.

**Inclusive Development in Extension Programs**

Published literature on the role of extension in helping women to make decisions on the adoption of improved farm practices is rather thin, even though women, especially in Africa, are major producers of food crops and are active and shrewd traders in local markets (Eicher, 2007). Many policy makers continue to remain woefully ignorant and generally neglect the role of women in African farming systems. They need to recognise that a very large proportion of the family farm labour force is female, and that women are in many cases pivotal to the success of agricultural development (Roberts 1989). Hence, there is an urgent need to include women and rural youth in African extension programs. Extension programs that aim to popularise novel technologies and farm implements must stress ‘method demonstrations’ of women-friendly technologies — and the drudgery-reducing tools whenever possible!
Table 1. Typologies of Extension Technologies Practiced in Sub-Saharan Africa

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<td>2. Training and Visit (T&amp;V)</td>
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<td>5. Integrated agricultural development program</td>
<td>5. Project approach</td>
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<td>6. Farming Systems Research and Extension (FSR / E)</td>
<td>6. Farmer Field Schools (FFS)</td>
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<td>Participatory</td>
<td>1. Farmer information dissemination system</td>
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<td>2. Farming system research – extension</td>
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<td>Contract</td>
<td>1. Commodity development</td>
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<td>Farming</td>
<td>2. Commodity focused</td>
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<td>Rural</td>
<td>1. Community development</td>
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<td>Development</td>
<td>2. Integrated Rural Development Programs</td>
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Table 2. Initiatives of Modern Agricultural Extension Methods in Africa

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<tr>
<th>Extension Methods</th>
<th>Initiatives in Africa</th>
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<tr>
<td>Mobile Phone-based Advisory Services</td>
<td>National Farmers Information Service (NAFIS) — a voice-based service in Kenya</td>
<td>Tucker and Gakuru (2009)</td>
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<td><a href="http://www.nafis.go.ke">www.nafis.go.ke</a></td>
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<td>Web-based Advisory Services</td>
<td>INFONET — a web-based service promoting organic farming</td>
<td><a href="http://www.infonetbiovision.org">www.infonetbiovision.org</a></td>
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<td>African Forum for Agricultural Advisory Services (AFAAS) — a continental platform for mutual learning and innovation among agricultural extension and advisory services providers across Africa</td>
<td><a href="http://www.afaas-africa.org">www.afaas-africa.org</a></td>
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<td>Market Information System</td>
<td>Agricultural Marketing Information Service (AMIS) in Cameroon</td>
<td>USAID (2013)</td>
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<td></td>
<td>Agricultural Input Market Information and Transparency System – AMITSA (East Africa)</td>
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<td>Esoko (many countries in Africa)</td>
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<td>Infotrade Market Information Services (Uganda)</td>
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<td>Lima Links (Zambia)</td>
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<td>Livestock Market Information System – LMIS (Ethiopia)</td>
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<td>MFarm (Kenya)</td>
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<td>Nokia Life Tools (Nigeria)</td>
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<td>Regional Agriculture Trade Intelligence Network – RATIN (East Africa)</td>
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<td>Zambia National Farmers Union – ZNFU (Zambia)</td>
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<tr>
<td>Corporate Social Responsibility</td>
<td>Provision of extension services, input supply and capacity building in Nigeria by CSR activities of Oil &amp; Gas, FBOs, NGOs and Manufacturing companies</td>
<td>Mafimisebi (2011)</td>
</tr>
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Compiled by the authors
Corporate Social Responsibility

The challenges faced by the public extension system provide a space for pluralistic extension to involve various actors and service providers such as 'private agri-business companies', NGOs, and 'producer organisations' in the dissemination of agricultural technologies. Such agencies have additional manpower, knowledge, skills, and expertise, and most of them leverage corporate social responsibility (CSR) funds for overall development of agriculture. CSR is a business approach that contributes to sustainable development by delivering economic, social and environmental benefits for all stakeholders. There are many successful CSR projects on agriculture in India. For example, The Housing Development Finance Corporation (HDFC) bank in India provided assistance to farmers in soil and water conservation, water management, construction, renovation and maintenance of water-harvesting structures for improving surface and ground water availability, in partnership with the Village Development Committees. It spent about 930 million Indian rupees (US$12.9 million) for this purpose. Similarly, M/s Mahindra and Mahindra limited is operating a CSR project namely 'Krishi Mitra' in which it spends around 60 million Indian rupees (US$0.83 million) for the training of small and marginal farmers in effective farming practices including soil health, crop planning, and creating model farms with bio-dynamic farming practices to increase crop productivity. Similarly, the Cotton Corporation of India conducts demonstrations and adopts cotton-growing villages using its CSR funds. African countries could also explore CSR projects for cotton development.

Conclusion

This paper highlights the neglect and apathy toward agricultural research and technology dissemination in Africa. It needs the attention of agricultural scientists to introduce a few of the novel extension methods listed in this paper to bring about the desired changes in African cotton growers' knowledge, attitude and cultivation behaviour, which could catalyse an increase in cotton productivity. This paper recommends extension technologies such as large-scale field demonstration to improve the production in low productivity areas; FFS to impart knowledge; advisory services to swiftly transfer the required technical, market and weather information; training programs to teach skills; MIS to provide market information; women- and rural-youth-targeted programs for inclusive development; and CSR to foster public-private partnerships in technology transfer for the sustainable and profitable cotton production in Africa.

References


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The textile and apparel industry provide a significant source of income and employment in many countries, particularly in Asia. In the last decade, Southeast Asian countries such as Bangladesh and Vietnam have emerged as powerful manufacturing and exporting countries of textiles and garments. However, these countries are highly dependent on imported raw materials, such as cotton, because domestic production only supplies 1% of their textile industry needs.

In sub-Saharan Africa, cotton-producing countries export about 90% of their fibre. Cotton is produced by small-scale farmers; whose average plot size is approximately 2.4 hectares. According to the latest data in ICAC’s 2017 report on production practices, a total of 3.6 million farmers grew cotton during the 2016/17 season. On the other hand, cotton consumption in sub-Saharan Africa has remained steady over the last two decades, with an average annual consumption of 240,000 tonnes between 1999 and 2018. Currently, Ethiopia, Tanzania, Nigeria and South Africa are the major cotton-consuming countries in sub-Saharan Africa.

According to figures from the World Bank, from 2008-2017, exports of textiles and garments from sub-Saharan Africa only accounted for 2% of total export revenue, which reached US$212 billion in 2017. However, in recent years, governments in countries like Ethiopia — the second-most populous nation of the region — have encouraged diversifying their export revenues by driving key sectors, including textiles and apparel. In 2012, Ethiopia exported US$71.2 millions of textiles and garments, a number that grew to US$ 94.1 million by 2016, a 32% increase. Similarly, textile and garment exports increased its share of total exports from 2.46% to 5.46% during the same period.

The Ethiopian cotton sector currently meets 70% of the domestic industry’s raw material requirements. Cotton consumption in Ethiopia is expected to increase in coming years as a result of expansion in the textile industry due to foreign investment from countries such as China, India, and Turkey, among others.

According to the Ethiopian Investment Commission (EIC), several foreign companies have committed to investing about US$2 billion in industrial parks to accelerate textile production and garment manufacturing.

According to the 2016 ICEX Report, Ethiopian textile products have free access to the European Union and US market through
various global agreements. The textile sector is part of the Government’s Growth and Transformation Plan (GTP), which was established in 2010 and expanded in a second version, GTP II, with all the objectives set out for 2020. The purpose of this plan is transitioning Ethiopia from an agriculture-based economy.

Potential Employment

The textile-apparel industry is a significant element of the economy, in both financial and social terms, as it is a major source of employment and foreign exchange. Data from major textile producing countries show that the textile and garment industry provides tremendous scope for employment generation. India has a strong textile industry. According to the Indian Ministry of Textiles, the textile and garment sector is the second-largest job provider in the country. In its most recent report, the Ministry of Textiles said that the textile industry provides direct employment to 45 million people, and indirect employment to 60 million more. Because cotton accounts for 60% of the raw material used by the textile industry, it has been estimated that the production of cotton textiles and garments generated about 27 million jobs and supported 36 million people with indirect employment, likely in the transportation, trade and retail sectors. Given that India produces about 5.3 million tonnes of cotton, it can be inferred that one tonne of cotton fibre provides direct full-time employment to about five people.

Furthermore, Bangladesh’s textile-apparel sector provided direct and indirect employment to 4.5 million and 1.5 million people, respectively. In 2016, the consumption of cotton fibre in Bangladesh reached 1.4 million tonnes. Therefore, it can be deduced that one tonne of cotton fibre employs about four people.

Closer to home, in South Africa, the textile-apparel sector generated about 120,000 jobs. Cotton consumption is approximately 22,000 tonnes, which would imply that one tonne of cotton employs at least about five people.

If all cotton-producing countries in the region fully develop their textile and apparel industry, it could generate slightly more than a six-fold increase in jobs. West African countries — where 75% of the cotton is currently produced and almost entirely exported — would have the most significant impact on the African continent’s economy. As cotton consumption in southeast Africa is about 32%, job generation could increase from 570,000 to 1.8 million people.

A critical analysis points out high employment potential in the textiles and apparel sector, compared to ginning,
24 The ICAC Recorder, March 2019

Spinning and weaving. While the employment potential from the possible complete use of domestically produced cotton could be more than 4.7 million persons in West Africa, at least 1 million people could benefit from direct employment in southern and eastern Africa. Combined, countries such as Burkina Faso, Mali, Benin, Côte d’Ivoire, Cameroon and Sudan export more than 1 million tonnes of raw cotton annually. The total cotton produced in Burkina Faso, Mali and Benin has the potential to generate 3.3 million jobs, with each country getting the benefit of at least 1 million full-time jobs if the entire cotton crop is consumed locally.

**Challenges**

Africa has generated interest from the international textile and garment industry. The continent has abundant cheap labour, most countries have free trade agreements, and the textile industry can integrate the production of cotton fibre all the way through the manufacturing of the finished garments. In the last decade, the population of sub-Saharan Africa has increased by 228 million people, and it currently exceeds one billion inhabitants. The United Nations forecast that the world’s population will increase from 7.9 billion in 2019 to 9.8 billion in 2050,

<table>
<thead>
<tr>
<th>Country</th>
<th>Production</th>
<th>Mill Use</th>
<th>Exports</th>
<th>Existing</th>
<th>Additional</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.33</td>
</tr>
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<td>0.2</td>
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<td>0.11</td>
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</tr>
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</tr>
<tr>
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<td>NA</td>
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<td><strong>TOTAL</strong></td>
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<td><strong>142</strong></td>
<td><strong>271</strong></td>
<td><strong>0.57</strong></td>
<td><strong>1.08</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Country</th>
<th>Production</th>
<th>Mill Use</th>
<th>Exports</th>
<th>Existing</th>
<th>Additional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burkina Faso</td>
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<td>5</td>
<td>294</td>
<td>0.02</td>
<td>1.18</td>
</tr>
<tr>
<td>Mali</td>
<td>305</td>
<td>5</td>
<td>283</td>
<td>0.02</td>
<td>1.13</td>
</tr>
<tr>
<td>Benin</td>
<td>278</td>
<td>3</td>
<td>256</td>
<td>0.01</td>
<td>1.02</td>
</tr>
<tr>
<td>Côte d’Ivoire</td>
<td>185</td>
<td>5</td>
<td>174</td>
<td>0.02</td>
<td>0.7</td>
</tr>
<tr>
<td>Cameroon</td>
<td>109</td>
<td>4</td>
<td>93</td>
<td>0.02</td>
<td>0.37</td>
</tr>
<tr>
<td>Togo</td>
<td>50</td>
<td>3</td>
<td>44</td>
<td>0.01</td>
<td>0.18</td>
</tr>
<tr>
<td>Chad</td>
<td>26</td>
<td>2</td>
<td>27</td>
<td>0.01</td>
<td>0.11</td>
</tr>
<tr>
<td>Nigeria</td>
<td>51</td>
<td>65</td>
<td>7</td>
<td>0.26</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1309</strong></td>
<td><strong>92</strong></td>
<td><strong>1178</strong></td>
<td><strong>0.37</strong></td>
<td><strong>4.71</strong></td>
</tr>
</tbody>
</table>

**Table 1. Potential Employment in the Textile and Apparel Sector in Southern and Eastern Africa**

**Table 2. Potential Employment in the Textile and Apparel Sector in West Africa**

![Figure 6. Hand spinning in Africa](image)
with sub-Saharan Africa accounting for more than half of global population growth. Additionally, according to the International Monetary Fund (IMF), the region’s GDP grew by an average of 4.1% in the last decade and it is forecast to grow at an average rate of 3.9% over the next five years. However, the region faces many challenges before it can become the new world’s supply hub for textiles and garments. The countries in the region should work on the development of policies favouring new investments in infrastructure, training, implementation of environmental policies, financing programs, and promotion of exports through the signing of new trade agreements.

Another major challenge for the textile-apparel industry in Africa is the importation of second-hand clothing and other worn articles (Harmonized system code 6309). From 2013-17, the average export value of these products was US$3.95 billion. The five-year (2013-2017) average
Table 3. Trade of Second-Hand Clothing and Other Used Articles

<table>
<thead>
<tr>
<th>EXPORTING COUNTRIES</th>
<th>IMPORTING COUNTRIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Country</td>
<td>US$ Million</td>
</tr>
<tr>
<td>United States</td>
<td>724.2</td>
</tr>
<tr>
<td>Germany</td>
<td>414.7</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>389.3</td>
</tr>
<tr>
<td>South Korea</td>
<td>260.2</td>
</tr>
<tr>
<td>China</td>
<td>215.9</td>
</tr>
<tr>
<td>Netherlands</td>
<td>169.6</td>
</tr>
<tr>
<td>Others</td>
<td>1,776.30</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>3,950.20</td>
</tr>
</tbody>
</table>


Restrictions on imports of second-hand clothing — together with the promotion of the textile-apparel sector — would provide a significant increase in job creation and resources in the region. However, according to the World Food Programme (WFP), approximately 75% of the African population lives on less than US$2 per day, and half of it on less than US$1.25 per day (http://www.wfp.org/fais/quantity-reporting). While the second-hand clothing sector poses a problem for the domestic textile and garment producers, the affordability of low-cost clothing for consumers in low-income countries is significantly more important than the product quality. Also, trading of second-hand clothes generates jobs in importing countries, as they require personnel to transport, classify, clean, repair, restore, and distribute the clothes.

Self-Employment, Entrepreneurship and Revenue Generation

The value of cotton by-products — such as stalks, short fibres and seed meal — is grossly optimised in Africa. Across the world, proven technologies are available that can enhance the value of by products, which not only generates additional income, but also provides employment and entrepreneurship opportunities.

Studies (Patil et al., ICAC RECORDER June, 2018) showed that:

- Removing gossypol using a microbial technology results in a net income (profit) of US$33 per tonne of seed meal.
- Short fibres into absorbent cotton results in a net income of US$770 per tonne.
- Creating briquettes from cotton stalks provides a net income of US$7.0 per tonne.
Creating pellets from cotton stalks provides a net income of US$ 15.0 per tonne, and the power generated from cotton stalks results in a net income of US$ 15.0 per MW per hour.

The study also showed that one megawatt (MW) of power could be generated from 50 tonnes of cotton stalks. These calculations were extrapolated to the commercial value-added potential of cotton by-products in Africa to show that countries in West Africa could generate an additional income of US$78 million by removing gossypol from seed-meal, US$71 million by producing absorbent cotton from short fibres, US$ 57 million by producing fuel-briquettes, and US$123 million by producing fuel-pellets.

Similarly, about US$80-100 million could be generated by utilising cotton products in southern and eastern Africa by producing absorbent cotton, fuel-briquettes, fuel pellets, power generation, and removal of gossypol from seed meal.

This concept note highlights the fact that cotton crop provides a tremendous opportunity for trade and employment. Unfortunately, Africa has not been exploiting cotton fibres and cotton by-products either for value addition or for employment. Africa produces fibres worth about US$2.5 billion. If the fibres are processed to produce textiles and apparel, the export revenues could reach an estimated US$ 30 to 90 billion depending on the kind of products produced. Interestingly, value addition of cotton seed-meal and cotton stalks could generate revenues worth about US$400 million apart from generating more than 200,000 MW environment-friendly electric power in the continent. Even conservative estimates show that the 1.5 million tonnes of cotton fibres produced in Africa can provide direct employment for about 6.5 million persons and indirect employment to almost an equal number or even more. Textile technologies are not new, neither are the value addition technologies. The technologies are being used across the world to generate income and employment across the world. What Africa needs is a political will and an enabling environment that can transform the sector, that could eventually transform the socio-economic landscape of the cotton growing countries of the continent.

---

### Table 4. Value Addition to Seed Meal, Short Fibres and Cotton Stalks in West Africa

<table>
<thead>
<tr>
<th>Country</th>
<th>Seed production '000 t</th>
<th>Removing Gossypol</th>
<th>Absorbent cotton</th>
<th>Briquettes</th>
<th>Pellets</th>
<th>Power generation US$ Million</th>
<th>Power '000 MW</th>
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</thead>
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<tr>
<td>Burkina Faso</td>
<td>549</td>
<td>18</td>
<td>16</td>
<td>13</td>
<td>29</td>
<td>0.57</td>
<td>38</td>
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<td>Mali</td>
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<td>18</td>
<td>16</td>
<td>13</td>
<td>29</td>
<td>0.57</td>
<td>38</td>
</tr>
<tr>
<td>Benin</td>
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<td>15</td>
<td>12</td>
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<td>0.52</td>
<td>35</td>
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<tr>
<td>Cote D'Ivoire</td>
<td>333</td>
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<td>10</td>
<td>8</td>
<td>17</td>
<td>0.35</td>
<td>23</td>
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<tr>
<td>Cameroon</td>
<td>196</td>
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<td>6</td>
<td>5</td>
<td>10</td>
<td>0.2</td>
<td>14</td>
</tr>
<tr>
<td>Togo</td>
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<td>3</td>
<td>2</td>
<td>5</td>
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<td>6</td>
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<tr>
<td>Chad</td>
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<tr>
<td>Nigeria</td>
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<td>3</td>
<td>2</td>
<td>5</td>
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<tr>
<td>TOTAL</td>
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<td>71</td>
<td>57</td>
<td>123</td>
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<td>164</td>
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</table>

### Table 5. Value Addition to Seed Meal, Short Fibres and Cotton Stalks in southern and eastern Africa

<table>
<thead>
<tr>
<th>Country</th>
<th>Seed production '000 t</th>
<th>Removing Gossypol</th>
<th>Absorbent cotton</th>
<th>Briquettes</th>
<th>Pellets</th>
<th>Power generation US$ Million</th>
<th>Power '000 MW</th>
</tr>
</thead>
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<tr>
<td>Sudan</td>
<td>196</td>
<td>6</td>
<td>6</td>
<td>5</td>
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<td>0.2</td>
<td>14</td>
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<td>79</td>
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<td>3</td>
<td>2</td>
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<td>0.08</td>
<td>6</td>
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<tr>
<td>Zimbabwe</td>
<td>90</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>0.09</td>
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<tr>
<td>Tanzania</td>
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<td>0.17</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0.05</td>
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<tr>
<td>Ethiopia</td>
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<td>2</td>
<td>2</td>
<td>4</td>
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Grâce à ICAC, rester au fait de l’actualité, des tendances et des développements tout au long de la chaîne de valeur du coton sur :
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