

Organic Farming in the Tropics and Subtropics

Exemplary Description of 20 Crops

Cotton



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The cultivation guidelines are available in English, Spanish and German for the following crops:

banana, brazil nut, cashew nut, cocoa, coconut, coffee,
cotton, hibiscus, macadamia, mango, papaya, peanut,
pepper, pineapple, sugar cane, sesame, tea, vanilla.

The cultivation guidelines for **Bananas, Mangoes, Pineapples and Pepper** were revised in 2001 for the United Nations Conference on Trade and Development (UNCTAD) by Udo Censkowsky and Friederike Höngen.

In 2002 two more guidelines, for **Rice and Date palms**, were published in English.

The cultivation guideline for **Cotton** was revised in 2004 by Saro G. Ratter.

All the authors emphasize, that the cultivation recommendations at hand can just provide general information. They do not substitute technical assistance to the farmers with regard to the location.

All indications, data and results of this cultivation guidelines have been compiled and cross-checked most carefully by the authors. Yet mistakes with regard to the contents cannot be precluded. The indicated legal regulations are based on the state of the year 1999 and are subject to alterations in future. Consequently all information has to be given in exclusion of any obligation or guarantee by Naturland e.V. or the authors. Both Naturland e.V. and authors therefore do not accept any responsibility or liability.

Furthermore the authors kindly call upon for critical remarks, additions and other important information to be forwarded to the address below. The cultivation guidelines will be updated regularly by Naturland e.V.

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Organic Cotton Cultivation

1. Introduction

1.1. Botany

The cotton plant belongs to the Malvaceae family. Over 30 species have been discovered (among others: *Gossypium hirsutum* L., *G. barbadense* L., *G. arboreum* L.). Cotton as a tropical crop originates from several locations (southern Africa, south-east Asia and Peru). There are annual and two-year species, as well as perennial varieties. It produces a yellow, white and purple-red blossom, and is a hermaphrodite.

1.2. Varieties and countries of origin

World wide there are ca. 33 mill. hectares of cotton crops. Economically, the most important varieties are *Gossypium hirsutum* and *Gossypium barbadense*.

***G. hirsutum*:**

- Upland cotton
- 80-90% of world market
- short to medium fibres (2-3 cm; middle stapled variety)

***G. barbadense*:**

- Sea Island cotton
- 10-20% of global market
- high-quality, long to very long fibres (3-4 cm; long stapled variety)

In addition, the annual *G. herbaceum* or the hardy cotton bush *G. arboreum* produces fibres with a length of 1.8-2.2 cm. Long stapled varieties are cultivated mostly in Egypt and Peru. The middle stapled varieties from the USA, short stapled varieties in Asia *G. barbadense* is more susceptible to pests due to its long vegetation period *G. hirsutum*, that ripens far quicker (some varieties after only 150 days).

All of the cotton varieties with coloured fibres, formed from crossings between wild varieties (from Peru) and crops, have provoked a certain interest in the natural textile processing industry. Until now, mostly brown, green and beige varieties had been cultivated.

Organic cotton production is most widely spread in the USA (ca. 4000 ha). Yet ecological cotton projects also exist in Egypt, Argentina, Brazil, Greece, India, Mali, Nicaragua, Paraguay, Peru, Tanzania, Turkey and Uganda.

Examples of varieties used on organic cotton plantations	
Egypt	Giza 75, Giza 85
Argentina	Pima
Paraguay	Repapes, Linea 100, Deltapine 90
Peru	Tanguis, Pima
Turkey	Nazilli 84, Nazilli 87
India	H – 8 and - 10, JKH 1, JK – 4, Ankur - 09, - 651 and - 2534, Mahabeej, Jawahar Tapti

1.3. Uses and contents

Cotton can be seen as a classic dual purpose plant (fibres and oil).
A harvest yielding 1000 kg of cotton/ha can be broken down thus:

- ca. 320 - 420 kg fibres (raw cotton)
- ca. 200 - 250 kg seed cakes or flour
- ca. 100 – 150 kg oil
- ca. 200 kg shells
- ca. 20 kg retained seeds
- ca. 40 kg dirt

The fibres (lint-fibres, lint) are used in the production of materials (threads, fabrics, etc.), whilst the linters (fluff separated from the cotton seeds) are used to produce cellulose fibres and other cellulose products, thick threads and stuffing materials, as well as being used for the production of paper.

Oil produced from the seeds can be used as edible oil, among other things. When oil is produced from the cotton seeds and pelleted feed used as fodder, care must be taken to remove the Gossypol that forms in the oil/cakes by heating it. Gossypol is poisonous to humans and animals with normal stomachs (e.g. pigs), only ruminants can digest cakes containing Gossypol without a problem. The seed shells can be used as raw fodder for animals, as straw, dung or as fuel.

2. Aspects of plant cultivation

2.1. Site requirements

In its early stages of growth, cotton requires an arid climate with a plentiful supply of water. Afterwards, the weather needs to be dry, especially after the capsules have opened, for if rain can enter at this stage it will have a detrimental effect on the quality. The vegetation period generally lasts around 180-220 days (varieties such as *G. hirsutum*. that mature rapidly can be harvested after only 150 days). Very high yields have been reported from the arid areas of the CIS and in Egypt using

irrigation. Because cotton loves the heat, yet is also highly susceptible to frost, temperatures of around 26-28°C are ideal for its development. Lots of sun has a very positive effect during the blossoming and fruit setting periods, in cases of 50% and more cloud during the vegetation period it makes little sense to plant cotton. Cotton cannot withstand shade. Cotton is also a short-day plant, and such conditions will accelerate its growth. The correct climatic conditions are generally found between the 28° northern and 47° southern latitudes.

A strong wind can suck the fibres out of the capsules and blow them away. Today's varieties are tolerant with regard to salinity (up to a salinity of 0.5-0.6%). The soil's pH value should be between 6 and 8. In addition, cotton also requires deep, well-drained and ventilated soil, in order to properly develop its system of tap-roots (resistance to drought).

The site's elevation plays a large role when planting coloured varieties of cotton, because the intensity of the sun's rays has a strong effect. At least the green varieties tend to bleaching when the intensity increases too much (Peru).

2.2. Seeds and shoots

The fertilisation process is generative. Most wild *Gossypium* varieties are perennial. Annual varieties are most generally used for cultivation, which conclude their development cycle during one single vegetation period. Local and regionally produced seeds should be used, which will have developed a tolerance or resistance against the pests most commonly found in the region. Because the sale of seeds is usually controlled by government authorities, it is important to try to acquire untreated seeds of the desired variety early enough.

During the last few years, hybrid seeds have been developed that provide high yields. Yet this method makes it impossible to use self-produced seeds from the crop, and a new supply of seeds must be bought for the next season.

Because cotton can be affected by various root and damping off diseases, in certain cases, it is worthwhile considering pre-treating the seeds. In contrast to conventional cotton crops, only micro-organisms, which work antagonistically, are used. In Egypt, for example, the seeds are treated with *Bacillus subtilis*, *Gliocladium penicilloides* and/or a suspension of trichoderma. In order to improve the nutrient availability for the young plants in India, the seeds are additionally treated with azotobacter and bacteria strains capable of breaking down phosphorous.

2.3. Sowing methods

If the cotton is to be planted by machines, then the seeds need to be rid of the fluff that surrounds them (otherwise "the seeds stick together"). This is not necessary when the seeds are sown by hand. The temperature should not fall below 18°C whilst sowing, 35°C is optimal. The seeds should not be sown at a depth of more than 5 cm.

The density depends upon the method utilised (manual or by machine). Bio-dynamic farmers in Egypt sow several seeds by hand every 20 cm into the prepared planting rows (distances between the rows 60-70 cm). Between three and four weeks later, the plants are inspected and all but the two strongest specimens removed. The plant population of rain-fed cotton of small-scale farmers in Tanzania is much lower. The farmers sow cotton by broadcasting the seeds on the flat land or in rows at a spacing of 90 cm between and 30 – 50 cm in the rows. Some farmers sow also on ridges with the same spacing.

Mechanical methods usually leave 70 cm (50-120 cm) between the rows and 20 cm (20-60 cm) distance between the seeds. When the harvest is done mechanically, varieties such as *G. hirsutum* that produce few branches are sown every 8-10 cm with a distance between the rows of 15-20 cm.

Cotton is either planted on flat soil, ridges or in furrows. Furrow drilling is employed mainly as a protection against quicksand. Ridges are used in soils, which are difficult to drain, and in regions with little rainfall, as this eases irrigation and facilitate the seeping in of the water into the soil. Its disadvantages are more difficult sowing and tilling of weeds. The cotton is sown in the lower third of a ridge in high-content soils and the upper third for low content soils. The seeds should be watered as soon as possible after sowing.

During the first 3 weeks, the shoots can offer little resistance against weeds, but this improves until the thick crop growth has no more problems in the area. For this reason, a suitable position in the crop rotation, suitable soil cultivation method and preparation of the seed beds should be taken care of to prevent an excessive growth of weeds during the early growth phases. On irrigated soils, irrigation is carried out prior to sowing in order that the weed seeds germinate and grow. The resulting growth of weeds can then be easily removed by appropriately cultivating the soil, before the cotton is sowed. The final soil treatment before planting should include the spreading of compost.

2.4. Diversification strategies

comp. chapter 2.6.

2.5. Supplying nutrients and organic fertilisation management

2.5.1. Nutrient requirements

A cotton harvest of 550 kg/ha will extract 40 kg N, 16 kg P₂O₅ and 17 kg K₂O (established during examinations of conventional cotton plantations) from the soil. Cotton requires most of its nutrients during the first 60 days of growth (ca. 2/3). Supplying too much nitrogen will lead to excessive vegetative growth with negative effects on the yield. These effects are caused by a reduction of forming of bolls and

a reduced crops resistance to certain insects (e.g. *P. gossypiella*). Moreover, the ripening is delayed.

2.5.2. Strategies for supplying organic manure

A central feature is an appropriate crop rotation system with a high proportion of legumes (e.g. clover as a pre or intermediary crop) to provide sufficient nitrogen. Because cotton places one-sided nutrient demands on the soil, its ratio in the system should not be more than 1/3 (varies according to site). The following systems of crop rotation are well documented on organic cotton plantations:

1. Crop type	2. Crop type	3. Crop type	4. Crop type	Country
Cotton	Peanuts/ Sesame	Wheat/Barley		Turkey
Cotton	Sorgo	Sesame	Peanuts	Paraguay
Cotton with sunflower as trap crop	Sorgo, Maize, Sesame	Peanuts, Mung beans, Pigeon peas		Tanzania
Cotton in mixed systems with onions and garlic	Wheat	Egyptian clover		Egypt
Cotton in mixed systems with peanut/mung beans	In rotation with maize, wheat, leguminous, fodder crops			India
Cotton	In rotation with grains, tomatoes, vegetables, fodder legumes			USA
Cotton together with vetch as a green fertiliser	C together with vetch as a green fertiliser	Oats, maize, pumpkin, Kerstings groundnut		Argentina
Moco-cotton	perennial cotton in rotation with maize, beans and leucaena			Brazil

In the course of these crop rotation examples, green manure plants are generally planted between the individual crop types, depending on the water supply. In Turkey, for instance, positive results have been achieved by using a vetch/barley mix 6 months before the cotton is planted (winter season).

In more arid regions and without the possibilities of irrigation it is not possible to grow green manure plants during a second growing season. For example in Tanzania the farmers get only 1 harvest per year and the recommended crop rotation has a minimum of 3 years. The first year after cotton the farmers grow cereals like sorghum or maize or other cash crops like sesame. In the third year the farmers grow legumes where they have a big choice. Possible is for example

peanuts, mung beans, local beans, chick peas, cow peas, pigeon peas. Then only in the third year comes cotton again. This minimum of 3 years crop rotation helps also to reduce the *Striga* infestation in maize and sorghum, which is quite common in the area and encouraged by the traditional practice of growing cereals on the same plot for several years. So the conversion to organic cotton cultivation helps the farmers to increase their maize and sorghum production.

In addition, compost, decomposed animal dung and mulching material are also used to supply the soil with sufficient organic material to support the cotton's growth. Potassium can be supplied by spreading wood ashes, and phosphor by adding rock phosphate. Usually, the soil is prepared before the cotton is sown by spreading compost (pre-mixed with ashes and rock phosphate).

An example of fertilisation from Egypt:	
Compost	45-50 m ³ compost (with up to 30% mixed in soil, cow dung and straw)
Phosphate	400-700 kg 13% Egyptian rock phosphate mixed in with the compost, acc. to a soil analysis
Potassium	200-470 kg ashes mixed in with the compost depending on the soil
Sulphur	For soils with an extremely high salt content 200 to 450 kg of fertilising sulphur will partly "desalinate" the soil

Onions and garlic sown between the cotton crops (strip cropping) will encourage Mycorrhiza, the roots of the onion plant can break down phosphates and produce Sesteindialkylsulfid, which can reduce the growth of pathogenous fungi in the soil. In addition, lucerne (*Medicago Sativa L.*), as a nitrogen-rich source of food, is also sown in strips in-between the cotton rows in order to draw pests away from the cotton. Additional planting of, for example, leucena or prosopis can also provide nitrogen and mulching material.

An example of fertilisation from Maikaal bioRe India:	
Farm Yard Manure or Compost or Vermicompost	7 tons per acre 5 tons per acre 3 tons per acre
Castor De Oiled Cake	100 kg per acre
Phosphate	Rock phosphate 25 kg per acre
Bio-dynamic Preparations	BD 500: 100 g per acre + BD 501: 2 g per acre

Foliar Feed (spray)	Biogas slurry: 1 l fermented slurry in 10 litre of water Cow urine: 1 l in 10 litre of water Vermi wash: 1 l in 10 litre of water
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The Field Research Coordinator of the company Maikaal bioRe Ltd. explains the fertilisation practices of his 1.200 small-scale farmers as follows:

“To keep the soil fertile bioRe India is recommending proper crop rotation. Inter-cropping and border-cropping are being promoted, various spatial arrangements are being tested (e.g. with sunflower, cowpea or pigeon peas).

For improving soil fertility bioRe farmers in India are applying compost to the soil, which they prepare in the villages as cow dung and other organic waste are easily available in the villages, the compost is prepared through NADEP method by making heaps with sufficient moisture, which in turn generates employment for the rural youths in their own villages. To increase microbial activities in the soil, bioRe is also promoting the use of biodynamic preparations, which improve the quality of the produce.

Adding pond soil of rural areas has also given very good results in crop production and is extensively adopted by the farmers of this region.”

(Source: Mr. Mahesh Ramakrishnan, Field Research Coordinator, Maikaal bioRe (India) Ltd., personal communication, 2003)

The organic small-scale farmers in Tanzania can still afford to pay less attention on fertilisation because they have large areas available for cultivation and the soils are still quite fertile. The most important measure for fertilisation is the crop rotation with the integration of legumes. The next step is then the application of farmyard manure. They are advised to utilize 10 to 30 tons of manure per hectare. Other fertilisers are not used in the area. Also the small-scale farmers in Uganda use no external fertilisers because the soils are still quite fertile.

This is not the case for the organic small-scale farmers in Bénin, Sénégal and Mali, where the cotton production is more intensive and the soils less fertile.

In Bénin there are many smallholders without enough livestock to get sufficient farmyard manure. They are advised to use per hectare 250 kg of bat manure (guano) mixed with 50 kg of ash but in practice these quantities are seldom reached.

In Mali the organic smallholders are advised to use 14 to 18 t/ha of manure and a natural phosphate fertiliser (PNT = Phosphate Naturel de Tilemsi) at a rate of 400

kg/ha but the average use of the farmers is only about 10 t/ha of manure and 116 kg/ha of PNT.

2.6. Biological methods of plant protection

Preventative or combating methods are already known for all of the important pests and diseases that can occur on organic cotton plantations. In the long-term, it is safe to presume that a high level of pest and diseases will significantly diminish following the introduction of an organic cultivation system.

Yet this requires a successful plant protection management system. The farmer should inform himself in time:

- Which important infection agents are present in the region,
- Which preventative strategies he wishes to implement against them on his site,
- Which combating measures exist against a heavy infestation,
- Which permitted resources are available for organic systems,
- How these are applied
- When it is correct time to apply them
- Whom he can turn to in an emergency (advice).

The following **preventative measures** should thereby be strictly adhered to:

Selecting crop rotation:

As cotton is not well compatible with itself, it is not advisable to have a larger ratio than 1/3 in the crop rotation. Other mallow plants (e.g. hibiscus) must be excluded from the rotation, or at least not planted on the same soil. It is also important to check that no cotton is grown on any of the neighbouring plots. On the whole, a diversified crop rotation works best.

Mixed crops with plants that act as a repellent:

Mixed or strip cultivation with onions, garlic, chillies, chrysanthemums or hot peppers have proved their worth because of their repellent effect against, among others, bugs, white fly and cotton leafworm (*Alabama argillacea*). Rotted liquid manure can also act as a repellent (and be simultaneously used as a fertiliser).

Cultivation of trap crops:

Trap crops manage to keep pests away from the cotton by offering a more attractive source of food. Strip cropping using lucerne (*Medicago sativa* L.) within the cotton plants is, for example, practised in the USA and Paraguay, in order to keep pests such as different bug species (*Dysdercus spp.*, *Lygus spp.*), *Helicoverpa spp.*, *Spodoptera littoralis*, *Platyedra gossypiella* and aphids away from the cotton.

Sowing sorgo before the cotton (on neighbouring plots) can help to build up a population of useful insects, which can then combat cotton pests when they appear at an early stage (e.g. aphids).

A similar strategy can be followed by planting *Hibiscus esculentus* against the pest *Podagrica spp.*, planting *Lablab niger L.* against the pests *Helicoverpa spp.*, *Spodoptera littoralis* and *Bemisia tabaci*, or nasturtium against *Tetranychus cinnabarinus* (these are based on experiences culled from Turkey and in Sudan).

During 9 years of organic cotton growing in Tanzania the experiences have shown that the most important cotton pest *Helicoverpa spp.* can be controlled with sunflower as trap crop to such an extent that the threshold for an economic application of insecticides is not reached in most cases.

The recommended practice is to sow one row of sunflower around the cotton plot as a living fence and one row of sunflower all 10 meters in the plot. The sowing time has to be very close to the cotton sowing so that the sunflower will be in the flowering stage when the infestation period starts. The sunflowers attract the moths of *Helicoverpa spp.* to lay their eggs. The caterpillars are feeding on the sunflower however without destroying the production of sunflower seeds. So the farmers can get an additional income from the sunflower seeds.

The caterpillars on the sunflowers show also the phenomenon of cannibalism so that they reduce their number itself (Source: Dr. Braun, gtz-IPM project, personal communication, 1997).

The positive effects of sunflowers are also shown in the results of a study that was carried out by an entomologist on behalf of the GTZ-IPM project in Shinyanga. The researcher found out that in organic cotton plots with sunflowers were up to ten times more useful ants compared with cotton plots without sunflower. It is known that these ants are reducing the eggs and larvae of the African bollworm (*Helicoverpa armigera*). (Source: Varela, Ana (1996) "Ants as mortality factors of the African bollworm *Helicoverpa armigera* in smallholder cotton fields in Tanzania").

A booklet about the natural enemies of the African bollworm names especially the ant species *Myrmecaria* and *Pheidole* as important. "On sunflower, ants were observed to reduce bollworms by as much as 85%." (Source: van den Berg, H. + Cook, M.J.W., (1993) "African bollworm and its natural enemies in Kenya", P. 33, CAB International + NRI, International Institute of Biological Control, Kenya Station). Many contracted smallholders in Tanzania confirm the positive effects on the cotton yield by cultivating sunflower as trap crop and even many conventional neighbours in the region started copying this cheap and easy method of preventive pest control.

Pigeon peas (*Cajanus cajan*) can also be a useful trap crop for pests like *Helicoverpa spp.* but it is not so easy to synchronise the flowering stage of the trap crop with the infestation period of the pest. The local pigeon pea varieties in Tanzania start the flowering too late to be an efficient trap crop. Early maturing varieties or sowing of pigeon peas in the previous year could resolve this problem. In the bioRe India project the pigeon peas are successfully use as trap crop in cotton.

Trap crops planted in autumn (e.g. maize) can be used in combination with a pheromone against hibernating boll weevils.

Leaving a strip of natural vegetation around the cotton plot can be useful against aphids and other pests.

Choosing a site:

Cotton should be planted in healthy soil wherever possible. In principle, sites that are infested with weeds should not be sown with cotton, but first cultivated with an appropriate rotation crop in order to prepare it. Care should be taken that no cotton is planted in the neighbouring plots.

Sowing time:

The choice of when to sow plays an important role. Cotton sown too early will possibly become infested by the pest population that has already developed there. In Tanzania the late sown cotton is often attacked by African bollworm (*Helicoverpa armigera*) that developed on maize or sorghum plots. At the end of the season the risk of the late season pest cotton stainers (*Dysdercus spp.*) is higher on late sown cotton while it is a minor problem on early sown cotton.

Mulching of harvest residues:

Careful mulching of the remains of a cotton harvest can help prevent the survival of pests (e.g. *P.gossypiella* in seeds and boll weevil, *Anthonomus grandis*). In the case of heavy infestations with wilting diseases, such as bacterial blight (*Xanthomonas malvacearum*), Anthracnose (*Glomerella gossypii*), verticillium-wilt (*Verticillium alboatrum*) or fusarium-wilt (*Fusarium oxysporum*) it is recommended to remove the residue and then apply for composting.

Sufficient, balanced supply of nutrients:

A plant that receives balanced nutrients is more vigorous, and therefore less susceptible to infestation. As already mentioned, supplying too much nitrogen will lead to an infestation by pests.

Choosing a variety:

It is hereby important to choose varieties adapted to the site conditions, and that are resistant to, or can tolerate, the main pests. In addition, general varieties have proven their worth that matures quicker, thereby shortening the time span they can be infested. Gossypol-free are not so well suited to organic plantations because Gossypol (just like other terpenoide chemical compounds) has a repellent effect on certain insects (e.g. against *Helicoverpa spp.*, *Spodoptera spp.* and *Pectinophora spp.*).

How easy or difficult it is to choose a suitable variety show the examples from Tanzania and India.

While in Tanzania there is only 1 cotton variety per production zone the bioRe farmers in India use 9 out of more than 50 different varieties according to their specific needs and preferences. It follows a list with the advantages and disadvantages of the varieties used in India, which shows the different aspects that can be important for the decision.

S.No.	Variety	Advantages	Disadvantages
1	H-8	Early variety Less pest attack	Short staple length Not suitable for summer sowing
2	H-10	Late variety Suitable for summer sowing Good staple length	Susceptible to pest attack Not suitable for light soil
3	JKH-1	Good staple length Suitable for second crop	Susceptible to drought Shading of square is more
4	Ankur-09	Early variety Long staple length	Not suitable for summer sowing Susceptible to water logging
5	Ankur-2534	Long staple length Suitable for rainy sowing	Susceptible to bollworm
6	Ankur-651	Good variety for heavy soil Drought resistant	Not suitable for light soil Boll size reduces in later picking
7	Mahabeej	Staple length better than Jawahar tapti Resistant to sucking pest	Not suitable for light soil
8	Jawahar Tapti	Resistant to diseases and bollworm Requires less water	Susceptible to sucking pest Short staple length
9	JK-4	Good staple length Resistant to disease and bollworm Requires less water	Not resistant to sucking pest.

(Source: Mr. Mahesh Ramakrishnan, Field Research Coordinator, Maikaal bioRe (India) Ltd., personal communication, 2003)

Planting of boundary areas:

Planting 2-3 rows of trees or hedges along the boundaries provides a habitat for birds, improves climatic conditions and reduces the amount of water needed for cotton.

Checking the infestation level of cotton pests:

In Tanzania the gtz-IPM project has developed a method to check the infestation level of the key pest *Helicoverpa armigera*. The method is called "scouting" and it

works by counting the squared buds on 30 plants of 1 acre. If the number of squared buds comes up to 15 the economic threshold is reached and the farmers are advised to spray an insecticide. The organic farmers then apply an oily formulation of neem. This “scouting” method works much faster than looking for the pests itself and helps to avoid many applications of insecticide (in organic and in conventional farming).

Light traps allow seeing the start of pests moving into the cotton plot and at the same time reducing the number of moths laying eggs on the cotton plant. In Tanzania the farmers use a simple kerosene lamp in a water basin as light trap. These are put in the fields at rate of one per acre for about two hours after sunset. The reduction of moths can help to reduce the number of sprayings.

Direct combating measures:

Direct methods of combating pests are also available for organic plantations, yet are only to be used in emergencies (and not as preventatives). It is necessary that the cotton, and any pests which may eventually develop, should be regularly inspected in order to be able to decide whether a direct method is to be used or not (see chapter above).

If the critical threshold is reached and there is an immediate threat for the cotton harvest the organic farmers need to have insecticides available that are allowed in organic farming. There are several botanical insecticides, which proved to be efficient against important cotton pests.

In India the bioRe farmers can choose among 3 commercial neem formulations and the self-made preparations made with crushed neem seeds. In Tanzania the farmers can get one neem formulation imported from Kenya and another from India to control *Helicoverpa armigera*. Against the late season pest *Dysdercus spp.* the farmers use a locally formulated Pyrethrum preparation with black wattle extract (*Acacia mearnsii*) as UV-light stabilisator.

Beside the neem products there are also some other plants that can be useful to produce botanical insecticides. In Tanzania the Ukiriguru Research Institute tested with promising results an emulsion of *Jatropha curcas* oil against *Helicoverpa armigera*. In Mali it has been tested against Sorghum pests and a report from Malawi states: “The oil and aqueous extract from oil (active principle probably phorbol ester) has potential as an insecticide, for instance in the control of 4 insect pests of cotton including cotton bollworm (Solsoloy 1995) and on pests of pulses, potato and corn. ... (Malawi Agroforestry Extension Project Marketing & Enterprise Program Main Report, Publication No. 47, page 46, July 2002)

In West African countries like Bénin and Mali the farmers are experimenting with mixtures of plant extracts and other ingredients. Experiences from Bénin give the following recommendations for 1 ha:

3 sprayings during early season with a preparation of
 1.5 kg pounded neem seeds in water, fermenting over night and then filtered
 1 litre cow urine
 20 papaya leaves
 local soap diluted in water
 total of 10 litres

Then later in the season the following preparation without cow urine in order to avoid excessive vegetative growth:

2 kg pounded neem seeds in water, fermenting over night and then filtered
 5 cloves of garlic
 20 papaya leaves
 local soap diluted in water
 total of 10 litres

Since 1999 organic cotton growers in Mali use a mixture of neem and “Npeku” oil (*Lannea microcarpa*) as botanical insecticide. The preparation for 1 ha is done as follows:

- 500 g grounded neem seeds in 10 litres of water for 3 to 5 days and then filtered
- Add 40 to 160 ml of “Npeku” oil (according to plant stage, see table below) and mix well to get an emulsion

Cotton stage	Quantity of neem powder	Quantity of water	Quantity of Npeku oil
<i>Dose per ha</i>	<i>g</i>	<i>lt</i>	<i>ml</i>
Growth	500	10	40
Flowering	500	10	80
Formation of bolls	500	10	160

Instead of the “Npeku” oil the organic cotton farmers in Mali take also the oil of “KOBİ” (*Carapa procera*) in the same way.

The following is a list of available pest control methods:

Pests	Biological combating methods
African (or American) cotton bollworm, corn earworm, tomato fruitworm: <i>Heliothis / Helicoverpa</i>	green pheromone traps and light traps for moths - for monitoring: afterwards, <i>Trichogramma chilonis</i> Ishii-cards to reduce the new egg generation and <i>Bacillus thuringiensis</i> against larvae; <i>Brinckochrysa scelestes</i> Baculovirus against <i>Helicoverpa zea</i> and <i>Heliothis virescens</i> successful in USA, against <i>H. armigera</i> in Australia and China; Hand-picking of damaged capsules; neem, <i>Melia volkensii</i> extract; In India and Tanzania: neem formulations
pink bollworm <i>Platyedra gossypiella</i>	pheromone traps, use of pheromones "Gossyplure"; neem, <i>Melia volkensii</i> extract;
spiny bollworm <i>Earias insulana</i>	Delta pheromone traps, afterwards PB ropes*; neem, <i>Melia volkensii</i> extract;
tobacco caterpillar, cotton leafworm <i>Spodoptera littoralis</i>	Water traps made out of plastic bottles (with pheromone traps; open on all sides); Traps; polyedric virus; Baculo virus; neem;
Cotton worm <i>Alabama argillacea</i>	<i>Bacillus thuringiensis</i> ; Extract from peppers (caution when using); pellitory of Spain;
America: Mexican boll weevil <i>Anthonomus grandis</i>	Pheromone against beetles; also against larvae or caterpillar <i>Bacillus thuringiensis</i> ;
Africa: bugs like <i>Dysdercus spp.</i> , <i>Lygus spp.</i>	Tanzania: Pyrethrum formulation with black wattle extract as UV light stabilisator may be Metaricium preparations; <i>Bacillus thuringiensis</i> ;
Glasshouse white fly: <i>Bemisia tabaci</i>	Yellow boards covered in paste at shoot-tip level; 3% potassium soap in acute cases; nicotine extract; <i>Beauveria bassiana</i> ; Plant traps: <i>Lablab niger</i> ; <i>Trichogramma chilonis</i> Ishii;. <i>Brinckochrysa scelestes</i> ; Emergency: pellitory of Spain (neem)
Aphids, cotton aphid (<i>Aphis gossypii</i>)	Yellow boards covered in paste at shoot-tip level; <i>Bacillus thuringiensis</i> ; 3% potassium soap in acute cases; ii extreme cases nicotine extract, neem, chilli, garlic, <i>Lantana camara</i>
Red spider (mites) (<i>Tetranychus cinnabarius</i>)	Sulphur preparations; <i>Beauveria bassiana</i>

Thrips (<i>Thrips tabaci</i>)	<i>Bacillus thuringiensis</i> <i>Orius tristicolor</i> (predator bugs)
cicada (<i>Jassidae</i>) esp. <i>Jacobiassa lybica</i> in Africa	Repellent plant extracts from: neem, chilli, garlic and <i>Lantana camara</i>

*PB-ropes: Plastic tubes strengthened with wire, which contain slow-release confusing scents. Attach a PB rope to every 15th plant, in each fifth row, halfway up the plant. The confusion created is so strong that hardly any eggs will be laid.

Yellow traps, pyrethrum and also sulphur extracts do not work specifically enough (useful insects are also affected). For this reason, these preparations should only be used when absolutely necessary, and when no other alternatives are available.

2.7. Crop cultivation and maintenance

Along with continual monitoring of the crop (monitoring the proliferation of pests) and the eventual possibility of using combating measures, the most important tasks before the harvest are tilling weeds, spreading organic fertiliser (compost, liquid manure) and irrigation.

2.7.1. Weed management

Weed proliferation must especially be counteracted during the first 3 weeks of growth, as the cotton plants will not yet have developed sufficient resistance in this time (see: seed bed preparation). After compost has been applied, the weeds, which then grow, can subsequently be tilled, either manually or mechanically, and disposed of.

Under the conditions of rain-fed and small-scale organic cotton production in Tanzania the weed control is the main yield-limiting factor. It is even more important than pest control or fertilisation. The problem in this cropping system is the availability of labour for weeding by hand hoe because the seeds are traditionally broadcasted and not sown in rows. In order to use ox-drawn cultivators (= ox-weeders) for weeding the farmers have to improve the seed bed preparation and change the sowing method. When the cotton (or also other crops) is sown in rows the weeding can be done much faster, which can reduce the competing weeds and improve the water household of the soil. The tilling of the soil can increase the infiltration of water and reduce the evaporation after a rainfall. If irrigation is not possible this measure can be very beneficial for the cotton crop.

2.7.2. Irrigation

The beds should be irrigated before sowing, to aid the tilling of weeds, and then again directly after the cotton has been sown. At sites with little rainfall (e.g. Egypt)

the soil must be watered at least every 2 weeks. The intensity with which the soil is irrigated (amount and duration) depends upon which type it is. The soil must not be allowed to get muddy, which would cause a reduction in the decomposition of organic substances. Plantations at sites where it does rain, additional irrigation may be necessary (e.g. if there are dry spells during the season).

In India some bioRe farmers have even access to simple drip irrigation systems. However the investment costs are 40 times higher compared to the furrow irrigation system. A research work is under way to check if this high investment can be cost-effective.

2.8. Harvesting and post harvest treatment

2.8.1. Harvest

The use of defoliant before the harvest is not allowed. In order to defoliate ecologically, stopping irrigation will help. A further possibility is to wait until the first ground frost appears at sites where this occurs. After this, the leaves will die off, and the natural process of defoliation takes place.

If the cotton is to be harvested manually, then it is not necessary for all of the plants to ripen simultaneously, as several harvests will take place. Yet should the harvest be performed mechanically, then all of the cotton plants must be ripened to the same degree. One method of inducing ripening is to trim the shoot apex and apply silicates. In this way, the vegetative growth of all of the plants is stopped at the same time.

In Egypt the harvest begins when 70 % of the seed cases have ripened. Manual harvesting is generally performed in two stages.

Harvesting must be performed carefully, because the cleaner the cotton is, the higher the prices paid for it will be. Mechanical harvesting produces only inferior cotton, because many dirt particles find their way into the cotton during the process. The quality of handpicked cotton rests in the carefulness of the picker.

The harvest residues can be chopped up immediately following the work, and worked back into the ground. In Turkey the cotton farmers collect the cotton stalks on big heaps and use it as firewood. The composting of the stalks would be better but it is at least an improvement compared with the common practice in Tanzania to burn the stalks directly on the field.

2.8.2. Post harvesting methods

After harvesting, it might be worthwhile cleaning the cotton by hand, if many particles remain stuck to the crop (unclean harvest). The storage place must be dry, damp storage can lead to large reductions in quality and the growth of fungus and resulting mould (e.g. aspergillus).

If the organic product is being stored in a single warehouse together with conventional cotton mixing of the different qualities must be avoided. This is best achieved using the following methods:

- Training and informing of warehouse personnel
- Explicit signs in the warehouse (silos, pallets, tanks etc.)
- Colour differentiation (e.g. green for the organic product)
- Incoming/dispatched goods separately documented (warehouse logbook)

It is prohibited to carry out chemical storage measures (e.g. gassing with methyl bromide) in mixed storage spaces. In Tanzania the warehouses for organic cotton are sprayed with a natural pyrethrum formulation against storage pests like cotton stainers (*Dysdercus spp*). Wherever possible, storing both organic and conventional products together in the same warehouse should be avoided.