ORGANIC COTTON FARMING

IN

KUTCH, GUJARAT, INDIA

G.J. Jackson

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CONTENTS

1. INTRODUCTION AND ACKNOWLEDGEMENTS

In February 2004 the author visited the Agrocel[1] station near Mandvi, Kutch. In conversation with the General Manager, Mr. Hasmukh Patel, it emerged that Agrocel was engaged in a project with the following objectives and descriptors:

1. To help recreate economically, environmentally and socially sustainable livelihoods for smallholder cotton farmers in India [i.e. "organic" cotton].

2. To address the problems of bankruptcy, rural-urban migration, worsening soil quality, crop vulnerability to pest attack and adverse climate as well as lack of market visibility.

3. A key feature is the training, to international standards, in record keeping that will be given to Agrocel, who operate a network of farmer service centres throughout the region and who can keep records on behalf of the farmers. Agrocel have built up relationships of trust with the farmers over a period of 12 years, and they are very well placed to implement quality farming improvements with them.

4. Agrocel will also begin the creation of a community approach to marketing via the creation of a cotton bank and employment in-house of a cotton grader. Local knowledge of the fibre quality, together with the farming records kept at the Agrocel service centre will enable the farmers to act as a group to supply the international market.

5. Other partners[2] in the project will be making the necessary market links to give the product a sharp identity and high profile exposure, and thus create end-uses in Europe leading to sale of fibre to selected textile intermediaries.

The results of the project to date were outstanding, with 330 cotton farms in Kutch and other districts of Gujarat converted to organic production. Yields of organic seed cotton were surprisingly high, typically:

1,000-1,125 kg/ha for purely rain-fed cotton

2,500-3,000 kg/ha when sown under irrigation, grown through the rainy season, and supported by irrigation when required.

These results had been written up in internal reports for the project, documenting the project itself and the results in terms of numbers of farmers recruited, yields, quality, gross and net returns, all of which were remarkable (see Section 6). However so far no paper had been published externally on the project and no scientific investigation had yet been carried out into the reasons why such high yields were being obtained: comparisons with non-organic cotton farms in terms of soil quality, fertiliser practices, pest populations and losses due to them, and so on.

[1] Agrocel Industries Ltd. Services Division. Agrocel is part of Excel Crop Care Ltd., Mumbai.
[2] Traidcraft Exchange, U.K.; Vericott Ltd., U.K.; International Resources for Fairer Trade, Mumbai. The project was part-funded by Shell Foundation, London.

Accordingly it was agreed that the author would return in October 2004 to prepare this report for external publication and in preparation for a comparative study on organic and non-organic cotton, to be carried out during the 2005 season by Agrocel scientists. The results of that study will be published in due course.

The author wishes to make it clear that for this report he acted only as facilitator and scribe. It contains information provided by the Agrocel team and others, and the author wishes to record his grateful thanks for the kindness and hospitality of Kantibhai Shroff, Dipesh Shroff, Preeti Shroff, Hasmukh Patel, Shailesh Patel, Dr. K.P. Baraiya, Dr. M.C. Pandey, Birendra Prasad, Pravin Parekh and Rangapara Gordhan. Thanks are also due to Maveen Pereira of Traidcraft, U.K., and Girish Kowale and Pravin Chopade of International Resources for Fairer Trade, Mumbai. The author has drawn on a document on integrated crop management for cotton by Dr. C.S. Pawar[3], who kindly also commented on the draft of this report. Finally I would like to thank Prof. Graham Matthews of Imperial College, London, for his valuable questions and comments.

[3] Production Program for ICM Cotton. Shree Vivekanand Research & Training Institute, Mandvi, Kutch. Email: pawarcs@hotmail.com

2. GLOSSARY, ABBREVIATIONS AND ACRONYMS

ac	acre, 0.4 hectares
ASP	ammonium superphosphate
black gram	*Vigna mungo*
B.t.	*Bacillus thuringiensis*
castor	*Ricinus communis*
cluster bean	*Cyamopsis tetragonoloba*
cm	centimetre(s)
cowpea	*Vigna sinensis*
cumin	*Cuminum cyminum*
das	days after sowing
date	*Phoenix dactylifera*
DAP	di-ammonium phosphate
FYM	farmyard manure
g	gram(s)
green gram	*Vigna radiata*
groundnut	*Arachis hypogea*
ha	hectare(s)
horse gram	*Cicer aeritium*
ICM	integrated crop management
IPM	integrated pest management
jute	*Corchorus olitrius*
kg	kilogram(s)
lentil	*Lens esculentus*
lucerne	*Medicago sativa*

maize	*Zea mays*
mango	*Mangifera indica*
m	metre(s)
mm	millimetre(s)
mn	million(s)
neem	*Azadirachta indica*
okra	*Hibiscus esculentus*
pearl millet	*Pennisetum glaucum*
pest	any organism (weed, disease, nematode, insect, mite, or other) which causes economic damage to the crop
pigeon pea	*Cajanus cajan*
ppm	parts per million
q	quintal(s), 100 kg
RH	relative humidity
Rs	Indian Rupees. £1 Sterling = Rs 80
sapota	*Achras sapota*
sesame	*Sesamum indicum*
sorghum	*Sorghum vulgare*
soyabean	*Glycine max*
sun hemp	*Crotolaria junsia*
tds	total dissolved solids
te	metric tonne(s), 1000 kg
tulsi	*Oscimum sp.*
wheat	*Triticum aestivum*
WP	wettable powder

3. PRESENT STATUS OF COTTON FARMING

3.1 Area of Cotton

About 30,000 ha of cotton were grown in Kutch in 2002-3, and the area is increasing because both yields and prices have been high in recent years. Agrocel began the conversion of farmers to certified organic cotton production in 1997. The project part-funded by the Shell Foundation began in 2001 and by the 2003-04 season there were 149 certified group farmers in Kutch and a further 181 in Surendranagar. In Gujarat State as a whole there were thus 330 group farmers (620 individual farmers, as a single farm is often owned by several people) with a total area of 944.2 ha.

3.2 Cotton Varieties

Before the introduction of hybrids, farmers used to grow "Desi"[4] cotton – varieties of the indigenous *Gossypium herbaceum* and *G. arboreum*. These varieties, which are still extant, are characterised by resistance to drought (being deep-rooted), and to pests (they have very hairy leaves which deter sucking pests, they have a hard pericarp and high levels of gossypol which deter bollworms, and they are resistant to leaf-curl virus). *G. herbaceum* is relatively common in Kutch; it grows 1-1.5 m tall and has a fibre length of 12.5-23 mm. However the popular variety Deviraj[5] is an improved selection of the species, made by Indian scientists in the 1980's, with a fibre length of 25-28 mm and greater yield potential. The rainfall in Kutch (see Section 4.3) is not enough on its own to sustain a good crop, but if the farmer has a small dam or borehole which will permit say two irrigations then improved Desi cotton can yield well. The yield potential of Desi cottons in general is low, and yields range from 500-1,200 kg/ha under rain-fed (unirrigated) conditions to 800-2,500 kg/ha under supporting irrigation; in general yields under supporting irrigation are 1,250-2,000 kg/ha. However in very exceptional cases, where e.g. a farmer has only one hectare and has a high degree of involvement, yields of 5,000 kg/ha have been recorded from *improved* Desi varieties such as Deviraj when all factors are favourable. Desi varieties are sown after the start of the rainy season, in late June through July; first flower will be about 90-100 das (mid-late October) depending on conditions, and the plant has 1-2 flushes of flowers. First pick will be at 160-180 das and the plants will be pulled at 210-240 days.

Hybrid varieties of the American species *G. hirsutum* cover the greatest proportion of the cotton area of Kutch. The hybrids are mainly grown under irrigation, being shallower rooted, and can thus be planted early, 15 May-15 July. In the relatively rare cases where they are grown under rain-fed conditions they will be planted at the onset of the monsoon rains; however the hybrids are not drought resistant and a good yield will be very much dependent on good rains. First flower will be 50-55 das and there will be 3-4 flushes of flowers. First pick will be around 140 das. Under irrigation yields can be very high, e.g. 3,000 kg/ha (up to 5,000 kg/ha in exceptional cases); however the hybrids require a high level of inputs and are not pest resistant, and this makes growing them under rain-fed conditions a very chancy business. The plants are pulled at about 180 days and this allows a second rotational crop to be grown on the same irrigated land in the year.

[4] "Desi" = local, traditional
[5] "Devi" = goddess; "Raj" = ruler

A very interesting comparison between cotton-growing conditions in Kutch and Punjab/ Haryana can be made with the hybrid Ankur 651[6], which is grown in both areas. In the dry climate of Kutch it yields 2,500–3,000 kg/ha, while in the humid conditions of Punjab/Haryana it yields only 1,500-2,000 kg/ha.

The split of cotton types grown in Kutch in the 2004-05 season is approximately:

- 21,000 ha *B.t.* hybrid
- 4,000 ha non-*B.t.* hybrid
- 5,000 ha Desi

3.3 B.t. Transgenic Cotton

Plantings of B.t. cotton in Kutch are about 70% of the total area, i.e. about 21,000 ha, and are increasing because the technology is seen by farmers as successful. However Monsanto's "Bollgard" accounts for only some 10%, or 3,000 ha. The reasons for this are interesting. When Monsanto did their original trials in Maharashtra State an Indian company allegedly purloined the technology and produced its own B.t. cotton. They put this seed on the market unregistered as a new variety, without claiming it to be B.t., and at a fraction of the Rs 1,600/500g/ac that Monsanto were charging for theirs. Naturally this "variety" gained a very good reputation and became very much in demand, especially as it proved to be tolerant to wilt caused by *Fusarium oxysporum*. Furthermore farmers discovered that, unlike "Bollgard", seed could be saved[7] and gave good results in the F2 and even F3 generations (commercial B.t.'s produced by companies are hybrids and therefore in general cannot be used in the F2 generation; the illicit B.t. must have been a B.t. parent, i.e a pure variety, and therefore did well as F2 and F3). Farmers are now even said to be producing their own F1 B.t. cotton, though this is illegal. When the illicit B.t. was discovered the Government banned the company producing it but the damage was done: the B.t. gene was loose in Indian cotton, the vital refugia policy for bollworm resistance was unenforceable, and Monsanto's market was irreparably damaged.

[6] Ankur 651 is an intra-*hirsutum* hybrid, resistant to leaf-curl virus and tolerant to jassid attack; it has very small leaves with broad lobes and is short, compact and early; it has 1 monopod and 23-25 sympods and grows to about 90 cm height; it matures in 170 days; it has 28 mm medium staple fibre and 32.5% ginning out-turn; it is suitable for wheat-cotton rotation.

[7] To separate and save seed for re-planting, farmers use a small ginning unit or a hand gin. Such self-saved seed is not de-linted for planting, but to prepare it the farmer will coat the seed with a soil and water slurry which is then allowed to semi-dry, allowing the seeds to be handled individually (see Section 4.7).

4. GENERAL COTTON FARMING PRACTICES

The basic recommendations for non-organic farming are set by the Government Institutes.

4.1 Land Holdings

In Kutch a small farm is regarded as being roughly 0.5-7 ha, a medium sized farm as 8-12 ha and a large farm as up to 40 ha. Generally speaking the practices on medium and large farms are the same.

4.2 Soil Types

The soil in Kutch is mostly sandy loam but there is heavy black soil in some areas.

4.3 Rainfall, Water Quality and Sunshine

The mean annual rainfall in Kutch is 336 mm but it is extremely variable, both geographically on a single day and from one year to the next. The coastal town of Mandvi has the distinction of having received the lowest and highest rainfall in the District: 2 mm in 1987 and 1,971 mm in 1984. In the 20th. century there were 41 drought years, but in the District capital Bhuj 468 mm fell in one day in July 1959. Generally speaking anything from 250-400 mm in a year is regarded as "normal", and crops can be grown with 150 mm given even distribution of rainfall over the rainy season (June-September).

Kutch district is an island, bounded on two sides by sea and the other two sides by salt marsh, and no rivers enter from outside. Thus for irrigation the only source is the water table which is dropping due to excessive extraction, and is now at 75-135 m. As a result there is underground ingress of sea water, and near the coast there can be as much as 10,000 ppm tds (mostly sodium chloride); inland a typical value would be 1000-2,000 ppm. However water quality is beginning to improve due to efforts since 1989 in rainwater harvesting, watershed management and recharge measures.

Annual solar radiation can be as high as 3,200 hours.

4.4 Crops Grown

An irrigated farm will typically have a mix of crops: there will be fodder for cattle and water buffalo – mainly sorghum, lucerne (a year-round crop), pearl millet and perhaps maize. Cotton is the main cash crop, and other crops may be pearl millet, green gram, cowpea, sesame, sorghum to some extent, castor bean, groundnut, cluster bean, wheat, cumin, and kitchen garden crops including fruit. On larger farms in recent years there has been an increase in plantation crops such as date palm, mango and sapota.

A non-irrigated farm, if rains are poor, can produce short-duration crops such as sesame, gram, pearl millet and fodder. If rains are good wheat and cumin can be taken as a second crop after these.

Rotation practice is very variable. Some farmers understand the theory behind it and practice proper rotation. Others do not and may grow cotton on the same land year after year; surprisingly, it is said that in Kutch yields do not deteriorate, perhaps due to high inputs of

natural fertiliser (the cattle population of Kutch is higher than that of humans – 1.4 mn against 1.25 mn, so FYM is available in large quantities). Rotation is of course very important for organic farming, and is described in Section 5.3.

4.5 Fertilisation Practices

The following are all used by farmers in general: urea, DAP, ASP, rock phosphate, gypsum, potash, ferrous sulphate, sulphur, micronutrient/trace element preparations, cow dung and urine, vermicompost[8], neem cake, castor cake, green manure, azotobacter preparations, phosphate-solubilising bacteria preparations, green algae soil[9]. Farmers also dig out windblown soil, which collects in mounds in sheltered places during the dry season, and spread it on their fields; such soil is said to be very fertile. Of course at the bottom end of the scale some farmers are growing Desi cotton with no fertilisers of any kind, or any aftercare beyond hand weeding, and still getting a small crop.

In non-organic cotton DAP is applied before sowing; alternatively FYM or green manure is applied into the furrow (See Section 4.6). Urea or ammonium sulphate may be applied, with the first split at 35 das to encourage vegetative growth before flowering, the second at 60 das at boll-setting, and maybe a third at 80-100 das, each with an irrigation afterwards. Note that in rainfed cotton urea is not normally applied. It is not uncommon for farmers to exceed the recommendations for urea in the belief that it makes "better" cotton, though in reality too much urea can attract insects, especially sucking pests, to the more luxuriant plants.

4.6 Land Preparation

After harvest of the previous crop there will be one deep ploughing, nearly always by tractor (on smaller farms the tractor would be hired). This will be followed by two tine harrowings then one blade harrowing. Furrowing is then done, with the furrows being moved half a width from the previous year so the new furrow lies at a previous ridge; the "row and column" system is not used in Kutch. Into the furrows is then added any organic material such as FYM, vermicompost, castor cake, neem cake etc. and the land is then "planked" to fill the tops of the ridges into the furrows. The field would then be irrigated if appropriate. After this DAP may be applied into the furrow using a seed drill; in a rainfed Desi field the farmer would not normally go to the expense of applying DAP in case rain does not come. The seed is then sown (see Section 4.7).

For hybrid cotton the ridge-to-ridge spacing is 120-180 cm depending on soil type (180 cm in heavy soil) and variety. For Desi cotton the ridge spacing is 90 cm.

4.7 Sowing

Hybrid seed is dibbled into the ridges by hand for the most part, though a seed drill may be used on larger farms. The farmer puts in one seed per plant hole; germination is normally

[8] Vermicompost is made from chaffed plant stalks, leaves and other waste farm material mixed with cow dung and urine. A worm culture, in Kutch mainly *Eisenia foetida* and *Eudrilus eugenae*, is added. The vermicompost is ready in 45-50 days.

[9] Check dams are used on farms to preserve water, either to replenish the water table or for irrigation; when the water eventually dries out the surface soil is rich in green algae and this soil is scraped off and used as a fertiliser.

85%, and any gaps are filled after 8-10 days. The standard recommendation for plant spacing in hybrid cotton is 90-150 cm x 60-90 cm, which gives around 10,000 plants/ha. Hybrid seed is sown at 1.125 kg/ha (sold in packets of 450 g/ac).

Desi seed is normally sown by drill in a continuous line along the furrow, then thinned to the correct spacing of 45-60 cm x 30 cm which gives around 32,500 plants/ha. On small fields it would be sown by hand. Sowing is at 10-15 kg/ha.

An irrigated field would be watered before sowing. In a rainfed field the seed (Desi) will be sown when rain is expected.

4.8 Crop Protection

Hybrid varieties are susceptible to damping-off, caused by *Pythium sp.*, and wilt caused by *Fusarium oxysporum*. Thus hybrid seed bought in the market may be treated with thiram + imidacloprid, the latter being for early season sucking pests.

The main weeds are as follows, with the most serious ones marked *:

*Commedina nudiflora**
*Cynodon dactylon**
*Cyperus rotundus**
*Dactylotenium aegyptium**
Digera arvensis
Echinochloa crus-galli
*Eluropus villosus**
*Parthenium hycrophorus**
Zizyphus rotundifolia

Weeding is mostly done by hand two, or more often three, times, with inter-row cultivation for heavy infestations. It is very rare to use herbicides in cotton, though they may be applied around the edges of fields if there is much infestation. In general weeds are not much of a problem because the land is continuously cultivated and the rainfall is low.

On a non-organic farm pests will be sprayed using the standard chemicals. The main sucking pests are:

Aphids	*Aphis gossypii*
Jassids	*Amrasca bigutella bigutella*
Thrips	*Thrips tabaci*
Whitefly	*Bemisia tabaci*
Mites	*Tetranychus urticae*
White mealybug[10]	*Maconelicoccus hirsutus*

The main bollworms are:

American bollworm	*Helicoverpa* (=*Heliothis*) *armigera*
Spotted bollworm	*Earias vittella*
Pink bollworm	*Pectinophora gossypiella*

[10] Infestations of white mealybug are often caused by the use of too much insecticide and too many sprays.

The main leaf-eater is:

Cotton leafworm *Spodoptera littoralis*

4.9 Harvesting and Field Clearance

Picking is always done by hand. Hybrid cotton has a first pick around 140 das, Desi cotton at 160-180 das.

After the final pick the stalks are pulled either by hand, using a forked lever, or by tractor. The crop residues are either chaffed by the tractor or by rotovator and then composted, or are used as firewood for cooking etc.

5. ORGANIC COTTON FARMING PRACTICES

The recommendations described below are those set by Agrocel, but are derived from farmers' own experience.

5.1 Varieties

Most of the certified organic cotton farmers in Kutch (149 in total) grow Desi cotton, var. Deviraj (non-B.t.), of which Agrocel supplies seed at Rs 40-50/kg.

Agrocel supplies non-B.t. seed of the *G. hirsutum* hybrid variety H-6 to 10-15 organic farmers, and a large number of conventional and ICM farmers, at Rs 300/450 g.

Note that, because certification of organic seed is very expensive, amounting to perhaps Rs20/kg, the Agrocel seed is not certified as organic. However this seed is allowed under international organic standards if no certified seed is available.

5.2 Crops Grown, Land Preparation and Sowing Practice

These are all the same as for non-organic farming.

The organic farmer is encouraged to plant as many trees as possible around field boundaries. Specifically, a minimum of one tree per acre of "amli", *Camarandus indica*, which has leaves rich in nitrogen, and of "khijada", *Prosopis cinerala*, which has leaves especially suited for composting. "Amli" is held to encourage earthworm populations. Trees with medicinal, herbal or biopesticide properties, such as neem, which can also provide firewood, are also planted. The farmer should allow vegetation to flourish on the boundary to provide refuge for beneficial parasites and predators.

5.3 Crop Rotation

This has particular importance in organic farming. Recommended crops for rotation with cotton are pigeon pea, groundnut, sesame, cowpea, pearl millet, black gram, green gram, horse gram, soyabean, okra. Okra is not recommended immediately after cotton as both are Malvaceae.

A typical three-course rotation would be cotton-legume-castor-cotton, while a typical four-course rotation would include sorghum or pearl millet or sesame after the castor.

In a continuation of the initial 3-year project to grow, process and market organic cotton, the partners in the project are now preparing to include three organic rotational crops: sesame, castor and green gram, plus their processed products.

5.4 Mixed Cropping and Intercropping

The following are recommended by Agrocel.

Under irrigation, plant one row of cotton to one row of groundnuts (bunch variety, i.e. non-spreading, which has short duration, 105 days to harvest). If desired there can be up to three rows groundnuts. Soya bean, cowpea, water melon or sweet melon can also be planted at 1:1.

In rainfed fields, intercrop with sesame or a legume such as green gram, black gram, horse gram, lentil or bunch groundnut at a ratio of anything from 1 row cotton to 1 row intercrop up to 1:3.

Inter-planting in the rows is a common farmer practice, and the author saw a rain-fed field of very sandy soil in Rapar sub-district where the farmer made no inputs of any kind, other than self-saved seed and hand weeding, where the cotton (believed to be Desi var. V-797) was inter-planted liberally with clusterbean, black gram, green gram, sesame and water melon. Surrounding this cotton were fields belonging to other farmers containing pearl millet plus sorghum (*bicolor* as well as *vulgare*), and castor.

Okra should not be inter-planted or inter-cropped with cotton as it encourages whitefly, spotted bollworm and pink bollworm.

5.5 Fertilisation Practices

Great attention is paid to soil condition and fertility. The Agrocel recommendations are as follows.

Biofertiliser as seed treatment: mix 200 ml water + 200 g raw sugar + 200 g *Azotobacter* or *Azospirilum* culture, to treat 5 kg of seed.

To be applied as set out for conventional farming:

vermicompost	500 kg/ha
FYM	20-25 te/ha (irrigated) 7-10 te/ha (rainfed) However if neem and castor cake and vermicompost are also used the farmer practice is to decrease FYM.
castor cake	up to 125 kg/ha (higher rate if less FYM is applied)
neem cake	up to 125 kg/ha. If termites are a problem, increase neem cake and decrease castor.

Castor cake is rich in NPK.

Neem cake has less NPK but is especially good for improving soil quality, making is looser and more friable, and increasing porosity and moisture retentive capacity. However, more than 125 kg/ha is phytotoxic.

Azotobacter or *Azospirilum* culture can be applied at 10 kg/ha, either added to vermicompost or FYM as above, or moist soil, and applied in the furrow at or before sowing.

Cow urine may be added to irrigation water.

Biomass is added to the soil as green manure, chiefly *Susbenia sp.*, jute, sun hemp or *Senna indica*. *Susbenia* is particularly useful in saline soil as it not only fixes nitrogen but removes salt. Mulching is also important, using whatever is available to add biomass and conserve moisture: chaffed straw, sugarcane leaves, date leaves, coconut leaves etc.

5.6 Crop Protection

5.6.1 Seed Treatment

Desi seeds are fairly resistant to disease but if wilt is expected then one of the following treatments may be used for both Desi and hybrids:

a. syrup of "cactus" (actually Euphorbiaceae), which the farmer will make on farm

b. *Trichoderma viride* as a purchased preparation

c. cow urine + cow dung + flour of pearl millet which has been allowed to decay for 25 days (if no pearl millet is available, use any wood or cow dung ash)

d. a slurry made of soil taken from within 1 cm of banyan tree roots

e. a slurry made of soil from termite mounds, ground up; this is said to be good against fungal and virus diseases.

5.6.2 Weed Control

Organic practices are the same as for non-organic fields, though of course synthetic herbicides are never used.

5.6.3 Insect and Mite Control

Generally speaking, insect and mite pests pose much less of a threat in Kutch than in other northern parts of India such as Punjab, Haryana, and N.E. Rajasthan. This is probably due to the climate of Kutch which is drier, and which is also cooler later in the crop season from mid- late October, when the cotton is most at risk from pest attack. Thus Kutch is particularly suitable for organic cotton production.

<u>Organic Control Products</u>

Microbial products:	*Beauveria bassiana, Verticilium lecanii, Bacillus thuringiensis*, nuclear polyhedrosis viruses, *Trichoderma viridis*
Botanicals:	neem oil, neem cake, castor cake
Minerals:	sulphur

<u>Pest Population Dynamics</u>

Helicoverpa armigera Egg laying on cotton starts in mid-July and the first generation of larvae peaks in late August. After a slight decrease in early September the second generation of larvae will peak in late September to early October. The population then suddenly decreases with the end of the monsoon rains and the onset of cooler and drier weather. Hybrid cotton is planted with irrigation in the second half of May, and has first flowering 50-55 das, i.e. mid-July; this is very susceptible to attack by *Helicoverpa* but the few organic farmers who grow hybrid H-6 will spray with neem oil, B.t. etc. or simply ignore the infestation. However Desi cotton, grown by the great majority of organic farmers in Kutch, is sown from mid-June. It does not start to flower until 90-100 das, i.e. mid-October,

so the *Helicoverpa* populations will have declined with the onset of cooler drier weather before the plants became susceptible to attack.

Earias vittella starts laying eggs on cotton in late July and continues through August. The early eggs are laid on the growing tips which are destroyed, but this causes branching of the plants which is desirable (and indeed encouraged by de-topping the plants) so no control is necessary at that time. Later larvae attack the bolls but Desi varieties, with their hard pericarp and high levels of gossypol, are not a favoured host. Hybrid H-6 can be damaged but the farmer acts as for *Helicoverpa*.

Pectinophora gossypiella is a late-season pest, appearing in early October. However in Kutch it does not appear to attack Desi cotton, again probably because of the hard pericarp and high levels of gossypol. For hybrid H-6 once again the farmer acts as for *Helicoverpa*.

Spodoptera littoralis is a sporadic pest, not occurring every season. It may first appear in early September and can be found until late September or early October. Organic farmers employ egg-mass picking, B.t., neem oil etc.

Amrasca bigutella bigutella is an early-season pest appearing in the crop at about 30 das and peaking during July/August, though it may remain a threat until mid-October. It used to be found mainly on hybrids but is now also found on Desi, though to a much lesser extent due especially to the hairy leaves and also to the high gossypol content of Desi. Where necessary the organic farmer will treat with neem oil or other botanical insecticide.

Aphis gossypii first appears at the beginning of August but only remains for 15-20 days. It may re-appear in late October and remain until the end of the season; this late attack can be very serious, covering the leaves with honeydew and mould and stopping photosynthesis, and making the plants and cotton fibres very sticky and discolouring the cotton. Again, this is mainly a pest of hybrids which would be treated with neem cake extract (see below under Neem Cake), or *Verticilium lecanii*, or *Beauveria bassiana*, all mixed with sulphur 80% WP or micronised sulphur. Desi cotton is very much less affected than hybrids by *A. gossypii* and is not normally treated.

Thrips tabaci is now a more serious pest than aphids, jassids and whitefly. It appears about 30 das in hybrids and the farmer will spray with neem oil or other botanical insecticide, or a biopesticide such as *Verticilium lecanii* or *Beauveria bassiana*. Thrips are not a problem for Desi, probably due to the hairy leaves and high gossypol content.

Bemisia tabaci occurs late September through October and up to harvest. Like the other sucking pests it attacks the hybrids but is not a serious problem on Desi. If necessary the organic farmer will treat as for thrips.

Tetranychus urticae has increased in the past three years and now occurs as a pest in sesame, chilli, cotton, tomato, pigeon pea etc. In hybrid cotton it may infest from mid- late August and remain till early October. It has not been seen in Desi cotton. The organic farmer will use sulphur (wettable or micronised) or neem oil.

Maconelicoccus hirsutus attacks both hybrid and Desi cotton, appearing in late September and becoming more serious as the climate cools; it remains up to harvest. Treatment with *Verticilium* or *Beauveria* appears to be effective.

Indigenous Traditional Knowledge

Farmers throughout India use a large number of different concoctions to control or deter pests. While in general there is no scientific evidence as to the efficacy of these treatments they must be taken seriously because farmers would not go to all this trouble if they were useless.

The following are common components of such mixtures, used for "bollworms", "pests" etc.: cow urine, cow dung, buttermilk, whey, *Datura* (which contains a toxic alkaloid), aloe vera, neem, tobacco leaves, raw cane sugar, *Jatropha eureus* leaves, *Lantana camera* leaves.

The twigs or juice of the shrub *Calatropis giganteum* are widely used against termites.

Farmers also use a wide variety of methods to attract beneficial organisms into their crops. E.g. in a dry area the farmer may place bowls of water in his field to attract insectivorous birds (see Section 5.8), and bird perches are often provided within the cotton; some farmers buy puffed rice in the market and spread it in the field to attract omnivorous birds which will then eat insect pests. *Sorghum vulgare* secretes a sticky substance from the flowers which attracts *Trichogramma chilonis*. Some of these ideas are referred to below.

Hand-picking of larger *Helicoverpa* larvae is sometimes used.

Trap Cropping

Maize planted within cotton fields (20 rows cotton to 1 row maize) fulfils two functions: conserving natural enemies and acting as a trap crop. Maize pollen is a very favourable food for adult predatory species. Maize is also very attractive to *Myzus persicae* which does not attack cotton but which will in turn attract predatory *Coccinella spp.* whose larvae prey on *Helicoverpa* eggs. The farmer may cut the maize and use it as fodder. It may also be allowed to mature; it becomes attractive to ovipositing *Helicoverpa* during "silking", the same time as flowering and boll setting in hybrid cotton, but is more attractive than cotton so will reduce bollworm attack on the cotton. (Ideally, for use as a trap crop, maize should be planted with a succession of sowing dates and the silks and cobs removed afterwards to prevent survival of *Helicoverpa* larvae). The maximum population of *Helicoverpa* is in August and September when maize is in the field; the second generation prefers pigeon pea (which tends to flower over a long period) or gram to cotton.

In addition to inter-row planting, trap cropping by planting on field boundaries is highly recommended, and the following are used:

sunflowers	2-3 lines: the yellow petals attract *Helicoverpa armigera* to lay eggs.
tulsi	contains methyl eugenol which attracts fruit flies.
castor	attracts *Spodoptera littoralis* to lay eggs, and also *Bemisa tabaci*. The farmer will collect the leaves bearing *Spodoptera* egg masses and destroy them.
sesame	attracts grasshoppers.

tobacco	attracts *Spodoptera littoralis* (see above) and also woolly aphid. Conserves chrysopid and coccinellid populations. Is used as an organic insecticide.
okra	attracts *Bemisia tabaci* and *Earias vitellana*
yellow marigold	grown as a cash crop for the bright yellow flowers which are sold in the market-place. However the petals attract moths to lay eggs and as the flowers are harvested every two days this gets rid of the eggs.

FYM

Fully decomposed FYM is believed to contain beneficial microbes, particularly Actinomycetes, which are supposed to work against e.g. pupae of *Helicoverpa* in the soil via the same mode of action as spinosad insecticide. Further investigation is required.

Neem Oil and Cake, Castor Cake

Neem oil, containing azadirachtin, is pressed out from dried neem berries and is bottled and sold for use against a wide range of insect pests. The cake residue is bagged and sold as fertiliser but it is also useful against insect pests: it makes the crop bitter and discourages termites, sucking pests and nematodes, and also wireworms on potatoes, onion and garlic.

Neem cake extract is made by soaking cake in cow urine for 36 hours or more; the strained extract contains azadirachtin and is said to be more effective against sucking pests than neem oil.

Castor cake is believed to act against fungal diseases.

5.7 Harvesting

The processes are the same as for non-organic cotton.

5.8 Case Example

The Agrocel field office manager for Rapar sub-district in north-east Kutch, Mr. Rangapara Gordhan Kaharbhai, stated that they have had certified organic farmers since 2003 and there are now 128 certified organic cotton farmers in the sub-district[11]. Less than 1% of the area is B.t. cotton, and no other hybrids are grown; the remaining 99% is Deviraj (85%) and other Desi varieties such as V-797 (14%). Typically yields up to 2,500 kg/ha are achieved, though 5,000 kg/ha has been recorded when all factors were favourable. Even among non-organic farmers there is very little pesticide application and generally speaking in this sub-district Desi is very successful. He thinks organic farming is good for some farmers: there is very little difference in yield between organic and non-organic farms, and indeed some organic farmers get higher yields because of the attention they pay to proper fertilisation and soil fertility. In addition the organic cotton fetches a premium so is the farmer is very happy. Many more farmers in the sub-district now want to move to the organic system.

[11] Plus 10 certified organic sesame farmers. Some of these may plant certified organic cotton as a rotational crop in 2005.

Vagaji Rajabhai

A certified organic cotton farmer with 6 ha of very sandy soil in Rapar sub-district. He now has a borehole which can give supporting irrigation. Near his house he grows kitchen garden vegetables, fruits such as papaya and makes small amounts of vermicompost for the garden. He has planted some fruit and neem trees near the cotton field but not on the boundaries.

He has one cotton field of 3.2 ha (he knows the area because he has title deeds for the land). When visited by the author on 15/10/04 the cotton (Deviraj) was at first flower stage. It was very variable both in plant stand and height and it was pure cotton with no intra- or inter-row mixed cropping. The farmer had applied rock phosphate at 187 kg/ha, FYM at 10-12 te/ha, castor cake at 375 kg/ha, compost bought from Agrocel at 375 kg/ha, *Azotobacter* culture at 3.75 kg/ha, *Rhizobacter* culture at 1.875 kg/ha and phosphate-solubilising bacteria at 1.875 kg/ha (note that these apparently precise quantities are derived from rounder numbers given in kg/ac).

There was grass present in the field but not severe and it was being controlled by bullock-drawn inter-row cultivation. He has some problem with termites which he controls by pushing stems of *Calotropis giganteum* into the soil nearby; he said this attracts the termites to the sticks and away from the cotton. His other main pest is the Nilghai antelope, a protected animal which eats the young bolls. He has little trouble from other pests. For early season *Helicoverpa* he places bowls of water in the field; in the arid area this attracts insectivorous birds which feed on larvae. He also uses pheromone traps for mass trapping of male *Helicoverpa* moths, though he has only 5 for his 3.2 ha field (N.B. he is *not* using these for monitoring because he does not spray, though 5 is far below the recommended number of traps for mass trapping which in any event is not effective for *Helicoverpa*). The author on 15/10/04 found no evidence of bollworm attack and only a very low population of jassid and whitefly. In general the cotton was very clean and in excellent condition.

This is his second year of organic cotton production after a 2-year conversion period (prior to that he used only urea, not pesticides). Unfortunately his organic yields cannot be compared with his non-organic experience because he put in the borehole went he went organic. In his first organic year he got 1,875 kg/ha. This year he expects to get 2,000-2,500 kg/ha. He is happy with his experience of organic production; he feels his soil fertility has improved and he gets a premium from Agrocel for his cotton.

6. ORGANIC COTTON FARMING RESULTS

The results of organic farming must be measured not only in terms of yield and profits but also in societal and environmental terms. The societal and environmental benefits have been very well documented in numerous cases in India and around the world and it may be taken that they apply equally to the growing of organic cotton in Kutch. This report therefore deals more specifically with the yields and profitability of the system compared to those of non-organic cotton farming.

In assessing the financial return from organic farming it is important to take into account the fact that Desi cotton is a whole-season crop: after harvest the farmer cannot grow anything else in that crop cycle. On the other hand the farmer growing hybrid varieties under irrigation, whether organically or not, whether in Kutch or in other areas such as Punjab/Haryana and Andhra Pradesh, can grow two or even three crops per year.

The Agrocel/Shell Foundation project has had certified organic Desi and hybrid cotton farmers since 2001, following two years of conversion. The following table, derived from Pawar (ibid), shows the results for *hybrid* cotton (no comparable data for Desi cotton are available at the time of writing). Note that the data are averages for farms under the different systems, and are not year-on-year progressive through chemical to in-conversion to organic.

Item	Non-Organic Farming			Organic Farming		
	IPM	ICM				
	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04
Yield kg/ha	3,000	2,950	2,875	2,625	2,500	2,750
Expenses Rs/ha	32,217	29,330	27,827	23,330	23,055	22,250
Market Price Rs/kg	22.5	24.0	22.0	20.0	22.0	27.0
Agrocel Price Rs/kg**	N/A*	26.0	N/A*	23.0	25.0	29.2
Gross Earnings Rs/ha	67,500	70,800	63,250	60,375	62,500	80,190
Net Earnings Rs/ha	35,332	41,470	35,422	37,045	39,445	57,940

* Agrocel did not purchase the cotton

** Included in the Agrocel purchase price is also the value of some materials given free

These results echo a common finding across India as recorded by Menon[12]: after conversion to organic cotton, farmers find that their yields go down but eventually recover to roughly the

[12] Organic Cotton: Re-inventing the Wheel. A Compilation on Organic Cotton. Meena Menon. In Preparation.

same as before; their expenses are far less, they get a premium for their cotton, and their net earnings are substantially higher.

Not all farmers report this pattern, though the end result is similar: Dr. M. Pandey reported one farmer growing hybrid cotton who used to harvest 6,000 kg/ha before turning organic; now organic, he gets 2,250 kg/ha, but because he sells at a premium and has far lower input costs his net earnings are higher than before.

On the other hand some organic farmers, probably due to increased awareness and the attention paid to soil fertility, get higher yields than before.

The quality of the organic cotton produced is believed subjectively to be better, in that garments made from it feel softer.

The numbers of farmers benefiting under the project are as follows:

Farmers in Kutch growing organic cotton in 2003	139
Farmers in Kutch growing organic sesame in 2003	10
Total farms in Kutch certified for organic production 2003	149
Total farmers in Gujarat State certified for organic farming	330

Neem cake and oil are made from neem berries collected in the dry season as a supplementary source of income. Collection and processing of neem berries into cakes and oil created 3,117 person-days of employment in one year, with a collection of 97 te of neem berries. This employment is particularly beneficial to the elderly who are no longer able to work in the fields and can earn about Rs 100 in a day collecting up to 5 kg from just two neem trees.

It is interesting that after Agrocel began the organic cotton programme their sales of conventional pesticides have fallen but their sales of organic products such as neem cake and oil, castor cake, compost bio-inoculum and rock phosphate have risen.

7. DISCUSSION

Conventional wisdom has it that under organic farming systems yields are reduced, and perhaps quality also, but this is compensated for by lower input costs and higher prices for the harvested product so that net earnings are similar.

This is not the general pattern observed in Kutch. The results reported here show that organic cotton farmers have yields similar to and sometimes in excess of those they obtained before turning organic. Because they obtain the organic premium and have far lower input costs, their net earnings are on average far higher.

Not only that: organic cotton in Kutch yields much more than irrigated sprayed hybrid cotton in e.g. Punjab. The Punjab Agricultural University Research Farm has published the following standards for expected yields from 5 varieties:

Desi varieties -	Moti	2,112 kg/ha
	LD 694	1,750 kg/ha
	LD 327	2,875 kg/ha
Hybrid varieties -	Ankur 651	1,750 kg/ha
	White Gold	1,625 kh/ha

The table in Section 6 shows organic hybrid yields in Kutch to average 2,500-2,750 kg.ha.

The question is, *why* does organic cotton in Kutch yield so highly when it is not sprayed with synthetic chemical pesticides, and *why* does it yield more than in irrigated cotton areas such as Punjab and Haryana? Only when we understand this can we foresee the prospects for expansion of the Agrocel organic model to other parts of India. The scientific comparative study between organic and non-organic cotton farming in Kutch, to be carried out by Agrocel in 2005, should provide answers to these questions. However from the information gathered in this report some probable factors may be assessed.

1. The Desi varieties comprising most of the organic cotton have a high silica content and hairy leaves which are known to deter jassids, aphids and whiteflies. They also have a high gossypol content and a hard pericarp to the boll, which deter bollworms.

2. Desi varieties need less water so require only 1-2 supporting irrigations; thus the RH within the crop is lower. Also in Kutch the climate is much drier than in e.g. Punjab and Haryana, and insolation is very high. The sandy soil of Kutch reflects the sunlight back up into the crop further raising the temperature and reducing the RH compared with the black soil of Punjab and Haryana. This in general provides a less favourable environment for insect pests particularly *Spodoptera* which requires a high RH.

3. Desi cotton has a recommended plant population of 32,500/ha and so there are more plants available to compensate for pest attack than is the case with hybrids, which are grown at 10,000/ha.

4. The Desi varieties reach first flowering at about 90-100 das so they are not at serious risk from *Helicoverpa* attack until late October, by which time the monsoon rains have ceased, the temperature and RH have fallen, and *Helicoverpa* is no longer a serious threat.

5. The Desi varieties are tolerant of diseases such as wilt.

6. Fertilisation with urea, particularly in excess as often happens, increases the vegetative growth and general succulence of the crop making it more attractive to pests. The organically grown cotton plant is smaller, tougher and hardier.

7. Because of the high population of cattle in Kutch, FYM is cheap and readily available. Cotton being a cash crop is well fertilised with FYM.

8. The farmer who has converted to the organic system tends to be more interested and involved with crop husbandry, more likely to use crop rotation including green manuring, and more likely to pay attention to soil fertility. These are vital factors in the production of a good cotton crop.

9. Pest populations in Kutch are generally much lower than are found in Punjab, Haryana, N.E. Rajasthan, Andhra Pradesh etc. In Punjab, for example, the climate is both hot and humid, rain is frequent, the hybrid varieties are irrigated six times, and this creates a highly favourable environment for *Helicoverpa* and other pests.

What are the prospects for expansion of the Agrocel organic system to other parts of India? The main factor listed above which is peculiar to Kutch is climatic: both macroclimatic, and microclimatic due to irrigation practice and soil type etc. However climatic factors have a major effect on pest populations and it is doubtful in the extreme if organic cotton could be successful in wetter, more highly irrigated parts of the country where pest populations are very high. The ready availability of cheap FYM in Kutch is also important.

The answer for the more difficult parts of the country must lie in ICM, as already promulgated by Agrocel. Under this system all the appropriate aspects of the organic system are employed, with great attention being paid to farmer education and to soil fertility and the growing of a healthy crop, but synthetic chemical pesticides are used when necessary as judged by pest monitoring, and are applied with high standards of safety and efficiency. The Agrocel ICM Production Programme is being continually updated and improved.

However the Agrocel organic model as developed for this project may be suitable, even in the more difficult parts of the country, for farmers who can devote interest and effort to the crop. It deserves every support in its promulgation.

8. CONCLUSIONS

1. The project has been successful well beyond its original targets. Throughout Gujarat State 330 farmers have been converted to organic cotton production, 149 of them in Kutch District. Some of these farmers are now also growing organic sesame in rotation. Processing and marketing links have been set up and the system is now becoming self-sustaining. In the coming years the project will be expanded to include more farmers growing organic cotton, sesame, castor and green gram.

2. Yields of organic cotton in Kutch are similar to, and in individual cases often in excess of, those obtained under the preceding non-organic system.

3. Yields of organic cotton in Kutch are on average greater than those obtained under non-organic systems in States such as Punjab, Haryana, Rajasthan and Andhra Pradesh.

4. As yet we have no scientific evidence as to why Kutch organic yields are so high compared to systems where synthetic fertilisers and pesticides are used. However the probable factors are the low pest populations due to the dry climate and to the widespread use of Desi varieties, the great attention paid to soil fertility, and improved farmer awareness of good crop husbandry.

5. The same factors probably explain why yields of organic cotton in Kutch are so high compared to non-organic cotton in other parts of India.

6. Organic cotton is almost certainly impractical for most farmers in wetter and more highly irrigated parts of India where pest populations are high, and for such zones ICM should be promulgated. Nevertheless, organic cotton could probably be much more widely grown than at present.