academicJournals

Vol. 8(32), pp. 4293-4298, 22 August, 2013
DOI: 10.5897/AJAR2013.7491
ISSN 1991-637X ©2013 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Review

The sustainability of cotton production using genetically modified seeds by emerging smallholder farmers in South Africa: a global and African pesrpective

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Accepted 22 July, 2013

This review focuses on the sustainability of adoption of genetically modified seeds by developed countries like United States, Australia and developing countries such as China and India. It then zooms into the African perspective in relation to countries that adopted Bt cotton. The review indicates that the Bt technology has played a critical role improving cotton yields and reduce the cost of regular spraying for bollworm insects. South Africa is one of the few developing countries, and the only one in Africa that has adopted genetically modified crops for commercial production.

Key words: Sustainability, Bt cotton, *Bacillus thuringiensis*, smallholder farmers, genetically modified.

INTRODUCTION

International overview

Cotton production in the world

Cotton is grown mainly for the fiber although a small quantity of the seed is used as a source of food, feed and oil for both human and animal consumption. Cotton seed is refined before it is utilized for human consumption to remove gossypol which is toxic to humans and monogastric animals (Jia, 1998). Table 1 shows a list of top ten countries ranked as the top producers of cotton lint.

Cotton engineered to produce insecticidal proteins of *Bacillus thuringiensis* referred to as Bt cotton has been one of the widely adopted and effective transgenic seed grown worldwide. In 2001 roughly 4 million hectares of land was reported to be cultivated with Bt cotton globally (Brookes and Barfoot, 2006). According to Williams (2001), the United States of America accounted for nearly 2.4 million hectares (60%) of Bt cotton planted that year. China recorded plantings of nearly 1.5 million hectares and Australia roughly 0.1 million hectares (James, 2001). Other countries that were the first adopters of Bt cotton includes Argentina, Indonesia and Mexico (Bennet et al., 2006).

ADOPTION OF GENETICALLY MODIFIED SEEDS IN THE WORLD

Bt cotton was officially approved for sale in India in 2002 (Qaim, 2002). Prior to this time, India had been battling to

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control bollworm infestation that halved the yields. Within a decade after the approval, Bt cotton was adopted by nearly 7 million farmers and today they cover 97% of the area planted with the cotton in India (Qaim, 2002). The high adoption rates were mainly due to simplification of regulatory procedures and well established bio-safety records by the Ministry of Environment and Department of Biotechnology hence leading to expeditious commercial release (Karihaloo and Kumar, 2009).

As a result, cotton production in India has risen with the use of the hybrid Bt cotton seeds, benefitting farmers and helping the country to become net exporter of the cash crop. A study jointly undertaken by the Council for Social Development (CSD) and Bharat Krishak Samaj (BKS), showed that overall production of cotton has grown by 9.25% since introduction of Bt cotton in 2002/2003 and farmers income jumped up to nearly 375% (Karihaloo and Kumar, 2009). Of all the crops and countries engaged in GMO (genetically modified organisms controversies today, only a few are as important as Bt cotton in India. In India, the cultivation of hybrid Bt cotton seeds which began in 2002/2003, has seen the average income of farmers increasing by almost 575% with average net returns at Rs 64, 113, 96 per hectare. The average nationwide cotton yields went from 302 kg/ha in the 2003/2004 season to a projected 481 kg/ha in 2011/2012 by 59% overall (Abhiyan and Abhiyan, 2012).

From China's perspective, current estimates suggest that as much as 95% of all cotton grown in that country is of the genetically modified variety. Vast planting of transgenic crops producing insecticidal proteins from the bacterium have helped to control several major pest and reduce the need for insecticide sprays (Abhiyan and Abhiyan, 2012)

In 1991, the biotechnology research centre of the China Academy of Agriculture Sciences (CAAS) initiated a major research program to develop cotton varieties that would contain a gene that would produce a Bt toxin which would control cotton bollworm (Alston et al., 1995). The first successful genetically engineered cotton plant was produced in 1993; by 1999, twenty new cotton varieties containing the Bt gene had been produced. In 1995, CAAS started testing these varieties in experimental fields regulated by the Ministry of Agriculture. In 1997, the Chinese bio-safety committee approved four CAAS varieties for commercial use in nine provinces, in 1998 farmers planted 10, 000 ha of CAAS Bt cotton (Deng, 1999). CAAS had difficulty selling more of it in 1998 because the government seed companies, which have regional monopolies on cotton seed sales, were not interested in distributing it. As a result CAAS formed a joint venture to commercialize Bt cotton called Bio-century Transgenic Corporation Ltd. This partnership greatly increased Bt seed cotton production in the country (Jia, 1998).

In the United States, the gene technology for managing insect pests was approved for commercialization by the US Environmental Protection Agency (EPA) in October 1995 and is now available from several seed companies in the country, as well as from many other cotton growing countries around the world (Rabobank, 1996). Preservation of Bt technology is critical for cotton producers across the US cotton Belt because of increasing insecticide resistance and production cost (Abhiyan and Abhiyan, 2012). Frequent introduction of new transgenic cotton varieties creates a need to continuously evaluate their cost effectiveness and to develop efficient plans for their deployment.

All Bt cotton plants contain one or more foreign genes derived from the soil-dwelling bacterium, *Bacillus thuringiensis*, thus, they are transgenic plants (Hardee et al., 2000). The insertion of genes from Bt causes cotton plant cells to produce insecticide proteins, often referred to as cry proteins. These insecticide proteins are effective in killing some of the most injurious caterpillar pest of cotton, such as the larvae of tobacco budworms and bollworms.

OVERVIEW OF AFRICAN CONTEXT

Cotton growing is an important livelihood strategy for large numbers of rural household in Africa. The crop is grown mainly on small family farms with a scale less than 4 ha (Gouse et al., 2002). Burkina Faso is by far the biggest cotton producer in Africa, where about three million people are involved in growing the crop (Hillocks, 2009). Cotton farming provides an income to small holders living in drier areas, where there are no other alternative crops that can be produced. Cotton is also a demanding crop in terms of crop husbandry and pest management. Hillocks (2009) indicated that the average yields in most Sub-Saharan Africa countries are well below the yield potential of current varieties under rainfed conditions. In Eastern and Southern Africa, yields of 500 to 700 kg/ha of seed cotton are typical for varieties with a yield potential closer 3,000 kg/ha (Abhiyan and Abhiyan, 2012).

According to Abate et al. (2000), cotton is one of the most important cash crops in West Africa and is a vital catalyst to economic development in that region. Cotton is the most important agricultural export and constitutes a major share of export earnings in Africa. Cotton has been produced in West Africa since the colonial era, where it was concentrated in the semi-arid regions. The occurrence of diseases and insect pressure limited agricultural development in wetter, higher potential areas. The area under cotton production keeps expanding; therefore production principles need to be improved for crop protection (Abhiyan and Abhiyan, 2012).

Insects are a major threat to cotton, about 15% of the world cotton production is lost due to insect attack every year (Oerke, 2005). In West Africa, the numbers are higher, with about 23% of cotton production lost to insect

Table 1. Top 10 International cotton growing countries.

Rank	Country	Production (million bales)
1	China	33.0
2	India	27.0
3	United states	18.0
4	Pakistan	10.3
5	Brazil	9.3
6	Uzbekistan	4.3
7	Australia	4.2
8	Turkey	2.8
9	Turkmenistan	1.6
10	Greece	1.4

Statista (2013).

Table 2. Genetically modified crops approved for commercial release in South Africa.

Crop	Year first approved	Season first approved
Insect resistant cotton	1997	1997/1998
Insect resistant maize	1997	1998/1999 (yellow)
Herbicide tolerant cotton	2000	2001/2002
Herbicide tolerant soybeans	2001	2001/2002
Herbicide tolerant maize	2002	2003/2004
Stacked gene cotton	2005	2005/2006
Insect resistance		
Herbicide tolerance		

Source: Gouse et al. (2008).

(Vognan et al., 2002). Among insects, the cotton bollworm complex is the most damaging to cotton yields in West Africa (Vaissayre and Cauquil, 2000). In particular, the major bollworm pest throughout West Africa is American bollworm, which is found throughout the region. The other bollworm varies from country to country, and includes the pink bollworm, spotted bollworm, spiny bollworm and red bollworm. Damage to cotton plants is characterized by feeding activity on squares (flower buds), flowers, and cotton bolls. Flower and boll damage is the most severe as it results in the shedding of the plant's reproductive parts and drastically reduces potential yield (Abhiyan and Abhiyan, 2012).

Chemical insecticides are used extensively in cotton production to control insect pest, with the primary target being bollworms. The number of sprayer per crop season varies between locations and from one year to the next. Cotton producers spray about six times per year, although as many as ten sprayings can be required.

OVERVIEW IN THE SOUTH AFRICAN CONTEXT

South Africa is one of the few developing countries, and the only one in Africa that has adopted genetically modified crops for commercial production (Gouse et al., 2002). The first field trials of transgenic crops on the African continent were initiated in 1989 with an application to the South African Department of Agriculture from the US seed company Delta and Pine land, which used South Africa as an over wintering haven for field trials of cotton. This application was approved according to guidelines established by the South African Committee for Genetic Experimentation (SAGENE), a scientific advisory committee set up in 1979 to monitor and advice on the development of GMOs in the country.

Insect resistant cotton has been produced since the 1997/2002 period, herbicide tolerant cotton has been made available for commercial production and tolerant soybeans have been introduced on a small scale. Table 2 indicates genetically modified seeds approved to be produced in South Africa.

A survey conducted in 2006 estimates that the area planted under GM crops now stands at 609 000 hectares (Gouse et al, 2008). According to this survey, the GM share of soybean crop in South Africa stands at 59%, while GM maize holds a 29% market share of maize and GM cotton makes up about 90% of the area planted with the crop.

In general this modern technology is well suited for high technology farming, but now it has also made an appearance in the low input management agriculture system. South Africa is marked by a strong system of intellectual property rights (IPR) and a dualistic agricultural system with large and small holder farmers operating under similar but not identical market access conditions. Genetic modification technologies have been characterized by an impressive adoption rate in South Africa.

According to Gouse et al. (2002), large scale cotton farmers reported pesticide and application cost savings and peace of mind about bollworms as the major benefits of Bt cotton. Small holder farmers indicated financial savings on pesticides and yield increases as the major benefit and reason for adoption of Bt cotton.

ADOPTION BY SMALL HOLDER FARMERS

According to Gouse et al. (2002), the rapid adoption rate of Bt cotton earlier on by small holder farmers in the Makhathini flats of Kwazulu Natal has been the focus of considerable international attention since it is one of the earliest examples of widespread planting of GM crops by resource poor farmers. The experience with GM cotton brought benefits initially, and this story became frequently quoted as testimony that GM crops can indeed have a positive impact on small holder farmers in developing countries.

The project of introducing Bt cotton to small holder cotton farmers was further roll on to Mpumalanga in the Nkomazi area. The Nkomazi area has always been the biggest contributor of cotton production in the country. The Bt technology was received with great hope as it addresses the challenges of insects and weed control. According to DARDLA (2011) about 259 smallholder farmers planted Bt cotton in Nkomazi area over nine villages. A total of 600 hectares was reported planted in the 2011 season with the Bt seeds. The successful yields gains received by farmers in the 2011 season opened the negotiations for prospects of building a ginner in the future.

EMPLOYMENT IN THE COTTON INDUSTRY

According to Department of Agriculture, Forestry and Fisheries (DAFF) in 2003, it was estimated that the primary cotton industry employed on average an estimated 58, 950 seasonal and 6, 550 permanent workers. This numbers were expected to increase to 154, 215 seasonal and 17, 135 permanent workers should local cotton production increase to 74, 000 tons annually, or in a scenario where small holder farmers produce 27% of the crop at 74 000 tons of cotton lint, an increase of 112, 534 seasonal and 12, 504 permanent workers, as well as an additional 11, 533 small holder farmers was expected.

In the 2008/2009 production year, employment figures were estimated at around 7, 000 cotton farm workers and for the 2009/2010 production year, employment figures increased to 8, 000 cotton farm workers due to increase in the area planted. According to the strategic plan developed by cotton South Africa (2004), the cotton industry was planning on broadening participation to enable small holder farmers to contribute on average 25% of the national crop by 2007 and 35% by 2014, to raise productivity which will improve the social life of the rural poor who depend on cotton farming for survival.

COTTON MARKETING STRUCTURE

Local cotton and cotton lint are marketed in the following three ways. Firstly, the seed cotton is sold by the producer to a ginner who gins the cotton and in turn sells the cotton lint for his own account to spinners and the seed to processors, either directly or by making use of agents. The ginner determines the price the producer obtains for his seed cotton and the producer relinquishes ownership of the cotton. Secondly, the producer may decide not to sell his seed cotton to the ginner, but contracts the ginner to gin it on his behalf on payment of a ginning fee. In this case, the cotton lint and seed remains the property of the producer who then either markets these products himself or contracts the gin or someone else to market the cotton lint on his behalf. Lastly, the producer can also gin. He then either markets the cotton lint and seeds himself or contracts someone else to do it on his behalf.

In the ginning process seed cotton is separated from the fibre. The purchase of seed cotton takes place in terms of the grading standards applicable to handpicked and machine picked cotton and linked to the South African grading standards for lint. The latter serves as a norm for the sale of the cotton lint. In the event of any disputes arising during the delivery of the cotton that cannot be resolved to the satisfaction of both parties, the Quality Control Department of cotton, South Africa is accepted as an impartial body in the role of arbitrator.

During the same period of declining cotton production, the industry experienced improvement in cotton producer prices which began increasing in 2007/2008 and at the same time a peak was attained at approximately R4 700 per ton in response to improvement in international cotton prices. In 2008/09 market seasons, there was a slight decline in prices of seed cotton due to low production levels and low demand for South African seed cotton. In the 2009/2010 and 2010/2011 marketing season, average producer prices of seed cotton started to increase again. The change between 2009/2010 and 2010/2011 period represent 11% increase in the average

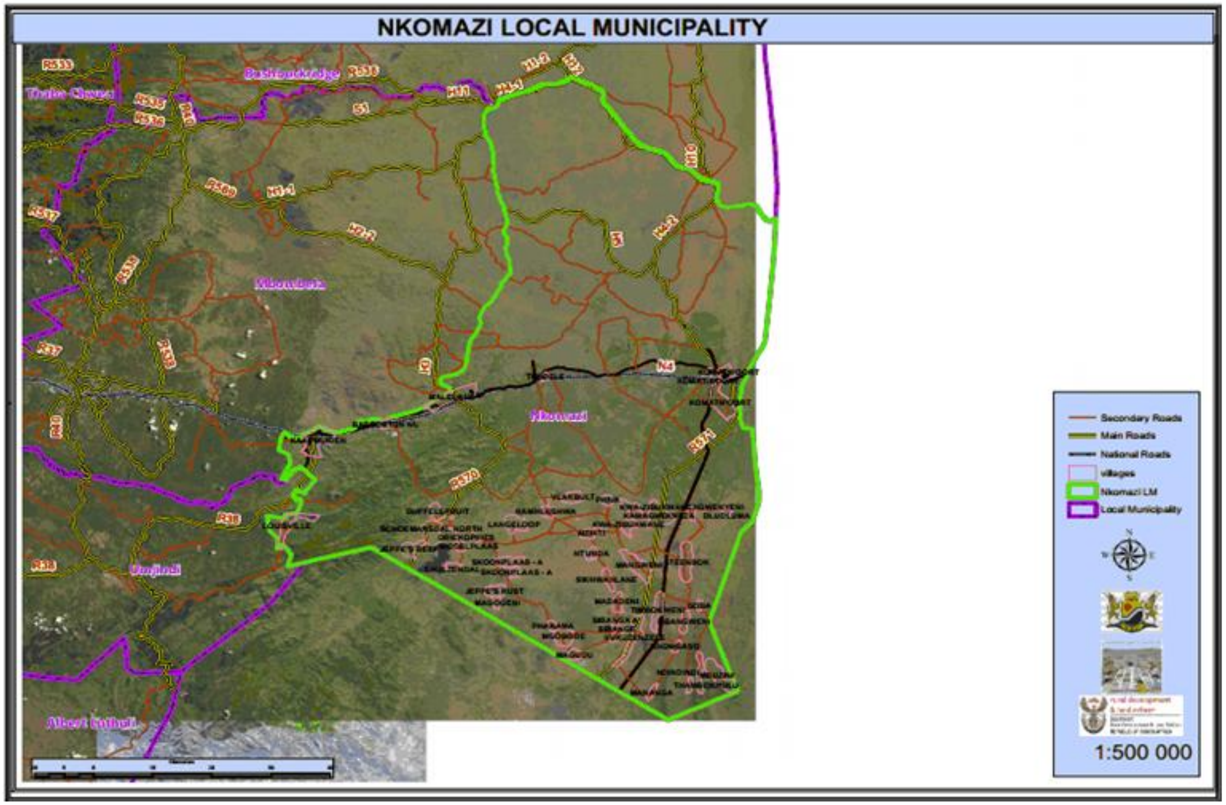

Figure 1. Map of Nkomazi municipality. Source: DARDLA (2013).

producer prices of seed cotton.

COTTON PRODUCTION IN THE NKOMAZI AREA OF SOUTH AFRICA

Nkomazi is located in the eastern part of the Lowveld area in the Mpumalanga province. It lies 350 km east of Gauteng bordering Mozambique and Swaziland. The Nkomazi area has a potential of about 3, 500 hectares that can be cultivated with cotton. The leading tribal village in cotton production includes Steenbok, Brink, Albersnek, Mangweni, Mbangwane and Tsambokhulu. Figure 1 shows a map of the Nkomazi area in the Mpumalanga province of South Africa.

PERSPECTIVE OF NKOMAZI AREA IN RELATION TO COTTON PRODUCTION

Cotton production has been a culture in this part of the province and it has been produced for many years. However, it must be mentioned that the scale of production has decreased tremendously of late as a result of factors such as, poor market prices, high production costs, and uncertainty of rain distribution due to climate change and development of the sugar industry which resulted in conversion of some potential cotton lands for sugarcane production.

It is for this reason the Mpumalanga Department of Agriculture, Rural Development and Land Administration (DARDLA) is implementing a strategy to revive cotton production in the area where farmers are supplied with production inputs such as seed and chemicals.

The aim of the Department is to assist farmers by providing them with a cotton ginner which will buy all cotton produced by farmers in the region. It also affirms that building a ginner will require volumes of cotton in order to run efficient (DARDLA, 2011).

Cotton planted in this part of the province is mainly on dry land and the farmers are planting Bt cotton sponsored by the Department with some other production inputs.

CONCLUSION

This review indicates that genetic modified cotton seeds brought hope in the South African cotton industry. The adoption of Bt cotton comes after many studies have demonstrated its benefits. These include significant yield gains as well as reduced insecticide and labour usage in different countries. Before the introduction of Bt technology, farmers relied on a full time spray program to control the problematic bollworm complex. The types of insecticides that farmers used on bollworms are among the most toxic, killing even beneficial insects and endangered the environment.

The information gathered from regional and international reports further reveals that the use of genetic modified seeds has benefited farmers by reducing sprayings for insect pest and easy control of weeds by spraying herbicides. However the global challenge remains the preservation of seed technology by following the correct and sustainable production principles by farmers.

ACKNOWLEDGEMENTS

The University of the Free State, WWF South Africa and World Vision Swaziland are highly appreciated for their invaluable support throughout the preparation of this review paper. Special thanks go to all authors cited in the text.

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