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Organic Cotton Crop Guide

A manual for practitioners in the tropics

Frank Eyhorn, Saro G. Ratter,
Mahesh Ramakrishnan

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FiBL Research Institute of Organic Agriculture

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The Maikaal Research Team

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Contents

1 Introduction

1.1 About this guide

This guide was developed as part of the research project 'Growing Organic Cotton Under Groundwater Stress: Lessons from the Maikaal bioRe Project' (project period: 2002–2005). The Research Institute of Organic Agriculture (FiBL), Switzerland, implemented this project in collaboration with the International Water Management Institute (IWMI), India, and Maikaal bioRe (India) Ltd. It is funded by the Swiss Agency for Development and Cooperation (SDC) and the World Wide Fund for Nature (WWF), Switzerland. The information documented in this guide is based to a large extent on the experience and know-how of the Maikaal bioRe extension team. This was complemented by experiences with other cotton projects in India and in Africa and with information available from literature and the Internet.

Training of organic cotton farmers in Kirgistan. (Photo: Helvetas)

The guide aims to provide useful information and guidance to organic cotton farmers and to extension workers involved in organic cotton production on smallholder farms in the tropics. According to the authors, there is no one best 'package of practices' for organic cotton farming, as the conditions differ from farm to farm with specific soils, climatic conditions, production facilities, availability of labour, and the individual objectives and skills of the farmer. Therefore, this manual tries to impart an understanding of an organic farming system and to point out the available management options. It is meant to provide a sound basis for the farmer's decision making process and shall serve as a source of ideas for improvements. In any case, the suitability of the suggested methods in a specific setting needs to be explored on the respective farms and the methods potentially need to be adapted and further developed.

The manual can be used for training purposes in combination with the Organic Cotton Training Manual, which contains transparency slides, recommendations for interactive training elements, and material for group exercises[1].

Although this manual is about cotton, readers need to keep in mind that cotton is only one crop grown on an organic farm in rotation (or intercropping) with a number of other crops. These other crops, like pulses, maize, sorghum, wheat, chillies, vegetables, and sugarcane, are also important for cash income, for home consumption or for fodder purposes. A more general overview of organic crop production is provided by the IFOAM Training Manual on Organic Agriculture in the Tropics, complemented by the IFOAM Training Manual on Organic Agriculture in Arid and Semi-arid Regions [2].

[1] Free downloads are available at www.shop.fibl.org
[2] See www.ifoam.org or www.shop.fibl.org

1.2 Why organic cotton?

Organic cotton still only occupies a tiny niche of far less than 1% of global cotton production. However, the number of farms converting to organic cotton and the number of projects is constantly increasing. At present, organic cotton cultivation is reported in the following countries:

- Africa: Benin, Burkina Faso, Egypt, Mali, Mozambique, Senegal, Tanzania, Togo, Uganda, Zambia, Zimbabwe
- Asia: China, India, Kyrgyzstan, Pakistan
- South America: Argentina, Brazil, Nicaragua, Paraguay, Peru
- Middle East: Turkey, Israel
- Europe: Greece
- USA
- Australia

There are a number of reasons to grow cotton organically. The negative impacts of conventional cotton farming on the environment and health are obvious and well known. Some people may say: «Why should I care about chemicals in cotton growing? We do not eat cotton." But if you look at the fact that around 60% of the cotton weight harvest is cotton seed that is processed to edible oil and cattle feed, you realize that the bigger part of cotton production enters the human food chain. We also know that the pesticides sprayed on cotton do not only affect the target pest. Beneficial insects and other animals are killed, too, so that pests that formerly were of minor importance now have become a major problem (for example, whitefly and aphids). In some areas of Andhra Pradesh the ground water has become so polluted with chemicals that people need to buy their drinking water from outside. In addition, many of the farmers and labourers spraying the pesticides face health problems that cause them to miss a lot of work and have additional costs for medical treatment. There are many cases in India where farmers have even died after applying chemical pesticides. In the hospital of Warangal, Andhra Pradesh, up to a thousand farmers per month are treated because of pesticide intoxication.

Organic seed cotton

Advantages of cultivating cotton organically

	Conventional Cotton	Organic Cotton
Environment	• Pesticides kill beneficial insects • Pollution of soil and water • Resistance of pests	• Increased bio-diversity • Eco-balance between pests and beneficial insects • No pollution
Health	• Accidents with pesticides • Chronic diseases (cancer, infertility, weakness)	• No health risks from pesticides • Healthy organic food crops
Soil fertility	• Risk of declining soil fertility due to use of chemical fertilizers and poor crop rotation	• Soil fertility is maintained or improved by organic manures and crop rotation
Market	• Open market with no loyalty of the buyer to the farmer • Dependency on general market rates • Usually individual farmers	• Closer relationship with the market partner. • Option to sell products as 'organic' at higher price • Farmers usually organized in groups
Economy	• High production costs • High financial risk • High yields only in good years	• Lower costs for inputs • Lower financial risk • Satisfying yields once soil fertility has improved

Figure 1: Advantages of growing cotton organically, as compared to conventional farming

In central India, many conventional farmers have faced a decline in soil fertility over the past two decades. In some cases the soil got so hard that the farmers had to give up groundnut cultivation. While cotton yields were on the decline, increasing amounts of fertilizers and pesticides were needed to maintain the crop. Declining yields and increasing input costs, in combination with the frequent droughts, have left many farmers in a debt trap.

When speaking to smallholder organic cotton farmers in developing countries, the following motivations are stated as the most important ones:

- To improve the fertility of the soil (softer soil, greater absorption of water, better water holding capacity, healthy crops);
- To reduce the production costs and thus the financial risk;
- To get a better price for the cotton (organic premium);
- To get rid of the negative effects of conventional farming: declining yields, resistance of pests and diseases, health hazards of chemicals;
- To improve the profitability of the farm in the long run.

Market demand for textiles made from organic cotton mainly exists in Europe, the USA, Canada, Japan and Australia (see Chapter 8.3). Some large companies become involved with organic cotton textiles in order to improve their corporate image with respect to environmental and social accountability. The main reasons for consumers to buy textiles made out of organic cotton are:

- To reduce the risk of skin irritation and allergies;
- To protect the environment from toxic chemicals;
- To support sustainable agricultural production in the country where the cotton is grown;
- To ensure that the farmers in developing countries receive a fair price.

A comparison of the impacts of conventional ('chemical') and organic farming on the environment, health, soil fertility, the cotton market, and the economy on the farm level is depicted in Figure 1.

1.3 Growing organic cotton – A system approach

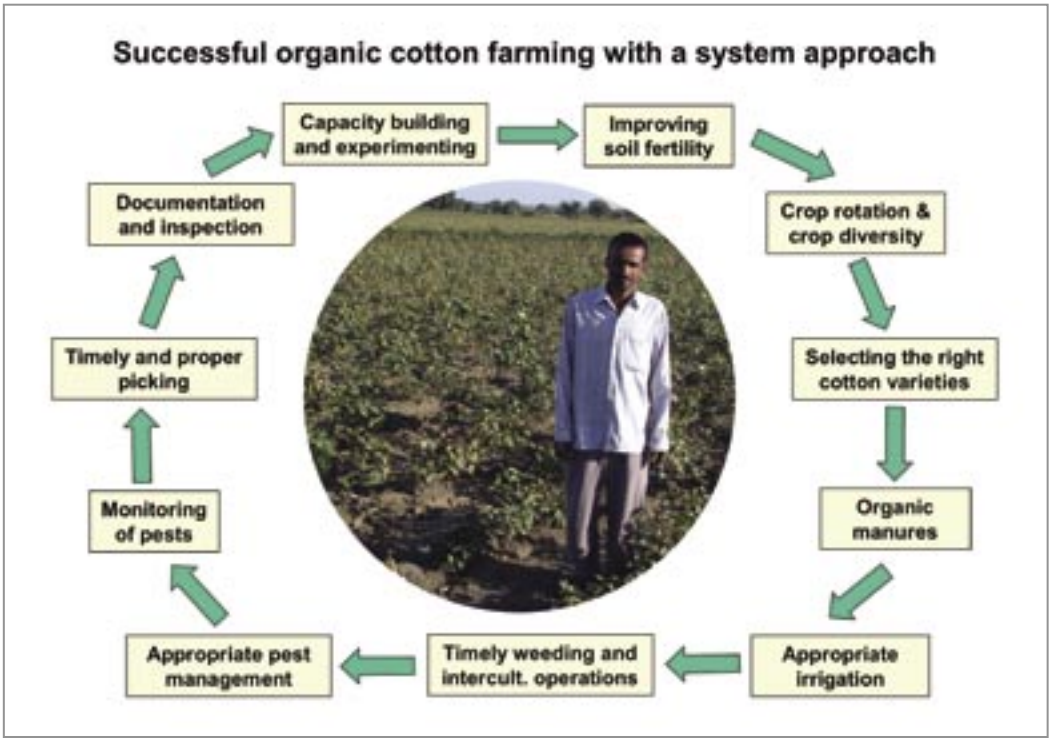


Figure 2: Successful organic cotton farming with a system approach

Converting a farm to organic production does not simply mean replacing chemical fertilizers and pesticides with organic ones. Organic cotton must be grown in a diverse and balanced farming system that also includes the other crops. Instead of troubleshooting, organic farmers should try to prevent problems and avoid substitutes to conventional inputs as far as pos-

sible. This requires a thorough understanding of nutrient and pest management and the ability to continuously observe and learn.

To get satisfactory yields and income in organic cotton farming it is necessary to adopt a number of integrated measures in a system approach, ensuring that the interaction among soil, plants, environment and people is well balanced. The 'ingredients for success' all need to be applied together (Figure 2):

1. Suitable measures to improve and maintain soil fertility;
2. Establishment of crop rotation and crop diversity; fostering natural balance;
3. Selection of varieties suitable to the conditions (soil, availability of irrigation, market requirements);
4. Appropriate types and amounts of manures at the right time;
5. Timely crop management such as intercultural operations, weeding and irrigation;
6. Careful monitoring of the crop and sufficient protection against pests according to the concept of economic threshold level;
7. Timely and proper picking of the cotton;
8. Sufficient documentation for inspection and certification;
9. Capacity building and experimenting for continuous improvement.

1.4 Organic standards

Farmers who wish to sell their produce as 'organic', whether in domestic markets or in export, need to be certified as organic. For this they need to strictly follow the national regulations[1] and-organic standards of the respective target country. For organic cotton to be exported to Europe, the European Regulation on Organic Farming (EEC 2092/91[2]) defines the basic requirements to be fulfilled. Other target markets have their own standards, e.g. the US (NOP[3]) and Japan (JAS[4]). A premium price is possible only if there is mutual trust between producers and consumers. The consumer wants to be sure that the product is really organically produced. The organic farmer also needs to be protected against unfair competition from other farmers who use the term «organic» in a fraudulent way.

Organic standards define the minimum criteria to be fulfilled (e.g. which fertilizers are not permitted), but not necessarily best practices (e.g. how much organic manure should be applied). Important requirements of most organic

Figure 3: Important requirements of organic standards relevant in cotton farming

[1] For India the standards under the National Program of Organic Production; see www.apeda.com
[2] EU regulation; europa.eu.int/eur-lex/en/consleg/main/1991/en_1991R2092_index.html
[3] National Organic Program; www.ams.usda.gov/nop/NOP/standards/FullRegTextOnly.html
[4] Japanese Agriculture Standard; www.maff.go.jp/soshiki/syokuhin/hinshitu/organic/eng_yuki_175.pdf

standards relevant for cotton farms to be certified organic are given in Figure 3.

A basic summary of organic standards relevant for organic cotton as per the EU regulation is given in Annex 10.3.

In 2002, during the International Conference on Organic Textiles (Intercot), the development of a global organic textile standard was initiated by IVN and IMO[1]. The standard defines criteria for organic textiles from the harvesting of fibres to the labelling of ready-made textiles. It also covers processing requirements (e.g. regarding toxicity and biodegradability of materials used) and social criteria. The standard is expected to facilitate the certification process and to provide end consumers with a credible assurance system for organic garments.

1.5 Bio-dynamic farming

The system of bio-dynamic farming is a special type of organic agriculture which fulfils all principles and standards of organic farming but goes a step further: bio-dynamic farming includes a spiritual dimension of agriculture. It is founded on a holistic and spiritual understanding of nature and human beings and builds on the research work of the Austrian philosopher Rudolf Steiner in the 1920s[2]. He developed a new approach to science which integrates observation of natural phenomena and spiritual dimensions. In the words of Steiner: "Matter is never without Spirit, and Spirit never without Matter."

Some of the principles of bio-dynamic farming are:

- The Farm Organism: A farm is considered as a whole organism, integrating plants, animals and humans. There should be just the right number of animals to provide manure for fertility, and these animals should be fed from the farm itself.
- Bio-dynamic preparations: Certain naturally occurring plant and animal materials are combined in specific preparations and applied in highly diluted form to compost piles, to the soil, or directly to the plants. The forces within these preparations are to organize the elements within the plants and animals.
- Cosmic rhythms: The rhythms of the sun, moon, planets, and stars influence the growth of plants. By timing the activities of tillage, sowing and harvesting according to the bio-dynamic calendar, the farmer can use this influence to benefit the crops.
- Vitality: Besides the physical and chemical characteristics, matter has a vital quality that influences organisms. Thus, bio-dynamic farmers strive for product quality, not just quantity.

As far back as 1928 the bio-dynamic movement developed the Demeter brand for labelling products from certified bio-dynamic farms[3].

1.6 Inspection and certification

In order to support farmers in the certification process and to reduce costs, farmer groups can be organized within an internal control system (ICS). For this, each farmer needs to sign a contract with the organization in which they declare their commitment to following the specific organic standards of the project. The extension workers of the project advise the farmers in organic crop production techniques and help them with the necessary record-keeping. Internal inspectors inspect the farms several times a year, and an internal certification committee decides about sanctions against defaulting farmers.

At least once a year, an external certifier inspects the functioning of the ICS and re-inspects a certain percentage of the farms at random (Figure 4). If the external inspection finds that the ICS is not functioning properly, for example because defaulting farmers are not discovered and excluded from the project, the entire project risks losing its organic certification and thus the option of selling the cotton and other crops at a premium price. Therefore, internal control systems can only function if there is a spirit of trust and cooperation among the involved farmers and between the farmers and the organization responsible for the ICS.

[1] International Association Natural Textile Industry (IVN), Germany; Institute for Market Ecology (IMO), Switzerland.
[2] www.biodynamic.org.uk/FAQ.htm
[3] www.demeter.net/

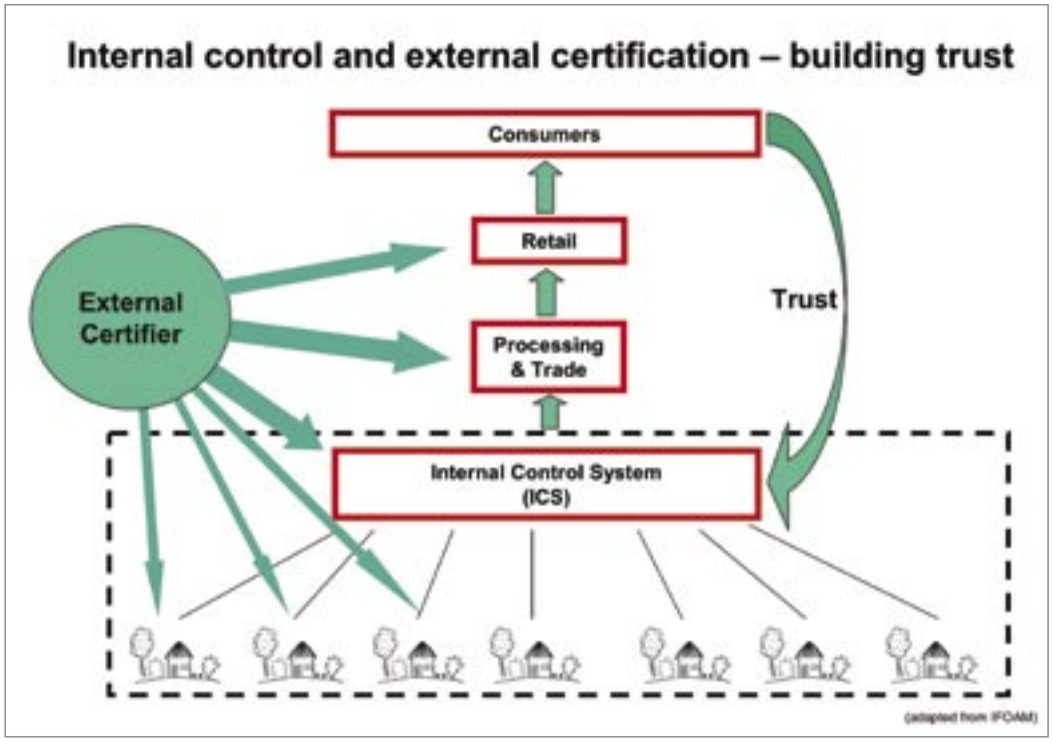


Figure 4: Internal and external control in an organic cotton project (adapted from IFOAM)

1.7 Organic cotton and Fair Trade

Fair Trade is a trading partnership that seeks greater equity in international trade, particularly focusing on the rights of marginalized producers and workers in developing countries. Trade relations are facilitated by a number of Fair Trade organisations, most of them being associated with the International Fair Trade Association (IFAT)[1]. Fair Trade Labelling Organizations International (FLO)[2] operates a Fair Trade certification scheme based on generic and product-specific standards. Many Fair Trade organizations, however, have their own labels and standards.

Important principles of Fair Trade include:

- Transparency and accountability based on democratic decision-making processes;
- Capacity building to develop producers' independence;
- Payment of a fair price, usually fixed as a minimum price and a Fair Trade premium;
- Gender equity;
- Safe and healthy working conditions;
- Encouragement of environmental production practices.

Fair Trade certification does not require that an operation is organic; it can also be applied to conventional production. However, some smallholder cotton projects choose both organic and Fair Trade certification. FLO has developed product-specific Fair Trade standards for cotton production (seed cotton)[3]. The most important requirements for smallholder organic cotton projects to achieve Fair Trade certification by FLO can be summarized as follows:

- Smallholders: More than 50% of the volume must be produced by small producers (not structurally dependent on permanent hired labour).
- Democratic structure: An organizational structure is in place that enables control by the members and ensures that the use of the Fair Trade premium is democratically decided by the members.
- Labour issues: No forced or child labour, salaries are in line with the official minimum wages, freedom of association and collective bargaining.
- Environment: Development of a water management plan in areas of acute water shortage.
- Trade: Fixed buying commitments at the beginning of the harvest season, guaranteed minimum prices and payment of Fair Trade premium. Pre-financing of up to 60% of the contract value, if requested by the seller.
- Commitment to continuous improvements in all fields (progress requirements).

[1] www.ifat.org
[2] see www.fairtrade.net
[3] see www.fairtrade.net/sites/standards/sp.html

2 Cotton

2.1 The importance of cotton

Cotton bales

Cotton has been used for producing garments for at least 8,000 years. Cotton is the most important fibre crop with an estimated world production of 23 million tons of fibre (lint) in 2004-05[1]. The three largest producers are China, the USA, and India, followed by Pakistan, the countries of the former USSR, and Brazil. India is the third-largest producer of cotton, producing about 12% of the world production, but, due to low productivity, it has the largest area under cotton cultivation (ca. 9 million ha). Nowadays, the livelihood of 17 million people in India depends on cotton farming[2]. The Indian cotton textile industry contributes 38% of the country's export earnings. In some African countries like Burkina Faso, Mali, and Benin, cotton plays an even more dominant role in agricultural exports.

World market cotton prices fluctuate to a great degree and have come down considerably over the last two decades. According to Oxfam and other NGOs, this is partly due to high farm subsidies in the US[3]. By-products of cotton include the edible oil gained from the seeds, and the seed cakes and husks are used as fodder and manure.

Cotton production worldwide uses more than 20% of all insecticides used in agriculture[4]. In many areas, irrigated cotton cultivation has led to depletion of ground and surface water sources. Many conventional cotton farmers in developing countries are in a crisis due to decreasing soil fertility, increasing production costs, resistant pests, or low cotton prices. In this scenario, an increasing number of farmers turn to organic cultivation in order to restore soil fertility, reduce production costs, or to get a better price for their certified organic harvest.

2.2 Requirements of the cotton crop

The cotton species *(Gossypium)* belong to the Malvaceae family (like okra and hibiscus). Their wild relatives are hardy perennial shrubs with hairy leaves and short fibres. Cotton is grown in a wide range of climatic conditions in temperate, subtropical and tropical regions of all the continents. Ideal conditions are in regions with long vegetation periods without frost, high temperature (ideally around 30°C), ample sunshine, and a rather dry climate (Figure 5). It requires a minimum of 500 mm water from rain or irrigation between germination and boll formation. Cotton is very sensitive to waterlogging, which causes a reduction in yields (more boll shedding) even when the plant appears to be unaffected. It prefers deep, well-drained soils with a good nutrient content. The clay-rich vertisols (so-called 'black cotton soils') are ideal. With their long tap roots penetrating up to three meters in such soils, cotton plants can sustain short periods of drought. However, cotton is also grown on less ideal sites with shallow, sandy soils, both under irrigated and rain-fed conditions. This requires adapting the selection of varieties and management practices.

[1] Source: International Cotton Advisory Committee, World Statistics
[2] Source: www.tve.org/ho/doc.cfm?aid=604
[3] www.oxfam.org/eng/pdfs/pp020925_cotton.pdf
[4] Source: www.pan-uk.org/pestnews/pn28/pn28p23.htm

Cottonseeds take about 4 days to germinate after coming in contact with water. During the first two weeks, growth of the leaves is slow as it is mainly the root that grows, penetrating deeply into the soil to ensure water supply. After this, strong vegetative growth builds up the leaves and branches, until the first flower buds emerge. Flowering starts at the first node of the first fruit-bearing branch and from one node to another along the branch. Flowers are white/yellow when they open, turning pink the following day. Pollinated flowers take three to four weeks to reach the final size of the pods, and another two to three weeks to dry out and open. Normally only about 1/3 of the flowers develop bolls, and this rate can drop to 10% when conditions are unfavourable, as in the case of drought, waterlogging, cool weather, or heavy insect infestation. Bud and boll dropping can be caused by both deficiency and excess of nutrients, or of moisture. However, the plant can pick up and compensate for loss of buds or bolls by prolonging its production of flowers if the unfavourable conditions last only for short periods, and if it is not too late in the season.

Development stages of cotton from bud (right) to boll

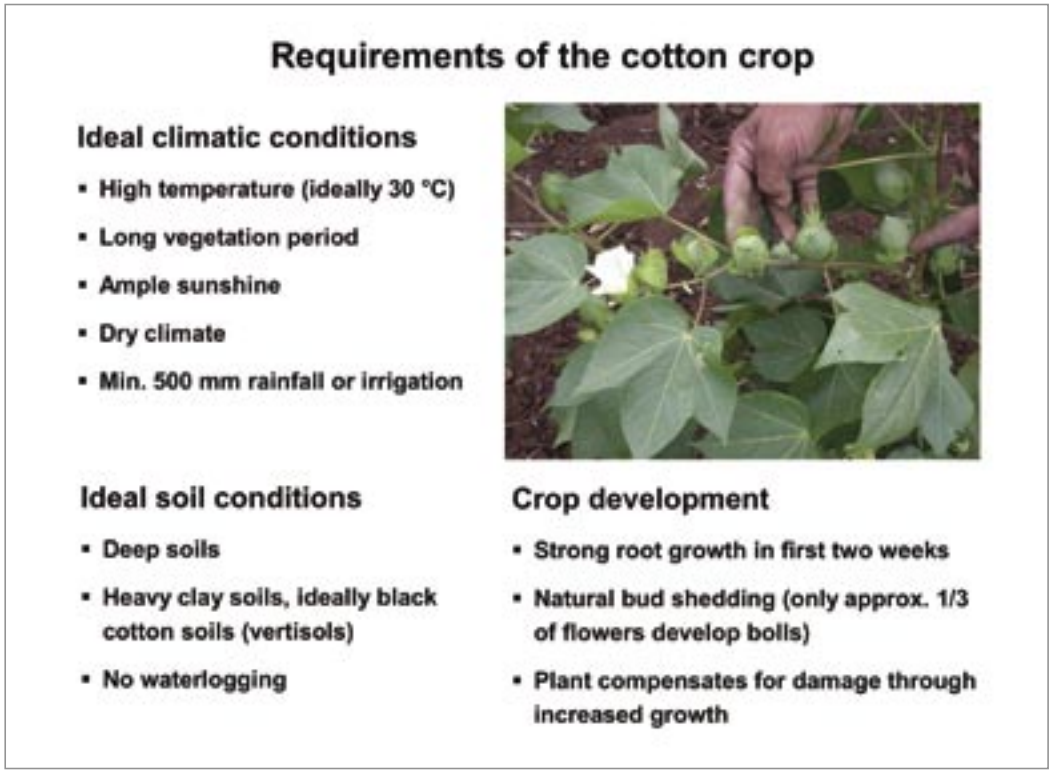


Figure 5: Requirements of the cotton crop

2.3 Selecting the right cotton varieties

By far the most widely grown cotton species is *Gossypium hirsutum*, often called American Upland cotton, which is available in a large number of hybrid varieties. Some countries grow *Gossypium barbadense* (Sea Island cotton), spinning its long fibres into extra-fine garments. In India and Pakistan, a number of local 'desi' varieties of *G. herbaceum* and *G. arboreum* are grown besides the 'American hybrids'. They are usually more resistant to pests and to drought, but most have a shorter staple length and thus fetch lower prices in the market.

There are a large number of different cotton varieties available on the seed market, and research stations and seed companies continually release new varieties. Most of them are bred for producing high yields under high-input conditions: fertilizers, pesticides, and irrigation. Organic farmers, however, are more interested in robust varieties that are resistant to or tolerant of pests and produce satisfying yields with medium manure supply. Some varieties, however, combine the advantages of the 'desi' varieties (hardy, drought resistant) with those of the *hirsitum* varieties (high yield, long fibres). These varieties could be of great interest, especially for organic farmers with less irrigation.

To select the most suitable varieties, farmers should consider the site conditions (soil quality, rainfall, availability of irrigation water, etc.) as well as the conditions of the farm (availability of manure, possibility for pest management, etc.). Where irrigation is a constraint and rainfall is erratic, it is preferable to use varieties that require less water (e.g. those with less leaf area). In addition, farmers need to consider the buyers' requirements concerning staple length and other fibre quality aspects (see Figure 6).

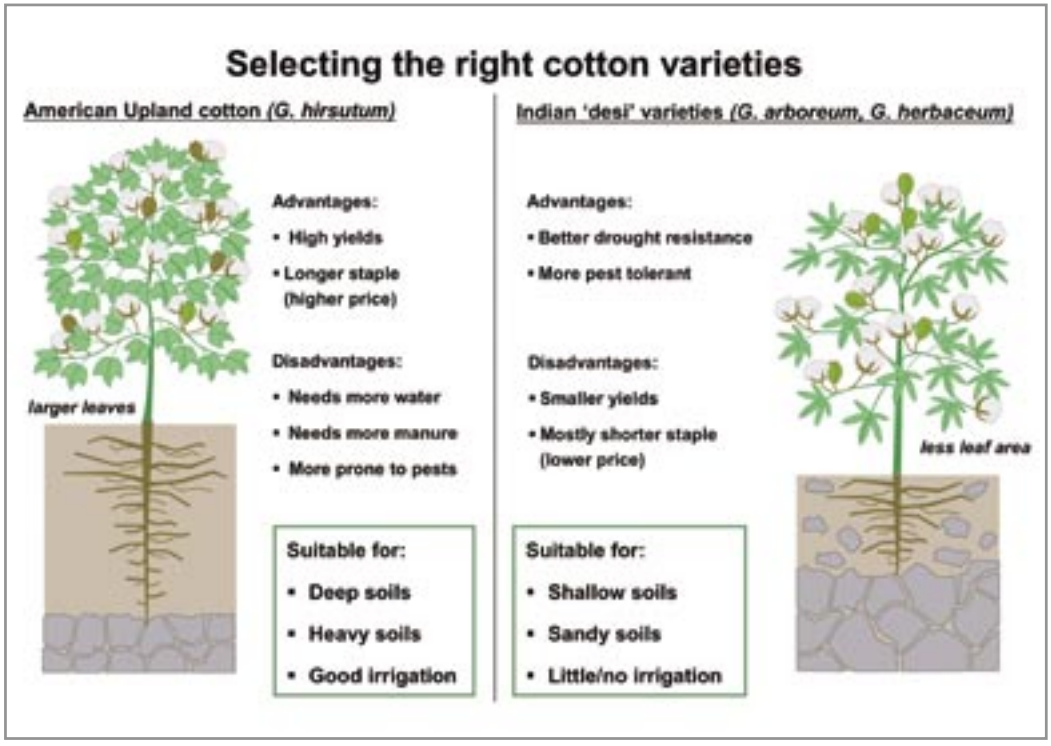


Figure 6: Comparison of American upland cotton and Indian 'desi' varieties

Identifying suitable cotton varieties for a particular field requires a great deal of observation and experimentation. It can also be useful to talk to extension workers or other farmers about their experience with a certain variety and its expected yields, water requirements, resistance to pests, and fibre quality. In some countries, however, the government authorities regulate which cotton varieties can be grown.

The cotton varieties that are most popular among organic cotton farmers in the Nimar region of Madhya Pradesh, India, and their properties are listed in Table 1.

Variety	Suitable sites	Staple length	Remarks
H-8	Medium soils, little to medium irrigation available.	25–26 mm	Most popular variety; good yields in organic farming; suitable for monsoon sowing; drought tolerant.
H-10	Deep, heavy soils.	26–27 mm	Ideal for summer sowing; not suitable for light soils.
JK-4	Medium soils	27–28 mm	Resistant to diseases and bollworm; susceptible to sucking pests; requires less water.
JKH-1	Deep, heavy soils; irrigation.	27–28 mm	Good yields in organic farming; ideal for heavy soil; susceptible to droughts.
Ankoor-09	Medium soils, not for heavy soils.	26–27 mm	A short duration crop suitable where a Rabi crop is grown; not suitable for summer sowing; susceptible to waterlogging.
Ankoor 651	Heavy to medium soils.	27–28 mm	Ideal for late-summer sowing and monsoon sowing; suitable for heavy soils.
New research varieties:			
Jawahar Tapti	Dry areas, little irrigation.	24–25 mm	Hardy; requires less water; resistant to bollworm, but short fibres.
Surabhi	Medium to dry areas.	28–32 mm	A non-hybrid with long fibres.
Devi Raj	Dry areas, little irrigation.	27–28 mm	A variety grown in Gujarat.

Table 1: Cotton varieties grown by organic farmers in the Nimar region, Madhya Pradesh, India

Seed issues

Cotton is self-pollinating, but cross-pollination also occurs; thus, controlled breeding is necessary to maintain the quality of varieties. Most of the cultivated cotton varieties are hybrids that are propagated by seed companies and cannot be multiplied without the parent lines. In India, research stations have also developed a number of non-hybrids, the seeds of which can be re-grown for a number of years. Organic cotton farmers in Mali also use the cotton seeds from their own harvest. Breeding of varieties specifically suited to organic farming conditions remains a challenge to be tackled in coming years.

Testing cotton varieties for organic farming in Kirgistan (Photo: Helvetas)

Bt cotton

In organic agriculture the use of genetically modified organisms (GMO) is not allowed. For some years, seed companies have been promoting genetically engineered 'Bt cotton'. It contains genes of the same micro-organism, *Bacillus thuringiensis,* that is used in bio-control against a number of insect pests, also by organic farmers. The Bt cotton plant thus continuously produces an insecticide that is to prevent bollworms from feeding on it. However, bollworms frequently develop resistance, forcing the seed companies to develop new varieties of Bt cotton. Also, there is a risk that the development of resistance makes Bt sprays less effective, thus harming organic farmers.

The cultivation of Bt cotton involves higher financial risk, since the seeds are considerably more expensive and usually the crop is grown with high inputs of fertilizers and pesticides against sucking pests. In India, many conventional farmers who tried Bt cotton complained about crop failure, due possibly to inappropriate varieties, unfavourable climatic conditions, or adulterated seeds. Despite the benefits promised by its promoters, growing Bt cotton seems to be a high-risk strategy.

Organic farmers find it more and more difficult to get cottonseed material that is guaranteed GMO-free. Some certification bodies use test stripes to check whether cotton plants contain GMO.

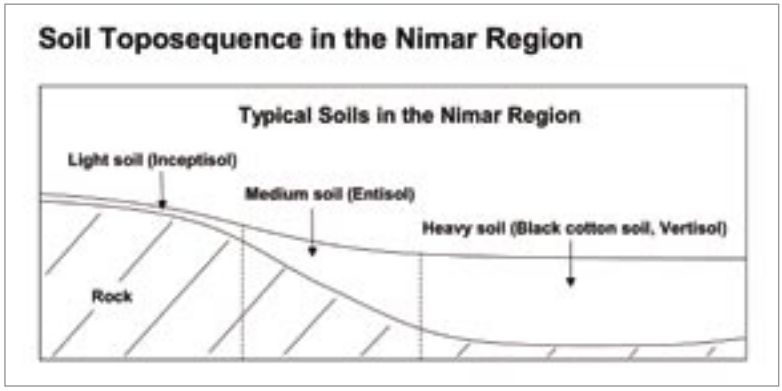
3 Soil Fertility Management

3.1 Soil properties

The best strategy for improving and maintaining soil fertility in cotton primarily depends on the soil types present on a farm. Soil types in the Nimar Region, India, can be broadly grouped into light soils (Inceptisol), medium soils (Entisol) and heavy soils ('black cotton soil', Vertisol). Their distribution in the landscape mainly depends on the profile (see graph below).

Light soils usually have a lower water-retention capacity, and the nutrients are more easily leached out than in heavy soils. In light soils, the application of compost is particularly important for increasing water retention and nutrient supply. As these soils are less suitable for intensive production, the variety and crop selection should be adapted accordingly (robust, frugal, and drought-resistant cotton varieties and rotation crops). Intercropping of more drought-resistant crops like sorghum, safflower, sesame, or castor can help to reduce the risk of complete crop failure in drought-prone areas. Soil cultivation should be shallow and kept to a minimum in order to avoid soil erosion and enhanced decomposition of organic matter.

In deep or heavy soils (e.g. black cotton soil), intensive production is possible with sufficient inputs of organic manures, intensive crop rotation, and green manuring. Frequent shallow-soil cultivation helps to improve soil aeration and nutrient supply. It also reduces evaporation and suppresses weeds. When the cotton crop is well established (after 6–9 weeks) it is recommended to apply additional organic manure (e.g. vermi-compost or oil cakes) and to earth up ridges in order to accelerate decomposition of manures and to bury weeds. The soil properties and management recommendations for light and heavy soils are given in Figure 7.



Soils in the Nimar Region, India, usually follow a sequence, with light and sandy soils on elevations and deep and heavy soils in depressions and river belts

Soil profile in a cotton field in India

Soil types and their management

Light soils	Heavy soils
Shallow; roots do not penetrate very deeply	Deep; roots penetrate deeply
Light colours	Dark colour; cracks when dry
Sandy; easy to cultivate	Rich in clay; muddy when wet, hard when dry
Low water retention capacity → affected by drought!	High water retention capacity → less risk of being affected by drought
Nutrients easily get leached out → need sufficient compost; supply of mineral fertilizers in several doses	Very fertile → need sufficient manures because of high productivity
Drought-resistant crops: sorghum, maize, pigeon pea (desi varieties), moong, millet, castor; desi cotton varieties	High performance crops: chilli, soya bean, banana, sugarcane, hybrid cotton varieties, pigeon pea (hybrid varieties); wheat
Intercrop to reduce risk of crop failure	Intensive crop rotation; green manures
Compost and mulching to improve water holding and nutrient supply	Compost to activate soil life and improve soil structure
Shallow ploughing, little soil cultivation	Deep ploughing, frequent intercultural operations (shallow soil cultivation)
Increase infiltration with trenches and bunds	Risk of waterlogging!

Figure 7: Properties and management recommendations for light and heavy soils

3.2 The importance of soil organic matter

Cotton prefers fertile soils with good water holding capacity and sufficient nutrient supply (see Chapter 2.2). On many farms, the continuous application of chemical fertilizers has led to a loss of soil fertility. This is mainly due to a lack of organic matter – the residues of plant material and organic manures remaining in the soil. The application of nitrogen fertilizer accelerates the decomposition of organic matter.

Organic matter has a very crucial significance for soil fertility improvement (Figure 8). It ensures a soft and loose soil with good porosity and thus good infiltration of water. The organic matter particles act like tiny sponges, thus keeping the soil moist for a longer time. Organic matter takes up and releases nutrients so that they are available to the crop. Last but not least, organic material feeds and hosts a huge number of beneficial soil organisms, such as earth worms and microbes, which continuously work toward improving soil fertility.

Thus, for getting good, stable yields it is important that organic farmers ensure a continuous supply of organic material to the soil – not only for cotton! The most important source of organic matter are the residues of the crops grown on the field itself (leaves, stalks, roots etc.). Therefore, balanced crop rotation, intercropping, and mulching are the most efficient ways to enhance soil fertility. This is complemented by the application of farmyard manure, compost and organic manures such as oil cakes, press mud, etc. (see Chapter 4.5).

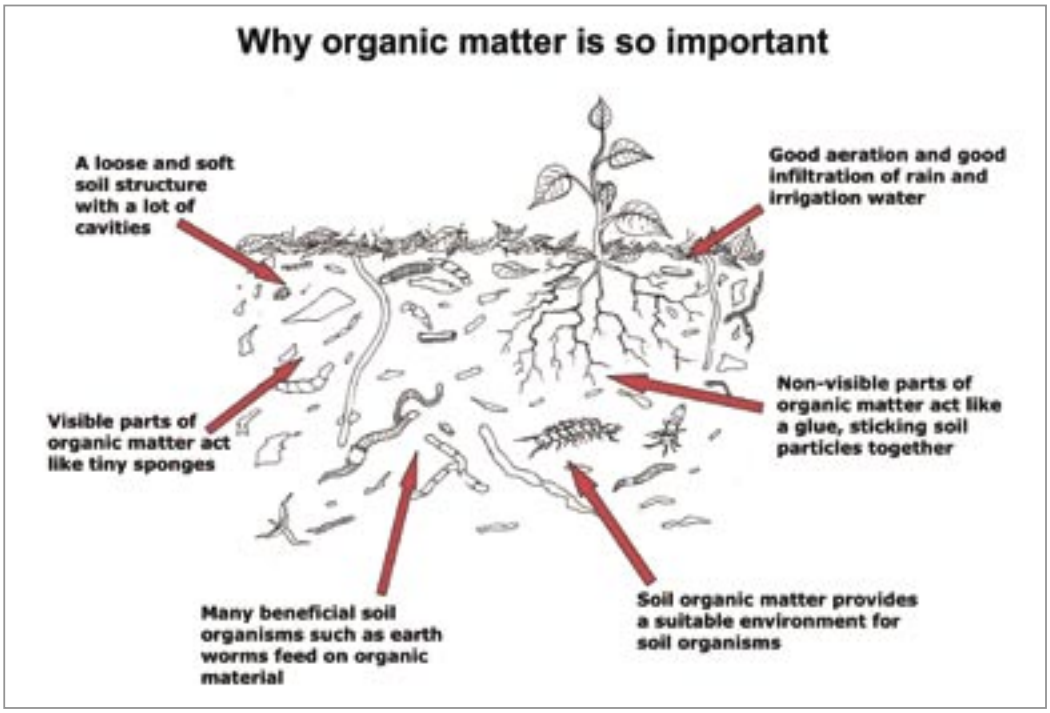
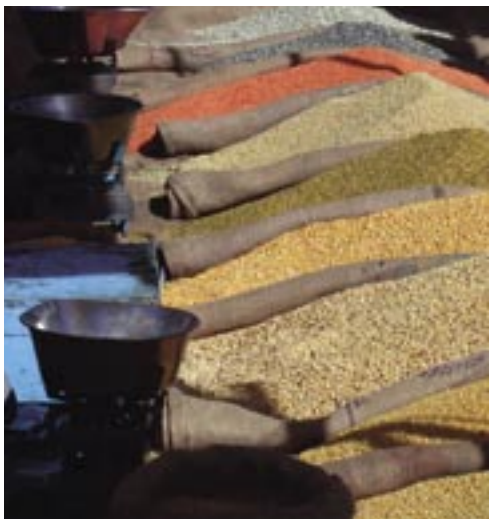


Figure 8: The importance of organic matter for soil fertility

3.3 Crop rotation – rotation crops

It is important that organic cotton is grown in rotation with other crops. This helps to improve and maintain soil fertility and ensures balanced nutrient contents in the soil. If cotton is grown continually on the same field, yields are likely to decrease. Crop rotation and mixed cropping also help prevent build-up of pest populations, diseases and weeds. Pests find it more difficult

Wheat grown in the winter season (Rabi) after cotton



Pulses and cereals in an Indian market

to move from one host plant to another, and they are controlled by a number of beneficial insects hosted by the rotation crops or intercrops. Crop diversity also reduces a farmer's risk, making farmers less vulnerable to crop failure and to fluctuating prices. Further, it helps prevent a shortage of labour in peak seasons, as labour requirements are more evenly distributed throughout the year.

Depending on the climatic conditions, the market situation and the availability of land, there are a number of suitable rotation patterns, with cotton grown every alternate or every third year. Which rotation pattern is the most suitable one for a particular farm depends on a number of factors: soil properties, irrigation facilities, crop prices, market access, and – last but not least – the skills and preferences of the farmer. Figure 9 lists some suitable rotation patterns from organic cotton projects in India and Africa.

Crop rotation – rotation crops

Rotation Type	1st year	2nd year	3rd year
Pulses + cereals	Cotton (winter crop: wheat or pulses)	Pulses (soya, moong beans, cow pea, black gram, pigeon pea), maize or sorghum	Cotton (winter crop: wheat or pulses)
Vegetable	Cotton (winter crop: wheat or pulses)	Chilli, onion or other intensive vegetable crop	Cotton (winter crop: wheat or pulses)
Sugar cane	Cotton	Sugar cane	Sugar cane
Diverse rotation (from Tanzania)	Cotton	Sesame, safflower, sorghum or maize	Pulses (moong, chick pea, cow pea, pigeon pea, groundnut)
Rotation with herbal plants (from Egypt)	Cotton (winter crop: wheat or pulses)	Herbs (anise, basil, fennel etc.)	Maize with clover intercrop

Figure 9: Some crop rotation patterns from organic cotton projects in India and Africa

On organic farms, cotton should not be grown in fields where the previous year's crop also was cotton (no 'cotton after cotton'). The reason is that if cotton is grown year after year in the same field, the soil nutrients get depleted, pest populations increase and there is a risk for soil-borne diseases. At least for one year, but preferably for two years, another crop should be grown between two cotton crops. If very small land holdings force farmers to grow cotton after cotton, they should, in any case, use an intercrop (e.g. moong bean, cow pea, or chick pea, for harvesting) or a green manure crop (e.g. sun hemp or cow pea, to be cut and ploughed back into the soil before flowering).

Particularly good yields are achieved when cotton is grown after pulses (soy bean, chick-pea, pigeon pea, groundnut etc.), horticultural crops like chillies or vegetables, and after sugarcane and wheat. Organic farmers in particular should take care to include pulses in the rotation, as they increase the nitrogen content in the soil by fixing nitrogen from the air.

In some places a crop of wheat, pulses or fodder can be grown after cotton in the winter season. In India, where sufficient irrigation is available, farmers usually uproot the cotton crop before the second flush, in order to grow a wheat or chickpea crop in the 'Rabi' season. Growing wheat instead of continuing to harvest the cotton is usually more remunerative, as the gains from the wheat crop more than compensate for the loss in cotton yields and the additional production costs. However, sufficient availability of irrigation water and of labour are important pre-conditions for this.

3.4 Green manures and intercrops

Green manure crops for cotton (mainly pulses like sun hemp or cow pea, or mixtures containing pulses and cereals) are usually sown between the cotton rows after the cotton seedlings have emerged. They are cut before or at the time of flowering, and are either used as mulch or incorporated into the soil. Intercrops like maize or pigeon pea can be grown in rows every few meters, replacing a row of cotton. Sunflower can also be used as an intercrop (an effective trap crop, see Chapter 5.3.2), with 10–15 m distance between the rows in order to reduce competition through shade. Smaller pulses like moong bean, black gram and cow pea, or small millet varieties, can be grown in-between the cotton rows, or between the individual cotton plants. Intercrops are usually allowed to mature and are cut and used as organic mulch after the seeds are harvested (Figure 10).

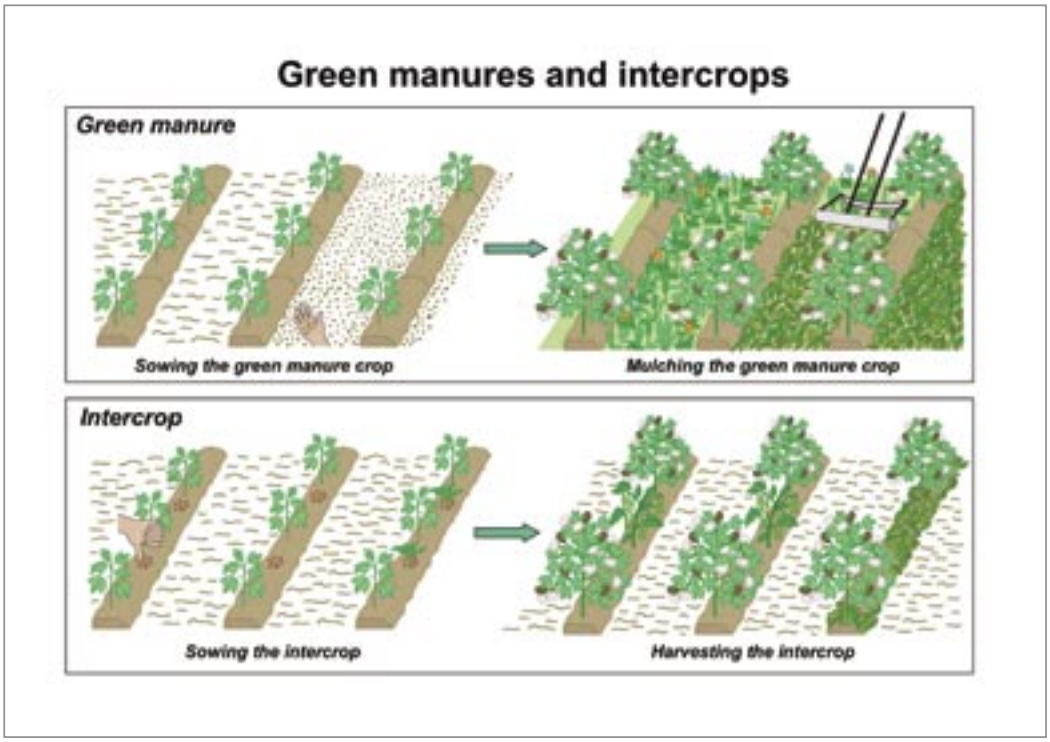


Figure 10: Green manures (cutting at the time of flowering) and intercrops (cutting after harvesting the seeds) for cotton

Both green manures and intercrops have the following benefits:

- Distract pests from the cotton crop (especially sucking pests);
- Attract and host beneficial insects;
- Take up nutrients from the soil which would be lost to the crop;
- Fix nitrogen from the air (pulses and other legumes);
- Make nutrients available to the cotton crop when decomposing;
- Build up organic matter (better soil structure, water retention, overall fertility);
- Suppress weeds;
- Produce mulch that keeps the moisture in the soil;
- Reduce soil erosion through rain or wind;
- Provide additional yield;
- Can serve as fodder for cattle.

On the other hand, green manure and intercrops do compete with the cotton crop for water, light and nutrients. Thus, appropriate timing of the sowing and cutting is very important in order to get maximum benefit with minimum competition.

Farmers in Nagpur and Yavatmal, India, have had good experiences with using the 'Nagpur mixture' as a green manure, consisting of the seeds listed in Table 2 (approximate quantity for 1 ha):

English name	Scientific name	Hindi name	Quantity of seeds (for 1 ha)
Sunhemp (jute)	*Crotalaria juncea*	Sun beeja	5 kg
Pearl millet	*Pennisetum typhoideum*	Bajra	5 kg
Moong bean	*Vigna radiata*	Moong daal	5 kg
Black gram	*Phaseolus mungo*	Urid daal	5 kg
Chickpea	*Cicer spp.*	Channa	5 kg

Table 2: Composition of the green manure "Nagpur mixture" used for cotton in central India.

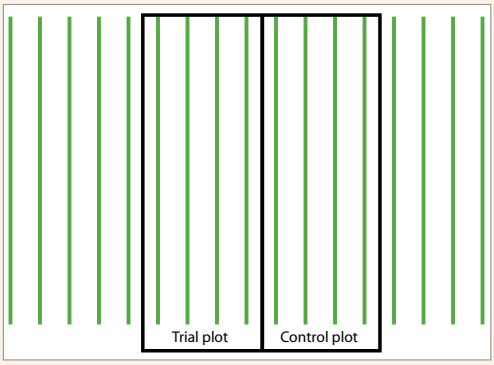
Nodules of pulses host nitrogen fixing bacteria

The Nagpur seed mixture is sown between the cotton crop about 2–4 weeks after the germination of the cotton seedlings, just before the first intercultural operation. The green manure is cut (by hand or with a weeder) after approximately four weeks, when the pulses start flowering.

In India, the most popular intercrops for cotton are moong bean, chick pea (black gram), cow pea and pigeon pea. Sorghum and maize are grown as trap crops. To reduce competition for light, water and nutrients with the cotton crop, the intercrop should only be grown in every alternate row. The rows are preferably oriented in an east-west direction. Pulses are particularly suitable green manures and intercrops, as they fix nitrogen from the air with the help of beneficial bacteria hosted in root nodules.

Trials on green manures and intercrops

To try out alternative options for green manures and intercrops, farmers can set up simple plot trials on their farms. For this, the farmer organizes the necessary seed material and selects a suitable field for the trial. In the field, the farmer chooses an area in which the soil is more or less the same. He marks a number of cotton rows for the intercrop or green manure, and an equal number of cotton rows of the same length without intercrop or green manure as a control plot. The trial plot and the control plot are harvested separately so that the yields can be compared. The yields and the value of the intercrop should also be taken into consideration when comparing the new method with the previous system.



Possible layout of a trial plot and control plot in a cotton field.

Crop Nutrition

4.1 Nutrient requirements

Crop rotation and intercropping with legumes, recycling of crop residues and the application of farm-produced organic manure (FYM and compost) need to form the basis of nutrient management in organic cotton farming. Organic farmers should not try to copy conventional fertilizer application schemes by simply substituting NPK-fertilizers with organic manures. It is very important that above all they preserve the nutrients that are already available in the soil and on the farm: prevent soil erosion, use all available crop residues and organic wastes, and do not burn crop residues or cow dung.

Like other crops, cotton requires the full range of nutrients in a well-balanced composition. The cotton plant requires two-thirds (2/3) of these nutrients during the first two months of its growth. To ensure sufficient nutrient supply (especially of nitrogen) during this phase, it is recommended that a basal dose of well-decomposed compost or farmyard manure be applied at the start of the growing season, and be complemented with one or two head applications of compost and an organic manure rich in nitrogen (e.g. oil cakes, poultry manure from extensive rearing). Head applications of manure should be applied 2–3 weeks before the start of square bud formation, as the nutrients are not instantly available but only get released once the manure decomposes (see Figure 11).

A harvest of 500 kg seed cotton extracts approximately 36 kg nitrogen (N), 14 kg phosphate (P_2O_5) and 15 kg potassium (K_2O equivalents). Parts of these nutrients may be replaced through nitrogen fixation by legumes (N) and through weathering of minerals (P and K).

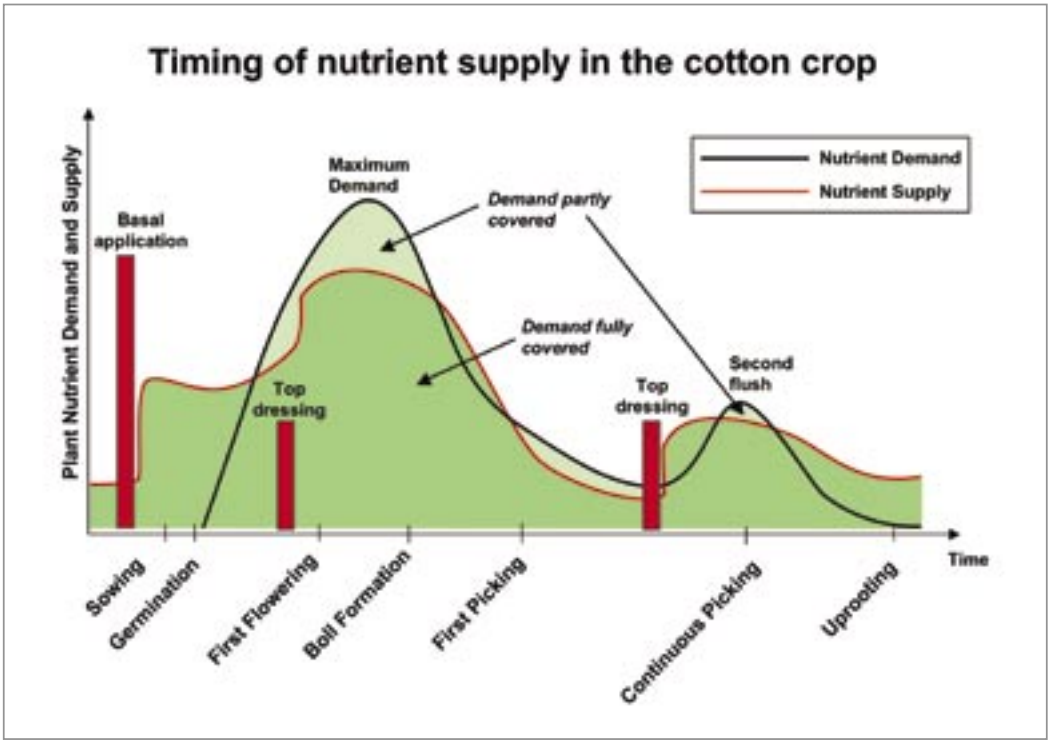


Figure 11: Nutrient demands of cotton and timing of manure applications

4.2 Uptake of nutrients

In organically managed soils, the crops mainly depend on the nutrients supplied by minerals and by the organic matter in the soil. These take up, store and release nutrients (through exchange, weathering, and decomposition). Soil organisms play a vital role in this process and should be supported through careful soil cultivation and regular application of organic matter. Measures to improve overall soil fertility (microbial activity, structure, moisture retention) are more likely to result in increased yields than merely applying fertilizers.

The most widespread nutrient deficiencies in tropical cotton fields are in nitrogen, phosphorus, sulphur, zinc and boron. Soil tests have their limitations in providing useful information on nutrient deficiencies, as they only measure the easily available nutrients. The availability of nutrients to the crop, however, depends on a number of factors such as the activity of soil micro-organisms, the root system of the crop, and the water content in the soil.

It is possible that the uptake of nutrients is hindered by waterlogging (the roots then lack air) and dryness (there is no nutrient uptake without water). Excess nitrogen, phosphorus and potassium also disturb the uptake of certain other nutrients like calcium, magnesium and micronutrients (Figure 12). In the case of a cotton crop showing deficiency symptoms, it is not always necessary to apply additional manure or fertilizers. It may be more efficient to stimulate microbial activity and to overcome the inhibiting factors, e.g. through soil cultivation, irrigation, and incorporation of biomass.

Phosphorus deficiency symptoms on a cotton leaf

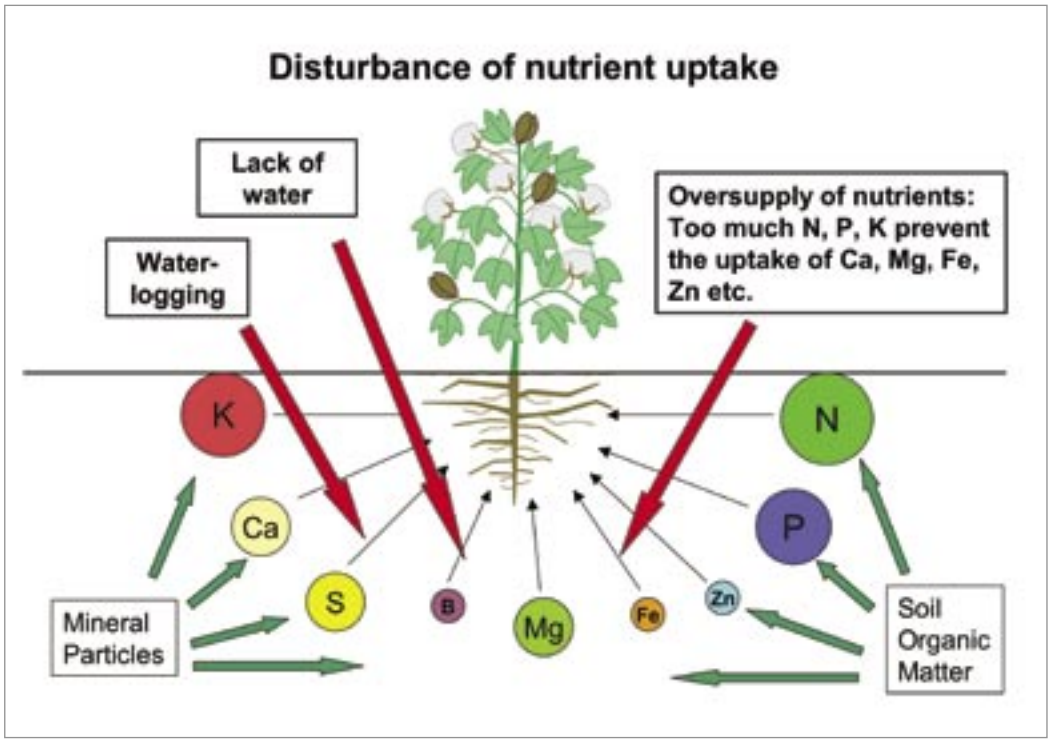


Figure 12: The uptake of nutrients (represented by coloured circles) and its disturbance (red arrows). K = potassium, Ca = calcium, S = sulphur, B = boron, Mg = magnesia, Fe = iron, Zn = zinc, P = phosphorus, N = nitrogen

Nitrogen immobilization

In the first two months of growth, the cotton crop may be short of nitrogen because micro-organisms use the nitrogen in the soil for the decomposition of carbon-rich (sturdy) organic material. As a result, the leaves of the cotton plants look yellowish, growth is stunted and overall crop development is slow. This phenomenon known as 'temporary nitrogen immobilization' may occur when sturdy crop residues or manures (e.g. straw-rich farmyard manure or undecomposed press mud) are present in the soil. To decompose this material, microbes require nitrogen, which is not available to the crop for a certain period of time. To avoid this situation, collect the sturdy crop residues before ploughing the fields and prepare compost out of them. Compost should be kept moist and should be turned at least twice so that it decomposes well. It should be applied to the field early in the season so that the decomposition has already started when the cotton is sown. At the time of sowing, nitrogen-rich manures such as oil cakes can be applied to prevent this problem. Oil cakes take 1-3 weeks until they release nitrogen through decomposition. Soil cultivations (intercultural operations) speed up the decomposition of organic matter and thus increase the nutrient supply to the crop.

4.3 Application of manures and fertilizers

Suitable application doses of nutrients in organic cotton depend on the soil condition, the previous crop, and the expected yield. Table 3 shows the nutrient quantities recommended for organic cotton for soil of average fertility cultivated with high-yield varieties. A considerable portion of the required nutrients, however, can be supplied through decomposing residues of the previous crop, and through nitrogen fixation by leguminous crops.

Organic manures like compost and cattle dung contain the full range of nutrients including micronutrients in a balanced composition. Thus, where organic manures are applied in sufficient quantity, usually there is no deficiency of micronutrients.

Farmers can achieve the desired nutrient input through the following steps (in order of priority):

1. Practise crop rotation, and grow leguminous crops (e.g. pulses) as intercrops or as green manures;
2. Use all biomass available on the farm (do not burn crop residues or cow dung!); mix wood ash into the compost heap;
3. Use whatever biomass is cheaply available nearby (e.g. weeds, leaves, press mud, agricultural processing wastes);
4. Only then complement with purchased organic manures (e.g. oil cakes) and natural mineral fertilizers (e.g. rock phosphate, gypsum, muriate of potash).

Approximate nutrient contents of important organic manures and natural fertilizers (minerals) are given in Figure 13.

Nutrient	Quantity per ha	Possible sources
Nitrogen (N)	100–120 kg/ha	Residues from previous crop, nitrogen fixation through pulses, compost, vermi-compost, FYM, DOC, liquid manures
Phosphorous (P_2O_5)	50–60 kg/ha	Residues from previous crop, compost, FYM, rock phosphate, wood ash
Potassium (K_2O)	40–50 kg/ha	Residues from previous crop, compost, FYM, muriate of potash, wood ash

Table 3: Recommended nutrient doses in average organic cotton fields, to be adapted to local conditions

Organic manures and natural mineral fertilizers for cotton

Manure/Fertilizer	Comment	Nitrogen (total N)	Phosphate (P_2O_5)	Potash (K_2O)
Compost	Soil improvement	0.6–1.5 %	0.5–1.0 %	0.5–2.0 %
Farmyard manure	Less stable humus	0.7–1.5 %	0.5–0.9 %	0.4–1.5 %
Vermi-compost	Very stable humus	0.6–1.5 %	0.4–0.9 %	0.5–1.0 %
De-oiled Castor	N- and P-supply	4.5–6.0 %	0.8–1.8 %	1.3–1.5 %
Cane press mud	Soil improvement	1.4–1.8 %	0.1–1.0 %	0.4–0.6 %
Rock phosphate	P-supply, in compost heap	0	15–30 %	0
Muriate of potash	Natural potassium fertilizer	0	0	ca. 60 %
Wood ash	K, Mg, Ca, Mg etc.	0	1–3 %	1–8 %

Note: Figures are given in percent of dry matter. The nutrient contents vary from source to source.

Figure 13: Approximate nutrient contents of important organic manures and natural fertilizers

Table 4 proposes a nutrient management plan for cotton for achieving the recommended nutrient input. However, this should only be a rough guideline and needs to be adapted to the specific conditions of each farm and field.

Caution: A too-high supply of nitrogen-rich manures can cause:

- Strong vegetative growth of cotton (many leaves instead of bolls);
- Increased shedding of square buds;
- Plants to become more attractive to sucking pests like aphids, whitefly and jassids;
- Potentially lower yields!

Manure or measure	Recommended quantity (per ha)	Comments
Crop rotation	Preferably grow cotton on plots where the previous crop was pulses, chillies, vegetables, banana, or sugarcane.	The cotton crop benefits from the high nutrient level of the previous crop.
Green manure / intercrop	If possible, grow leguminous crops (e.g. pulses) as intercrop or as a green manure.	Leguminous crops increase the nitrogen content in the soil by fixing it from the air.
Compost, cow dung or press mud compost	Initial application: 10–13 tons cow dung, or 7–10 tons compost, or 6–7 tons vermi-compost. Top dressing (decomposed compost, together with DOC): › 3 weeks after sowing: 1.5–2.5 tons › 10–12 weeks after sowing: 1.5–2.5 tons	Compost and cow dung should be well decomposed. The quantity can be reduced if the previous crop was pulse or a horticulture crop, or if pulses are grown as green manure or an intercrop.
De-oiled castor cake (DOC), or other oil cake	Top dressing (mixed with compost): › 3 weeks after sowing: 150–350 kg › 10–12 weeks after sowing: 150–350 kg	Apply the lower dose if the previous crop was a pulse, or if sufficient compost of good quality was applied initially.
Rock phosphate	50–70 kg per ha, application together with the compost.	Mix into the compost when setting up the heap; do not apply it directly to the soil. Increase the quantity to 100 kg in case of P-deficiency (soil test).
Muriate of potash	Only in case of K-deficiency (soil test): 50–70 kg per ha.	Usually the potassium (K) present in compost and organic manures is sufficient. Add wood ash to the compost.
Foliar application of vermi-wash, diluted biogas slurry or diluted cow urine	Start 4 weeks after germination of the cotton until the first bolls open, every 2 to 3 weeks: one litre cow urine or vermi-wash in 10 litres water.	Strengthens and nourishes the plant, deters pests. For second flush in Rabi season (India), start spraying again in November and December.

Table 4: Recommended nutrient management plan for organic cotton

4.4 Compost

Composting is the process of transforming organic material of plant or animal origin into high-value organic manure in heaps or pits. Compared to uncontrolled decomposition of organic material, decomposition through composting is faster. It heats up as part of the process, which results in a product of higher quality. If compost heaps are properly maintained, loss of nutrients (especially nitrogen) can be kept low. Compost provides the crop with well-balanced 'food' and helps to increase the soil organic-matter content. Compost has both a long-term and a short-term effect on plant nutrition as nutrients are continuously released over a period of time.

There are two general types of composting: 'continuously fed' and 'batch fed' systems:

- Batch fed systems (all material is set up at once): During the first few weeks after setting up the compost, the material gets very hot. Weed seeds, diseases and pests are killed as a result of the high temperature. The process is fast (within a few weeks), fewer nutrients get lost, and the final material is of high quality.
- Continuously fed systems (material is added again and again): These systems do not heat up during the composting process. They are handy if there is a continuous supply of wastes (e.g. from cleaning the cow sheds). However, they lack the advantages of the heating phase and thus decompose less completely. Vermi-compost heaps are a good example of a continuously fed system.

Compost heaps in the Maikaal bioRe project, India.

The value of the compost very much depends on the material used, and on how well the compost is set up and maintained. If the compost is too dry or too wet, a lot of nutrients (especially nitrogen) get lost and the quality of the compost is low. Thus, proper set-up of the compost and sufficient turning pays off. The results of nutrient analysis done on samples from manure and compost heaps in the Nimar Region, India, prove this (Figure 14).

Compost and farmyard manure – proper handling pays off!

Nutrient contents of different compost and dung heaps collected in the Nimar region, India

Manure / Compost type	Nitrogen (total N)	Phosphate (P_2O_5)	Potash (K_2O)
Cow dung heap, well maintained	1.5 %	0.7 %	0.8 %
Cow dung heap, poorly maintained (too wet)	0.9 %	0.5 %	1.2 %
Compost in good condition (with heat process and turning)	1.3 %	0.9 %	0.8 %
Compost, poorly maintained (too dry)	0.8 %	0.5 %	0.5 %
Vermi-compost in good condition	1.5 %	0.9 %	0.7 %
Vermi-compost, poorly maintained	0.6 %	0.4 %	0.7 %

Figure 14: Nutrient contents (% dry matter) of samples of different compost and dung heaps collected on organic farms in the Nimar Region, India

Setting up a compost heap or pit

Compost heaps are easier to build than pits, but they also dry out more easily. In pits, however, there is a risk of waterlogging during the wet season. During the dry season, when little water is available, composting in pits may be more appropriate than heaps since humidity is conserved better. When setting up a compost heap or pit, the following points should be kept in mind:

- Location: The compost is ideally located near the source of the composting material and the fields to which the compost will be applied. The site should be shady and near a water source. Water-logged sites should be avoided.
- Timing: A compost heap should be set up when a lot of plant material is available, i.e. towards the end of the rainy season (fresh material, weeds) and after the harvest of the main crops (crop residues). If the farm does not supply enough plant material, it may be collected from outside sources.
- Size: The compost heap should reach a size of at least 1 cubic metre to allow for the proper composting process. To allow sufficient aeration it should not be more than 2.5 m wide and 1.5 m high.

Some materials that can be used for making compost:

- Crop residues: stalks and roots of cotton, maize, sorghum, straw etc.;
- Weeds from fields, field borders, fallow lands etc.;
- Twigs from trees and shrubs, leaves;
- Fodder residues left by the animals after feeding;
- Cow dung and dung of other animals (poultry, goat etc.);
- Biogas slurry;
- Kitchen waste;
- Agricultural processing by-products like sugarcane trash, press mud, husks, cotton dust etc.;
- Take care that no plastic gets into the compost!

Compost ingredients: stalks, weeds, twigs, cow dung, soil, rock phosphate, wood ash and water

Other material can be added to the heap in order to improve the quality of the compost:

- Cow dung mixed with water, or biogas slurry for sprinkling on each layer;
- Rock phosphate (quantity depending on soil condition);
- Wood ash or sugarcane ash (if available);
- Soil.

For ideal composting , the mixture should consist of approximately:

- One-third sturdy and bulky material (chopped twigs, stalks, roots of maize and sorghum etc.);
- One-third medium-to-fine material rich in carbon (straw, dry leaves, left-overs from fodder, dry weeds etc.)
- One-third fine material rich in nitrogen (cow dung, dung of other animals, green leaves, kitchen waste etc.)

Layers of different materials in a compost heap

Steps in preparing compost of good quality (see Figure 15):

1. Chop coarse material like stalks and twigs.
2. At the bottom of the heap or pit, put twigs and other coarse materials to allow for good drainage of excess water.
3. Pile up alternate layers of coarse material (carbon-rich, such as stalks, twigs, dry leaves) and material that decomposes quickly (nitrogen-rich, such as cow dung, green leaves, weeds).
4. In every alternate layer, spread some rock phosphate and wood ash.
5. Sprinkle the layers of coarse material with cow dung slurry or biogas slurry.
6. Add thin layers of soil to prevent loss of nitrogen, and to inoculate with soil organisms.
7. Cover the heap or pit with a 10-cm thick layer of straw or leaves in the initial stage, and with sacks or plastic sheet in the final stage to prevent potassium and nitrogen being leached out (during the rainy season) and drying of the heap (during the hot season).

8. The compost should be kept in moist condition, but not too wet. When we press a handful of compost the material should stick together, but no water should come out of it. If the compost gets too dry, sprinkle water over it.

9. Thoroughly mix the compost heap or pit by turning it after 2–3 weeks and again after another 1–2 months.

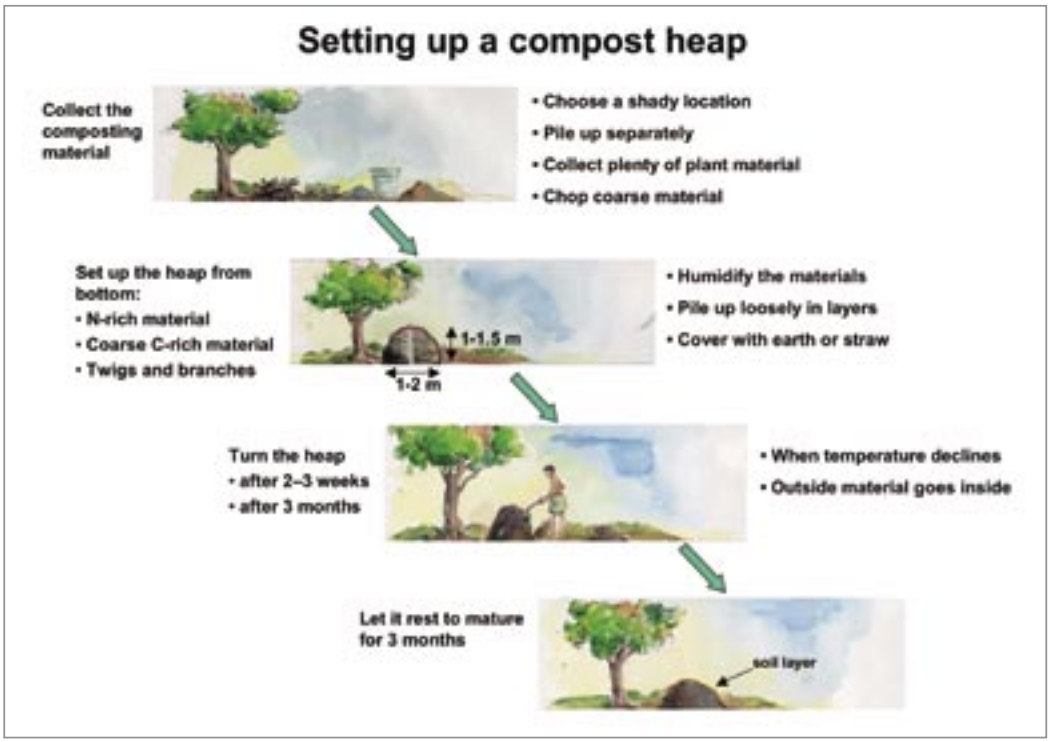


Figure 15: How to make good compost

Two to three weeks after building up the compost heap, it will have decreased to about half its original size. This is the right time to turn it for the first time. After another 1–2 months the compost heap should be turned a second time. Turning the compost helps to accelerate the process, and it is important to getting good quality manure. It ensures that material from the outside of the heap can decompose properly by being put into the centre.

Vermi-compost

Earthworms are very good for transforming dead plant material into excellent manure. In vermi-compost production, half-decomposed material and cow dung is continuously added to the heap or pit. Thus, there is no heating phase, which would kill the worms. The excreta of the worms have high nutrient levels and a growth-promoting effect on plants. During this process some experienced farmers prepare 'vermi-wash': water is sprinkled over the heap or pit, and the excess water is collected in a container beneath the heap. The vermi-wash can be used as a liquid fertilizer and plant tonic. It can even help plants to get rid of sucking pests like aphids.

Earth worms produce vermi-compost of high quality

Earthworms are very sensitive to changes in moisture and temperature. They need a continuous supply of food and protection from ants and termites. To remove the compost, let the top of the heap dry out so that the worms move to the deeper layers. Though vermi-compost is definitely high-quality organic manure, it requires more labour and continual care compared to ordinary composting methods.

4.5 Organic manures

Compost and farmyard manure are important to improve and maintain soil fertility and to provide a base supply of nutrients to the crop. However, during flowering and boll formation cotton has a particularly high nutrient demand which usually cannot be fully satisfied with the available amounts of compost and farmyard manure (FYM). Thus it is recommended that additional organic manures be provided during this phase, like de-oiled cakes (castor cake, neem cake), poultry manure, goat and sheep manure, bone meal, food processing wastes, press mud compost etc. However, note that manures from intensive rearing (e.g. chicken rearing) are not permitted according to most organic standards. An overview of the nutrient contents of important organic manures is given in Chapter 4.3, Figure 13.

Handling of cattle manure

The handling of the cattle manure during storage and application has enormous effects on its quality and value. In particular, large quantities of nitrogen can be lost, but other nutrients like phosphorus and potassium can also be leached out. Therefore, the following measures should be taken:

- At night, cattle should be kept in sheds or on places with sufficient bedding material such as straw of maize or sorghum, cotton stalks, dry leaves, or empty maize cobs to absorb the dung and urine.
- The manure should not become too wet or too dry. During storage, the manure heaps should be protected from rain and sun.
- It is best to use the manure for composting together with plant material. The heaps or pits should be turned once or twice during this process (see Chapter 4.4).
- After application in the field, the manure should be incorporated into the soil as soon as possible in order to prevent gaseous loss of nitrogen.

Adding bedding material in the cattle shed has the following benefits:

- Some of the bedding material serves as cattle feed;
- Nutrient losses are reduced;
- More organic manure can be produced;
- The quality of the organic manure is improved;
- Pests like stem borers in maize and sorghum stalks are destroyed.

Cattle grazing on fields after harvest

The transportation and application of farmyard manure or compost to the fields involves quite a lot of labour. An easy way to apply manure to a field is to allow cattle to graze on it after the harvesting is over. The cattle feed on the crop residues, and at the same time fertilize the field with their dung. This also helps to kill pests like stem borers and bollworms living in stalks and unpicked pods.

If the cattle are fed cottonseed oil cakes, an important part of the nutrients sold with the harvest can be turned back to the soil in form of manure. This is a good example of recycling, as some of the material exported from the farm with the seed cotton comes back to the farm, serves as fodder for the cows and oxen, and finally as a fertilizer for the next crop.

4.6 Natural mineral fertilizers

Fertilizers based on minerals of natural origin (rock phosphate, muriate of potash, gypsum, lime etc.) are permitted in organic farming to a limited extent, but they should be applied only when the soil is deficient in the respective nutrient (soil testing), and only in addition to organic manures.

Rock phosphate and ash should be added to the compost when setting up the heap or pit, so that the nutrients get absorbed by the organic matter. If rock phosphate is applied directly to the fields, a lot of the phosphorus gets lost as it becomes permanently fixed to the mineral particles in the soil.

Muriate of potash is a natural salt containing 60% potassium dioxide (K_2O). It should only be applied to the field when there is a deficiency of potassium in the soil (soil test). High application doses can harm the beneficial soil organisms.

Oil seed crops such as cotton, soybean and groundnut require a lot of sulphur, which in some fields can become deficient. In this situation, gypsum (which contains 17–20 % sulphur) can be applied to the field at the ratio of 50–100 kg per ha. Lime is mainly applied to acidic soils, which are rare in black cotton soil regions.

4.7 Liquid fertilizers

Part of the nutrients needed in the later growth stages of the crop can be provided by liquid manures like cow urine, biogas slurry, or fermented manures. They are sprinkled on the soil, applied with irrigation water, or diluted and sprayed as foliar fertilizer. Liquid manures have the advantage that the nutrients are available almost instantly. Thus they can be used to fine-tune nutrient supply. Table 5 provides some examples of liquid manures used by Indian organic cotton farmers.

'Amruth pani', a liquid fertilizer used in India

Liquid manure	Preparation	Application
Cow urine	Collect cow urine. Mix 1 l of cow urine with 15 l of water.	Spray the mixture on the cotton plants every two to three weeks during boll formation (40 litres per ha).
Slurry (from cow dung or biogas)	Take 10–15 kg slurry, tie it in a piece of cloth and suspend it in a drum of 100 litres water for 10–15 days, so that the water in the drum turns grey to blackish.	Mix slurry solution and water 1 : 1 in a spray pump and spray 1 month after sowing, every 2 to 3 weeks, until the first bolls open.
Vermi-wash	Collect vermi-wash from vermi-compost heaps. Mix one litre of vermi-wash with ten litres of water.	Spray the mixture at 2-to-3 week intervals during boll formation.
'Amruth pani'	Mix 250 g cow ghee (purified butter) + 10 kg cow dung + 500 g honey and dilute it in 200 l of water.	One-time application. Apply it 3 weeks after sowing, by drenching the soil near each plant.
'Jeev amruth'	Mix 15 kg cow dung + 15 l cow urine + 2 kg pulse flour (e.g. of gram or pigeon pea) + 250 g raw sugar ('jaggery') and dilute it in 200 l of water.	Two-time application. Apply 3 weeks after sowing, and again after 2 to 3 weeks.
'Mathka khad' (Clay pot dung)	Mix 15 kg cow dung + 15 l cow urine + 250 g black jaggery. Keep for 8 days in an earthen pot ('mathka'), then dilute in 200l of water.	Two-time application. Apply it 3 weeks after sowing, and again after 2 to 3 weeks.
'Charota' (*Cassia tora)*	Fill a drum with the charota weed. Fill it with water and cover the drum with a piece of cloth. Let it ferment for 1 week.	Dilute the liquid 1:1 with water and spray or sprinkle it on the cotton leaves.

Table 5: Liquid manure preparations used by organic cotton farmers in India

4.8 Bio-fertilizers

Bio-fertilizers contain beneficial micro-organisms that increase the availability of nutrients. Usually, organically managed soils that receive compost and other organic manures already contain most of these beneficial microbes. The application of bio-fertilizers can further increase their number and activity. When converting a farm from chemical to organic farming, the application of bio-fertilizers can help to revive the soil. To find out whether a specific bio-fertilizer has a real beneficial effect in the field, farmers can conduct a simple plot trial, treating one part of a field while leaving the remaining part untreated.

Some micro-organisms that are commercially sold as bio-fertilizers:

- Rhizobium is a bacterium hosted in the root nodules of pulses and other leguminous crops. It enables the crop to fix nitrogen from the air (see Figure 16).
- Azotobacter and Azospirillum can fix nitrogen in a similar manner as Rhizobium, but without being associated with the roots of a crop.
- Phosphorus Solubilizing Bacteria (PSB), like Pseudomonas, help to make phosphorus that is bound to the mineral particles in the soil available to the crop.
- Mycorrhiza (VAM) is a beneficial fungus associated with the roots of many plants. It helps them in taking up water and nutrients.

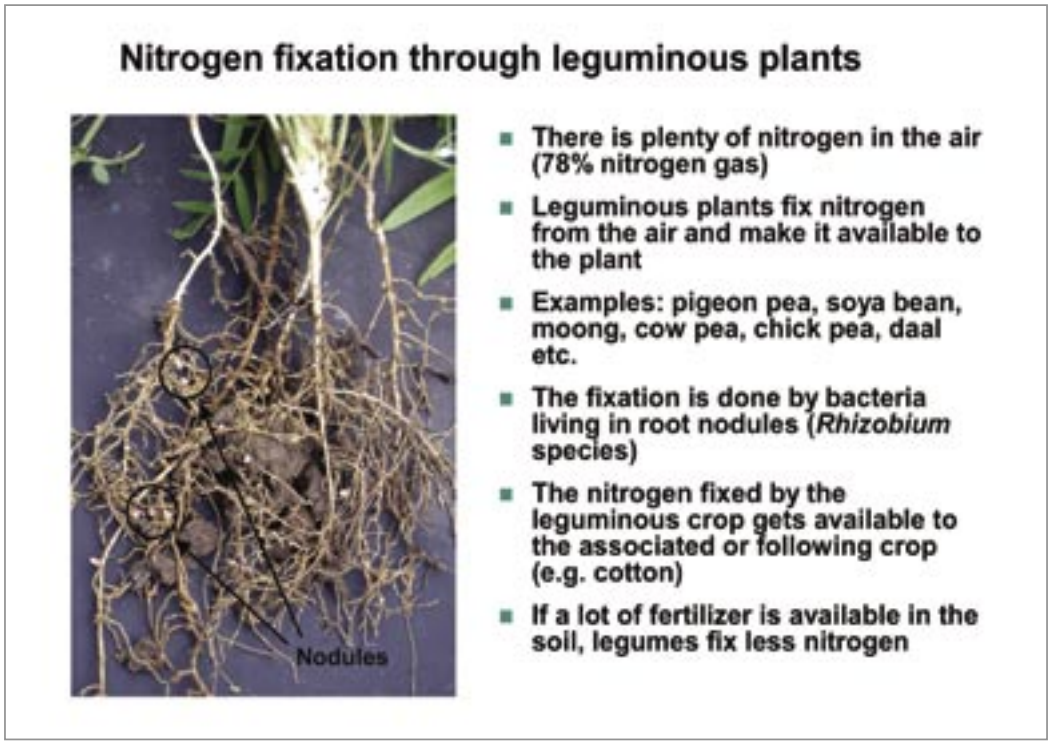


Figure 16: Nitrogen fixation by leguminous plants

4.9 Bio-dynamic preparations

Bio-dynamic preparations are uniquely fermented natural and organic substances that are used to steer humus-forming processes in the soil, vitalize plant growth and harmonize life on the holding with that of its immediate and more distant surroundings[1].

There are two groups of bio-dynamic preparations: spray preparations (BD 500 and 501) and compost preparations (see Table 6). BD 500 consists of cow manure and is sprayed on the soil prior to planting and sowing in order to stimulate healthy root growth. BD 501 consists of ground quartz and is sprayed onto growing plants in order to stabilize plant metabolism and enhance the qualitative development of the plant. During processing, these preparations are exposed to environmental influences by burying them in the soil inside a cow horn. Before being applied, very small amounts of these prepared substances are dissolved in water and stirred rigorously for one hour. In this way, the dynamic effects concentrated in the prepared manure and quartz meal are released into the rhythmically moved water and become effective for soil and plants.

Compost preparations consist of Nos. 502–507, all of which are made from plant substances and are applied to composts and other farm manure. The actual amount of the substances used is small. The preparations work 'dynamically', regulating and stimulating the process of growth. Preparations BD 502 to 506 are used to prepare a Compost Compound Preparation (CCP).

Name of the preparation	Purpose	Recommended application
BD 500	For soil management	125 g/ha. It is sprinkled on the moist soil before sowing, in the evening after 6.00 pm. Before application, the solution is stirred in water for 60 minutes both clockwise and anticlockwise.
BD 501	For crop management	5 g/ha. It is sprayed on the plant at the time of flowering, in the morning hours before sunrise. Before application, the solution is stirred in water for 60 minutes both clockwise and anticlockwise.
CCP	For soil management	125 g/ha. It is sprinkled on the moist soil before sowing, in the evening after 6.00 pm. Before application the solution is stirred in water for 60 minutes both clockwise and anticlockwise.

Table 6: Bio-dynamic preparations recommended for organic cotton production

[1] http://www.biodynamic.org.uk/FAQ.htm

5 Pest and Disease Management

5.1 Keeping your cotton crop healthy

A large number of pests feed on cotton: caterpillars (e.g. bollworms), beetles, bugs, aphids, jassids, whitefly, thrips, mites etc. The healthy cotton plant has some means of defence. It compensates for affected shoots and leaves through additional growth, and produces substances that deter insects from feeding on them (e.g. gossypol). In conventional farming, cotton is considered a crop that is highly sensitive to pest attack. Large quantities of chemical pesticides like organophosphates and pyrethroids are sprayed to keep them under control. This, however, eventually results in the pest problem increasing, as the natural enemies of many pests are decimated. First and foremost, organic cotton farming tries to prevent pests from even becoming a problem. The best way to do this is to establish a diverse and balanced farm ecosystem. If possible, varieties that are less susceptible to pest attack should be grown (hairy leaves, higher gossypol content). An overview of the preventive measures used to keep a cotton crop healthy is shown in Figure 17.

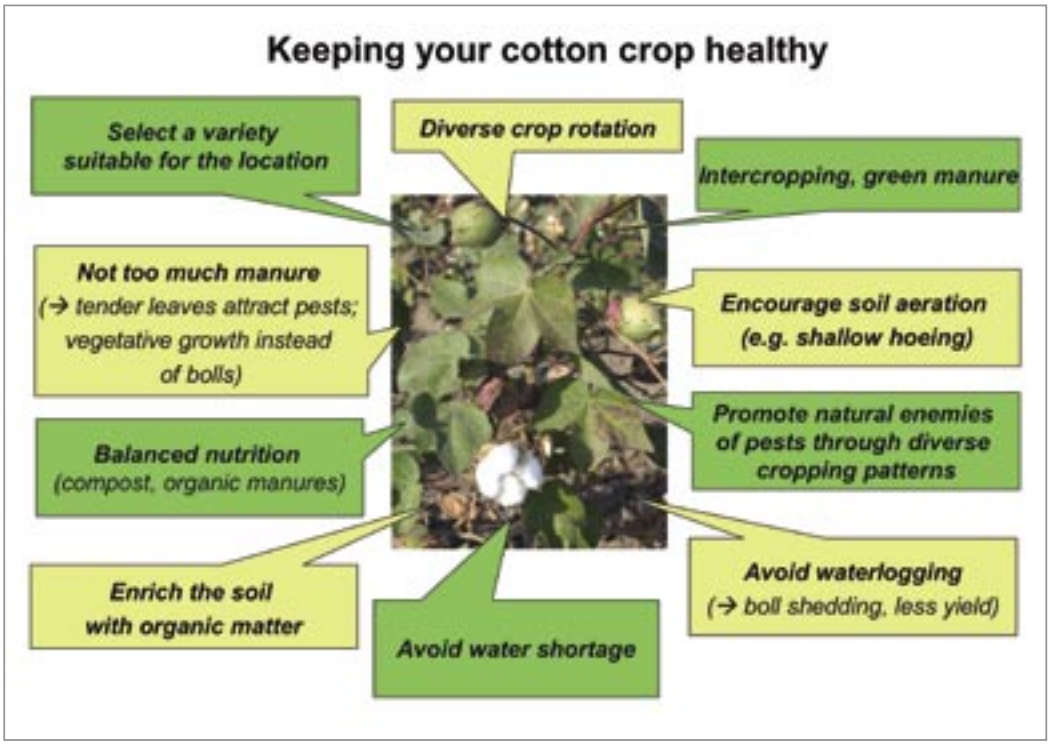


Figure 17: Measures used to keep a cotton crop healthy

Good soil fertility and balanced nutrition (through compost and other organic manures) support plant health. Farmers can optimize soil conditions through shallow soil cultivation and careful, timely irrigation. Diverse cropping systems and natural habitats enhance control of pest populations by means of natural enemies, like birds and beneficial insects. Intercrops like pulses and trap crops like sunflower or maize, distract pests from the cotton plants. Some pests multiply faster if the same crop is grown on the same field year after year. It is therefore important to rotate the different crops within the farm, not growing cotton in fields that had cotton in the previous season.

Sucking pests (aphids, whitefly and mites) and some other small pests (especially thrips and jassids) usually attack plants that are stressed. Stress can be caused by unbalanced nutrition (too many or too few nutrients, especially nitrogen). A farmer in central India concludes from his own observations, 'With high fertilizer application, the cotton leaves are getting soft and sweet.' Stress can also be caused by water shortage or waterlogging. Just like humans or animals, plants also have a kind of im-

mune system, which usually enables them to fight an attack of sucking pests. In stress situations, this immune system works less effectively. Therefore it is important to avoid stress situations for the plant. This primarily means:

- → Neither too little nor too much manure (no 'overfeeding').
- → Careful irrigation, avoiding dryness and waterlogging.
- → Shallow soil cultivation (intercultural operations) to encourage soil aeration and decomposition of organic matter.

With these preventive measures properly implemented, the pest problem in organic cotton is surprisingly minor. A certain level of pest attack will not significantly reduce the cotton yield. Below the 'economic threshold', the cost and effort to control the pest is higher than the damage it causes. In this regard, one should take into account both the cost of the pesticide and the labour for fetching water and for spraying. As long as pest infestations remain below the threshold levels, farmers should wait and see whether the natural enemies are able to control the pests, which would result in negligible damage to the crop.

5.2 Important cotton pests and their management

Knowing the major cotton pests helps farmers to find the right strategy for managing them. The following chapters provide a description of selected cotton pests relevant for organic cotton cultivation in the semi-arid regions of central India. The descriptions of the insects are adapted from PAN's Pest Management Information Service[1]. For details on the suggested preventive measures, please refer to Chapter 5.3. The natural pesticides marked with * are described in Chapter 5.4.2.

[1] See www.oisat.org

5.2.1 Bollworms and other caterpillars

American bollworm *(Heliothis (or Helicoverpa) armigera)*

Other names: Cotton bollworm; Hindi: Hari elli
Significance: Major pest in cotton
Damage: Attacks buds in square stage, flower and boll.
Natural enemies: Assassin bugs, predatory beetles, ants, lacewing larvae, spiders, parasitic wasps (e.g. Trichogramma), parasitic flies, praying mantis
Life cycle: The young larva feeds on tender leaves, buds, flowers, and later bores into the bolls. While feeding, its head and part of the body are inside the boll. They deposit faeces at the base of the entrance hole. Eggs are pinhead-size and yellowish-green in colour. They are found singly laid on the surface of the leaves. Larvae vary in colour from bright green, pink and brown, to black, with lighter undersides. Alternating light and dark bands run lengthwise along their bodies, the heads are yellow and the legs are almost black. Mature larvae drop to the ground to burrow into the soil to pupate. Pupae are yellowish-green and turn brown as they mature. Adult moths are grey to brown in colour and have dark spots on the front wings. They are active at night and hide in vegetation during the day. The total development period from egg to adult is 34–45 days.
Prevention:
- Crop rotation
- Trap crops: sunflower, okra, castor
- Hand-picking of infested buds and bolls
- Encourage natural enemies (ladybird beetles, lacewings, spiders, hoverfly etc.)
- Removing cotton stalks
- Cattle grazing after picking is over
- Pheromone traps, light traps

Direct control:
- Bt spray, NPV spray
- Neem spray*
- Botanical preparations (ginger, gliricidia, marigold, 'Top Ten'* etc.)
- Buttermilk spray*
- Trichogramma cards
- Garlic-chilli-onion repellent*
- Hand-picking of bollworm

Pink bollworm *(Pectinophora gossypiella)*

Other names: Hindi: Gulabi elli
Significance: Important pest in late-season cotton
Damage: Attacks squares and bolls. The lint gets cut and stained resulting in yield and quality losses. Damaged bolls are vulnerable to boll rot fungal infection.
Natural enemies: Assassin bugs, predatory beetles, ants, lacewing larvae, spiders, parasitic wasps (e.g. Trichogramma), parasitic flies, praying mantis
Life cycle: Larvae burrow into bolls through the lint to feed on seeds. They do NOT deposit faeces at the base of the entrance hole. Eggs are very small, slightly elongated, and laid at the bottom of the green bolls. Young larvae are tiny, white caterpillars with dark brown heads. When mature, they are about 12 mm long and have wide transverse pink bands on the back. Pink bollworm adults are small, greyish-brown moths.
Prevention:
- Crop rotation
- Trap crops: sunflower, okra, castor
- Hand-picking of damaged capsules
- Encourage natural enemies
- Removing cotton stalks
- Cattle grazing after picking is over
- Pheromone traps, light traps

Direct control:
- Bt spray, NPV spray
- Neem spray*
- Botanical preparations (ginger, gliricidia, marigold, 'Top Ten'* etc.)
- Buttermilk spray*
- Trichogramma cards
- Garlic-chilli-onion repellent*
- Hand-picking of bollworm

Spotted bollworm *(Earias vittella)* and Spiny bollworm *(Earias insulana)*

Other names: Hindi: Chitkabri elli (spotted bollworm)
Significance: Usually not a major problem in organic fields.
Damage: Wilting of shoots, shedding of buds. Damaged bolls do not open well.
Natural enemies: Assassin bugs, predatory beetles, ants, lacewing larvae, spiders, parasitic wasps (e.g. *Trichogramma)*, parasitic flies, praying mantis
Life cycle: Spotted bollworm larvae bore into the shoot of the cotton plant and also bore holes into the bolls. Young bolls have small holes with excreta inside. Eggs are small, round and light blue-green in colour. The larvae are spindle-shaped, greyish-brown or greenish in colour. The pupa is enclosed in a cocoon shaped like an inverted boat. The forewings of the adult moth are silvery-green to straw yellow with three transverse lines of a darker shade.
Prevention:
- Crop rotation
- Trap crops: sunflower, okra, castor
- Hand-picking of damaged capsules
- Encourage natural enemies
- Removing cotton stalks
- Cattle grazing after picking is over
- Pheromone traps, light traps

Direct control:
- Bt-spray, NPV spray
- Neem spray*
- Botanical preparations (ginger, gliricidia, marigold, 'Top Ten'* etc.)
- Buttermilk spray*
- *Trichogramma* cards
- Garlic-chilli-onion repellent*
- Hand-picking of bollworm

Cutworm *(Agrotis spp.)*

Other names: Hindi: Podha katne wala keeda
Significance: In some fields an important pest.
Damage: Seedlings are often cut off at ground level.
Natural enemies: Parasitic wasps, ground beetle, birds, lacewing, praying mantis, weaver ant
Life cycle: Cutworm larvae can be found in the soil (up to a depth of about 5 cm) near the plant host. They always curl up when disturbed. Cutworms feed only at night. Eggs are tiny, pearl-white, round, and have a ridged surface. The full-grown larva is brown or brownish-black with a tinge of orange. The pupa is black or brown in colour. The adult has dark brown forewings with distinctive black spots and white and yellow wavy stripes.
Prevention:
- Early soil cultivation
- Apply neem cake or de-oiled castor cake before sowing
- Remove weeds in and around fields
- Encourage birds (spread turmeric-coloured rice, bird perches, trees, hedges)
- Promote natural enemies (spiders, ground beetles, lacewing, praying mantis)
- Seed treatment with asafetida
- Intercrop with coriander (repellent)

Direct control:
- *Pyrethrum* spray*, *Derris* or thyme spray
- Cutworm baits with *Bacillus thuringiensis*
- Hand picking at night
- Bt spray at night
- Spray solution of asafetida around seedlings
- Botanical sprays (basil, chilli, neem*, garlic)
- Giant milkweed* (*Calotropis procera,* Hindi: akaw) applied through the irrigation channel

5.2.2 Sucking pests

Aphids *(Aphis gossypii and others)*

Other names: Cotton aphid; Hindi: Maho
Significance: Important pest in fields with low population of natural enemies, high manure application, or water stress.
Damage: Heavy infestation causes crinkling and cupping of leaves, defoliation, square and boll shedding, and stunted growth. If the infestation is not too high, the plant can compensate for the damage. Honeydew excretion causes sticky cotton lint and thus problems with spinning.
Natural enemies: Ladybird beetles, ground beetles, lacewings, pirate bugs, parasitic wasps, hoverfly, spiders etc.
Life cycle: The mouths of the aphids are like tiny straws, with which they pierce the plant tissues to feed on plant sap. Aphids produce large amounts of a sugary liquid waste called honeydew. A fungus, called sooty mold, grows on this honeydew, turning leaves and branches black. The eggs are very tiny, shiny black, and are found in the crevices of bud, stems, and bark of the plant. Winged adults are produced only when it is necessary for the colony to migrate.
Prevention:
- Intercrop of moong, cow pea etc. (trap crops)
- Avoid heavy manure application
- Avoid waterlogging and water shortage
- Promote natural enemies (ladybird beetles, lacewing, hoverfly, damsel bug, ground beetle, spiders etc.) by providing habitat and growing flowering plants

Direct control:
- Neem spray*
- Botanical preparations (chilli, sweet flag, turmeric, tomato leaves, ginger, gliricidia, marigold, 'Top Ten'* etc.)
- Soft soap spray*
- Cow urine spray
- Flour spray*
- Garlic-chilli-onion repellent*
- Yellow sticky traps

Whitefly *(Bemisia tabaci and others)*

Other names: Hindi: Safed makhi
Significance: Becomes an important pest only when nitrogen level is high.
Damage: Attacks vegetative parts (sucking).
Natural enemies: Parasitic wasps, lacewing, ladybird beetles, spiders. Predators play a role when densities of whitefly are low, but cannot cope with high populations.
Life cycle: Whiteflies pierce and suck the sap in the leaves. This causes weakening and early wilting of the plant resulting in reduced plant growth. Their feeding may also cause yellowing, drying, and premature dropping of leaves that result in plant death. Like aphids, whitefly produces honeydews on which the black fungus sooty moulds grow. Whitefly is the most important carrier of plant viruses that cause diseases. Tiny white or brownish eggs are laid on the underside of leaves. Adults are about 1mm long with two pairs of white wings and light yellow bodies.
Prevention:
- Encourage natural enemies (lacewing, lady bird beetles, spiders)
- Ensure balanced crop nutrition
- Avoid heavy manure application
- Avoid waterlogging and water shortage
- Trap crop *Nicotiana* (flowering tobacco)

Direct control:
- Neem spray*
- Yellow sticky traps
- Botanical sprays (garlic, chilli, ginger, gliricidia, onion, marigold etc.)
- Flour spray*
- Soft soap spray*
- *Beauvaria bassiana* spray
- Spray of *Lantana* leaf extract*

Cotton stainer *(Dysdercus spp.)*

Other names: Red cotton bug, cotton stainer bug; Hindi: Lal keeda
Significance: Usually not a major problem in organic fields.
Damage: Sucks sap from flowers, buds, and bolls. If infestation is high the bolls open insufficiently and the lint quality is reduced (stains due to fungus infection).
Natural enemies: Parasitic wasps, spiders, assassin bugs
Life cycle: Cotton stainers feed both on immature and mature seeds. When sucking, they transmit fungus on the immature lint and seed, which later stain the lint with typical yellow colour, hence the name 'cotton stainers'. Heavy infestations on the seeds affect the crop mass, oil content, germination capacity of the seed and marketability of the crop. Eggs are laid in the soil or under plant debris. Nymphs look similar to their adult counterparts but without wings; they can only attack seeds in open bolls. The adult cotton stainers are true bugs with piercing and sucking mouthparts; they can even suck on seeds in closed bolls. Their colours vary from bright red to yellow to orange, depending on the species.
Prevention:
- Frequent soil cultivation to destroy the eggs (also along field borders)
- Encourage birds (spread turmeric-coloured rice, bird perches, trees, hedges) and spiders
- Avoid stand-over of cotton
- Clean the cotton seed stores

Direct control:
- Pyrethrum spray*
- Botanical sprays (Neem*, custard apple, garlic bulb, sweet flag, sweet basil, Derris species)
- Grazing of chickens
- Trapping with cotton seeds or baobab seeds and killing them on the spot

Spider mites *(Tetranychus spp.)*

Other names: Hindi: Makadi
Significance: Usually a minor pest in organic cotton fields. Mainly affects water-stressed plants
Damage: Sucks sap. Infested leaves may turn yellow, dry up, and drop in a few weeks.
Natural enemies: Lacewing, pirate bugs, predatory mites, rove beetles, predatory thrips
Life cycle: Generally, mites feed on the undersides of leaves. They use their sucking mouthparts to remove plant saps. Heavy infestation will result in a fine, cobwebby appearance on the leaves. The adult is very tiny; it looks like a moving dot. Note: Mites are not insects; they are related to spiders.
Prevention:
- Avoid water stress
- Encourage natural enemies

Direct control:
- Buttermilk spray*
- Coriander seed spray*
- Flour spray*
- Soft soap spray*
- Milk spray (diluted milk with water 1:10)
- Sulfur spray

5.2.3 Other pests

Cotton jassid *(Amrasca devastans, A. biguttula)*

Other names: Leafhopper; Hindi: Hara machar
Significance: Significant damage only if in very high numbers.
Damage: Attacks vegetative parts (sucking).
Natural enemies: Ladybird beetles, lacewings. Jassids are an important food source for natural enemies that will contribute to the suppression of bollworms later in the season.
Life cycle: Jassids feed on the upper surfaces of leaves, resulting in small white circles. Low levels of damage have little if any effect on the plant's growth. Jassid damage typically occurs from the lower leaves and progressively moves up to upper leaves.
Prevention:
- Intercrop of moong, cow pea etc. (trap crops)
- Avoid heavy manure application
- Avoid waterlogging and water shortage
- Promote natural enemies (ladybird beetles, lacewing) by providing habitat and by growing flowering plants

Direct control:
- Neem spray*
- Botanical preparations (e.g. 'Top Ten'*)

Thrips *(Thripidae, various spp.)*

Other names: Hindi: Teliya
Significance: Important pest in some fields.
Damage: Tiny scars on leaves and fruit, stunted growth. Damaged leaves may become papery and distorted.
Natural enemies: Lacewing, pirate bugs
Life cycle: Thrips feed by rasping the surface of the leaves and sucking up the released plant sap. The egg is very tiny and is impossible to see. The nymph is pale yellow in colour and does not have wings. The pupa has short wing buds that are not functional. The adult has a small, slender body, yellowish to dark brown in colour, with well-pronounced antennae. It can exist in two forms, winged or wingless.
Prevention:
- Balanced plant nutrition, not too much nitrogen
- Avoid water stress (shortage as well as waterlogging
- Trap crops (e.g. sunflower)
- Encourage natural enemies (lacewing, minute pirate bug)

Direct control:
- Spray of wood ash solution
- Garlic extract spray
- Neem spray*
- Soft soap spray*
- Flour spray*
- *Beauvaria bassiana* spray

Grasshoppers *(Locusta spp.; Schistocerca gragaria)*

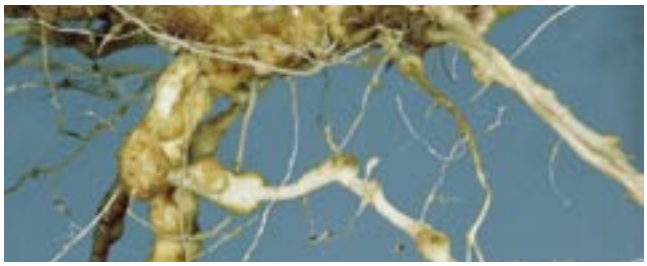
Other names: Locust; Hindi: Tidda, Kasara
Significance: Usually minor pests in organic cotton.
Damage: Especially affects young plants (leaves and stems).
Prevention:
- Soil cultivation to destroy eggs
- Trap crops
- Legume intercrop
- Frequent irrigation

Direct control:
- *Beauvaria bassiana* spray
- Pyrethrum spray *
- Put 10 g asafetida in a muslin cloth and place it in the irrigation channel.

Termites *(various species)*

Other names: Hindi: Demak
Significance: Usually a minor pest in organic cotton.
Damage: Attacking the root system.
Prevention:
- Crop rotation
- Soil cultivation
- Neem cake application

Direct control:
- Apply crushed leaves of giant milkweed (*Calotropis procera*) on the soil
- Salt (attention: risk of soil salinity)
- Flood irrigation



Root knot nematodes *(Meloidogyne spp.)*

Other names: Root knot eelworm; Hindi: Sutra krami
Significance: Usually a minor pest.
Damage: Feeds within the root system (forming knots), affecting nutrient uptake and plant growth, especially of seedlings. Secondary infection of fungus and bacteria.
Prevention:
- Crop rotation and intercrops
- Fallowing
- Intercrop of or mulching with marigold
- Soil cultivation, deep ploughing
- Remove weeds
- Application of well-decomposed compost

Direct control:
- Application of neem cake to the soil
- Botanical sprays: garlic extract, basil extract, fermented marigold extract

Photo sources

American bollworm	*Paolo Mazzei*
Pink bollworm	*Ministério da Agricultura, Brazil / Mississippi State University*
Spotted / Spiny bollworm	*Frank Eyhorn / Cotton SA*
Cutworm	*Clemson University*
Aphids	*Roland Smith / Phillip Roberts*
Whitefly	*North Carolina IPM Insectcorner*
Cotton stainer	*Cotton SA / Frank Eyhorn*
Spider mites	*Mississippi State University / Clemson University*
Cotton jassid	*P. Room / Frank Eyhorn*
Thrips	*North Carolina IPM Insectcorner / Frank Eyhorn*
Grasshoppers	*James Smith*
Termites	*Gerald J. Lenhard / Scott Bauer*
Nematodes	*Clemson University*

5.3 Preventing pests from becoming a problem

As mentioned in Chapter 5.1, the first step in organic pest management is to support healthy growth of the cotton crop. The second step is to prevent pest populations from building up and becoming a problem. The preventive measures described below can help in this.

5.3.1 Promotion of natural enemies

In a diverse field not treated with pesticides, natural enemies help the farmer keep pest attacks within tolerable levels. Natural enemy populations can be increased in the field by providing suitable habitats: intercropping of flowering plants, applying mulch, setting up bird perches etc. Important natural enemies are ladybird beetles, spiders, lacewings, parasitic wasps, ants bugs, etc. (Figure 18).

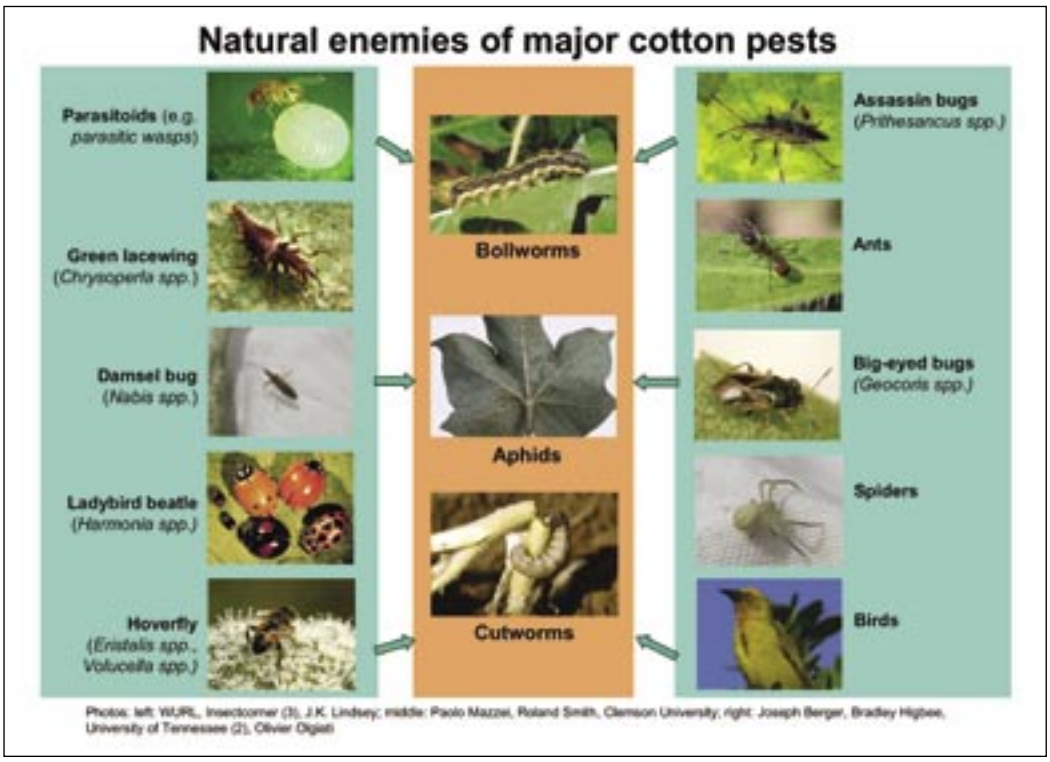


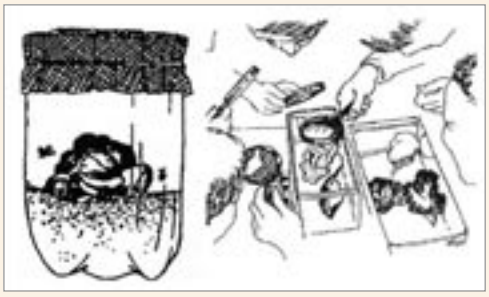
Figure 18: Important natural enemies of some major cotton pests

Generally speaking, the more plants growing in a field, the higher the number of different natural enemies. Intercropping of pulses or other crops in cotton is therefore an effective preventive pest-management strategy. A good example is sunflower: Studies in Tanzania have shown that cotton plots intercropped with sunflower have up to ten times more beneficial ants. These ants feed on eggs and caterpillars of the American bollworm and can thus reduce the pest population to a great degree.

To attract beneficial insects to the field, gaps in the rows of cotton seedlings can be re-sown with flowering plants like sesame, sunflower and marigold. Leaving a strip of natural vegetation around the cotton or planting rows of trees or hedges along the boundaries provides a habitat for birds and other natural enemies of insect pests. This can be useful against pests like bollworms, aphids, whitefly and cotton stainers.

Insect zoo – who eat's whom?

To see how natural enemies work, collect different varieties of pests (bollworms, aphids, jassids) and their natural enemies (ladybird beetles, lace wings, assassin bugs, spiders) from a cotton field and put them in a glass jar, together with some twigs of cotton (stuck in wet cotton wads to keep them fresh). Observe over 2–3 days which insects are eaten by others, and which survive.



Insect zoo with pests and predators (Source: CAB International)

5.3.2 Trap crops

Sunflowers serve as trap crops and attract beneficial insects

Some cotton pests prefer crops like maize, sorghum, sunflower, pigeon pea, hibiscus and okra (ladyfinger) to cotton. These crops can be grown along with cotton as a trap crop, so that the cotton crop is spared. Experience from Tanzania shows that sunflower is an efficient trap crop for the American bollworm. It is even reported that on sunflower plants bollworms attack each other (cannibalism). Sunflower can be intercropped in cotton in rows every 10 to 15 meters. The sunflower is sown together or shortly after the cotton so that it starts flowering when the American bollworm attack begins. The flowering plant also attracts a number of beneficial insects and birds. The sunflower seeds provide additional income to the farmers, and the plants can be used as fodder.

Using sunflower as a trap crop for American bollworm has the following advantages compared to maize and sorghum:

- Attractive to the moths for a long period, especially varieties which produce several flowers;
- Encourages cannibalism among the bollworms;
- Attracts beneficial insects when flowering;
- The productivity of the sunflower is hardly affected by the bollworms.

Maize, sorghum and okra can also be used as trap crops, but there is some question as to whether they might not actually contribute to increased bollworm populations. Some Indian farmers report that they had good success with intercropping marigold as a trap crop for American bollworm. Marigold also attracts beneficial insects and helps to control nematodes.

5.3.3 Pheromones

Some moths use pheromones to communicate for mating. The male moths can 'smell' the pheromones emitted by females over large distances and thus are able to find them. Synthetic imitations of these pheromones are used in dispensers that are spread in the field in large numbers to disturb the insects' communication so that egg laying can be prevented. Pheromones are non-toxic and do not affect beneficial insects. Each insect species has different pheromones. Pheromone dispensers against pink bollworm and other bollworms are commercially available.

A pheromone trap for pink bollworm

5.3.4 Removing crop residues

Some cotton pests can survive in cotton stalks and seeds. Therefore it is important that cotton be uprooted after the end of the harvest, and removed from the field or buried by ploughing the field. Cattle grazing after the picking is over destroys the remaining pests in the unpicked bolls and leaves.

5.4 Direct pest management methods

Only when the first two steps of organic pest management – strengthening the crop and preventive measures – are not sufficient to keep pest populations below the economic threshold, direct control methods should be used. The methods described below are recommended in organic cotton production.

5.4.1 Biological control

Biological control uses living organisms or germs to affect the pests. One prominent example is the use of 'Trichocards' containing thousands of eggs of the parasitic wasp T*richogramma*, a predator of the American bollworm. The wasps lay their eggs into the eggs of bollworms and eventually cause them to die. Similarly, the eggs of green lacewing can be used against aphids and other pests. However, timing of orders, delivery and application are crucial. In Uganda, organic cotton farmers rear and promote ants of the Acantholepis family for controlling a number of pests.

Other bio-control methods involve microbes and viruses attacking the pests:

- Bt spray: Bt (*Bacillus thuringensis*) is a microbe that is effective against leaf feeding caterpillars. Therefore, it is only effective against bollworm in its early stage, before it enters the bolls. Nighttime spraying increases exposure to Bt, since sunlight breaks it down. Bt preparations are commercially available in India under brand names like Dipel, Biolep, Halt-Bt etc.
- NPV: This virus (nuclear polyhedrosis virus) attacks American bollworm and causes its death. To multiply the NPV preparation locally, spray NPV on a cotton field, collect caterpillars affected by NPV, grind them and dilute with water.
- *Beauvaria bassiana:* This insect-disease–causing fungus affects cutworms and budworms. It works best during periods of high humidity. Preparations are commercially available.

Most bio-control products are only effective against a specific pest – for different pests, different species or strains are used.

5.4.2 Natural pesticides

There are a number of natural pesticides that can be used in organic cotton cultivation, and organic farmers continuously try out new ones. But little scientific research has been done on the efficiency of most of the locally prepared formulations. Therefore, farmers are encouraged to do their own experiments and trials to find out which natural pesticides are most suitable for their farms. Below we list some of the natural pesticides used by farmers in India and Africa.

Caution: Many natural pesticides also affect beneficial insect populations and thus should be used only when really necessary. Some plant extracts are also toxic to humans and animals and should be used with care.

Some plants used as botanical pesticides or repellents (marigold, chilli, giant milkweed, custard apple)

Neem spray *(Azadirachta indica)*

Ingredients: Neem kernel extract, containing azadirachtin
Target pests: Sucking pests, jassids, bollworms, thrips
Preparation: Farm-made: Pound 30 g neem kernels (that is the seed from which the seed coat has been removed) and mix in 1 litre of water. Leave overnight. The next morning, filter the solution through a fine cloth and use immediately for spraying. It should not be further diluted.
Commercial formulations like EcoNeem, NeemCare etc.: as per package description.
Remarks: Sprays from neem seed or leaf extract do not kill the insects directly but reduce their normal activities like feeding, moving and multiplying. Therefore the effect is not noticeable until after few days. The main advantage of using neem is that it is not harmful to most beneficial insects. To a limited extent, neem's active substance is also absorbed by the plants and thus affects the pest when they feed on the crop.
In India, commercial formulations of neem-based pesticides have an azadirachtin content of between 0.03 to 1.5%. When using a product with a low content, the application rate must be higher to achieve the same effect. High doses of neem oil, however, may have a negative impact on the crop. Therefore it is advisable to use a formulation with a high azadirachtin content made by a manufacturer that has strict quality control.

De-oiled neem cake *(Azadirachta indica)*

Ingredients: De-oiled cake of neem seeds
Target pests: Nematodes, cutworms
Preparation: Crushing, oil extraction
Remarks: Applied as manure to each cotton plant.

Pyrethrum

Ingredients: Powdered flower heads or liquid extracts of a daisy-like chrysanthemum (commercially available).
Target pests: Red cotton bug, cutworms, grasshoppers
Preparation: Commercial preparations: as per package instructions.
Remarks: Pyrethrum causes immediate paralysis or death to most insects, but also affects beneficial insects. The active substance in the pyrethrum extract is quickly destroyed when exposed to sunlight.

Botanical mixtures

Ingredients: Combinations of extracts from some of the following plants (*scientific* and Hindi names given in brackets): castor (*Ricinus communis,* arandi), thorn apple (*Datura metel*, datura), custard apple (*Annona squamosa*, sitaphal), neem (*Azadirachta indica*, kaduneem), lantana (*Lantana camara*, bara masi), sweet potato leaves (*Ipomea batata*, tameshar besaram) etc.
Target pests: Various insects that feed on the cotton plant. Especially effective against sucking pests.
Preparation: Crushing, adding to a container with water, fermenting for approx. one week. Or distillation.
Remarks: Some of the plant extracts act as a repellent (e.g. garlic, chilli), while others have a toxic effect on insects.

‚Top Ten'

Ingredients: Neem leaves (*Azadirachta indica,* kaduneem), (0.5 kg); leaves of the following plants (each approx. 200 g): custard apple (*Annona squamosa*, sitaphal), papaya (*Carica papaya*, papita), giant milkweed (*Calotropis procera*, ruimandar), karum tree (*Pongamia pinnata*, waikaranj), oleander (*Nerium indicum*, kannher); chaste tree (*Vitex negundo*, nirgudi), snakeroot (*Aristolochia bracteata*, tantani), Indian tinospora (*Tinospora cordifolia*, gulvel), castor (*Ricinus communis*, arandi); 0.5 kg cow dung, 0.5 litres cow urine; 20 litres water.
Target pests: All cotton pests, especially bollworms, jassids, aphids, whitefly
Preparation: Keep the solution for 30 days for fermentation. Use 6 litres stock solution diluted in 500 l water for one ha.
Remarks: Due to the combination of some very toxic plants, this preparation is likely to have a strong impact on beneficial insects, too, and could even harm those who apply it. Therefore, it should be used with care.

Garlic-onion-chilli repellent

Ingredients: 2.5 kg garlic, 2.5 kg onion, 7.5 kg green chilli. 10 litres water.
Target pests: Bollworm, sucking pests
Preparation: Crush the ingredients and mix in 10 litres water to prepare a stock solution. Add 500 litres of water to this stock solution for spraying 1 ha.
Remarks: This repellent does not kill the insects but deters pests from the crop.

Giant milkweed *(Calotropis procera)*

Ingredients: Leaves and upper part of the giant milkweed (*Calotropis procera,* Hindi: akaw)
Target pests: Termites, cutworms
Preparation: Crush 2 kg of fresh plants, put them into a jute sack and place it into the irrigation channel when irrigating the cotton field.
Remarks: Repelling effect.

Lantana leaf extract *(Lantana camara)*

Ingredients: 2.5 litres of lantana leaf extract, diluted in 500 l water, for 1 ha
Target pests: Whitefly
Preparation: Crush the lantana leaves, add water, prepare an extract, dilute in water.
Remarks: Effect not ensured.

Coriander seed spray *(Coriandrum sativum)*

Ingredients: 200g coriander seeds, water
Target pests: Spider mites
Preparation: Boil the crushed coriander seeds for 10 minutes in 1 litre water. Dilute with 2 litres of water. Spray early in the morning.
Remarks: Repelling effect.

Buttermilk spray

Ingredients: 300 ml buttermilk, in 15 litres water
Target pests: Bollworms and other caterpillars; spider mites (also in the chilli crop).
Preparation: Allow the buttermilk to ferment for 3 to 4 weeks. Ideally keep it in a bottle in a straw heap so that the temperature is kept constant. Mix 300 ml of the fermented buttermilk in 15 litres of water.
Remarks: Mechanism not fully clear.

Flour spray

Ingredients: 2 cups of fine white flour; half cup of soap (sticker), water
Target pests: Aphids, spider mites, thrips, whitefly
Preparation: Stir the flour into the water. Add the soap and stir again before spraying.

Soft soap spray

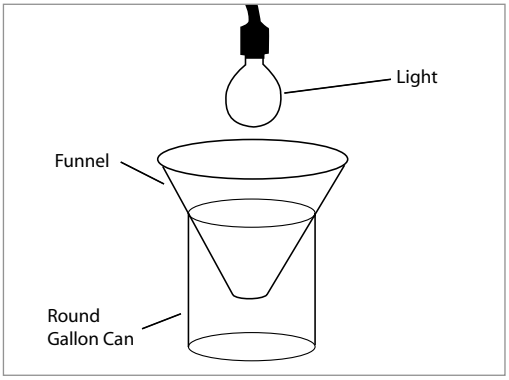
Ingredients: Soft soap, water
Target pests: Aphids, jassids, whitefly, thrips
Preparation: Stir 15 g soft soap into 15 litres water.
Remarks: Soft soap sprays also affect beneficial insects and should only be used as the last resort.

5.4.3 Mass trapping

Traps can help reduce the population of certain pests, especially of moths (the adults of caterpillars). If used at an early stage, they can prevent mass multiplication. There are several types of traps:

- Light traps attract night-active flying pest insects (6–10 p.m.).
- Sticky traps of yellow colour.
- Pheromone traps attract the male moths that get stuck in the trap.

Traps are especially useful for monitoring pest populations.



Light trap (for night-active flying pest insects)

5.5 Monitoring pests

A key to successful pest management in cotton is a careful and continuous monitoring of pest levels in the cotton fields during the critical growth period (approx. 4 weeks after sowing up to the second harvest). Monitoring helps to determine when a pest population reaches the economic threshold and, therefore, when direct control measures need to be implemented. For monitoring, farmers randomly inspect a number of cotton plants while crossing the field in diagonals (see the picture from Tanzania).

Table 7 lists economic threshold levels established for IPM in conventional farming. They should be cross-checked with local advisory services or agricultural research stations to adapt them to local conditions.

Scouting for pests while crossing the field in diagonals (Source: GTZ IPM-project Shinyanga)

Pest	Economic threshold level
American bollworm *(Helicoverpa)*	1 larva per 5 plants, or 5–10% damage to bolls, or 15 flared squares with a hole on 30 plants
Pink bollworm *(Pectinophora)*	5% rosetted flowers
Spotted bollworm *(Earias)*	1 larva per 5 plants, or 5–10% damaged shoots or bolls
Cotton leafworm, tobacco caterpillars *(Spodoptera)*	2 larvae/10 plants or 3 skeletonized leaves with young larvae
Cotton stainer	2–3 individuals per leaf
Aphids	20% infested plants
Jassids	5–10 insects per plant
Thrips	5–10 nymphs/adults per leaf
Mites	5% infested plants
Whitefly	5% infested plants

Sources: Aventis and Avena; AGREVO; Stoll 2000

Table 7: Threshold levels of important cotton pests

For monitoring American bollworm populations, farmers in some African cotton projects use simple pegboards for scouting (Figure 19). They check 30 randomly selected cotton plants for flared square buds (rosette shape, infested by bollworms), moving the pegs in the board one step ahead for every inspected plant (upper line) and for every infested bud (lower line). If 15 flared square buds are found, the economic threshold is reached and spraying of neem-based formulations is recommended.

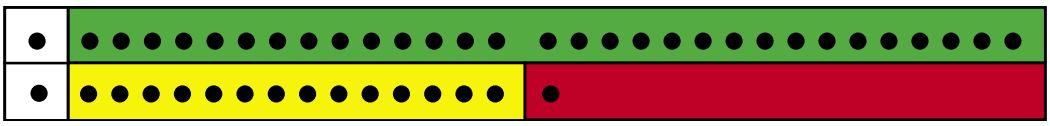


Figure 19: Design of a peg board used for monitoring American bollworm populations

Steps in scouting for American bollworm:

- Start scouting 8 weeks after germination until the bolls open. It is a continuous process, done weekly.
- Checking is done in 2 diagonals of the cotton field, starting 5 steps inside the field from one corner.
- Check the cotton plant next to you, counting all newly opened flared squares (those with changed shape due to bollworm attack; not dropped squares) on this plant. Move the marker forward in the right part 1 hole per flared square.
- After finishing with this plant, move the marker in the left part 1 hole.
- Continue with another plant after every 5–10 steps up to the end of the diagonal (then 15 plants should be examined), moving the markers forward accordingly. Then start with the second diagonal from the other corner.
- Continue the procedure until 30 plants have been inspected; or 15 flared squares are found. When the stick for the flared squares reaches the red zone, the economic threshold is reached and spraying of a natural pesticide is recommended for the same day.
- Don't spray when there are less than 15 flared squares.

5.6 Seed treatment

Conventionally produced cotton seeds are frequently treated with chemicals prohibited in organic farming. Thus, organic cotton farmers need to ensure that they get untreated seeds (no GMO varieties!), if possible from organic multiplication. Organic cotton projects can facilitate the supply of suitable untreated seed material or arrange for their own seed multiplication programme.

Fertile soil and balanced crop rotation should largely prevent damage by pests and diseases caused before and during germination. Where these preventive measures are not sufficient, a number of alternative treatments of seeds can be used. Some suggested methods are shown in Table 8.

Seed Treatment	Effect	Remarks
Dipping in cow urine	Protects seeds from cutworm and wireworms. Supports good germination and development of the initial roots.	As spoilt seeds float up in the cow urine, it also helps to remove damaged seeds.
Coating with cow dung and termite soil (or clay)	Protects seeds from cutworm and wireworms. Supports good germination and development of the initial roots.	Mix cow dung, termite soil and some water. Rub the seeds in this mud until small balls form, each containing one seed.
Treatment with asafetida (Hindi: hing)	Protects seeds and seedlings from cutworms.	Mix 5 g asafetida in 200 ml water and sprinkle on 1 kg cottonseeds. Mix well.
Trichoderma or *Bacillus subtilis*	Prevents root diseases.	Suspensions of these beneficial micro-organisms are commercially available.
Treatment with Azotobacter and phosphorus solubilizing bacteria (PSB)	Enhances the uptake of nitrogen and phosphorus.	Suspensions of these beneficial micro-organisms are commercially available.
Bio-dynamic preparations BD 500 and CCP	Supports germination.	See Chapter 4.9

Table 8: Methods suggested for preventive treatment of cottonseeds

5.7 Diseases

In most of the semi-arid tropical regions, diseases are not a big problem in organic cotton. Diseases that occasionally occur and methods for preventing or treating them are given below:

- Bacterial blight: Leaves show oily black spots; stems turn black; defoliation and boll shedding if infestation is high. Can be prevented by using resistant varieties. Treatment: cow urine spray.
- Root rot and boll rot: Caused by various fungi and bacteria. Treatment: cow urine spray.
- *Fusarium* wilt: Practice crop rotation; remove cotton stalks after harvesting. Apply well-decomposed compost. Avoid infected seeds.

6 Soil Cultivation and Weed Management

6.1 Preparing the field

In soil and seedbed preparation the same 'good farming practices' should be followed as in conventional farming. Ploughing should be done before the start of the summer season (March and April in India), so that insect pests and weed seeds are exposed to the sun and dry out. Soil cultivation speeds up the decomposition of crop residues and compost, thus making nutrients available to the crop. In heavy and medium soils, deep ploughing is recommended every few years.

Once the cotton crop has come up and the first top dressing of organic manure has been applied (e.g. De-oiled castor cake (DOC) and compost), earthing up ridges helps suppress weeds and reduces evaporation of soil moisture.

Earthing up ridges in organic cotton in Mali (Photo: Helvetas)

6.2 Sowing

The ideal spacing depends on the soil type and the irrigation facilities. Where soils are light and little irrigation water is available, the spacing can be narrower (e.g. 2x2 feet) than in heavy soils and well-irrigated land (e.g. 4x4 feet). The spacing should be such that the mature crop covers the soil completely. The crop stand should be dense enough that weeds are shaded out. In Egypt and other places, organic farmers cultivate cotton on ridges, keeping 20 cm distance within the rows and 70 cm distance between the rows. However, cross-wise intercultural operations with a weeder are not possible in this system.

Marking the seed positions with sticks

Sow the cottonseeds at a depth of 3–5 cm and cover them with fine soil. This protects the germinating seed so it won't dry out. Depending on the seed quality and cost, 2 to 4 seeds are sown per spot. Re-sow cotton in gaps where the seeds did not germinate, or the seedlings have been destroyed, within 2 weeks after emergence of the young cotton plants. Seeds sown later will not produce much as they are shaded out by neighbouring plants. Therefore, it is better to fill these later gaps with trap crops such as sunflower, maize or pigeon pea. Ten to twenty days after emergence, remove weaker seedlings so that there are only one or two plants in each spot. If thinning is done too early, the seedlings could still die off; if it is done too late there is competition among plants, and chance of root damage when the seedlings are pulled out.

6.3 Weed management

Most important for successful weed management in cotton are proper crop rotation and timely soil cultivation. However, this does not mean that the cotton fields need to be kept free of weeds throughout the season. In the initial stage of crop growth, weeds take up nutrients which otherwise would be lost through leaching. These nutrients are returned to the soil and made available to the cotton crop when the weeds are cut and decompose. Once the cotton crop has developed a dense stand, weeds usually will remain below a level where they significantly compete with the main crop.

Some weeds are important hosts for beneficial insects, or act as trap crops, distracting pests from the cotton plant. Careful observation of weed populations and the use of shallow soil cultivation (hoes, weeders), combined with selective hand weeding, usually allow the experienced organic cotton farmer to 'keep on good terms' with weeds. To prevent the spreading of weed seeds through compost, it is important that composts containing weed seeds go through a heat phase, which destroys the seeds (see Chapter 4.4). Surveys in Tanzania have shown that timely weeding has a higher impact on increasing cotton production than fertilization or pest control.

While weed populations may increase during the conversion period, especially when switching from herbicides to mechanical weed management, weeds do not usually constitute a major problem in organic cotton farming once proper crop rotation is established. Organic farmers in India report that weeding got even less laborious after conversion to organic farming as the soil got softer, which made it easier to pull out weeds.

Intercultural operations with a bullock drawn weeder

7 Water Management

7.1 Irrigation in cotton cultivation

In many areas, cotton is grown with the help of irrigation from groundwater or surface water (rivers, lakes, tanks). Irrigation can increase cotton yields considerably, but can also lead to the depletion of these freshwater resources and to problems owing to soil salinization or waterlogging. Organic soil management usually leads to better soil structure and thus to better infiltration of water. Increasing soil organic matter also improves water retention in the soil and thus allows the crop to better sustain dry periods. Therefore, conversion to organic agriculture can help increase the water-use efficiency in cotton cultivation.

In irrigated cotton, the application system, intensity and timing of irrigation are crucial for good yields and healthy plants. When the cotton leaves start wilting in the morning sun, it is time for irrigation. In India, some farmers use a local plant called 'croton' to indicate water stress: When the croton plant first starts to wilt, it is time for the next irrigation. During the first 6–7 weeks after sowing, irrigation should be moderate in order to avoid too heavy vegetative growth, and to encourage cotton roots to penetrate deeply into the soil. For monsoon-sown cotton in India, the first irrigation should not be done until August, after the first square buds have formed.

The cotton crop is very sensitive to waterlogging, which causes increased boll shedding, thus affecting yields. Waterlogging causes general yellowing and stunted growth of the plant. It also reduces the availability of nutrients. Thus, in fields prone to waterlogging (heavy soil), measures done to improve soil structure (organic matter application) are more relevant than the application of fertilizers. It is important that furrow irrigation be done quickly (not exceeding 4 hours). This can be achieved by shortening the rows.

7.2 Water harvesting and saving

In rain-fed cotton, and in regions with limited availability of irrigation water (i.e. in most semi-arid cotton-growing areas), major emphasis should be given to increasing the infiltration of rainwater into the soil and to preserving soil moisture. For this, the application of compost and organic manures is crucial. Shallow soil cultivation (hoeing) breaks the soil capillaries and thus reduces evaporation. Mulching also helps to preserve humidity in the soil. In some regions, black plastic mulch is used, but its ecological and economical suitability is doubtful. Active rainwater harvesting through pits or trenches leading to wells can help to recharge groundwater levels and thus to improve the availability of irrigation water.

Where little irrigation water is available, alternate-furrow irrigation can still help irrigate the crop. If rains fail after the seedlings have germinated, it can even be worth it to save them through bucket irrigation, plant by plant.

7.3 Drip irrigation

In India, drip irrigation systems are becoming increasingly popular for cotton. They enable farmers to start cotton cultivation before the onset of the rainy season, to bridge dry periods and to protect at least part of their fields from drought. Drip systems make it possible to grow 'more crop per drop' as the water directly reaches the root zones of the plants and less is lost to infiltration and evaporation. It also discourages weeds from growing between the cotton rows. Fibre quality is also found to be higher in drip-irrigated cotton, as it allows better fine-tuning of the irrigation water quantity to the plants' needs. However, investments and labour requirements are higher, and intercultural operations become more difficult. Another possible disadvantage of drip systems in organic cotton is that the decomposition of organic manures is slower, as only a small part of the soil gets moist. In organic farming, the decomposition of organic manures is of particular importance for ensuring a continuous nutrient supply to the plant.

Recently, several new low-cost drip systems have come on the market (see Figure 20). They allow farmers to install drip-irrigation systems with lower investment costs, but the cheaper systems are usually less durable.

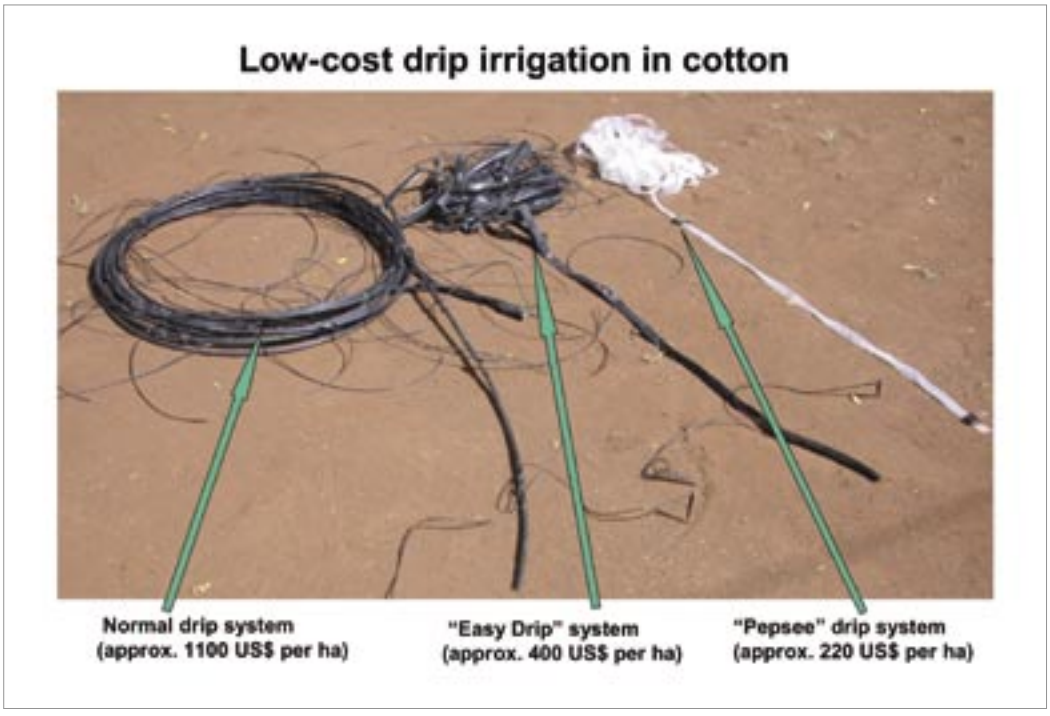


Figure 20: Drip, "Easy drip" and "Pepsee drip" systems for cotton

8 Harvest and Post-Harvest Operations

8.1 Quality issues in cotton picking

The quality of the cotton harvest depends on the length of the fibre (staple length), on the degree of contamination with non-fibre material such as leaves or dust, and on the portion of fibre damaged by pest or disease infestation. Good-quality raw material helps to produce yarns and garments of high quality, and thus eventually contributes to the market success of the organic cotton project. When cotton buyers fix prices, they usually take into consideration the quality of the seed cotton. Measures taken to improve the quality of the harvest therefore directly pay off for the farmers:

- Allow the cotton bolls to fully ripen and open.
- Pick the cotton after the morning dews have dried up, so that the cotton is dry and less prone to fungus when being stored.
- Pick the cotton into clean cotton cloth material, never into nylon or other synthetics (foreign fibres).
- Remove leaves, capsules and damaged bolls from the cotton harvest.
- Keep cotton of lesser quality separate with the help of a second, smaller picking bag.
- Picking delays can cause reduction of fibre quality, as the opened bolls are exposed to dew, dust and honeydew from insects longer.
- It is important that no unripe cotton is picked, as it will not absorb the dye well enough and thus is priced lower.

A major cost factor in cotton production is the labour required for cotton picking. The following suggestions might help to increase the efficiency of cotton picking, and to ensure a high-quality harvest:

- Use a long sack so that the weight rests on the ground;
- Keep the sack permanently open with a ring of flexible wood;
- Pick two rows at a time;
- Keep a separate, smaller bag for second-grade cotton.

8.2 Storage

An Indian farmer storing cotton in his house

If farmers store the harvested cotton before selling it, they should take care to prevent contamination from dust or chemicals, especially fertilizers, pesticides, and petroleum. Never use any storage pest control (e.g. DDT) on the harvested cotton!

No foreign fibre material (from clothes, human hair etc.) shall get into the cotton, as it can affect the quality of the yarn.

The storage place needs to be clean and dry. Damp conditions can lead to the growth of fungus, with significant loss of cotton quality. When organic harvest is stored in the same facilities with conventional cotton (e.g. in ginneries), care must be taken to clearly separate the organic, in-conversion and non-organic produce, and to avoid any mixing.

8.3 Processing and trade

Throughout the entire organic cotton processing chain, it is important to avoid contamination and to separate organic from conventional cotton (Figure 21). As most spinning mills and processing entities process organic and conventional cotton on the same machinery, it is important to clearly separate the cottons and clean the equipment before processing an organic lot. Some labels and brands have certain restrictions on which dyes can be used.

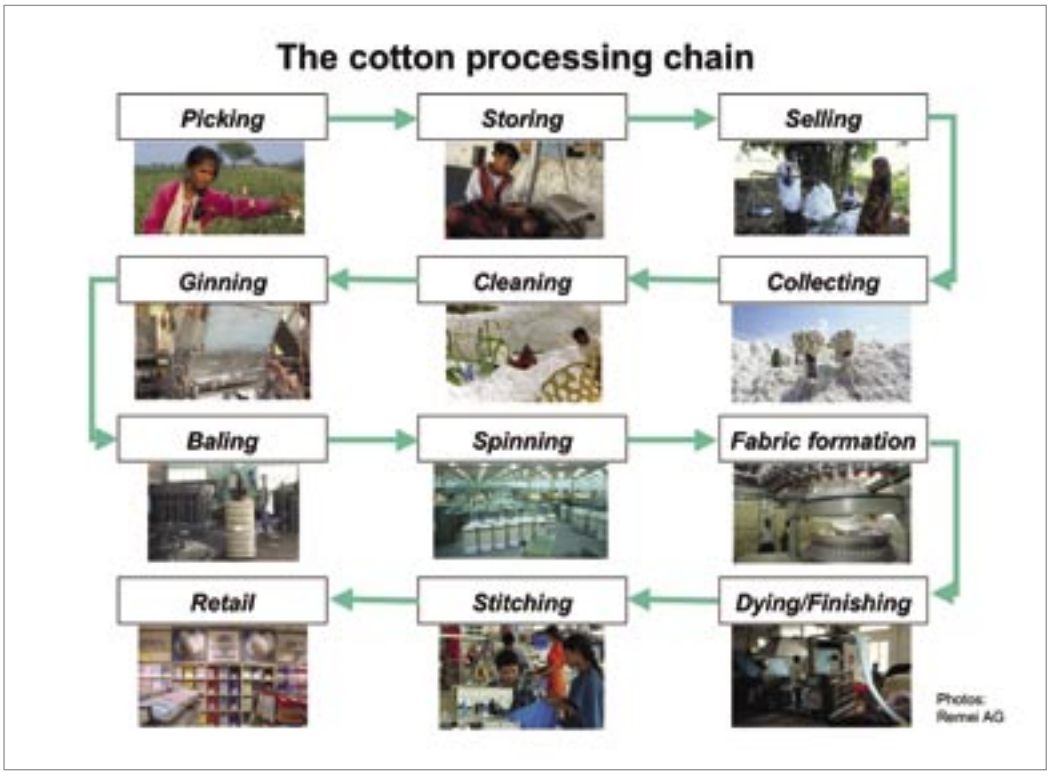


Figure 21: The cotton processing chain – from field to consumer

Major markets for organic cotton textiles are Europe (Germany, Switzerland, UK, and Sweden), the USA, and Japan. Initially, most organic cotton was processed into garments containing 100% organic cotton fibre. Recently, some large garment brands have decided to blend a certain percentage (usually 5–10%) of organic yarn into their entire range of articles rather than selling purely organic clothes. This could increase the demand for organic cotton fibre considerably. Companies can communicate to their customers that they support organic cotton farming, which helps them to improve their corporate image.

A T-shirt made from organic cotton reaches back to an organic cotton farmer in Mali (Photo: Helvetas)

9 Farm Economy

9.1 Managing the whole farm organically

Cotton is grown in rotation with a number of food crops that also need to be managed organically, if the farm is to be certified. Organic cotton farmers should make sure to have sufficient area under cultivation of other crops, especially pulses, to keep the soil fertile and to reduce pest proliferation (see Chapter 3.3). Diverse crop rotation reduces the farmer's dependency on fluctuating cotton prices, and helps to spread out labour requirements over a longer season. Crop diversity also contributes to better food security of the farm family and the region.
de cotton.

Organic cotton projects should also cover the rotation crops with their extension system. If only the cotton cultivation succeeds while the performance of the rotation crops is poor, the overall conversion to organic farming might not be viable. Together with the farmers, organic cotton projects should therefore develop suitable crop management methods for the main rotation crops. If necessary, access to suitable inputs for pest and nutrient management should be facilitated. Technical advice can be sought from other organic crop guidelines[1], or from research institutions dealing with the respective crops.

Organic cotton farmers can benefit even more if they also can manage to find a market with a better price for the rotation crops. Some projects try to organize export links for crops like soy bean, sesame or chilli. However, in some countries (e.g. India) the potential of selling the rotation crops with a premium price is even better on the domestic market. Projects can facilitate the establishment of market linkages, or even engage in marketing of the products.

Safflower – an alternative cash crop?
Safflower (*Carthamus tinctorius,* in Hindi called 'kusam') is a crop that can be grown in rotation with cotton well. Though originally it was used as a dye, it is now cultivated mainly for its seed, which is used for extraction of edible oil, and as feedstuff for birds. With its strong taproot it can draw moisture from deep in the subsoil, so that the plant can withstand dry conditions. In India, the crop is grown in the 'Rabi' or winter season in combination with crops like wheat and sorghum. Safflower is used as a 'support' crop in drought-prone cropping systems and can help prevent the spread of dry land salinity. As a long season crop, it extracts water from the soil for a longer period than cereal crops.

Safflower

[1] E.g. Naturland cultivation guidelines for various crops, http://www.naturland.org; ATTRA Organic Field Crops, http://www.attra.org/field.html; IFOAM Training Manuals, http://www.ifoam.org.

9.2 Strategies in cotton production

Generally, farmers' income (more accurately: the gross margin) from a crop depends on the yields, the costs of production, the price gotten on the market, and the production risk involved (Figure 22). Thus, there are four ways farmers can earn a better and more sustainable income through organic production:

- By increasing and sustaining crop yields through improved soil fertility;
- By reducing costs of production (especially for off-farm inputs);
- By getting a better price for their produce (organic premium, market access);
- By reducing the risks of production (especially of droughts and pest damage).

Organic farmers get the maximum benefit when they manage to combine all these approaches.

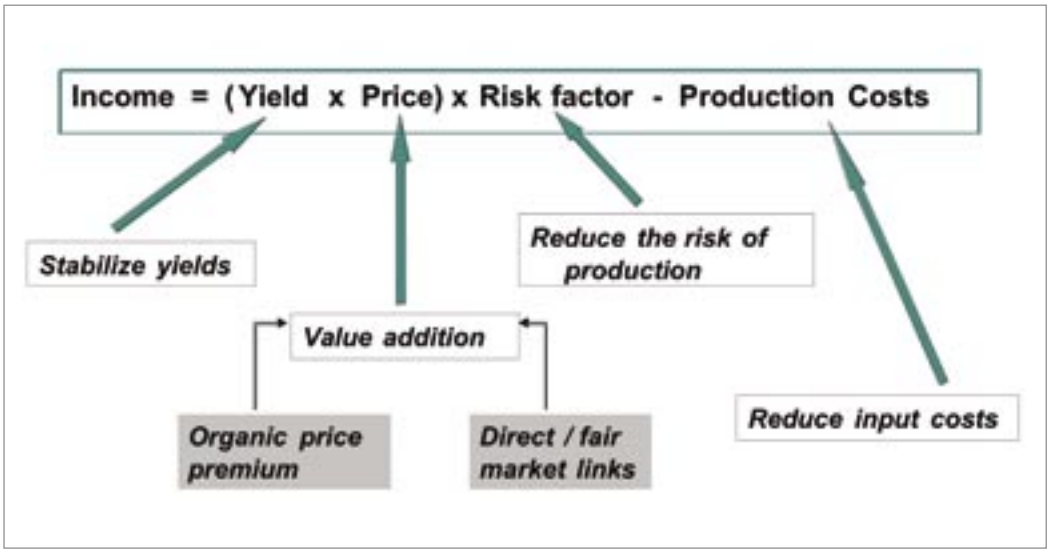


Figure 22: Ways to improve farmers' income through organic production

With organic cotton, it appears that farmers basically follow one of two different strategies to achieve good profits (Figure 23): The first strategy ("intensive organic") aims to achieve high yields through optimum nutrient supply and crop care. Farmers following this strategy typically buy organic manures from outside (cow dung, oil cakes), irrigate their fields intensively and take a number of measures to protect their crops. This is a strategy typically followed by farmers with more resources (larger land holdings, good irrigation facilities, fertile soils). The second strategy ("low cost, low risk") tries to reduce production costs and the risk of production, targeting medium yields. Farmers following this strategy basically try to produce all the inputs on the farm itself (compost, botanical pesticides, liquid manures etc.) and do most farming activities with family labour. This low external-input strategy can help to reduce risk in areas of frequent crop loss due to droughts, waterlogging or theft, as farmers need to invest less money into the crop. Of course it is not possible to draw a clear line between the two strategies. Still, this basic distinction can help farmers to make their farming more profitable, and extension services to adjust their services to the requirements of different farmers.

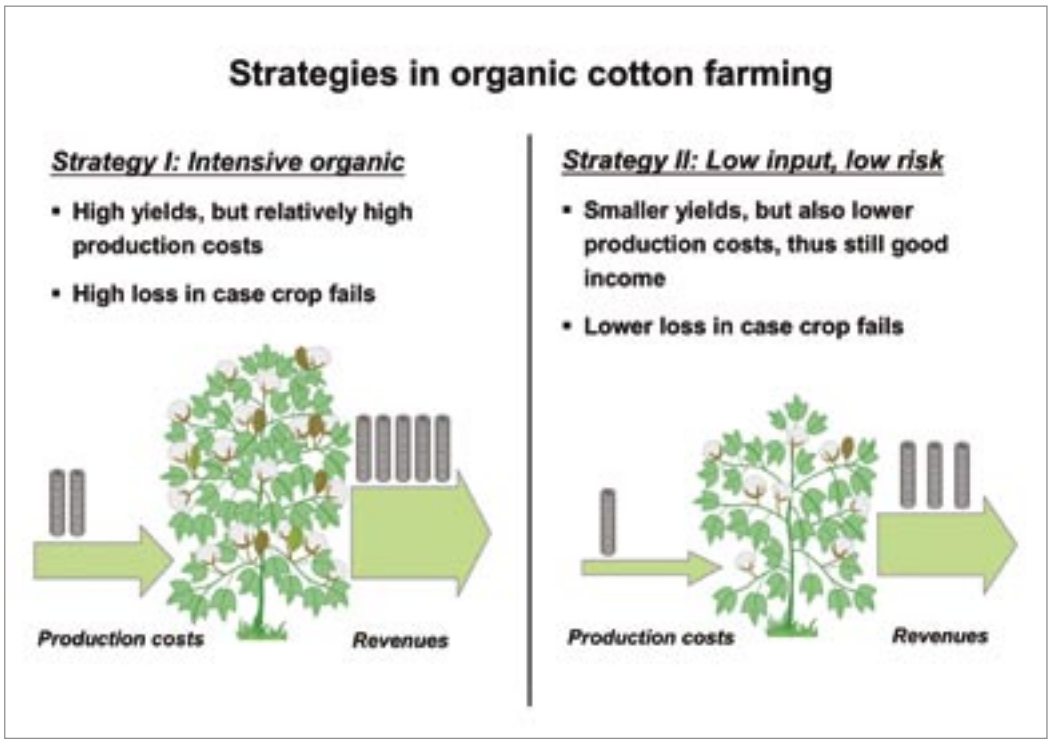


Figure 23: Two strategies for achieving good revenues from organic cotton.

The results of a study conducted in the Maikaal bioRe project in India showed that both strategies have been successfully implemented by the farmers. Table 9 shows the data for two farmers from this study. Farmer I is a small farmer with little irrigation, buying few inputs from outside and working the farm only with family labour. Farmer II is a wealthy farmer with good irrigation facilities, resources to buy in additional farmyard manure from other farms and dependent on hired labour.

Example farmers	FYM/DOC* (per acre**)	Production Costs (Rs.***)	Cotton Yields (seed cotton)	Profits (incl. premium)
Farmer I: Low-cost, low-risk	1.8 t FYM	2,094 Rs. per acre	420 kg per acre	9,825 Rs. per acre
Farmer II: Intensive organic	5.3 t FYM 260 kg DOC	5,849 Rs. per acre	790 kg per acre	22,473 Rs. per acre

* FYM = Farmyard manure, DOC = De-oiled castor seed cake; ** 1 acre = 0.4047 ha; *** 1 US $ = 48 Rs. Indian Rs. in 2004

Table 9: Examples of two organic farmers, one following a "low-cost, low-risk" strategy (Farmer I), and one an "intensive organic" strategy (Farmer II)

9.3 The economic performance of organic cotton

The yields and profits of organic cotton production vary to a great degree among different farms and different regions, and it is not easy to make a general statement on how organic cotton production compares with conventional production in economic terms. Even if the conditions of two farms were to be the same (climate, soil, irrigation sources etc.), the skills and practices of the farmers will have a great impact on the result.

Further, the results of a comparison depend on the production intensity of the conventional and organic farms. Similar to conventional farming, organic cotton production can also be more or less intensive regarding input use and productivity. While conversion to organic farming usually means a reduction in intensity (i.e. fewer external inputs, smaller yields), in some cases it can also lead to higher intensity – with intensive organic nutrient and pest management (Figure 24).

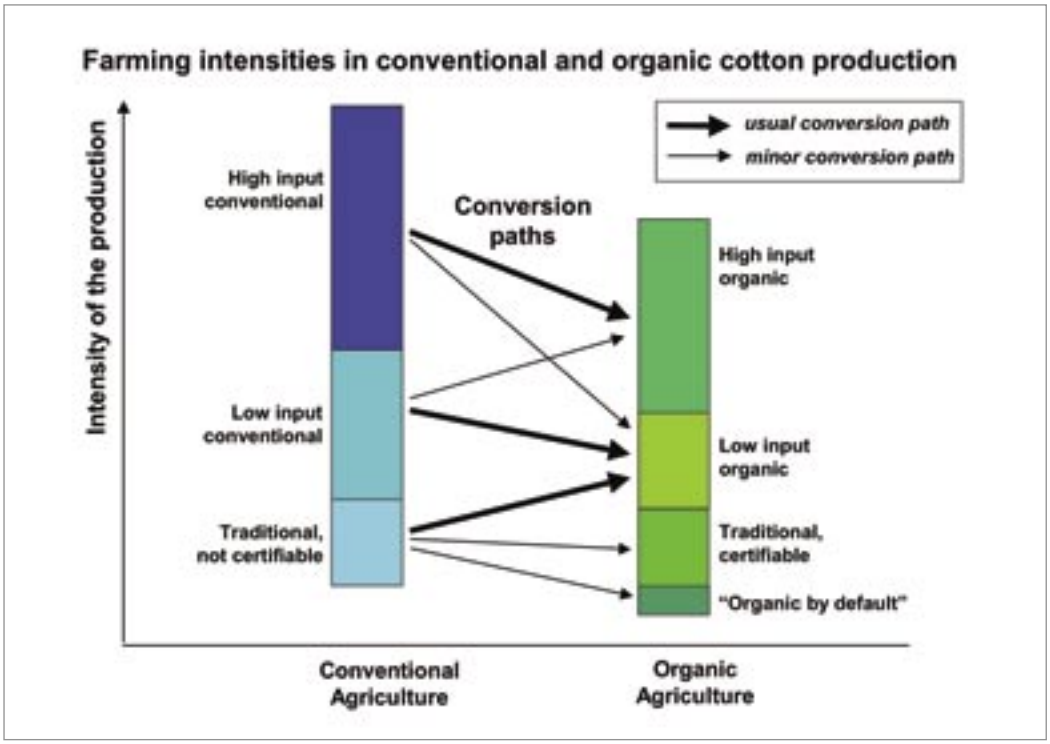


Figure 24: Farming intensities in conventional and organic cotton production. The arrows indicate typical paths of conversion from conventional to organic production

Most organic cotton projects in the tropics report that after going through a conversion period of 2–3 years, the cotton yields on organic farms reach roughly the same level as on conventional farms (20 % lower to 10 % higher yields). Costs for inputs (plant nutrition and pest management) are usually 20 - 80 % lower, depending on whether organic manures and pest management items are purchased from outside (e.g. oil cakes, Bt preparations) or are produced on the farm itself (e.g. compost, liquid manures, botanical pesticides). While organic cotton production usually involves more work in plant nutrient management (preparation of compost, application of organic manures), labour required for spraying and weeding is usually less. Thus, labour costs usually are about the same in organic and conventional cotton farming.

With similar yields, lower production costs (inputs) and a premium price (usually 10–20% over market prices), organic cotton farming can be far more remunerative compared to conventional cotton farming. However, for a comprehensive comparison of the performance of organically and conventionally managed cotton farms, the yields and production costs of the intercrops and crops grown in rotation with cotton also need to be taken into consideration.

It must be kept in mind that this comparison is valid for fully converted organic farms. During the initial years of organic management, the farm economy looks different (see Chapter 9.5).

9.4 Monitoring the economic performance

Comparing the yields and the profitability in organic and conventional cotton production is a difficult task because of the following reasons:

- There are big variations among different farmers (different soils, irrigation sources, equipment etc.).
- The conditions change from year to year (e.g. rainfall, prices).
- The yields of intercrops and rotation crops need to be taken into consideration.
- Exact field sizes are sometimes not known, and are difficult to measure.
- Not all farmers keep records of their inputs (manures, pest management items, labour etc.) and outputs (harvest of cotton and intercrops).
- It is difficult to estimate indirect costs (e.g. for training, negative health impacts of chemicals) and benefits (e.g. reduced production risk, food quality).
- Some advantages of the organic production system appear only over the long term (soil fertility improvement, balanced ecosystem).

Extension staff of Maikaal bioRe support a farmer in record keeping

Still, simple maintenance of crop records can help farmers and projects to get a fairly good idea of the economic performance of the crops and farms. Experience from several projects indicates that record-keeping can lead to improved performance as farmers become more aware of where they lose and where they gain. Annex 10.6 provides a template with which farmers can easily keep crop records (of cotton or other crops). It can help them to keep clear track of inputs, costs, harvests and revenues. With simple calculations, one can compile yields, total production costs and net profits. When records are kept over a period of several years, they provide insight into the changes in the farm economy, for example during the conversion period. Thus they can also help the farmer to fine-tune and optimize the production system.

If farmers are organized in a group, these crop records provide the organizers with valuable data for planning and monitoring. The data of all farmers in the project are compiled into a simple database[1]. The project's extension team can assist the farmers in record-keeping and help them to calculate the results.

9.5 The conversion process

Probably the most important hurdle for organic cotton production is the challenge of getting through the conversion process. During this phase, most farmers experience a drop in yields (10–50%, depending on the level of previous yields and the methods used), while at the same time measures to re-establish soil fertility require additional effort and labour. With proper organic management implemented, yields usually recover after 2–3 years, as the soil builds up organic matter and populations of soil organisms increased. Pest problems are also usually higher in the initial years, as the eco-system that got disturbed through the continuous application of chemical pesticides first needs to get into balance and populations of beneficial insects need to build up. It is also obvious that organic farming requires new skills, and, therefore, training and experimenting. With increasing experience, the performance of the farmer will improve, too.

Conversion to organic farming usually results in more diversity: in crops grown, in types of activities and in the solution of problems. Organic farming is a knowledge-intensive type of production, and thus competent extension services play an important role. Especially during the conversion period, it is crucial that farmers get competent and timely advice. Organic cotton projects could consider organizing trainings for farmers interested in conversion, in which they prepare for the conversion process. Rather than only promoting organic farming, extension staff should openly address the necessity of working hard during the conversion period and the possible problems to be expected.

Appropriate measures can help to reduce problems encountered during the conversion process. The initial drop in yields, for example, can be reduced through sufficient application of organic manures (if necessary brought in from outside the farm). It is also advisable to intercrop cotton with pulses (e.g. moong bean, cow pea), which supplies nitrogen to the soil and provides additional income. Other success factors in the conversion process are listed in Figure 25.

[1] A free template of record forms and a database for managing farm records is available at www.fibl.org/english/cooperation/projects/organiccotton.php.

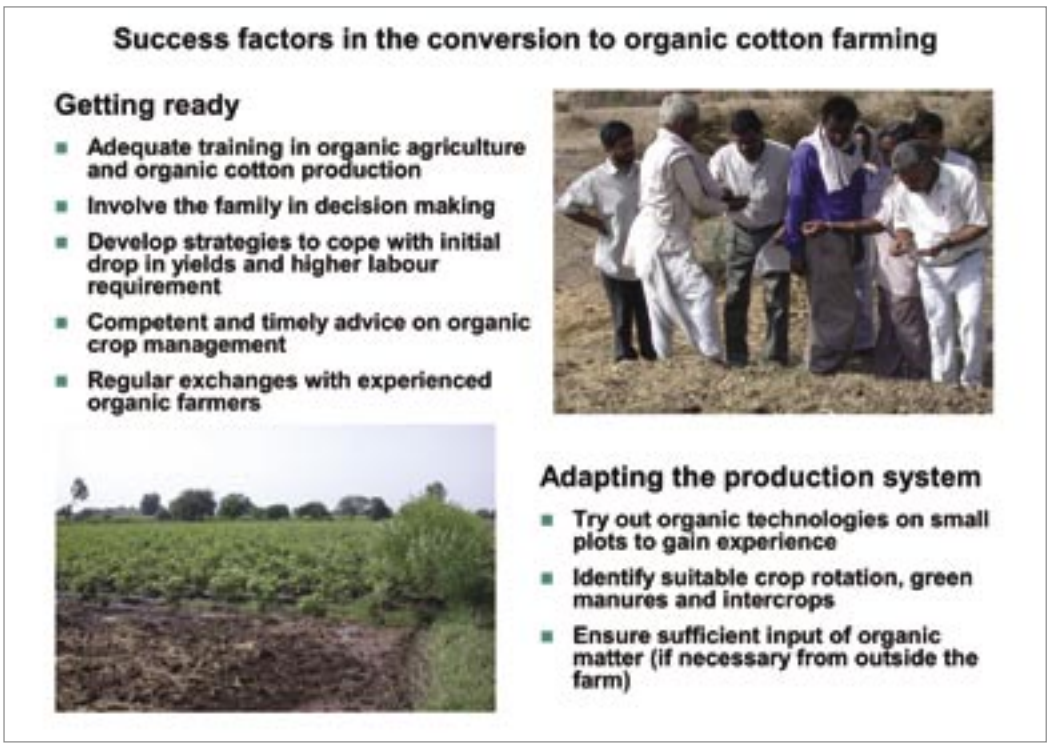


Figure 25: Success factors in the conversion to organic cotton farming

9.6 The role of women in organic cotton production

Although on many farms, especially in India, most decisions are still taken by men, women play an important role in organic farming. In India, their traditional responsibilities in cotton farming include looking after the animals and the dung, sowing, weeding, and picking. Men usually are responsible for soil cultivation, application of manures and sprays, and intercultural operations. Shifting to organic farming can therefore mean a shift in workload between men and women: The time needed for compost preparation and perhaps for weeding might increase as well, while the time needed for spraying pesticides usually decreases. Proper plant nutrition, timely weeding and careful picking, however, are crucial for getting good results in cotton.

Conversion to organic cotton farming is not only a question of production techniques; it has equally important implications for the social and economic level of the household. Thus the different perceptions and needs of the family members should be taken into consideration when thinking about conversion.

Organic cotton projects should ensure that women are included in decision-making processes, especially concerning the conversion process. For this, they should be encouraged to participate in training activities and meetings. Extension services of the project should always give special consideration to gender issues and also reach out to women. Having female staff on the team, and female farmer representatives in the organization, can help organic cotton projects to achieve these aims.

A lady farmer removing weeds in an organic cotton field in Mali (Photo: Helvetas)

10 Annex

10.1 Glossary

Asafetida	A hard resinous gum gained from the roots of a giant perennial fennel species. It is used as a spice in Indian cuisine, and in medical treatments.
Bio-dynamic agriculture	Special type of organic agriculture based on the research work and philosophy of Rudolf Steiner. It includes the use of plant-based or animal-based preparations and considers cosmic rhythms.
Border crop	Crop grown at the edge of organic fields bordering conventionally managed fields in order to reduce drift of pesticide sprays.
Certification	A process verifying the compliance of farm management with organic standards; based on inspection of the farm and its documentation.
Conversion	The process of changing the farm management from conventional to organic practices as per the organic standards.
Cotton lint	Cotton fibre without seeds.
Crop rotation	Sequence of crops grown in a field over several years.
De-oiled cake of castor (DOC)	Residues of crushed castor seeds after oil extraction. It is used as an organic manure rich in nitrogen (4–5%) and phosphorus.
'Desi' cotton	Indigenous cotton varieties grown on the Indian sub-continent, belonging to the species Gossypium herbaceum or G. arboretum.
Economic threshold	The level of pest infestation below which the damage caused by the pest is lower than the cost of control efforts.
Extension service	A support system for farmers, usually provided by the NGO or company organizing the organic project. Services may include training, technical advice, internal control, supply of farm inputs and marketing.
Fair trade certification	A certification scheme for trade relations between farmer groups or estates in developing countries, and 'Western' buyers or traders. Conditions for qualifying are defined in fair trade criteria. Fair trade projects can, but need not, be organic, and vice versa.
Farmyard manure (FYM)	Droppings and beddings of farm animals, usually of cattle.
Ginning	Mechanically removing the cotton fibres from its seeds.
Gossypol	Gossypol is a yellow pigment produced by the cotton plant, mainly found in cotton seeds. It protects the cotton plant from insects.
Green manure	A crop grown before or between the main crop rows, cut before maturation and subsequently ploughed in or used as mulch. It provides nutrients to the main crop through decomposition and helps to build up humus in the soil.
Gross margin	Crop or field output (mainly revenues from sales of crop) minus variable production costs (seeds, fertilizers, sprays, hired labour etc.).
Intercropping	Crop grown between the main crop rows, for harvesting. After harvesting, it may serve as mulch.
Internal Control System (ICS)	An inspection system managed by the project to ensure that farmers follow the agreed-upon organic standards. For certification, the functioning of the ICS is evaluated by an external agency.
Integrated Pest Management (IPM)	A combination of chemical and biological control methods, based on the concept of economic thresholds. Pest management in organic farming uses many biological control methods developed as a part of IPM.
Leguminous crops	= legumes (e.g. peas, beans, alfalfa, groundnuts); plants that produce seeds in pods. Most of them have root nodules containing bacteria that fix nitrogen from the air.

Micro-irrigation	Irrigation systems that apply water directly to the individual crop plants; especially drip irrigation (through tubes) and micro-sprinkler systems.
Mulch	Plant material such as straw, leaves, crop residues, green manure crops, saw-dust etc. that is spread upon the surface of the soil. A mulch cover helps protect the soil from erosion and evaporation, nourishes soil life, increases soil organic matter content and provides nutrients to the crop.
Natural enemies	See 'Predator'.
Nitrogen immobilization	Temporary nitrogen shortage in the soil due to decomposition of organic material that is low in nitrogen. Can be avoided through proper composting of farmyard manure and crop residues.
Nutrient exchange capacity	The ability of soil to take up and release nutrients. Nutrient exchange capacity is highest with clay particles and soil organic matter.
Organic agriculture (OA)	Holistic farming system that avoids the use of synthetic fertilizers and pesticides. It emphasizes the set-up of a balanced agro-ecosystem and is based on methods like crop rotation, intercropping, green manures, organic manures, biological pest control etc. The farm can be certified organic if the specified organic standards are fully met.
Organic manures	Manures derived from animal products or plant residues. They usually have considerable nitrogen content, and contain most other nutrients essential for plant growth.
Organic premium	Percentage or fixed amount paid for an organic product in addition to the prevailing market price for non-organic products.
Organic standards	Minimum requirements for a farm and its products to be certified organic. Organic standards are specific to certain regions (e.g. EU-regulation EEC 2092/91) or private labels (e.g. Naturland, BIO SUISSE).
Pheromone	Substance emitted by female insects in order to attract males. Synthetic pheromones are used to disorient male insects and thus to prevent mating.
Predator	Animal that attacks and feeds on other animals, such as an insect (e.g. ladybird beetle), bird or spider feeding on pest insects.
Resistance	Ability of a crop not to get affected by a disease or pest; or of a pest not to be affected by a pesticide.
Seed cotton	Cotton as it is picked (fibre along with seeds).
Seed treatment	Treatment of seeds to protect them against soil- and seed-borne diseases and pests, and/or to improve germination and initial growth. In organic farming, seeds treated with synthetic pesticides cannot be used.
Soil organic matter	Organic substances in the soil originating from animal and plant residues in various stages of decomposition and re-formation. Also referred to as humus.
Staple length	Average length of the cotton fibres. An important parameter for defining the quality and thus the price of the cotton.
Trap crop	A crop grown in order to attract pests and to distract them from the main crop. Pests thus can be destroyed by treating a small area, or by destroying the trap crop and the pests together.
Vermi-compost	Continuously fed compost system in which pre-decomposed organic material is eaten by large numbers of earthworms. Their faeces are high in silica and make an organic manure of excellent quality.
Water retention capacity	The ability of the soil to retain water and moisture.

10.2 Frequently Asked Questions, and some answers

Topic	*Questions (Q)* and Answers (A)	Chapters
Compost quantity	*Q: How can I produce sufficient compost?* A: Increase the number of cattle and utilize the dung (avoid burning of dung for fuel purposes). Use all available biomass in and around the farm for composting. Set up new compost heaps whenever possible. Encourage other people in the village to produce compost and buy from them (e.g. community employment schemes). Complement the compost application with liquid organic manures.	4.4
Compost quality	*Q: What can I do to improve the quality and nutrient content of my compost?* A: Mix material that is easily decomposable along with material that decomposes slowly (e.g. crop stalks of cotton, maize, sorghum etc.). Keep the heap moist (not too dry, not too wet), e.g. by covering it with sacks. In summer, set up the compost in pits and in the shade. Important: Turn the heap at least twice!	4.4
Timing of manure application	*Q: When should I apply the top dressing of DOC and compost to the cotton crop?* A: Apply the first dose three weeks after sowing, and a second dose 6 weeks after sowing, if required.	4.1
Slow initial growth	*Q: What can I do to improve the growth of the cotton crop when it is stagnating?* A: The growth could stagnate because of temporary immobilization of nitrogen due to decomposition of organic material low in nitrogen. Proper composting of farmyard manure and crop residues can help to prevent this problem. Apply organic manures rich in nitrogen (e.g. DOC) and cultivate the soil in order to accelerate decomposition.	4.2
Bud shedding	*Q: How can I prevent bud shedding (dropping of square buds)?* A: Avoid waterlogging! Do not apply too much or too little manure. Cultivate the soil with a weeder/hoe at the time of bud formation. Some bud shedding occurs naturally, however, and can't be avoided.	2.2, 4.1, 7.1
Crinkling of leaves	*Q: How can I prevent infestation with aphids and whitefly?* A: Avoid waterlogging and drying up of the field! Do not apply too much manure. Cultivate the soil with a weeder when aphid populations build up. Promote and protect natural enemies. Grow intercrops (e.g. moong) or trap crops (e.g. sunflower). If aphids and whitefly exceed the economic threshold, apply neem or other botanical sprays.	5.1, 5.2.2
Drop in yields	*Q: How can I prevent yields from dropping initially in the first years of conversion?* A: Ensure sufficient application of good-quality organic manure, especially compost. If necessary, buy organic manure from outside sources (FYM, press mud, DOC). Apply organic manures 1–2 weeks earlier than you used to apply chemical fertilizers, as they need time to decompose and release nutrients.	4.3, 9.5
Step-by-step conversion	*Q: Can I convert to organic farming step-by-step?* A: The conversion period for certification starts only when all standard requirements have been fully met. Before that, it may be advisable to gradually reduce the use of agro-chemicals and to build up soil fertility, so that there is less of a drop in yields in the first years of conversion. To gain confidence, farmers can try out organic practices in a part of their land.	9.5
Labour shortage	*Q: How can I avoid a labour shortage in peak seasons?* A: Build up good relations with your labourers. Diversify your farm (additional crops, dairy, compost production) so that labour requirements are spread over the year and you can provide work on a regular basis throughout the year. Plan well and treat weeds and pests in a timely manner.	9.1
Cotton quality	*Q: How can I improve the quality of the cotton?* A: Increase the amount of organic manures, especially compost, to improve soil fertility. Include pulses in the crop rotation. If potassium (K) is deficient in the soil, apply muriate of potash or wood ash. Spray BD 500 + 501. Ensure proper quality management in cotton picking and storage.	4.1, 8.1
Irrigation	*Q: What can I do if I have little irrigation water available?* A: Grow cotton varieties that are tolerant of dry conditions (e.g. local non-hybrids). Intercrop with drought-tolerant crops (e.g. pulses or safflower) to reduce the risk of crop failure. Practice water harvesting (trenches, small check dams). Use drip irrigation systems. Apply mulch and organic matter to increase the water retention capacity of the soil.	7.2, 7.3
Food crops	*Q: How can I sell food crops at an organic premium price?* A: Organize a group with other farmers. Ensure certification of all crops produced on the farms (e.g. group certification with an internal control system). Identify domestic or international buyers (e.g. with the help of the Internet). Adopt a quality management system for ensuring product quality (post-harvest handling, processing).	9.1

10.3 Summary of organic standards requirements relevant for organic cotton farms (based on the EU Regulation EEC 2092/91)

The following is a basic summary of the most important requirements set out in the standards of the EU regulation relevant to organic cotton farming. It attempts to describe the requirements in simple, non-technical language and may serve as a checklist for farmers and extension staff. For detailed requirements, please refer to the original EU regulation[1].

Conversion to organic agriculture

- The farm needs to complete the conversion period before products can be sold as 'organic'. The conversion period starts with the date of signing the contract with the company implementing the internal control system. After signing the contract, all the organic standards must be followed strictly.
- After 12 months of conversion, products can be sold with a label "in conversion to organic agriculture". Annual crops can be sold as "organic" after 24 months and perennial crops after 36 months.
- The full farm (all fields and all crops) must comply with the organic standards. This includes crops that are not to be sold as 'organic', or that are produced for personal consumption only.
  ➲ Partial farm conversion is only possible if the production units, facilities and management of the organic and the conventional operations are clearly separated (check with your certification body).

Crop production

- Organic seeds and propagation materials have to be used (conventional seeds may be used only if approved by the certification body). Conventional seedlings and chemically treated seeds are not allowed.
- For annual crops, farmers must either practice crop rotation or intercropping.
- The farmer shall ensure prevention of soil erosion, soil salinity and water pollution or depletion.
- The use of any genetically modified organisms (GMOs, like Bt cotton) is not allowed. Farmers shall make sure that seeds and plant material, and organic fertilizers and pesticides are free of GMOs.
- Farmers shall avoid over-manuring of land by keeping appropriate numbers of animals per farm area and applying appropriate quantities of manure.

Fertilization

- Chemical fertilizers (including urea!) are **never** allowed. Manures and natural fertilizers brought from outside the farm shall not contain any chemical fertilizers and shall not come from intensive animal husbandry.
  ➲ Organic manures, bio-fertilizers (rhizobium, acetobacter, mycorrhiza etc.), bio-dynamic preparations and botanical preparations are allowed.
- Natural mineral fertilizers (rock phosphate, muriate of potash, gypsum etc.) can be used only as a supplement to organic manures (compost, green manures etc.) if there is an obvious deficiency in the soil.

Crop protection

- The use of chemical pesticides (including herbicides, growth regulators etc.) is **not** allowed. Farmer's preparations of botanical pesticides from local plants are usually allowed (check with the certification body). Branded products of natural pesticides must be checked to see if they do contain prohibited ingredients.
  ➲ Allowed products are: bio-pesticides (Bt spray, trichoderma, NPV, pseudomonas etc.), Bordeaux mixture, natural sulphur, soft soap, and most plant-based products (neem, pyrethrum etc.; but not tobacco).
- If spray equipment from non-organic neighbours is used, these must be cleaned of any residues.
- Farmers must make sure to avoid spray drift from neighbouring fields. If this is a risk, buffer zones or border crops must be established
  (➲ General practice, not explicitly demanded by the EU regulation).

[1] http://europa.eu.int/eur-lex/en/consleg/main/1991/en_1991R2092_index.html

10.4 Useful reading and websites

Organic cotton in general

- Naturland (2004, 2nd edition): Organic Farming in the Tropics and Subtropics. Cotton. www.naturland.de
- Myers & Stolton (1998): Organic Cotton. From Field to Final Product. Intermediate Technology Publications. London.
- P. Ton. (2002). The International Market for Organic Cotton and Ecotextiles. Pesticide Action Network United Kingdom. www.pan-uk.org/Cotton
- ATTRA: Organic Cotton Production. www.attra.ncat.org
- Organic Cotton Europe: www.organiccotton europe.net
- Helvetas: Organic cotton. www.organiccotton.ch
- Meena Menon: Organic Cotton – Re-inventing the wheel. Deccan Development Society. www.ddsindia.com

Organizations dealing with organic cotton

- Organic Exchange, a platform of the organic cotton industry, providing market links and information, with a detailed world overview on organic cotton production. www.organicexchange.org
- The International Organic Cotton Directory: www.organiccottondirectory.net
- The Pesticide Action Network (PAN). The Cotton Project: Moral Fibre. www.pan-uk.org/Cotton
- Remei AG, Switzerland. Organic cotton projects Maikaal bioRe (India) and bioRe Tanzania. www.remei.ch
- Intercot, the International Conference on Organic Textiles. www.intercot.org
- Japanese Organic Cotton Association: www.joca.gr.jp/english
- Organic Trade Organisation (OTA). www.ota.com (search site for cotton)
- The Swiss NGO Helvetas supports organic cotton projects in Mali, Burkina Faso, Senegal and Kyrgyzstan. They also provide information about organic cotton. www.helvetas.org
- The Solidaridad-ETC Organic Cotton Programme India; with information and links on organic cotton. www.indianorganicproducers.org
- International Competence Centre for Organic Agriculture, India (ICCOA) provides services for organic cotton production and for marketing of organic products in India. www.iccoa.org

Chapter 1: Introduction

- IFOAM Training Manual for Organic Agriculture, Principles of Organic Agriculture (Chapter 2). www.fibl.org/english/publications/training-manual
- Organic standards:
  – EU regulation EEC 2092/91: europa.eu.int/eur-lex/en/consleg/main/1991/en_1991R2092_index.html;
  – US regulation: www.ams.usda.gov/nop/NOP/standards.html;
  – IFOAM norms: www.ifoam.org/standard/norms/cover.html
- IFOAM Quality Control Manual: Organic Production in Small Farmers' Associations, English/CD Rom. www.ifoam.org
- IFOAM Smallholder Group Certification/ Manual for producer groups. www.ifoam.org I-GO Publications
- IFOAM Smallholder Group Certification - Internal Control Systems (ICS). Complete Training Curriculum (free download). www.ifoam.org I-GO Publications
- Fair Trade: The International Fair Trade Association (www.ifat.org) and Fairtrade Labelling Organizations International (www.fairtrade.net)

Chapter 2: Cotton

- Crop profile of Gossypium hirsutum. www.fao.org/ag/agl/aglw/cropwater/ecocotto.htm
- Cotton on the Net – Gateway to the World of Cotton. www.cotton-net.com
- International Cotton Advisory Committee. Publications, links, events etc. on conventional cotton, with some references to organic cotton. www.icac.org
- Australian Cotton Cooperative Research Centre. www.cotton.pi.csiro.au/
- Cotton SA, an organization providing information on (conventional) cotton for South Africa, with some reference to organic cotton. www.cottonsa.org.za

Chapter 3: Soil Fertility Management

- IFOAM Training Manual for Organic Agriculture, Soil Fertility (Chapter 3). www.fibl.org/english/publications/training-manual
- Brandjes, P., van Dongen, P., et al. (1989): Green manuring and other forms of soil improvement in the tropics. Wageningen, Agromisa. www.agromisa.org

- Soil management manual for Australian cotton farmers (SoilPak). Although developed for conventional farming, it provides some useful general information and ideas. www.agric.nsw.gov.au/reader/6771

Chapter 4: Crop Nutrition

- IFOAM Training Manual for Organic Agriculture, Plant Nutrition (Chapter 4). www.fibl.org/english/publications/training-manual
- HDRA: Composting in the Tropics. The Henry Doubleday Research Association HDRA. 18 p. www.hdra.org.uk/publications/index.htm
- Nutripak, A practical guide to (conventional) nutrient management in cotton in Australia. www.cotton.crc.org.au/Publicat/Agro/Nutrient/NUTRIpak.htm
- World Fertilizer Use Manual, 'Cotton' section. Information on nutrient demand, deficiency symptoms etc. in conventional cotton. www.fertilizer.org/ifa/publicat/html/pubman/cotton.htm

Chapter 5: Pest and Disease Management

- G.A. Mathews (1994): Insect Pests of Cotton. CAB International. Wallingford.
- Online Information Service for Non-chemical Pest Management in the Tropics (OISAT). www.oisat.org/home.html
- G. Stoll (2000): Natural Crop Protection in the Tropics – Letting Information Come to Life. Magraf Verlag, Hohberg.
- Pest Management Guide; ATTRA; especially Biointensive Integrated Pest Management. www.attra.org/pest.html
- IFOAM Training Manual for Organic Agriculture, Pest, Disease and Weed Management (Chapter 5). www.fibl.org/english/publications/training-manual
- General information on (conventional) pest management in cotton; Australian Cooperative Cotton Research Centre; cotton.pi.csiro.au/Publicat/Pest/
- Integrated Pest Management (IPM) guidelines for cotton in the US; University of California. www.ipm.ucdavis.edu/PMG/selectnewpest.cotton.html
- CABI Bioscience Crop Protection Compendium. Includes many documents referring to cotton. www.cabi.org/compendia/cpc/index.htm
- CABI Bioscience Global Plant Clinic. http://82.43.123.182/globalplantclinic/index.htm
- CABI Bioscience, Ed. (2000). Conserving Natural Enemies. Farmer Participatory Training and Research Programme. Working with Natural Enemies Series. Ascot, CABI Bioscience. 249 p. plus tables. www.cabi-bioscience.org
- PAN Pesticides Database, with detailed information on (mainly chemical) pesticides. www.pesticideinfo.org/Index.html
- Cotton South Africa, with some material on (integrated) pest management. www.cottonsa.org.za/publications.html

Chapter 6: Soil Cultivation and Weed Management

- IFOAM Training Manual for Organic Agriculture, Soil Fertility (Chapter 3) and Pest, Disease and Weed Management (Chapter 5). www.fibl.org/english/publications/training-manual
- HDRA: Weed Control. The Henry Doubleday Research Association HDRA. 12 p. www.hdra.org.uk/publications/index.htm

Chapter 7: Water Management

- IFOAM Training Manual for Organic Agriculture, Water Conservation (Chapter 3.5). www.fibl.org/english/publications/training-manual
- International Water Management Institute (IWMI). www.iwmi.cgiar.org
- Micro-Irrigation Forum. www.microirrigationforum.com

Chapter 8: Harvest and Post-Harvest Operations

- Organic Exchange, a platform of the organic cotton industry, provides market links and information, with a detailed world overview of organic cotton production. www.organicexchange.org/

Chapter 9: Farm Economy

- Results and extension tools of the Organic Cotton Research Project. www.fibl.org/international/projekte/organiccotton.php
- IFOAM Training Manual for Organic Agriculture, Farm Economy (Chapter 7). www.fibl.org/english/publications/training-manual
- Clients first – A rapid market appraisal tool kit. Helvetas. www.helvetas.ch

10.5 Organic cotton crop calendar in central India

The following crop calendar lists the activities for organic cotton production as recommended by Maikaal bioRe, India. The crop calendar can be used as a template and source of inspiration, while the activities need to be adapted to the prevalent local conditions.

	Crop Management and general activities	Soil and water management	Pest management and crop care
April	› Remove crop residues, use for mulching and composting › Plan for the next cropping season: which crop on which field, which varieties, farm map, farm records › Organize inputs: seeds of cotton and intercrops, manures from outside, pest-management products, irrigation facilities › Visit trainings, study organic farming	› Plough the fields › Prepare compost › Turn of compost and manure heaps › Build water harvesting structures (trenches, bunds) › Summer cotton: apply FYM, compost.	› By deep ploughing you expose the hibernating insect pests, their eggs, larvae and pupae in the soil and kill them
May	› Summer cotton: mark the fields with sticks › Sow cotton in the second week of May › Sow border crop (at the time of sowing cotton) › Keep records › Gap fill ten days after sowing	› Irrigate › Apply DOC and compost three weeks after cotton germinates › Build water harvesting structures › Apply 'Matka khad' or 'Jeev amruth' (liquid manures) to summer cotton › For monsoon cotton: apply compost or farmyard manure	› Monitor for cutworms › If infested: control cutworms (pyrethrum, hand-picking, baits; irrigation with asafetida pouches in the irrigation channels)
June	› Monsoon cotton: mark the fields with sticks › Do not sow cotton until the third week of June, after sufficient rain has fallen › Sow intercrop or green manure (up to four weeks after sowing cotton) › Summer cotton: weed and fill gaps with trap crops › Record-keeping	› Summer cotton: intercultural operation › Irrigate summer cotton, if necessary › Prepare 'Matka khad' (liquid manure) › Spray BD 500	› Monitor for cutworms and aphids › If infested: control cutworms (see above) and aphids (neem, botanical mixture, cow urine, soap) › Prepare botanical sprays for pest management › Set up pheromone traps for spotted bollworm end of June
July	› Weed › Fill gaps with trap crop (sunflower, maize, pigeon pea) › Re-sow border crop and intercrop if germination was insufficient › Record-keeping	› Monsoon cotton: apply DOC and compost three weeks after cotton germinates › Intercultural operations, form irrigation furrows › Drain excess water in case of waterlogging › If monsoon is delayed, prepare irrigation channels and irrigate	› Monitor for aphids and jassids › Install light traps and sticky traps for monitoring bollworm populations › Set up pheromone traps end of July › Use of trichoderma viridae in case of wilting problem due to waterlogging in fields › Set up sticky boards for monitoring whitefly, jassids and aphids (end of July)
August	› Record keeping › Weed › Fill gaps with trap crop	› Possibly apply top dressing of DOC and compost, or with liquid manure › Drain excess water in case of waterlogging › Intercultural operations if necessary › Plough green manure into the soil › Apply DOC, rock phosphate, bone meal and/or compost as top dressing › Prepare irrigation channels	› Monitor for American and spotted bollworm › Spray cow urine as a repellent for sucking pest and to enhance the growth of the plant, or vermi-wash to strengthen plants › Spray neem, buttermilk or botanical mixtures if bollworms are beyond economic threshold › Distribute Trichocards against bollworm (August and September) › Summer cotton: Spray BD 501
September	› Prepare for picking summer cotton: prepare bags, clean the storage place, prepare registers to keep records of cotton picking › Visit other organic farms to learn about their practices	› Possibly apply top dressing of DOC and compost, or liquid manure › Intercultural operations if necessary › Irrigate, if necessary	› Monitor for American and spotted bollworm, and whitefly › Spray cow urine or vermi-wash to strengthen plants against sucking pests › Spray buttermilk or botanical mixtures, if bollworms are beyond economic threshold › In case of heavy bollworm infestation: spray Bt (e.g. Dipel) or NPV › Monsoon cotton: Spray BD 501

	Crop Management and general activities	Soil and water management	Pest management and crop care
October	› Pick cotton and keep records › Sell cotton › Visit other organic farms to learn about their practices	› Possibly apply top dressing of liquid manure › Intercultural operations, if necessary › Irrigate, if necessary (avoid both drought and waterlogging!) › Build up compost heaps with collected biomass and weeds	› Monitor for whitefly, spray neem-based formulations or botanicals if beyond economic threshold › Set up pheromone traps for pink bollworm › Prophylactic spray of neem to repel bollworms and to delay hatching of eggs › Spray of cow urine or vermi-wash to strengthen plants against sucking pests
November	› Pick cotton and keep records › Sell cotton › Sow wheat crop in summer cotton fields, if suitable and sufficient irrigation › Visit other organic farms to learn about their practices	› Possibly apply top dressing of DOC and liquid manure for inducing a second flush › Intercultural operations, if necessary › Irrigate as per necessity (avoid both drought and waterlogging!) › Apply compost to wheat fields (Rabi crop) › Build up compost heaps with collected biomass and weeds	› Spray Bt (e.g. Dipel) if pink bollworm is beyond economic threshold › Spray neem formulations if whitefly is beyond economic threshold › Spray botanical mixtures or pyrethrum if cotton stainer is beyond economic threshold
December	› Pick cotton and keep records › Sell cotton › Uproot of cotton after last picking › Sow wheat crop in summer cotton fields, if suitable and sufficient irrigation › Visit other organic farms to learn about their practices	› Possibly apply top dressing of liquid manure › Intercultural operations, if necessary › Irrigate to induce a second flush, if suitable › Apply compost to wheat fields (Rabi crop) › Build up compost heaps with collected biomass and weeds › Turn the compost heaps set up earlier	› Monitor for pink bollworm, whitefly and cotton stainer (red cotton bug); treat if beyond economic threshold (see above)
January	› Pick cotton and keep records › Sell cotton › Uproot cotton after last picking	› Intercultural operations if necessary › Irrigate as per necessity (avoid both drought and waterlogging!) › Build up compost heaps with collected biomass, crop residues and weeds › Turn the compost heaps set up earlier	› Monitor for whitefly and cotton stainer (red cotton bug), treat if beyond economic threshold (see above)
February	› Pick cotton and keep records › Sell cotton › Uproot cotton after last picking	› Build up compost heaps with collected biomass, crop residues and weeds › Turn the compost heaps set up earlier	› Monitor for whitefly and cotton stainer (red cotton bug), treat if beyond economic threshold (see above)
March	› Pick cotton and keep records › Sell cotton › Uproot cotton after last picking	› Build up compost heaps with collected biomass, crop residues and weeds › Turn the compost heaps set up earlier › Cultivate soil (plough)	

10.6 Template for keeping crop records

The following sheet is an example of a completed template with which farmers can easily keep crop records (see Chapter 9.4). The template is available on www.fibl.org/organiccotton.

Farmer Name: Gajendra Chouhan **Year: 2004** **Crop: Cotton** **Size under crop: 1.2 acre** **Intercrop: Moong** **Harvest intercrop: 15 kg**

Date	**Activity**	**Labour**		**Other Expenses (inputs, rent, irrigation etc.)**			**Crop harvest**	
d/m	Name or brief description of the activity	Own labour days	Hired labour costs	Name of the item	Quantity (kg)	Cost (Rs)	Quantity (kg)	Value (Rs)
25/5	Ploughed fields with bullocks		50					
6/6	Levelling and cleaning of fields		120					
25/6	Cotton seeds sown	2	100	Ankoor-651	2 pkts.	700		
5/7	Weeding	5	200					
6/7	Gap filling	1	20					
13/7	Sowing of moong (intercrop)	2	20	Moong seeds	0.5 kg	50		
20/7	Spraying for sucking pest	1		Econeem	100 ml	75		
25/7	Manure application	2	20	DOC (3 bags), compost 1ton		555		
5/9	Irrigation	2			20 hrs	400		
12/9	Spraying for bollworm		60	Dipel	200 ml	280		
20/10	Cotton picking		130				65	1,170
2/11	Cotton picking		180				90	1,800
3/11	Harvesting moong (15 kg)	1						
5/11	Irrigation	2			17 hrs	340		
12/11	Cotton picking		170				85	1,785
24/11	Cotton picking		210				105	2,310
12/12	Cotton picking		130				65	1,170
28/12	Cotton picking		360				180	3,600
30/12	Uprooting of cotton	1	100					
Totals:		**19**	**1,870**	**Totals:**	**------**	**2,400**	**590**	**11,835**

Average labour rate: 30 Rs./day — Intercrop value: 300 Rs.

Yield	**492 kg/acre**	**Total production cost**	**4,840 Rs.**	**Net profit** (incl. own labour)	**7'295 Rs.**	**6,079 Rs./acre**
(Crop harvest/land size)		(Own labour days * rate + hired labour costs + expenses)		Crop value + intercrop value – total production cost)		(divide by land size)

Authors

Frank Eyhorn completed his diploma (master level) in environmental sciences and a postgraduate course on developing countries at the Swiss Federal Institute of Technology (ETH). Since 2000 he has been with the International Cooperation division of the Research Institute of Organic Agriculture (FiBL), Switzerland. Besides developing extension tools like the *IFOAM Training Manual for Organic Agriculture in the Tropics*, he has focused on implementing and coordinating the institute's activities in India. Projects have dealt with system comparison research on organic cotton, certification schemes, development of a competence centre for organic agriculture, policy advice, and market development. Since 2002 he has been leading the research project on organic cotton at Maikaal bioRe (India), funded by the Swiss Agency for Development and Cooperation (SDC). In connection with this project he has taken up a PhD project studying the impact of organic cotton production on the livelihoods of Indian smallholders.

Mahesh Ramakrishnan obtained his masters degree in agriculture from Jawaharlal Nehru Agricultural University, Jabalpur in1996. He further completed a course on Managing Rural Development, organized jointly by ITAD Sussex and Imperial College of Science, Technology & Medicine (University of London) at its rural campus in Wye, United Kingdom in 2001. He has nine years of field experience at grassroot level in the area of rural development, organic research, extension, training and capacity building. Since 2003 he worked as Field Research Coordinator in the Indo-Swiss research project on organic cotton at Maikaal bioRe (India). He was responsible for the coordination and implementation of the field research activities and also implemented Participatory Technology Development activities for improving organic cotton production. He contributed to the IFOAM training manual for Organic Agriculture in the Arid and Semi-arid Tropics as a co-author for the chapter on organic cotton. Since 2005 he is working as organic cotton expert at the International Competence Centre for Organic Agriculture (ICCOA), Bangalore.

Saro G. Ratter is Engineer of Agriculture since 1998 and works as consultant for organic farming and project management. Since 1994 he is working for an organic cotton project in Tanzania. He has carried out feasibility studies, project evaluations and consultancies in Uganda, Kenya, Sénégal, Bénin, Burkina Faso, Turkey and India. He has participated with presentations on organic cotton themes at several conferences, for example the IFOAM Congress in Canada, organic cotton conferences in Bénin and Germany and the EU - Africa Cotton Forum in France. Other activities related to organic cotton have included updating the NATURLAND organic cotton manual, providing consultancy for a smallholder association in Paraguay on the development of organic and Fair Trade cotton, a WWF study and workshop on "Effects of cotton production on poverty and environment in Tanzania" as well as trade promotion activities at various trade fairs (e.g. BioFach and InNaTex). For many years, Saro Ratter is an active member of the PAN-Organic Cotton Working Group.

Designed primarily as a reference manual for extension workers and farmers, the *Organic Cotton Crop Guide* provides comprehensive practical know-how on organic cotton production in the tropics. The guide covers all relevant aspects from soil preparation and variety selection over crop nutrition and pest management to the economic performance of organic cotton farming. Rather than prescribing a fixed package of practices, the guide enables practitioners to design cotton-based organic farming systems adapted to their specific environmental and socio-economic context. Written in a simple and direct style, it contains numerous illustrations, tables and annexes.

The guide draws on 3 years of research on organic cotton farming conducted within the Maikaal bioRe project in India. It further integrates lessons learnt in other organic cotton projects in Asia and Africa. Information compiled from literature and the Internet supplements the research findings, making this guide the most comprehensive and in-depth book on organic cotton production presently available.

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