A REPORT ON BETTER MANAGEMENT PRACTICES IN COTTON PRODUCTION IN BRAZIL, INDIA, PAKISTAN, BENIN, BURKINA FASO, CAMEROON, MALI, SENEGAL & TOGO

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Better Cotton Initiative

Final Report

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Executive Summary

1. BCI aims to formulate a globally applicable definition of growing Better Cotton that also takes into account local conditions and circumstances.
2. With agreement from BCI, CABI analysed all documents referring to field cotton projects that have existed since 2003 in Brazil, China, India (Andhra Pradesh, Maharashtra, Gujarat and Karnataka states) Central Asia (Kyrgyzstan and Tajikistan) Pakistan, West Africa (Benin, Burkina Faso, Cameroon, Mali, Senegal, Togo) and Turkey, in terms of agreed parameters, including project objectives and adherence to BCI's production principles.
3. Scientific research papers that were reporting on experiments and field trials that were being conducted on aspects of cotton production in the 13 countries were also included in this process.
4. More than 2,000 project reports, review documents and scientific research papers were sourced and 320 contained relevant information. Information from these documents was inputted into an Access Database.
5. All field project reports referred to one of four best practises for smallholder cotton production, namely 'organic', 'IPM', 'Bt', and '*Fairtrade*'. No project reports were found that involved conventional or large scale cotton production. Several scientific research papers, which reported on the impact of FAO's IPM project in Asia, in terms of reduced pesticide use and improved farmers' incomes, were found. Codes of practise concerning pesticide use and marketing are available for organic, Bt and *Fairtrade* cotton and guidelines are available for FFS which enable farmers to develop local IPM strategies.
6. Each of these best management practises is compared with conventional cotton production and assessed according to BCI's production principles (version 1.0).
7. BCI selected between 13 and 37 field reports, review documents and research papers from Brazil, India, Pakistan and West Africa to be analysed in detail by CABI in order to identify tools that could contribute to growing Better Cotton.
8. Cotton production in Brazil, India, Pakistan, Benin, Burkina Faso, Cameroon, Mali, Senegal and Togo is analysed using information obtained from the field project reports, review documents and research papers.
9. According to information gleaned during this study, Brazilian cotton farmers are highly productive because they are supported by sophisticated research which ensures a regular supply of new technologies, including improved cotton varieties. Cotton production in India is constrained by poor seed supply and contaminated fibre; in Pakistan it is constrained by poor seed supply and limited technical support; in West Africa constraints include poor seed supply, poor marketing structures and lack of technical support.
10. From an economic and an environmental perspective organic and *Fairtrade* cotton are best management practises for smallholder, food insecure, cotton farmers, while IPM is the best practise for mainstream, larger-scale production and could qualify as a globally applicable definition of Better Cotton.
11. The Better Cotton Initiative could be highly relevant to millions of cotton farmers who are facing an uncertain future in 2009. Unfortunately there are a large number of external factors that are currently constraining smallholder cotton production and BCI is urged to address some of these issues as part of its vital initiative.

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We are grateful to the following people for sourcing field project reports, review documents and research papers; analysing this material according to BCI's principles during Component I and in some cases assisting with the identification and listing of appropriate tools for better cotton farmers under Component II:

- ***Brazil: Dr Yelitza Colmenarez, CABI Caribbean and Latin America; Cristina Sousa-Correia and Vera Barbosa, CABI Head Office***
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- ***Turkey: Christopher Stopes, EcoS Consultancy Limited***

Background

BCI's Aims and Objectives

BCI aims to formulate a globally applicable definition of Better Cotton that also takes into account local conditions and circumstances. To achieve this aim BCI is initially taking a regional approach with strong multi-stakeholder involvement to define Better Cotton in several important cotton growing regions, and is currently working in Pakistan, West Africa, Brazil and India as these countries provide a cross section of different cotton farming systems. BCI will also hold multiple forums to share what BCI is learning with all stakeholders.

BCI's philosophy is to develop a market for a new mainstream commodity, that is, it is seeking to affect a significant proportion of cotton production, rather than seeking to develop a niche market. Consequently, BCI does not intend that there be any specific premium paid for Better Cotton. Rather, BCI believes that a longer-term and more sustainable approach to improve the income and livelihoods of cotton farmers is to promote and support better management practices, tools and activities that are within the direct control of the farmer. For example, promoting practices and activities that can lead to:

- higher net income due to better quality cotton, higher yields, lower input costs, and/or better access to finance
- improved health conditions due to reduced toxicity of and/or exposure to pesticides
- improved yields, lower water use and input costs through improved soil fertility (e.g. reducing water logging and soil salinisation, increasing organic matter content)
- improved market access by decreasing contamination, and/or meeting increasing market demand for sustainable cotton

It is important to note that BCI does not expect farmers to introduce or adopt new practices without support, and will therefore endeavour to identify appropriate mechanisms, such as capacity building, access to finance and/or other resources.

Searching for Best Practises

In order to test and validate this position, BCI is therefore interested in finding data that supports its contention that there are inherent benefits to the farmer from the adoption of better management practices. One important potential source for this data are the various field projects or industry programmes that have, or are currently working with cotton farmers to address issues of environmental and / or social sustainability. While these benefits may be environmental, social or economic, it is the economic data derived from projects working with cotton farmers that are of most interest to BCI, and the data presumed to be most readily available.

Furthermore, BCI intends to start implementing the Better Cotton system in 2009. To assist BCI identify appropriate regions to conduct field tests in, and to prepare for expanding Better Cotton into new regions, BCI believes it is important to be aware of and to understand any recent and current field activities being undertaken with cotton farmers in the BCI focus regions. Such an understanding should help BCI collaborate and build upon existing activities in preference to BCI starting field-testing on a greenfield site. Also, identifying recent and existing projects will assist BCI to identify potential sources of funding for BCI field projects. CABI has been given the task of mobilising her scientific staff in Latin America, South Asia, Africa and UK to assist in the extraction and analysis of this data.

Objectives of CABI's Terms of Reference

The objectives of the following Terms of Reference for Component I are as follows:

1. To identify field projects and industry programmes that are working with cotton farmers (or have worked with cotton farmers within the last 5 years) to promote the adoption of practices that are relevant to one or more of the BCI principles (see attached draft framework)
2. To collate and list the following information and data from the field projects and industry programmes identified in 1.
   - details on the project (title of project, parties involved) funder, implementation authority/responsibility), total funding provided / available to the project, the rationale for the funding, summary of project objectives, region(s) in which project is being implemented, the number of farmers involved, issues faced during implementation, and how they were overcome or managed
   - evidence for the impact of the adoption of better management practices, either economic, environmental or social
3. To provide BCI with an assessment of the quality of the data generated by the field project
4. To identify the potential tools noted in the field projects that are available to assist farmers in growing 'Better Cotton", especially highlighting those linked to positive environmental, social or economic outcomes (e.g. Good Agricultural Practices, the method and structure of how the farmers were organized). This list of tools will be built upon and reported in Phase II.

BCI's principles (March 2008)

BCI's environmental principles

Better Cotton is produced by farmers who
- maintain the quality and availability of water
- use pesticides safely and responsibly
- care for the health of the soil
- preserve natural habitats
- care for & preserve the quality of the fibre

BCI's social principles

Better Cotton Initiative will
- respect and promote Decent Work for formal employees, smallholder farmers, informal workers, women and children
- facilitate producer organization for smallholders, including women

BCI's economic principle

Better Cotton Initiative will

- facilitate access to equitable finance for smallholders

BCI's Production Principles: Version 0.5 (28th April 2008):

Production Principles

Better cotton is produced by farmers who;

- minimise the use and impact of pesticides.
- use water efficiently and care for the availability of water.
- conserve natural habitats.
- care for the health of the soil.
- care for and preserve the quality of the fibre.

Enabling Principles

- Producing Better Cotton is an opportunity for Decent work
- BCI enables knowledge sharing and skills development
- BCI enables effective producer organisation
- BCI enables equitable access to responsible financial services

BCI's Production Principles: Version 1.0 (7th July 2008):

Crop protection principles

- Better Cotton is produced by farmers who minimise the harmful impact of crop protection practices
- Better Cotton is produced by farmers who use water efficiently and care for the availability of water
- Better Cotton is produced by farmers who care for the health of the soil
- Better Cotton is produced by farmers who conserve natural habitats
- Better Cotton is produced by farmers who care for and preserve the quality of the fibre
- BCI promotes Decent Work

Enabling Mechanisms

- BCI enables knowledge sharing and skills development
- BCI enables effective producer organisation.
- BCI enables equitable access to responsible financial services

Component I: Analysing field projects

According to the ToRs for this desk study, the following information concerning cotton field projects that have been in operation in the following regions, i.e. Brazil, China, India (Andhra Pradesh, Maharashtra, Gujarat and Karnataka states) Central Asia (Kyrgyzstan and Tajikistan) Pakistan, West Africa (Benin, Burkina Faso, Cameroon, Mali, Senegal, Togo) and Turkey within the past five years, i.e, since 2003, was required:

- Title of project
- Parties involved (funder, implementation authority/responsibility)
- Total funding provided/available to the project
- The rationale behind the provision of funding
- Summary of project objectives
- Region(s) in which the project is being implemented
- The number of farmers involved
- Availability of data indicating impact of project/programme

Data collection from field project reports, review documents and research papers

The information listed above was contained in many project reports and review documents. Some of these reports and documents were obtained from BCI, while others were requested from local research organisations, national and international NGOs and donors who had funded the projects. Review documents were also obtained from CAB Direct and via the internet.

An Excel spreadsheet was prepared in order to assist with the extraction of the required information from the field reports and review documents, using the headings taken from the above list and extra columns to input data concerning the project's adherence to the BCI principles were added. Copies of these spreadsheets were forwarded to colleagues, based in CABI offices in Trinidad, Islamabad, Delhi and Malaysia, who were responsible for compiling information from Brazil, Pakistan, India, China, and consultants based in Senegal and UK who were responsible for compiling information from West Africa and Turkey respectively. Relevant reports and documents were exchanged via CABI's ftp facility and progress was monitored by email, skype and telephone on a daily basis.

During the data collection process it became evident that all field projects that had been reported on involved smallholder farmers and thus had a development objective. The main aim of these projects had been to reduce the use of harmful pesticides and enable smallholder farmers to profit from cotton production thereby improving their livelihoods by implementing one of four best practises (IPM, Bt, Organic and/or *Fairtrade*). It was necessary, therefore, to include scientific research papers (subject to peer review and published in reputable journals) on improving cotton productivity in order to broaden our search and obtain reliable data on impact assessment and aspects of conventional and large-scale cotton production.

In excess of 2,000 project reports, review documents and scientific research papers were sourced and scanned for the required information, 320 of these contained sufficient information to warrant further in-depth scrutiny for data extraction. However, none of them contained sufficient information to fulfil 100% of data requirements.

1,056 project reports, review documents and scientific papers that were consulted during this process were down-loaded onto a CD and made available to BCI.

Populating the Database

Access, a relational database management system, was used as the vehicle to store the data gathered during Component 1 of the project. Initial planning was essential at the beginning of the data gathering process to ensure that the database fields matched those of the BCI objectives and principles (as set out in March 2008 –see page 2). Reconfiguration of database fields after set-up is very time consuming so it is necessary to be aware of all the required outputs before the database is initialised.

After importation of data from each region the information was sorted and checked for consistency. Blank fields indicated where project data was incomplete. The database was reconfigured during June 2008 to reflect the changes in BCI's principles, (Version 0.5 April 2008) when BCI's 'environmental', 'social' and 'economic' principles were transformed into 'production' and 'enabling' principles. This was a lengthy procedure as each record had to be re-coded according to its adherence to the new production principles/enabling mechanisms.

Challenges accessing source material for the database were also experienced by CABI colleagues globally. Identified source persons often had to be contacted repeatedly to obtain documents that they had promised initially and despite this several were not forthcoming.

A report on Component I was made available to BCI in June 2008.

Identifying Better Management Practises

According to the ToRs, following consultation with BCI's Environmental and Social co-ordinators it was necessary to collate and list the following information from the selected field projects:

- Evidence for the impact of the adoption of better management practices, *economic, environmental* or *social*, including an assessment of the quality of the data used to determine the impact.
- Data on the quality of the cotton produced by the project, especially length, strength and micronaire, and the level of contamination.
- Where possible, during this desk study, for those projects for which direct contact with the implementing institution has been established, information about challenges and difficulties faced during project implementation.
- The potential tools noted in the field projects that are available to assist farmers in growing 'Better Cotton", especially highlighting those linked to positive environmental, social or economic outcomes relevant to the draft BCI principles (eg. Good Agricultural Practices, the way in which farmers are organized), including listing any specific evidence for the impact (i.e. evidence for its justification as a BMP) of the adoption of better management practices

CABI selected projects that had promoted Better Management Practises according to BCI's sustainability principles and later BCI's production and enabling principles.

It was noted that although the field project reports referred to a range of different management practises that were said to conform to BCI's principles, very few of them contained the technical data needed before such practises could be recommended to farmers. This is because implementers of development projects are obliged to generate reports to satisfy donors that their funds have been well spent. Consequently many of the reports did not contain any scientific information and had painted a rosy picture in order to attract more funding. Furthermore, we found that very few of the projects had been scientifically assessed for their impacts on farmers' livelihoods[1] or the environment, either by project staff or by external scientists. These findings do not come as a surprise to the report authors as experience gained over many years has shown that critical assessments (scientific, economic, social) are rarely undertaken unless a major donor requires such information following a pan-regional / long duration project. Such assessments may also be classified as confidential and will not reach the wider scientific community.

Verifiable information on tools and best practises in cotton production could only be obtained from scientific papers. However, scientific papers that were available mainly reported on experimental work that is being conducted in developed and middle income cotton producing countries, including Brazil and China. Comparatively few research papers were found from

[1] A convincing impact assessment depends on the collection of baseline data at the beginning of the project which can subsequently be compared with the same set of variables at the end of the project. It is advisable to train target farmers in record keeping to assist with this process.

the other focus countries, particularly from Asia and West Africa, probably due to the scarcity of government funding for research, see Table 1.

All Better Management Practises, including defined codes of practise and their component tools that were identified from these reports, documents and papers were compiled in an Excel spreadsheet and forwarded to BCI in July 2008.

Table 1.

Comparative numbers of project reports/review documents and scientific papers retrieved

Type of document	Brazil	China	India	Central Asia	Pakistan	West Africa	Turkey
Project/review	14	12	23	59	15	100	3
Research	96	25	6	0	3	7	1

Since this was a desk study it was not possible to hold a dialogue with project implementers concerning the challenges and difficulties that they had faced during project implementation. This type of sensitive information is only likely to be revealed during field visits and face-to-face interviews.

Component II: Identifying Best Management Practises and their Component Tools

According to the TORs it was necessary to identify and list publications that contain recommendations on Good Agricultural Practices, Better/Best Management Practices, etc. that deal with one or more of the following aspects of cotton production:

- Pesticide use
- Integrated Pest Management
- Soil management
- Water management
- Fibre (lint) quality management
- Habitat management

Since current commercial cotton varieties are highly susceptible to a wide range of insect and nematode pests, pathogenic diseases and mid-season droughts, cotton farmers are advised to adopt a management practise that is based, first and foremost, on an effective pest management strategy, in order to prevent serious yield losses. Table 2 shows the major pests and diseases in five main cotton growing areas:

Table 2:

Major pests and diseases in 5 cotton-growing areas

	Africa	China	Central Asia	South America	South Asia
Major insect pest species	Jassids, *Helicoverpa armigera* *Pectinophora gossypiella*	*Helicoverpa armigera* *Lygus lucorum* *Pectinophora gossypiella*	*Helicoverpa armigera* *Pectinophora gossypiella* *Agrotis segetum*	*Anthonomus grandis* *Pectinophora gossypiella* *Spodoptera frugiperda*	*Helicoverpa armigera* *Pectinophora gossypiella* *Jassids,* *Bemisia tabaci*
Major diseases	*Fusarium oxysporum* f.sp. *vasinfectum* *Verticillium* spp. *Xanthomonas malvacearum*	*Verticillium* spp *Fusarium oxysporum* f.sp. *vasinfectum*	Brown root rot *Verticillium* spp. *Fusarium oxysporum* f.sp. *vasinfectum*	*Fusarium oxysporum* f.sp. *vasinfectum* *Verticillium* spp. *Xanthomonas malvacearum*	Cotton leaf curl virus (CLCuV) *Fusarium oxysporum* f.sp. *vasinfectum* *Verticillium* spp. *Xanthomonas malvacearum*

All the project reports, review documents and research papers that were obtained for this study referred to one of five best management practises[2] for cotton production, i.e. conventional, Bt (genetically engineered), IPM, organic or *Fairtrade*. Each of these best practises comprises a suite of tools for managing pests, soil fertility, water and fibre quality. Codes of practise for organic and *Fairtrade* cotton are also concerned with habitat management and the employment of child labour. The tools that make up these practises are discussed below in terms of BCI's current production and enabling principles (version 1.0). All tools, except those marked with an asterisk, may be interchangeable between the five best practises, subject to local research development.

1. Conventional cotton

Conventional cotton production is normally supported by national governments through their research and extension institutions because it is valued as a foreign exchange earner. Best practise in conventional cotton production depends on the regular application of external inputs, particularly pesticides and fertilisers to control the myriad of pests and increase yields. Extension workers, often assisted by agrochemical companies, are responsible for making recommendations on the variety of cotton to be grown, plus the rates and timing for applying of these inputs.

Since conventional cotton requires a high financial investment it is rarely profitable under rain-fed conditions (You & Chamberlin, 2004; Alweendo, 2008; Ikiara & Ndirangu, 2002).

- *Minimising the harmful impact of crop protection practises*

The most commonly used pesticides in conventional cotton production are 'extremely hazardous' WHO Class 1a and 'highly hazardous' WHO Class 1b[3] organochlorines, organophosphates and carbamates, such as endosulphan, monocrotophos and aldicarb, also 'moderately hazardous' WHO Class II synthetic pyrethroids such as deltamethrin, which are neurotoxins and extremely harmful to fish. Users are advised to wear full protective clothing, including overalls, boots, gloves and respirators to prevent poisoning. Unfortunately, the cost of this protective clothing and its inappropriateness to hot environments make it prohibitive, particularly for poor farmers and as a result cotton farmers suffer a much higher incidence of pesticide poisonings compared to those cultivating other crops.

A conventional system depends solely on effective pesticides to control damaging pests including boll worms, aphids, jassids and whitefly. In order to prevent the over-use of pesticides it is recommended that farmers scout regularly for cotton pests and only spray once the economic threshold is reached for each pest. The use of ultra low volume (ULV) sprayers can also save on pesticides but require a higher level of technical support than the traditional knapsack sprayers. Rotation with different types of pesticide is encouraged in order to reduce the build-up of pest resistance. Pyrethroids are currently being withdrawn from cotton fields in India because of widespread resistance by boll worms (CFC, 2008). Where resources allow, farmers may also apply herbicides to reduce weed problems and defoliants to assist with picking, which both have negative implications for the environment. Farmer training in pest recognition, scouting and estimating economic threshold levels is required to minimize the harmful impact of these crop protection practises, see Table 3.

- *Using water efficiently and caring for the availability of water*

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2 'Best practise' is defined as a process or series of methods (techniques or tools) that is recognised as being the most effective at achieving the desired outcome; for example see: http://www.fao.org/bestpractices/index_en.htm

3 http://ew.eea.europa.eu/ManagementConcepts/Greenp/F1056727684/F1074009377/F1074176905/F1074177047/HTML_Page1074178064/

Ultra Low Volume sprayers require 75% less water than knapsack sprayers (IRRI, 1986). Drip irrigation systems can also conserve water in conventional cotton production. Both of these technologies require farmers to have increased levels of skills and resources.

- *Caring for the health of the soil*

Soil fertility in conventional cotton is maintained through the application of NPK fertilisers at rates recommended by local research and extension. For optimum results nitrogen should be applied at peak flowering and adequate potassium should be available to assist boll maturation. In the long term, however, sole reliance on chemical fertilisers can lead to a reduction in soil pH, the reduced availability of crucial soil nutrients and the loss of organic matter.

- *Conserving natural habitats*

All WHO Class I and II pesticides (predominately insecticides) are damaging to mammalian life and are a threat to the diversity and survival of beneficial insects in natural habitats. Organochlorines tend to be persistent and can still be found in use in non-OECD regions. Monocropping is recommended in conventional cotton production, while intercropping or strip cropping with food crops is discouraged due to the likelihood of contamination with toxic pesticides. This reduces bio-diversity and mitigates against food security amongst smallholder subsistence farmers.

- *Caring for and preserving the quality of the fibre*

The quality of cotton fibre in terms of its length and strength depends on the cotton variety that is available to the farmer. Grading of conventional seed cotton is recommended in order to preserve the quality of the best fibre. Ideally this should begin in the field by picking into two bags; one for high quality lint and the other for poorer quality lint. Pickers' bags should be made of cotton to prevent the lint from becoming contaminated. Grading can also be done in farmers' compounds.

- *Knowledge sharing and skills development*

In a conventional system, government extension agents provide information to farmers via pre-determined messages, based on research and technical data from agrochemical companies and through on-farm demonstrations with farmers' groups.

- *Effective producer organisation*

Some governments support the creation of farmers' groups to facilitate the marketing of conventional cotton.

- *Equitable access to responsible financial services*

Conventional cotton farmers are encouraged to buy inputs on credit from the cotton marketing company who deduct the cost when they buy the seed cotton. Credit may also be available from agrochemical companies, ginneries and commercial banks. Payment for the crop is often made several months after it has been ginned and sold on the world market, which is a huge disincentive for smallholder producers who do not have access to bank loans. However the availability of credit for the purchase of inputs can cause farmers to become indebted, if yields are lower than expected and this has led to a high incidence of suicides in some cotton-growing areas of India. Expected yields of conventional cotton in a rain-fed system range from 200 to 500kg and in an irrigated system range from 500 to 1,800 kg of lint per hectare.

Table 3:

Comparative advantages and disadvantages of tools for conventional cotton in terms of BCI's principles

Tool	Advantages	Disadvantages
Use of WHO Class I pesticides	Kills most pests	Highly toxic to humans and the environment; full protective clothing needed; kills natural enemies; high cost of pesticides and application equipment; intercropping with food crops banned
Use of protective clothing	Protects against toxic pesticides	Full protective clothing is expensive and uncomfortable in the tropics; replacement respirator cartridges are rarely available
Farmer training in scouting and using economic threshold levels	Trained farmers use pesticides more judiciously	Farmer training needed
Rotation of pesticides	Reduces the incidence of pesticide resistance	Farmer training needed
Use of ULV sprayers	Conserves pesticide and water	Higher level of technical support needed
Use of herbicides	Reduces weed problems; saves labour	Increases input costs; harmful to the environment
Use of chemical fertilisers	Increases cotton yields	Increases input costs; continued use reduces soil pH and SOM
Use of lime	Increases soil pH	Costly to transport to individual farmer's fields
Use of drip irrigation	Conserves water	Increases capital costs.
Providing inputs on credit	Enables poor farmers to buy external inputs	Low prices paid for seed cotton may cause farmers to fall into debt
Monocropping and plant spacing	Increases cotton yields	Reduces biodiversity; reduces food security for smallholders
Use of defoliants	Assists picking	Increases input costs (risk of farmer debt); environmental risk
Grading cotton by picking into 2 bags	Graded seed cotton fetches a higher price	Pickers need training
Uprooting and destroying cotton plants after harvest	Reduces carry-over of bollworms	Increases labour costs

2. Bt cotton

Bt cotton can be used by large-scale, irrigated cotton producers as a best practise for reducing the need for pesticides within a conventional or an IPM system. Bt cotton is a transgenic variety that expresses a gene coding for a crystalline protein that is toxic to certain insects, particularly the American bollworm, *Helicoverpa armigera* and the pink bollworm, *Pectinophora gossypiella*. This gene originates from the bacterium *Bacillus thuringiensis*. Some Bt cottons also contain genes that confer resistance to certain antibiotics which has implications for human consumption of cotton seed oil (ACNFP, 1999). Care must be taken to avoid the development of resistance by *H. armigera*. This means that widespread planting of the same variety should be avoided or a belt of non Bt cotton should surround the field to create a refuge for bollworms. It is important that farmers do not to save Bt cotton seed as the progeny will have a decreased expression of the Bt toxin and this will also accelerate the development of resistance by the boll worm.

Bt cotton is currently being grown by farmers in Argentina, Australia, Brazil, China, Columbia, Mexico, India, South Africa and USA while plans are being made to introduce Bt cotton on a large scale in Pakistan next season. The effectiveness of Bt cotton depends on farmers having an ecological understanding of pest management.

Countries that are wishing to breed or introduce Bt cotton are strongly advised to sign, ratify and implement the Cartagena Protocol on Biosafety[4], see Box 1.

Box 1.

Biotechnical risks that are addressed by the Cartagena Protocol on Biosafety

- Micro-organisms in the soil destroyed and plant growth compromised.
- More competitive transgenic bacteria and viruses.
- Emergence of new resistant varieties that could over-run non-target species, creating an imbalance within the ecosystem.
- Spontaneous hybridisation (gene transfers) with related species (domesticated or wild) resulting in unanticipated changes in competitiveness, virulence or other characteristics of non-target species.
- Slightly modified DNA fragments escaping from the laboratory.
- The appearance of DNA fragments in the blood from ingested food or other products.

- *Minimising the harmful impact of crop protection practises*

Bt cotton has the potential of reducing the number of pesticide sprays required per season. For example, Monsanto claims that var. Bollgard can reduce pesticide usage by 2.5 times. In India, on average, Bt cotton reduces the number of pesticide sprays by 32–40 percent and reduces pesticide costs by 30–52 percent (Gruère, Mehta-Bhatt and Sengupta, 2008). There is evidence that many smallholder farmers are continuing to over-use pesticides on this crop, however (Grossrieder, *et al*, 2005).

[4] http://www.cbd.int/biosafety/protocol.shtml

- *Equitable access to responsible financial services*

The cost of seed for Bt cotton varieties is significantly higher than that of hybrid and open-pollinated seed (Ismael *et al*, 2002; Zhang *et al*, 2004). Gouse *et al* (2004) report that savings on chemical insecticides alone are not enough to offset the additional cost of Bt cotton seed in South Africa. This means that poor farmers who lack the skills necessary to cultivate a bumper crop of Bt cotton risk falling into debt.

- *Knowledge sharing and skills development*

Farmer training in IPM is needed in order to achieve the full benefits of growing Bt cotton. It is essential that farmers understand the strengths and limitations of planting Bt cotton and the training addresses problems associated with Bt cotton, such as the resurgence of sucking pests, the decline of Bt toxicity in mature plants and the danger of accelerating bollworm resistance by using farmer-saved seed. Trainers are strongly advised to share knowledge and develop skills using modified discovery learning exercises[5] during season-long farmer field schools. These farmer training schools equip farmers with the knowledge and understanding that will enable them to benefit from new transgenic crop varieties.

See Table 4 for the advantages and disadvantages of Bt cotton:

Table 4:

Comparative advantages and disadvantages of tools for Bt cotton in terms of BCI's principles

Tool	Advantages	Disadvantages
Use of Bt cotton varieties*	Resistant to *H. armigera*. Requires less pesticides	High cost of seed; new seed is required annually; resurgence of sucking pests
Use of non-Bt refugia*	Discourages development of *H. armigera* resistance	Alternative pesticides must be used; farmer training needed
Farmer training in IPM	Farmers learn how to use pesticides more judiciously	Season-long training may require donor support
Providing inputs on credit	Enables poor farmers to buy Bt cotton seed annually	Increased risk of untrained farmers falling into debt

Tools marked with an asterisk are specific to this best practise.

3. IPM cotton

Integrated Pest Management is a best practise for cotton production that has been widely promoted by the United Nations Food and Agriculture Organisation (FAO). It is based on the premise that smallholder farmers can be empowered to use pesticides and fertilisers more judiciously through experimentation and agro-ecosystem analysis. IPM strategies differ according to pest and natural enemy prevalence, cotton variety, soil type, climate, irrigation practise and farmers' resources.

[5] See: 'Discovery Learning: Bt cotton in China, CABI & NATESC

- *Minimising the harmful impact of crop protection practises*

A sustainable IPM strategy depends on re-training extension workers as learning facilitators, during Training of Trainers sessions (ToTs). These re-trained extension workers are responsible for conducting season-long, weekly training sessions, known as Farmer Field Schools (FFS) each involving 20-30 local farmers. Farmers learn how to identify and scout for pests and natural enemies and interpret the results of participatory research which compares normal, farmers' practises with IPM practises. Farmers are encouraged to keep records of their agro-ecosystem analyses and only spray with selected pesticides[6] when they judge that the natural enemy population levels are too low to cope with the numbers of pests that they have identified and counted on randomly selected plants, see Table 5. FAO has recently been successful in main-streaming the IPM approach into the government controlled research and extension services in Vietnam and Pakistan. Similar attempts are being made in some West African countries.

- *Using water efficiently and caring for the availability of water*

In areas where irrigation is used, the efficient use of water is part of the FFS curriculum. Bed and furrow planting regimes and water scouting to determine when to irrigate have proved successful strategies in Pakistan (CABI-SA, 2003). The new working practices were validated through season-long Farmer Field Schools.

- *Caring for the health of the soil*

The FFS curriculum normally includes discussions of and experiments with different rates and timings of fertiliser applications, as well integrating organic amendments, such as farmyard manure into the system.

- *Conserving natural habitats*

Recognising pests and their natural enemies is an important part of the FFS programme. Once farmers are familiar with the role of natural enemies they will be keen to conserve natural habitats in order to encourage the proliferation of these organisms. Where there is scientific support, the use of biological control, including pheromone traps can be introduced into an IPM strategy.

- *Caring for and preserving the quality of the fibre*

The quality of cotton fibre in terms of its length and strength depends on the variety that is available to the farmer. Preserving the quality of fibre at harvest time is an important topic in cotton FFS and grading the seed cotton is the same as for conventional cotton.

- *Knowledge sharing and skills development*

FFS are used to promote knowledge sharing and skills development.

- *Effective producer organisation*

Most FFS graduates are keen to form IPM clubs. With appropriate support these IPM clubs can develop into producer organisations.

- *Equitable access to responsible financial services*

The need for costly external inputs is reduced for farmers that undergo IPM training.

[6] For information on the side effects of pesticides and their impacts on beneficial insects go to: http://www.koppert.nl/e0110.html

Table 5:

Comparative advantages and disadvantages of tools for IPM cotton in terms of BCI's principles

Tool	Advantages	Disadvantages
Scouting for pests and natural enemies	Pesticides used more judiciously	Farmers require training
Agro-ecosystem analysis	Pesticides used more judiciously	Farmers require training
Conservation of natural enemies	Controls pests without pesticides; conserves natural habitats	Farmers require training
Introduction of biological control agents for key pests	Controls pests without pesticides	Research and release programmes needed
Use of pheromone traps	Selectively kill moths	Research support needed
Farmer-participatory research	Farmers become empowered to innovate	Trained facilitators required to organise and lead initially
Training of trainers	IPM becomes mainstreamed into government extension and research services	Donor or Government funding for initial training of trainers
Season-long farmer field school	Farmers retain a thorough knowledge of IPM practises	Requires a high level of donor support
Supporting IPM groups	IPM groups often develop into producer organisations	Initial Government support until groups are self-sufficient

4. Organic cotton

Organic cotton is a best practise for producing cotton without synthetic inputs and is grown according to codes of practise/standards[7] that are defined both locally and by importing states, such as the EU[8], in accordance with principles established by the International Federation of Organic Agriculture Movements (IFOAM)[9]. IFOAM accredits organic inspection organisations such as Ecocert, Krav and Soil Association that are mainly based in developed countries, to certify the cotton products. These organisations also work with farmers, both large and small-scale (irrigated or rain-fed) to draw up sustainable production strategies that eliminate the need for synthetic inputs and are appropriate to their respective environments. They also put in place internal control systems that will expose any seed cotton that was not

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[7] http://ifoam.org/about_ifoam/standards/ogs.html ;

[8] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31991R2092:EN:HTML

[9] http://ifoam.org/about_ifoam/principles/index.html

produced according the agreed guidelines. In the case of smallholder groups, the charge for the crop inspection service is usually covered by a donor during the first few years of the project. Successful marketing of organic seed cotton depends on the establishment of a processing chain in which the seed cotton is ginned and the lint is spun and woven separately and non-polluting dyes are used. Every procedure within this chain is subject to inspection if the lint is to retain its organic status. The cost of the processing inspections is normally borne by the end-user.

- *Minimising the harmful impact of crop protection practises*

In an organic system the use of conventional pesticides is banned and instead the use of home-made botanicals is recommended to control insect pests. The botanicals are made of locally available natural materials such as neem, chilli and fermented cow urine. In the longer term, the conservation of natural enemies is encouraged and, with the help of supportive research, biological control agents (including pheromone traps) may be incorporated into the system.

- *Using water efficiently and caring for the availability of water*

Soil moisture is conserved through the build up of SOM in an organic system, see below.

- *Caring for the health of the soil*

Soil fertility is maintained through the addition of organic amendments, including compost and farmyard manure and by practising crop rotation. Smallholder farmers are able to intercrop food crops in an organic cotton field, since there is no risk of contamination by toxic pesticides.

- *Caring for and preserving the quality of the fibre*

Organic cotton production, as with other best practises, involves choosing high quality seed to ensure the production of high quality fibre and on-farm grading of harvested seed cotton. Processed lint that is fully certified ‘organic’ by an international inspection agency will earn a premium on the world market.

- *Knowledge sharing and skills development*

Farmer training is an essential part of organic cotton production. This is normally funded by donors and implemented by national and international NGOs.

- *Effective producer organisation*

Smallholder organic farmers must be organised into producer groups to facilitate policing of the agreed code of practise and regular inspections by accredited inspectors. The organic premium is paid to individual farmers and reduces the financial risk normally associated with cotton production. An organic cotton production system is preferred by donors as part of a poverty alleviation programme. These donors often act as intermediaries by loaning the purchase price of the seed cotton to the producers until an international buyer can be found.

See Table 6. for the comparative benefits of an organic production system:

Table 6:

Comparative advantages and disadvantages of tools for organic cotton in terms of BCI's principles

Tool	Advantages	Disadvantages
Use of botanicals	No or minimal financial cost, low toxicity for humans and the environment; no protective clothing needed	May not be effective for all pests. May kill natural enemies. FPR needed.
Conservation of natural enemies	Controls pests without pesticides; conserves natural habitats	Farmer training in conservation methods
Biological control of key pests	Controls pests without pesticides	Research and release programmes needed
Use of organic amendments	Low financial cost; increases SOM, conserves soil moisture	Increased labour requirement
Farmer training	Promotes knowledge sharing and skills development	Requires donor support
Formation of producer groups	Enables organic farmers to market cotton as a group and get a fairer price	Initial Government or Donor support until self-supporting
Field mapping* and record keeping	Enables inspectors to certify the cotton; ensures traceability	High cost of inspection, initial farmer training in record keeping
Premium paid to individual farmers*	Reduces risks associated with cotton production	Producer groups sufficiently organised to distribute premium fairly

Tools marked with an asterisk are specific to this best practise.

5. *Fairtrade* cotton

Fairly traded cotton is also subject to defined standards/codes of practise – in this case the standards are set by the International *Fairtrade* Organisation[10]. This organisation is concerned with implementing ILO codes of practise concerning health and safety, by banning child labour and the use of WHO Class I pesticides. Large-scale cotton estates and smallholder farmers can apply for *Fairtrade* accreditation, however the latter must be organised into registered, 'democratic', producer groups and market their seed cotton jointly. The rules concerning child labour do not apply to smallholders who rely on family labour, although all children are encouraged to attend school. *Fairtrade* inspectors are employed to recommend appropriate agronomic practises and ensure compliance. Organic and IPM cotton can also be marketed according to *Fairtrade* regulations.

[10] http://www.fairtrade.net/fileadmin/user_upload/content/Generic_Fairtrade_Standard_SF_Dec_2007_EN.pdf

Table 7:

Comparative advantages and disadvantages of tools for *Fairtrade* cotton in terms of BCI's principles

Tool	Advantages	Disadvantages
Use of WHO Class II & III pesticides	Kills pests; less hazardous to farmers	Kill natural enemies; toxic to mammalian life.
Crop rotation and the application of organic amendments	Maintains soil fertility at low cost	The application of organic amendments may increase labour costs
Pre-export credit (up to 60% of purchase price) provided to producer groups*	Reduces risk; promotes equitable access to financial services	Producer groups sufficiently organised to receive credit
Premium paid to producer groups for community projects*	Reduces risks associated with cotton production	Producer groups sufficiently organised to use premium to finance community projects
Child labour forbidden in cotton estates*	Supports ILO laws; children able to attend school	Landless labouring families unable to earn extra income
Water bodies and watersheds protected; irrigation water consumption minimised	Encourages efficient use of water	Technical support required
Tree planting encouraged; areas reserved for the conservation of biodiversity	Reduces soil erosion; reduces water losses; provides fuel and animal fodder; conserves natural habitats for beneficial organisms	Local communities require targeted information on how to achieve good results
Crop planning and record-keeping	Promotes sustainable land use; enables crops to be certified	Initial training required for compliance

Tools marked with an asterisk are specific to this best practise.

- *Minimising the harmful impact of crop protection practises*

Fairtrade standards prohibit the use of WHO Class 1a and b pesticides.

- *Using water efficiently and caring for the availability of water*

Water bodies and water sheds must be protected, the use of irrigation water must be minimised.

- *Caring for the health of the soil*

Crop rotation is encouraged and an integrated approach combining fertilisers with organic amendments is recommended.

- *Caring for and preserving the quality of the fibre*

Farmers are advised to choose high quality seed and grade their seed cotton.

- *Knowledge sharing and skills development*

Any farmer training that is required must be provided by national or international NGOs.

- *Effective producer organisation*

Producer organisations must be officially registered, democratically constituted and able to negotiate contracts. The *Fairtrade* Organisation ensures that buyers pay a premium of US$0.05c per kg of authenticated cotton to the producer group as a whole. This money is to be used for funding community projects, e.g. the building/improvement of schools and clinics see Table 7.

Identifying and listing Tools

Field project reports, review documents and scientific papers that alluded to one of the above Best Management Practises or component tools and at least one of nine BCI principles in each of BCI's four focus regions were selected by Allan Williams for analysis using a specially prepared Word table to record the type of tool, its justification, possible constraints to its adoption and ways of measuring its success. The number of reports, documents and papers that were consulted during this process are shown in Table 8.

Table 8.
No. of reports, documents and papers that were analysed for the Tools Tables

	Brazil	India	Pakistan	West Africa
No. of reports, documents, papers analysed	37	15	13	23

The completed tables (including Portuguese and French versions for Brazil and West Africa) were forwarded to BCI in September, October 2008 and early January 2009.

Analysis of cotton production in BCI's four main focus regions.

The field reports, review documents and research papers that are referred to in this section are either identified in the following text by their database ID number or are fully referenced at the end of this report.

Analysis of cotton production in Brazil

During the last decade, under the influence of intensive research and development efforts, the technological pattern of cotton production has undergone radical changes in Brazil, particularly in the savanna region, known as Cerrados, to where the majority of the crop areas from the South and Northeast of the country have moved. Currently, nearly 80% of the cultivated area and 85% of the cotton production in Brazil is in the Cerrados. This has given rise to a modern and competitive cotton industry which is considered to be, one of the world leaders in terms of yield and fibre quality. Although cotton yields and fibre quality in the cerrado areas are both high (around 1,210kg/ha of lint) the cost of production has recently increased to levels (more than US$ 1,500.00/hectare) which are threatening the economics of the crop. The natural fertility of the cerrado soils is very poor, and cotton production generally requires high inputs in the form of soil pH correctors, fertilizers, insecticides and herbicides. Most of the cotton fields are sprayed at least 15 times during normal years, mainly against aphids, boll weevil, *Spodoptera frugiperda*, and *Heliothis* complex. At present, insecticides and fertilizers together represent up to 45% of production costs. One of the main agronomic issues affecting Brazilian cotton growers is the increasing resistance of insects to conventional insecticides. Large volumes of chemicals are being used on the cotton crops, and it has begun to show signs of ineffectiveness against some pests. Currently, the most commonly occurring and damage causing diseases of cotton in the cerrado areas are: Witches´Broom caused by *Colletotrichum gossypii* (South) var. *cephalosporioides*; Leaf-Rib Mosaic, *Ribeirão* Bonito form, which is a viral disease transmitted by *Aphis gossypii* also known as Blue Disease, and Ramularia spot caused by the *Ramularia areola* fungus. According to de Macedo (2006) cotton production in Brazil has been at a high cost to the environment, in terms of its impacts on natural resources and energy use.

Information gathered for this study describes several field projects in which smallholders in Goiás State were trained through Test and Demonstration Units in non-chemical control of key cotton pests and other appropriate management practises (ID 23; ID 35; ID 39; ID 421; ID 795; Almeida, ID 491, ID 492; Cartaxo, ID 423; ID 425, ID 426; Farias, ID 812; Freire, ID 446, ID 447, ID 814). However, most of the information on cotton production in Brazil was gleaned from 96 research papers which are reporting on work conducted by scientists sponsored by the Brazilian Agricultural Research Corporation (EMBRAPA). This mainly government-funded organisation supports cotton production for both large-scale, irrigated and small-scale, rain-fed systems through long term, scientific research into all aspects of crop improvement. Over the past five years this research has mainly focussed on plant breeding, genetic engineering, IPM, pesticide use, biological control, and soil fertility management:

i) Plant breeding

New varieties are bred through conventional and modern breeding techniques and the process of approval for the release of any promising new strain or variety for commercial cultivation is based on multi-year and location trials conducted by private and government institutions under the coordination of EMBRAPA. Current varieties in commercial cultivation have been developed mainly by the EMBRAPA system; by the States Research Institutes, by the Cotton Research and Development Foundations and by Private Companies. EMBRAPA-bred varieties are estimated to be grown on about 40% of the total cotton cultivated area (Macedo, 2006). Mechanised growers can now choose from several high-yielding cultivars of *G. hirsutum* L., which have high quality fibre and multiple disease resistance - mainly to ramulose (*C. gossypii var cephalosporioides*) bacteriosis (*Xanthomonas malvacearum*) Fusarium wilt-root-knot nematode complexes, *Alternaria* sp. and *Ramularia* sp., see Table 9.

Table 9
Characteristics of Brazilian Cotton Varieties

Variety	Seed cotton Yield Pot. (kg/ha)	Fibre Percent (%)	Strength gf/tex	2.5% Span length (mm)	Micronaire (μ/in)
BRS Aroeira	4,000	38.0	28.0	29.4	4.1
BRS Ita 90-2	4,500	38.0	30.0	29.1	3.9
BRS Sucupira	4,500	38.0	30.0	30.4	3.9
BRS Cedro	4,500	40.0	28.3	30.0	4.3
Epamig p1	3,000	39.0	22.5	28.0	4.2
IAC-23	2,500	40.0	27.2	28.0	4.3
IPR-94	5,000	38.0	28.6	29.5	4.4
CD 406	4,500	40.4	29.2	29.8	3.8
CD 407	4,500	40.0	29.2	30.1	4.0

Source : CONAB

EMBRAPA cultivars such as BRS 186 CNPA Precoce 3, BRS 187 CNPA 8H and BRS 201 are recommended for family farms in north-eastern Brazil (EMBRAPA, 2008). These yield up to 2,000kg/ha, tolerate drought, mature within 130 days; produce medium to long fibres (30-32 mm) and are adapted to manual harvesting.

Naturally coloured cottons have recently been rediscovered and are being grown by organic farmers in the north-east, semi-arid areas of the country, where the edaphoclimatic conditions permit cultivation without agrochemicals (ID 72; Silva *et al,* ID 2005). These varieties have now been included in a breeding improvement programme (Barros, ID 433).

ii) Genetic engineering

Brazil is one of the focal countries for the International Project on GMO Environmental Risk Assessment Methodologies[11] which involves capacity-building amongst public sector environmental scientists to enable them to develop and support environmental risk assessments of the release of GMOs. This is being done in the light of EU directive

[11] http://www.gmoera.umn.edu/

2001/18/EC[12] and the Cartagena Protocol on Biosafety. Particular emphasis has been put on assessing the impacts of Bt cotton in Brazilian agriculture. Scientists involved in this project found a high level of risk in that there are no significant genetic or cytogenetic barriers to Bt gene flow among the four cultivated and wild cotton (*Gossypium*) species, and viable hybrids involving GMOs have been shown to form spontaneously and be reproductively successful; in each cotton-cultivating region. They also found evidence of unattended feral cotton populations, which could be recipients of gene flow from Bt cotton, which had not been systematically surveyed. In addition, four target Lepidoptera were identified to be prone to developing resistance to the Bt gene. These species, *Heliothis virescens*, *Spodoptera frugiperda*, *Alabama argillacea* and *Pectinophora gossypiella*, have a variable history of resistance to pesticides in Brazil and elsewhere. Three species are closely associated with cotton and therefore likely to be exposed to more intense selection, but in the Midwest region of Brazil where most cotton is grown, *Spodoptera frugiperda* is also a significant resistance risk, particularly if Bt maize is also adopted there. The deployment of two-gene Bt cotton in Brazil combined with non-Bt cotton refuges was strongly recommended[13]

Gene flows between Gossypium species have been studied by Barroso (ID 454), and the impacts of GMOs on pest populations have been observed by a number of scientists (Santos, ID 428; Freire, ID 448; Degrande, ID 486; ID 857). The resurgence of pests associated with Bt cotton 'Bollgard' is being assessed by Degrande (ID 488 also ID 859). Isolates of *B. thuringiensis* have been evaluated and the toxins that they produce have been characterised (Lucena, ID 462) for their impact on bollworms (Lucena, ID 463).

Molecular markers are being used to study the cotton leaf-roll dwarf virus (CLRDV) using molecular markers (ID 811)

Efforts are currently being made to use biotechnical methods to obtain different varieties of green cotton (ID 803).

iii) Integrated pest management

Brazilian cotton suffers from a wide range of pests and diseases, necessitating fifteen pesticide applications per season. Many IPM methods have been evaluated (ID 21; Freire, ID 813; ID 828; ID 842; ID 857; ID 860; ID 861) and information on identification and control of pests is available (Miranda, ID 460, ID 476, ID 813).

Pheromone traps have been used to attract and kill moths of boll weevil *Anthonomus grandis* and army worm *Spodoptera frugiperda* in cotton fields throughout the season (Miranda ID 476). Silvie and Silvain (2005) have used pheromone traps to determine the incidence of adult pink bollworms, boll weevils and armyworms as part of a controlled spraying regime. In 2004, they found that populations peaked in mid-July and at the end of August.

Studies have been conducted on the impact of naturally occurring *B. thuringiensis* toxins on Lepidoptera (ID 806) Grossi-de-Sa, *et al* (2007)

The use of fungicides on Ramularia spot are being evaluated (Chitarra, ID 438, ID439) and resistance to this disease is being studied by Suassuna (ID 445).

Crop rotation has been found to prevent the over-wintering of several pests (Ferreira, ID 424; Salton, 2007); including impacts on nematodes. Ferreira has also investigated the effect of the herbicides that are used to kill mature cotton plants on the following crop and experimented with different methods of destroying the plants mechanically. Asmus (2007)

[12] http://eur-lex.europa.eu/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=32001L0018&model=guichett

[13] http://www.cabi.org/bk_BookDisplay.asp?PID=1892

has identified several soybean cultivars that are highly susceptible to *Rotylenchulus reniformis* and confirmed that many cereals and are poor hosts for this nematode pest.

iv) Pesticide use

New insecticides are being tested (Santos, ID 430). New sprayers have been tested under field conditions by Reny (ID 431; ID 801). Eight pesticides (acetamiprid, aldicarb, carbendazin, carbofuran, diuron, imidacloprid, methomyl and teflubenzuron) were found in groundwater samples from cotton fields located in "Primavera do Leste", Mato Grosso state; 18% of them contained at least one of the pesticides (with concentrations ranging from 0.78 to 68.79 µg L-1). Many of the detected concentrations exceeded the target levels set by the European Union (Carbo, *et al*, 2008).

v) Biological control

Biological control can be achieved through the on-station multiplication and release or on-farm conservation of natural enemies (predators and parasitoids). Several EMBRAPA scientists have identified large numbers of natural enemies and are assessing their impact on selected cotton pests, particularly the pink bollworm *Pectinophora gossypiella* and the boll weevil, *Anthonomus grandis* (Ramalho, ID 435; Silvie & Silvain, 2005; ID 542). Miranda. (ID 458, ID 406) lists *Podisus nigrispinus, Geocoris* spp., *Nabis* spp., *Orius* spp., *Zellus* spp., the green lacewing *Chrysoperla* spp., *Cycloneda sanguinea, Scymnus* spp., *Calosoma* sp. *Lebia concinna* and *Dorus* sp. as potential natural enemies. *Trichogramma* spp. and *Cerastomicra intmaculata* are said to be effective parasitoids, while fungi such as *Beauveria bassiana* and *Nomuraea rileyi* and the nuclear polyhedrosis virus are recommended micro-pathogens. Recommendations on the application rates and timing of the fungal bio-control agent *Beauveria bassiana* have also been made. Laboratory reared *Trichogramma* spp., *Telenomus* spp. and *Bacillus thuringiensis* have been used to suppress the cotton leaf worm, *Alabama argillacea,* and other Lepidopterans in Bt cotton (Rodrigues, ID 437;ID 860). The effect of pesticides on natural enemies is being studied by Degrande (ID 487) also ID 858. It should be noted that many of these natural enemies require unsprayed areas of natural flora in which to breed and overwinter.

Myrothecium leaf spot caused by *Myrothecium roridum* has been found to cause 60% yield loss in cotton (Meyer *et al*, 2006). The Pacific mealybug, *Planococcus minor* has recently been identified as a new pest of cotton (ID 25; Bastos *et al,* 2007).

vi) Improving soil fertility

The natural fertility of cerrado soils is extremely low and the application of limestone is a critical first step in fertility improvement of newly opened land. Aluminium saturation, low available N, P and K and micronutrient deficiencies are the rule. For viable agricultural production, these soils must be limed, fertilised and treated with micronutrients on a continuous basis. As a consequence, much scientific work has been focussed on improving the fertility of cotton soils (ID 60; Ferreira, ID 424; Barcelos, ID 456 ; Sanata, ID 465; Barbosa, ID 474; Carvalho, ID 455; ID 845).

Direct seeding experiments are being conducted by Chitarra, (ID 480) Junior (ID 481, ID 482, ID 483, ID 484, ID 485) and Salton (2007) these involve mulching with crop residues to improve the availability of soil nutrients (ID 853).

Soils in north-east Goias have been analysed for calcium and iron levels in order to improve fibre quality (Freire, ID 466). Fertiliser timing and annual nutrient loss per ha following a crop of cotton has been calculated by Ferreira and Santana (ID 424). Uptake of nitrogen and boron has been studied in rain-fed systems (ID 794) and growth regulators have been used to control nutrient uptake. The incorporation of organic materials such as sewer silt and crop residues has been shown to improve soil water-holding capacity (Silva, *et al,* 2005).

Composted cattle manure was found to increase the yield of coloured cotton BRS 200, however the uniformity of fibre length decreased and the index of short fibres increased with the increment of the levels of organic manure (Silva *et al,* 2005).

Analysis of cotton production in India

India is the third largest cotton producer and has the largest area of land (89,200 ha in 2004-05) in the world under production of this crop, including one third under irrigation. 60 million people are employed in the cotton sector and Indian textiles make up 30% of her total exports. However, productivity is amongst the lowest in the world, at between 300 and 463 kg per ha. Farmers grow too many different and mixed varieties and fail to grade their seed cotton adequately, resulting in a high trash content and fibre with variable staple lengths. Many of India's gins are old, inefficient and poorly maintained and produce fibre which is highly contaminated. As a result textile manufacturers often resort to importing fibre from overseas in order to meet demand. A series of 'mini-missions' have been conducted by the Ministry of Textiles in order to confront these problems and address the challenges posed by some recent World Trade Organisation agreements. The objectives of the mini-missions were to increase cotton productivity, reduce cultivation costs and improve fibre quality (ID 167; ID 168; ID 169; ID 170; ID171; ID 703; ID 704; ID 705; ID 706).

Field projects in India have been restricted to the promotion of IPM and organic production strategies, while the use of Bt cotton is being encouraged without any significant farmer training. Most research papers that were recovered were concerned with the impact of IPM practises and issues surrounding Bt cotton.

i) Integrated pest management

Despite the Indian government's stated aim, since 1985, of making IPM the main plank of its plant protection strategy, Madhavilatha *et al* (2007, ID 165) found that 63% of farmer's surveyed in Kurnool district remained unaware of IPM practises. Some IPM strategies are suggested in government documents (Min of Ag, 2003-04). According to Vasantha and Buchareddy (2006, ID 164) the majority of small, medium and big farmers in Guntur district perceived that the initial cost of IPM strategies is expensive, the net profit is meagre and the consistency of profits are irregular, in addition the majority of small and medium farmers said that IPM practises require extra labour and the majority of big farmers had the opposite opinion. This was said to be due to limited access to key IPM inputs such as pheromone traps, migration of pests from non-IPM to IPM fields and poor quality training.

The number of pesticide sprays was substantially reduced in IPM fields (from 2-3) compared with 6-7 in conventional/'farmers' practise' fields of irrigated cotton in north India and this was reflected in the increased numbers of natural enemies and increased parasitism of *H. armigera* eggs by *Trichogramma chilonis* (Tanwar, *et al*., 2007, ID 128).

Majumdar and Gole (2006) calculated that the viability of cotton production could be increased by intercropping it with pigeon pea in the Vidarbha region of Maharashtra.

An IPM FFS initiative in Trichy area, Tamil Nadu, in 1997 helped farmers reduce their high input costs and increased the stability of cotton cropping systems through use of intercrops. One of the major benefits of reducing the number of pesticide applications, apart from financial, was that women were saved hours of time previously spent hauling water from 3 km away for 10 applications by knapsack spraying (ID 145).

The 5 year regional FAO-EU IPM programme began in 1999 (ID 127). In India it was implemented in Karnataka, Maharashtra and Andhra Pradesh in 2000 and state funds were subsequently allocated to continue and expand project activities in all three states. With the help of trained government extension and NGO facilitators, a total of 35,828 FFS farmers graduated over the first 4 years. Women's participation in FFS increased from 7% in 2000 to 20% in 2004. This was particularly significant since a socio-economic and gender analysis of cotton production showed that: women provide 64% of the work; the crop is often collaboratively managed by husband and wife; and 50 % of female-headed and marginal (women-run) households grow cotton. In 2004, the state governments assigned 600 trained extension staff to promote IPM and allocated funds for ToT, FFS and farmer to farmer training, as well as for the support of 380 FFS alumni groups.

An impact study of 287 farmers who had been involved in the FAO-EU IPM project in India and Pakistan, showed that cotton farmers who graduated from FFS had 16.9 point scores for recognition of natural enemies as compared to 2.3 points for non-FFS (exposed) farmers (Ooi and Kenmore, 2006).

Mancini *et al* (2007, ID 124) conducted a livelihoods assessment of the FAO-EU IPM project amongst 95 respondents in Warangal District, Andhra Pradesh and Dharwad District, Karnataka State and found that the cotton IPM FFS provided an opportunity for farmers to improve their farm management skills, reduce cultivation costs, limit pollution as well as occupational exposure to hazardous chemicals and improve crop productivity. Mancini *et al* (2006, ID 125) also carried out five independent household level evaluations in twenty FFS villages between 2002 and 2004 and discovered that poor farmers and women are disproportionately affected by pesticide poisonings and that women's labour is used more often for alternative IPM practises that replace spraying. Reddy and Suriamani (2005, ID 129) discovered that the majority of 485 FFS farmers from five villages understood the need to adhere to recommended health and safety measures for pesticides and that many non-FFS farmers had been influenced by these positive attitudes.

ii) Organic production

Rajendran, et al (2000) describe organic farming practises for cotton and noted that there is an increase in organic carbon in the soil and a build-up of natural enemies in the environment after 5 years of cropping at the Central Institute for Cotton Research, Nagpur. The Indian Council for Agricultural Research has listed 56 indigenous practises that have been collected from cotton farmers in all cotton-growing districts of India (ID 960). A list of locally occurring natural enemies – predators, parasitoids and pathogens is available (ID 961). Oxfam reports that a traditional Tamil Nadu non-hybrid variety called 'Surabhi' from the Central Institute of Cotton Research in Coimbatore has an excellent staple length and is therefore popular with buyers (Gala, 2006). It also has resistance to both pests and diseases such as bacterial leaf blight, and grows well in conditions similar to those in AP, which makes this variety most suited to organic production. Moreover, the Surabhi seed costs Rs130 per acre, as opposed to Rs450 per acre for hybrid cotton and Rs1,600+ per acre for GM Bt cotton. It will give a standard yield of 300 to 400 kg per acre in poor conditions, though in good conditions it can yield 800 kg per acre.

An approved package of practises for cotton production in Andhra Pradesh has been written by Sabesh (CICR, 2006-07) including recommended varieties, land preparation, seed treatment, cropping systems, deficiency symptoms, agronomic practises, pesticides and IPM practises.

iii) Bt cotton

The documentation and commercialisation of Bt cotton varieties (var. MECH-12 Bt, MECH-162 Bt. and MECH-184 Bt) is detailed in ICRISAT's status report (ID 956). The insect resistance in these hybrids was introgressed from Bt containing Coker-312 (event MON531) developed by Monsanto, USA, into parental lines of Mahyaco's (Maharashtra Hybrid Seed Company) proprietary hybrids. Some of the concerns raised by this report include the need for a refuge crop to reduce the build-up of Bt resistance, the genetic uniformity of the three varieties, the high cost of the Bt cotton seed which is leading to the creation of counterfeit seed markets, aggressive advertising by seed companies and lack of awareness on the part of growers. Farmers that planted one or more these three Bt cotton varieties during 2002-03 reported that bolls per plant, yields and staple length were less than other non-GM hybrid varieties. The impact on bollworms could not be assessed because there was a low incidence of this pest during the season (ANGRAU, 2004). Kranthi and Kranthi (2005) did not find any evidence of *H. armigera* resistance to Bt genes during work sponsored by Mahyaco and Monsanto.

According to a Gujurat State report (ID 964) farmers who cultivated the Hybrid Cotton Bt. Mech - 184 suffered huge economic loses due to wilt disease; Bt. Mech- 162 was found to be vulnerable to boll worm indicating that the expression of Bt. gene is insignificant and Bt. Mech-12 was found to susceptible to sucking pests. The Report of State Department of Agriculture in Maharashtra confirmed the findings from Andhra Pradesh concerning the occurrence of wilt in Bt varieties, however this wilt was said to be physiological.

Analysis of cotton production in Pakistan

The irrigated cotton belt in Pakistan extends over 1,200km, between latitudes 23º and 33º N of the Indus valley. Although one hundred percent of Pakistan's cotton fields are irrigated, rainfall provides a significant contribution to the overall soil moisture. Pakistan is the fourth largest cotton producer and the third largest consumer, with the cotton industry contributing 30% of the country's GDP. Currently, however, both the total area planted to cotton and cotton yields are in decline due to the high prevalence of poor quality, uncertified seed, late planting and the rising cost of fertiliser. Over the past five years, research into cotton production has been restricted to on-farm varietal trials, determining changes in pesticide use and measuring the impact of FFS, all other documents that refer to cotton work during this period relate to donor-funded field projects that were concerned with promoting IPM.

Twelve field project reports were analysed during this desk study and most of these were concerned with reducing dependence on pesticides and implementing IPM methods. A government project in Baluchistan trained farmers to estimate economic threshold levels for major pests before spraying with pesticides, in an effort to reduce pesticide use (ID 255).

The FAO-EU IPM Cotton Programme for Asia was said to have had its greatest impact in Pakistan, where it involved 12,999 farmers who were trained during 525 season-long FFS held over four years in both Sindh and Punjab (ID 253; ID 257; ID 265). Women Open Schools (WOS) were set up to bring more women into the training programme and this resulted in the development of a team of 37 expert women facilitators, 53 WOS and the training of over 993 rural women (ID 263; FAO, ID 266; ID 277).

Unpublished impact studies have shown that the number of FFS farmers below the official poverty line was reduced by 12% as compared to a control group, within three years (FAO ID 266; ID 253, 2004). Khan *et al* (2004 ID 965) used the Environmental Impact Quotient (EIQ) Model to measure changes in pesticide use as a result of this programme amongst just 120 farmers (60 FFS farmers and 60 non-FFS farmers). Results from this 0.5% sample showed that the training had significantly reduced the number of poisoning incidences at household level by 46%, total workdays lost by 83% and expenditure for poisoning treatment by 74%. A 1% sample of FFS-trained farmers showed a significant increase in 'human capacity', time spent on field observations, cotton yield, gross margin and a significant reduction in the amount of seed and pesticides used per unit area (Khan, ID 254). Although FAO's recommendations had included plans to expand these impact assessment studies to investigate the long-term impacts of this programme, which would be completed before 2008, no such reports or scientific papers have been found.

As a result of the IPM programme, Sindh Province included FFS expertise in the job description of its agricultural officers, and Punjab has launched a major programme expansion initiative to conduct 3,500 year-long FFS in cotton-wheat management between 2004 and 2008. No field reports on this expansion are available so far.

The Community Integrated Pest Management project in Punjab, funded by the Asian Development Bank (ADB) involved 8,274 farmers (ID 256; ID 261; ID 256; ID277; ID 260). The objectives in the 2-page Technical Assistance Framework Completion Report included: (i) pesticides use reduced by 50%, and (ii) cost reduced and farm income increased by 10%. Reports on the impacts of this project that were compiled by the National Integrated Pest Management Programme (NIPMP)[14] for the FFS plots in 2001/2002 indicate that the average yield and gross revenue were higher by about 11%, expenditure fell by 22% (primarily contributed by 50% reduction in pesticide spraying), and profits rose by 46%. In the TA Completion Report (ID 966) it was anticipated that the yield level of cotton would eventually increase by 20% as a result of the program but that it was too early to assess the program's effect on the average yield level. NIPMP have not yet produced any scientific papers to support these assertions.

The South Asia Cotton Water project (CABI, ID 264; ID 262) focused on water and pesticide reduction and through FFS training managed to reduce the number of irrigations by 33.4% and pesticide applications by 56.5%.

The government of Pakistan is planning to implement *Bacillus thuringiensis* (Bt) cotton technology - in a bid to double the country's cotton production by the year 2015. For this policy to succeed it will need to be supported by farmer-training to reduce the risk of insect resistance and the enforcement of laws that prohibit the sale of counterfeit seed.

Analysis of cotton production in West Africa

Although African cotton represents only 10-15% of world exports, it is of critical importance to many African countries since it may be the largest source of export receipts. The cotton sector is also key to rural poverty reduction, employing about six million people in West and Central Africa. Unfortunately, cotton production in West Africa is characterised by smallholder production that has weak government support in terms of research and development. Many

[14] The NIPMP was launched in 2000 as a joint implementing unit for the ADB and EU IPM projects and is led by the National Agriculture Research Center (NARC) of the Pakistan Agriculture Research Council (PARC) in the Ministry of Food, Agriculture and Livestock (MINFAL).

foreign companies have recently acquired equity in former government-owned cotton marketing organisations in order to secure consistent and timely supplies. These companies control the provision of inputs and other services to farmers and are often the sole buyer of the entire cotton harvest. Ginning facilities in all West African countries are old and inefficient, poor infrastructure delays the delivery of inputs and the transport of harvested seed cotton to the ginning factories, while imported vegetable oil is cheaper than locally processed cotton seed oil (UNCTAD, 2008).

Many donor-funded field projects have been implemented in this region. Most of these have been concerned with poverty alleviation, through improved cotton production, since cotton is the most important cash crop for farming families in marginal areas. GTZ has reported on ways of alleviating poverty and conserving natural resources in cotton producing areas (ID 565; ID 940). FAO began implementing a new phase of the Regional Integrated Pest Production and Pollution Management (IPPM) Programme in Benin, Burkina Faso, Mali and Senegal in 2006. According to FAO, pilot tests in 3 villages along the Senegal River found 19 pesticides above detection level, with 90% being tens-to-hundreds of times above levels considered safe with respect to environmental and human health risks. In order to address this problem a three-pronged approach is being used:

- *The Human Health Risk* Assessment instrument evaluates the consequences of pesticide exposure from various environmental media including soil, air, water, and biota and via multiple pathways (ingestion, inhalation, dermal exposure). An aggregated exposure assessment characterizes acute and chronic risks over time for various sensitive sub-populations (infants and children; pregnant women; elderly; sick).
- *Community baseline surveys* are critical to identify the starting conditions in the communities by capturing essential details of cropping systems, pesticide use, agronomic practices, economic production details, local hydrology, farmer attitudes, etc,. Core data collected guides and informs the various activities and provides a base-line for measurements of economic and environmental impacts over time.
- *Communication and Awareness Raising* activities bring results back into the communities to illustrate the existence and importance of the multiple benefits derived from under-appreciated ecosystem services and also support recommendations to policy-makers for change.

Internal impact assessments of this programme indicated that cotton yields were 11 to 44% higher, while pesticide use was 57% lower in the IPM plots, and there was a drop in the recorded cases of pesticide poisoning in the cotton-growing areas (FAO, ID 892; ID 926; ID 927).

The sustainability of smallholder cotton production in West Africa has been examined by UNCTAD and ICAC (ID 899). Constraints to cotton production in West Africa and the impact of subsidies paid to US cotton farmers are reviewed (ID 623; ID 624; ID 897). Plans for a trans-border cotton programme in Mali and Burkina Faso are reported (ID 599). A regional project to support the cotton/textile sector has been submitted (ID 896; ID 916; ID 902). Strategies for improving competitiveness in the cotton sector are suggested (ID 901; ID 622). Concern has been expressed that Bt cotton may be introduced into West Africa without proper consideration of the economic and environmental impacts (ID 688).

Research into aspects of cotton production in West Africa has been extremely limited; one paper was found that referred to work done on varietal selection (ID 579) and another was reported on experiments with direct seeding (ID 591).

Analysis of cotton production in Benin

In Benin, cotton accounts for 40% of GDP and roughly 80% of official export receipts, much of it produced by smallholders. Since most of these farmers are poor (living on less than US$1 per day) any fluctuations in cotton world prices have an immediate impact on rural livelihoods. According to Minot and Daniels (2002) there is a strong link between cotton prices and rural welfare in Benin: the 40% reduction in farm level prices that occurred between January 2001 and May 2002, was predicted to result in a reduction in rural per capita income of 7 percent in the short-run and 5-6 percent in the long-run. This would have caused an eight percent increase in poverty, equivalent to an extra 334,000 people falling below the poverty line. Several development projects have been implemented amongst smallholder cotton farmers in Benin which provide support for low input cotton production in order to make this activity more profitable.

The Ecosanté project has been working with farmers to reduce pesticide poisonings in Benign One (ID 561) and to promote alternative methods of pest management (ID 578). Several NGOs have been collaborating in the Alafia Pendjari project (ID 619). The need to institutionalise organic cotton production is being advertised in a number of brochures (ID 577; ID 580; ID 581).

Sinzogan, *et al* (2004) document the collapse of the extension service following the reform of the cotton sector and its impact on the dissemination of new technologies in pest management. Factors that limit the adoption of IPM practises, such as spraying of pesticides according to damage thresholds and applying fertilisers at planting and flowering times were also investigated by Prudent *et al*, (ID 419; ID 560). They confirmed that farmers select low cost technologies and prioritise their food crops. Methods for investigating ways of managing the resistance of *H. armigera* to pyrethroids are suggested (ID 936). Lancon, *et al* (ID 579) demonstrated that farmers can select and breed new cotton varieties in their own fields.

Ways of strengthening the cotton sector are reported (ID 928) also methods for standardising cotton fibre (ID 944).

Analysis of cotton production in Burkina Faso

Burkina Faso is one of the poorest countries in the world, with a per capita gross domestic product (GDP) of $440. More than 80% of the population relies on subsistence agriculture, with only a small fraction directly involved in industry and services. Drought, poor soil, lack of adequate communications and other infrastructure, a low literacy rate and an economy vulnerable to external shocks are all longstanding problems. Cotton is Burkina Faso's major export crop and it is the largest producer in sub-Saharan Africa despite remaining subject to fluctuations in world prices. The need to increase the numbers of cotton farms (ID 617) and the risks that this will pose in terms of human health, environmental pollution and declining soil fertility is discussed by Guibert (ID 884). In 2008, there were 2,886 organic cotton producers in Burkina Faso (ID 588).

The FAO has implemented its Integrated Pest and Production Management project in this country (ID 927). The need to support the private sector and create a regional market for agricultural inputs is discussed (ID 589). An organic cotton programme supported by Helvetas and implemented through the Union Nationale des Producteurs de Coton (UNPCB) involved 663 smallholders, of whom 45% were women in 4 zones (Fada, Pô, Ioba and

Tiefora). Their total output was 150MT of seed cotton. Ecocert International certified the production in conformity with EU rules on organic agriculture. UNPCB was certified for Fair Trade by FLO-*Fairtrade* Labelling Organization. The minimum price paid to farmers was guaranteed at 245 FCFA/kg for organic cotton and 272 FCFA/kg plus a *Fairtrade* premium of 34 FCFA/kg for social projects (a total 306 FCFA/kg for organic-*Fairtrade* cotton). The quality of the 284 bales was said to be 'very good' and they received a classification of "Bola/S" and "Bola". The average fibre length was 1.1/8 inches. The average yield of 466 kg/ha seed cotton was below the expectations due to low soil fertility, lack of organic fertiliser and equipment, and farmer inexperience in organic agriculture. The best yield of 1,824kg/ha seed cotton was obtained by a woman in the Fada zone. To improve the equipment of farmers, the program supported the implementation of a credit scheme between the 32 newly created farmers' groups (GPCB Groupements des Producteurs de Coton Biologique) and the local existing microcredit institution "Caisses Populaires du Burkina Faso" (ID 610; ID 588). A GTZ-supported organic project has analysed the cost of some organic amendments (ID 943).

Technical support of cotton growers by cotton companies is recommended (ID 928). CIRAD has analysed cotton producers' organisations and proposed a programme of support (ID 618). The CFC has funded attempts to manage bollworm resistance to pesticides (ID 563).

Analysis of cotton production in Cameroon

Over 3.5 million Cameroonians depend on cotton directly and indirectly for their livelihood. However the sector has been in crisis since 2004 and there is concern that SODECOTON, the country's Cotton Development Company might not survive due to falling world prices and poor exchange rates (New African, 2007). Mbétid-Bessane *et al* (2006) reported that cotton farming families in Cameroon are becoming increasingly dependant on women's income from off-farm activities, in common with cotton farming families in many other Central African countries.

According to the *Fairtrade* Organisation, more than 32,000 cotton farmers in Cameroon are now producing *Fairtrade* cotton with the support of SODECOTON and this has increased their income by 30%.

There are several reports on organic cotton production in Cameroon (ID 590; ID). The role of SODECOTON in linking cotton farmers with the market is discussed (ID 903; ID 592). Studies in understanding farmers' perceptions of their socio-economic environment and how they develop management strategies have been conducted by CIRAD (ID 905; ID 900; ID 904). Kadekoy *et al* (ID 912) report that reform of the cotton sector has increased farmers' input costs by 30% and led to an increase in the formation of producer organisations in order to protect farmers' interests against exploitation by the private sector. These producer organisations need subsidies, credits and capacity building in order to survive.

CIRAD scientists have been experimenting with the Brazilian system of seeding cotton directly into mulch and obtained a 20% yield increase and labour savings of at least €1 per day in northern Cameroon (ID 591).

Analysis of cotton production in Mali

Cotton is virtually the only cash crop that is produced in Mali and one quarter of the population, mainly in the Sikasso, Segou, Koulikoro and Kita areas, depends on cotton for its livelihood. Cotton production grew from 500,000 tons in 1997 to a record 620,000 tons in 2003-2004, making Mali the largest cotton producer on the African continent. However, in 2004-2005 and 2005-2006, cotton production retreated respectively to 590,000 and 500,000 tons as the parastatal cotton company (Compagnie Malienne de Développement Textile) CMDT focused on quality of harvested cotton rather than quantity (US Bureau of African Affairs). Although Mali remains the second largest producer in sub-Saharan Africa, after Burkina Faso lack of investment in research and development is putting the industry in peril (Behrendt, 2006).

FAO reports on the impacts of the Integrated Pest and Production Management project and the need for a co-ordinated approach to research and technology dissemination (ID 892; ID 595). Coulibaly and Nacro (ID 420) claim that net revenues were 33% higher in the IPPM plots (US$150) than in the Farmer Practice plots (US$113). This important difference was explained by the lower production costs with IPPM ($0.17/kg) compared with Farmer Practice ($0.23/kg).

Organic cotton production by smallholder farmers is being supported by Helvetas and the effects of some botanical pesticides on cotton pests have been measured scientifically (ID 598; ID 553; ID 615; ID 551). The *Fairtrade* Foundation has been supporting the Dougourakoroni Cotton Producers Co-operative in Kita, south-west Mali since 2004. This co-operative has 169 members, each with a landholding averaging 7 hectares, producing a total of 1,000Kg of cotton per year. Members receive the guaranteed minimum farm-gate price of FCFA 238/kg (compared to the national base price of FCFA 34/kg) and an additional premium of FCFA 34/kg to invest in community projects. These have included drilling wells, building a clinic, nursery school and soap factory, providing equipment and training to members and improving food security. Lakhal *et al* (2008) compared conventional and certified organic cotton supply chains in Mali and concluded that organic cotton may be able to offer higher gross margins than conventional cotton.

The need to manage Mali's natural resources in cotton growing areas in the face of population growth is discussed (ID 874). Efforts have been made to standardise methods for testing cotton fibre (ID 572) and strengthen the cotton sector as a whole (ID 681; ID 593; ID 597; ID 701). The causes of declining cotton yields are suggested (ID 878). The economics of smallholder cotton production is assessed (ID 877; ID 879).

Analysis of cotton production in Senegal

Cotton accounts for approximately 3% of total exports and is grown in nearly every region of Senegal; however, production is concentrated in the south-east of the country. Farmers are obliged to sell their cotton to SODEFITEX (Société de Développement des Fibres Textiles) in which producer organisations have a 30% share. Senegal is aiming to increase cotton production through the support of irrigation projects and mechanisation over the next fifteen years (UNCTAD, 2008).

PAN-UK has reported on sustainable cotton production in Senegal and the impacts of reducing pesticide use on farmers' incomes (ID 603; ID 601). PAN Afrique has also assessed local IPM projects in terms of input costs (ID 690). FAO has reported on the impacts of their Integrated Pest and Production Management project and the need for a co-ordinated approach to research and technology dissemination (ID 926). The Koussanar organic project (ID 575; ID 574) implemented by Helvetas and ENDA-Pronat has reduced farmers' debts and improved household food security. Recommendations for assistance to artisans who make hand-woven textiles are made (ID 889). Cotton productivity in 2006/2007 season is reviewed (ID 890).

Analysis of cotton production in Togo

More than 200,000 people depend on the cotton sector for their income. It is primarily grown in the south of the country on small, rain-fed farms, each averaging 1 hectare. There are about 2,000 producers' associations who are responsible for input distribution and seed cotton delivery. Farmers in these associations are supervised by SOTOCO (Societe Togolais de Coton) (UNCTAD, 2008).

The consultant's report (Gergely, 2007) states that the decline in output of seed cotton recorded in the last two seasons is a direct consequence of the non-payment of producers by SOTOCO during 2003/04 and especially during the 2004/05 season.

According to SOTOCO the 2008/09 cotton harvest in Togo will be 40,000 tonnes, which is less than half the figure previously forecast and smaller than last season's crop of 55,000 tonnes, as a result of bad weather – drought in the north and floods in the south. Despite this many growers will be worse off: 165 CFA francs ($0.321) per kg will be paid for top grade cotton, down from 180 francs last season, and 145 francs will be paid for second grade material, up from 140 francs (Reuters 14.11.08).

Several NGOs are implementing organic cotton projects in Togo (ID 605; ID 872). Attempts have been made to learn about current cotton farmers' practises (ID 873).

Research by the Institut Togolais de Recherche Agromique is concerned with varietal selection and efficacy of chemical inputs (ID 873).

Analysis of cotton production under various production systems

The United Nations Food and Agricultural Organisation (FAO) estimates that 100 million rural households were involved in cotton production worldwide in 2001. Among the countries in which cotton is an important contributor to rural livelihoods are China, India, and Pakistan—where 45, 10, and 7 million rural households, respectively were engaged in cotton production. In African producing countries, including Nigeria, Benin, Togo, Mali, and Zimbabwe, the number of rural households depending on cotton for a cash income totalled 6 million (Baffes, 2004) .

Large-scale irrigated cotton can produce lint yields in excess of 1,800kg per ha (e.g. in Brazil and USA) while it may be less than 300kg for small-scale, rain-fed cotton in drought-prone areas of Africa (Gillham *et a*l, 1995).

1. Smallholder cotton production

Most of the cotton that is produced in India, Pakistan and West Africa is grown by smallholder, subsistence farmers, usually with less than one hectare of land. Smallholders who inhabit rain-fed, marginal areas experience frequent food crop failures and depend on the income from cotton to buy grain and other necessities required for their survival[15].

Potential yields of existing cotton varieties are low in non-irrigated, marginal areas because soils are poor and rainfall is unreliable. This means that it is extremely difficult for the vast majority of smallholder cotton farmers to make a profit from the production of this crop if they depend on a conventional farming system, considering the high cost of inputs and the consistently low prices paid for seed cotton. Resource-poor farmers are also extremely vulnerable to pesticide poisoning since they cannot afford to buy protective clothing.

Several field projects have been implemented in South Asia and West Africa in order to improve the livelihoods of poor farmers who are engaged in smallholder cotton production, through the reduction of external inputs using IPM or organic farming methods. Almost all of the field projects that were identified during this desk study were funded by external donors such as the Asian Development Bank, EU and bi-lateral agencies that are based in European countries, especially SIDA, Helvetas and GTZ. The field projects were implemented by technical institutions such as FAO, CIRAD, NRI and CABI, in collaboration with local scientific and extension staff. There were also several externally funded projects that were being implemented by local and international NGOs. In all cases these projects were said to be targeting the poorest farming families with best practises that reduced the need for pesticides and/or guaranteed, higher farm-gate prices, i.e. IPM, organic or organic + *Fairtrade*. Table 10 compares all five best practises in terms of the type of fertiliser and toxicity of the pesticides used, additional fees and premiums paid and the availability of export credit. Intercropping with food crops is only recommended for organic and *Fairtrade* systems where no or less toxic pesticides are used. Considering the high cost of fertilisers and Bt cotton seed, the high toxicity of WHO Class I pesticides and the associated risk of contaminating intercropped food

[15] During the 1990's Cargill Zimbabwe refused to pay cotton male farmers unless they were accompanied by their wives to ensure that profits were not squandered on beer and prostitutes (pers. com.).

crops, it is clear that smallholder, subsistence farming families are more likely to profit from using IPM methods, however they often gain even more benefits by forming producer groups and switching to organic or *Fairtrade* production.

Table 10.

Comparative benefits of five best practises for smallholder cotton farmers

Best practise	Chemical fertilisers used	WHO Class I pesticides used	Inspection fee required	Premium paid	Pre-export credit paid	Inter-cropping with food crops encouraged
Conventional	Yes	Yes	No	No	No	No
Bt	Yes	Yes	No	No	No	No
IPM	Yes	Discouraged	No	No	No	No
Organic	No	No	Yes	Yes	No	Yes
Fairtrade	Optional	No	Yes	Yes	Yes	Yes*

*Only recommended if less toxic, non-systemic WHO Class III pesticides are used.

Matthews and Tunstall (2006) believe that switching to organic cotton production would be a retrograde step, which ignores the technological advances that enable much higher yields to be obtained economically within an IPM system. They stress the need for improved training and extension services backed up by an on-going research programme for IPM/ICM utilising the most appropriate technologies. This can be achieved through continuing research into new technologies that benefit small-scale farmers, whether aiming at organic production or higher yields by integrating rational use of biotechnology and pesticides. This laudable vision depends on dramatically increased investment in research and development. Unfortunately, despite being dependant on export receipts from cotton, many African governments have presided over the collapse of their extension systems, failed to provide adequate funding for research and seem unable to ensure that farmers are paid on time for their crop.

Currently the International Cotton Advisory Committee (ICAC) provides limited support to cotton research and hosts a World Cotton Research Conference every four years (the next one will be held in New Delhi, India in 2011). Nevertheless, there are many outstanding gaps in our understanding of cotton production particularly in marginal areas. Furthermore, considering the widely differing rainfall patterns, soil types, pest prevalence, temperature variations and available resources that characterise cotton growing environments, it is unlikely that tools that have been developed in one area can the implemented in another area, without undergoing a period of adaptive research. Therefore, unless there is a significant increase in funding for cotton research in the less developed countries the huge yield differences that currently exist between the developed and the under-developed cotton-growing countries will be maintained.

2. Large-scale cotton production

Large-scale cotton production takes place in mesophytic regions of the world that have access to irrigation. Large-scale cotton production in developed and middle income countries, such as the USA, Brazil and Egypt, owes its profitability to continuing support from well-funded research institutions that have specialised breeding programmes. However, there are increasing concerns about the sustainability of monocropping conventional cotton over large areas due to contamination of groundwater and the loss of biodiversity and in recent years many large-scale producers have adopted IPM strategies to reduce the build up of resistance to pesticides and GM cotton varieties in order to control bollworms. In addition, the high cost of fertiliser is making cotton production unprofitable in some areas, particularly in the cerrado region of Brazil.

No reports on field projects involving large-scale cotton production were found during this desk study. This is because this type of production system does not involve resource-poor farmers and is thus not targeted for donor assistance.

Knowledge gaps: challenges and opportunities

Improved varieties for increased productivity

The variety of cotton seed that is selected for production is the most important factor in determining the season length, susceptibility to pests, tolerance to drought, final yield, ease of picking and fibre quality of the cotton crop. All farmers, both small and large-scale, need new, improved cotton varieties every 2-3 seasons in order to combat climate change and increasing pest virulence, as well to satisfying industry demands for increased fibre length and strength. This means that a dynamic cotton farming sector requires the support of well-funded cotton breeding institutions and a seed supply system that is easily accessible and can be trusted by farmers. Poor seed supply systems expose farmers to unscrupulous dealers and the planting of counterfeit seed can lead to dramatic crop failures:

While cotton farmers in rain-fed and irrigated areas of Brazil are benefiting from a regular supply of new and high quality varieties, farmers in India, Pakistan and West Africa are suffering from haphazard supplies of what is often inappropriate seed in terms of cost, susceptibility to disease and fibre quality. Brazilian cotton breeders are able to take advantage of the genetic resources that are locally available amongst the wide diversity of wild *Gossypium* spp.. However, the production of new improved cotton varieties by scientists in other countries is constrained by the absence of an international germplasm bank and the free exchange of genetic materials. ICAC see the genetic engineering as the solution to this problem (Chaudhry, 2004) and several countries, such as Brazil, Burkina Faso, Egypt, India and Pakistan are currently promoting GM cotton. Unfortunately, it will be difficult for small-scale producers to profit from GM cotton. This is because the cost of GM seed is likely to remain high while the technology remains in the hands of the private sector and in-depth technical training and on-going research support is needed to ensure that savings in pesticide use are realised and the evolution of bollworm resistance is avoided.

Trusted seed supply systems are also crucially important for increasing productivity. In India government certified seed, farmer-produced 'Truthfully Labelled Seed' or farm-saved seed is most commonly used by cotton producers (Gillham *et al*, 1995). However, recent releases of more valuable high-yielding hybrid, including GM cotton seed has provided a golden opportunity for traders to profit from the sale of mis-labelled and counterfeit seed. According to Textile News (Sept. & Nov. 08) random testing during 2007-08 has indicated that more than forty-five percent of seed in some areas of India was sub-standard and consisted of unapproved Bt varieties. The sale of counterfeit seed is said to be a major cause of the decline in cotton production in Pakistan last season.

Cotton breeding in West Africa is currently managed by CIRAD who link a regional network of local scientists and facilitates cross-country exchange of new varieties. Despite this the majority of smallholder cotton producers in Africa depend on their own saved seed or on seed that is a by-product of the ginning process because it is cheap and readily available. This seed may have poor viability, genetic impurities and risks spreading seed-transmitted diseases such as Fusarium wilt (Hillocks, 2001). Lack of good quality seed is one of the main causes of low cotton yields in sub-Saharan Africa.

Impact of global recession on demand for cotton

According the ICAC (November & December, 2008): Global cotton imports are expected to decrease by 12% to 7.3 million tons in 2008/09, resulting from a projected 6% decline in global cotton mill use, to 24.9 million tons. Lower expected global economic growth in 2009, projected declines in developed economies' income in 2009, tightening credit availability for spinning mills, and uncertainty regarding the consequences of the global financial crisis, are severely affecting cotton consumption worldwide. The projected decline in world cotton trade is driven by an expected 24% drop in imports by China to 1.9 million tons. Imports by the rest of the world are also expected to decline by 7% to 5.4 million tons. World cotton production is expected to decline by 6% in 2008/09, to 24.6 million tons, driven by a decline in cotton area caused by increased competition from grains and oilseeds and unfavourable fluctuations in the exchange rates of many producing countries during 2007/08. In particular, production is expected to fall by 30% in the United States to 2.9 million tons. Production is also projected down significantly in Turkey and Brazil, but could increase in India, Pakistan and Australia.

The falling demand that is detailed above is leading to a sharp decline in cotton prices on the world market: by 31st October the price was US57.05 cents per pound (US$1.26 per kg) which is 29% lower than it was in early August 2008. This was occurring when farmers were harvesting and selling a crop that was more expensive to produce than the previous year due to the significant increase in energy and fertiliser prices. This price fall has triggered government interventions aimed at supporting producer prices in some of the largest cotton producing countries, such as China, India and USA. As a result, the ICAC expects world cotton production to decline by 6% in 2008/09 together with stagnation in world cotton area until 2010[16].

In spite of the need for government intervention, the ICAC has reported that all government subsidies to the cotton industry, including direct support to production, border protection, crop insurance subsidies and export subsidies declined by more than half in 2007/08. Subsidies paid to farmers fell the most in USA and China and is a result of the World Trade

[16] http://www.icac.org/cotton_info/publications/press/2008/pr_november_2008.pdf

Organisation (WTO) ruling in October 2007 that US government subsidies to cotton farmers undermine free trade. A recent statement from the Director General of the WTO (2.12.08) confirmed this ruling:

'*Developed countries, US and EC in particular, have to slash the trade-distorting subsidies that they give to their cotton producers. Market access for cotton should be improved and export subsidies for cotton must be eliminated. For the full developmental gains to be made, developed countries and multilateral donors have to follow through on their aid commitments. And developing countries have to ensure that trade is properly mainstreamed in their development strategies.*'

The search for a Better Cotton system

The information collected during this desk study indicates that IPM is the most easily attainable best practise that is available to cotton farmers throughout the world. Although the tools associated with this practise may vary depending on the environment and the level of scientific support which is available locally, the overall objective of reducing external inputs to increase farmers' health and wealth remains the same. Thousands of smallholders in Asia and Africa have already been trained in IPM and the governments of China, India and Pakistan are currently mainstreaming the FFS approach into their respective extension services in order to promote this best practise even more widely. This mainstreaming process will be more difficult to achieve in West African countries however, considering the continuing demise of the extension service in Africa as a whole. It should be noted that Brazil, China, India and Pakistan are all committed to increasing Bt cotton production and FFS/IPM tools are highly relevant to the successful outcome of this policy. Increased financial benefits for poorer farmers can be gained when IPM is used as a stepping stone to accessing niche markets such as *Fairtrade* or organic which can offer better financial returns.

Nevertheless, there are still many external factors that can reduce the successful impact of a particular management practise and its associated tools and activities, in terms of the income and livelihoods of cotton farmers. The most important of these external factors are listed below:

- The scale of production
- The level of research support
- The local ginning capacity
- Access to quality seed
- Access to irrigation
- Access to timely inputs
- Production costs
- Price paid for seed cotton
- Access to credit
- Timely payment for the crop
- Availability of season-long farmer training

Since none of the above factors are under farmers' control, it will be extremely difficult to predict whether a particular practise will lead to improved livelihoods for cotton farmers, despite their inherent benefits in terms of BCI's 'crop protection' and 'enabling' principles. It should be recognised that most smallholder farmers are food insecure and unable to bear the risks associated with adopting new practises and tools without long-term support in terms of training and guaranteed increased profits as an incentive. Furthermore, BCI's crop protection principles that are concerned with the health of the soil and the conservation of natural environments are likely to incur additional labour costs for cotton growers that can only be met through significant yield increases (at no extra cost) or the payment of higher prices for seed cotton. The risks associated with the adoption of new practises can also be reduced by ensuring that the new version of BCI's principles takes account of smallholder farmers' need for food security[17].

Nevertheless, the Better Cotton Initiative could be highly relevant to the millions of cotton farmers who are facing an uncertain future in 2009. Although the promise to eliminate the subsidies paid to US cotton farmers should lead to a fairer marketing environment, the falling global demand for cotton and the associated decline in world cotton prices are bound to discourage cotton production amongst farmers who are able to switch to a more profitable cash crop and cause increased poverty for farmers in areas where there is no alternative. This means that a Better Practise system should not be limited to production practises that are within the direct control of farmers, but should also address some or all those external factors that are out of their control, as this will ensure that a longer term and more sustainable approach to improve the income and livelihoods of cotton farmers is achieved.

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[17] The 'Self-Sufficiency Index' for each household can be calculated as follows:

$$\frac{\text{Previous yield of staple food crop (kg/ha) X Landholding (ha)}}{\text{Minimum annual grain requirement (kg)}} \text{ X } 100\%$$

Minimum annual grain requirement = 365kg/yr for an adult; 274kg/yr for an adolescent (10-18yrs); 183kg/yr for a child (<10yrs).
Households with Self-Sufficiency Indices of less than 200% are considered to be subsistence farmers, households with Self-Sufficiency Indices of less than 100% are food insecure.

During a drought year almost all households are food insecure.

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