BACKGROUND PAPER

TRANSGENIC COTTON: ARE THERE BENEFITS FOR CONSERVATION?

A CASE STUDY ON GMOs IN AGRICULTURE, WITH SPECIAL EMPHASIS ON FRESH WATER

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This report was prepared for WWF by Philipp Thalmann and Valentin Küng, Kueng-Biotech and Environment, Bern, Switzerland.

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FOR MORE INFORMATION:

Bernadette Oehen
Project Manager, Genetic Engineering
WWF-Switzerland, Postfach, 8010 Zurich, Switzerland
Tel: +41 1 297 2121 Fax: +41 1 297 2100 E-mail: bernadette.oehen@wwf.ch

Christine Bärlocher
Project Manager, Fresh Water and Cotton
WWF-Switzerland, Postfach, 8010 Zurich, Switzerland
Tel: +41 1 297 2256 Fax: +41 1 297 2100 E-mail: christine.baerlocher@wwf.ch

Richard Holland
WWF Living Waters Campaign
P.O. Box 7, 3700 AA Zeist, The Netherlands
Tel: +31 30 693 7803 Fax: +31 30 691 2064 E-mail: TDAwaters@wwfnet.org

Biksham Gujja
WWF Freshwater Programme
WWF International, avenue du Mont Blanc, 1186 Gland, Switzerland
Tel: +41 22 364 9031 Fax: +41 22 364 0526 E-mail: bgujja@wwfnet.org

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Abbreviations

CGIAR	Consultative Group on International Agricultural Research
ERS	Economic Research Service
FAO	Food and Agriculture Organisation of the United Nations
GM	Genetically Modified
GMOs	Genetically Modified Organisms
ha	hectares (1ha = 2.471 acre; 1 acre = 0.4047 ha)
IFOAM	International Federation of Organic Agricultural Movements
ISAAA	The International Service for the Acquisition of Agri-biotech
Lb., lbs.	short for pound (s); 1 lb. = 0.4536 kg
MSMA	Mono-Natrium-Methyl-Arsenate
n.d.	no data
NASS	National Agricultural Statistics Service of the U.S.
NGO	Non-governmental organisations
RAFI	Rural Advancement Foundation International
USDA	U.S. Department of Agriculture
VCE	Virginia Cooperative Extension

1 Summary and Conclusion

1.1 Transgenic cotton acreage

Transgenic cotton has been cultivated worldwide for four years. In 1999 transgenic cotton was planted in only two (i.e. U.S. and China) of the six top cotton-producing countries with the U.S. as the leader. U.S. cotton farmers grew transgenic cotton on almost 57% of the total cotton acreage, whereas in China transgenic cotton was cultivated only on 3%. Compared to transgenic corn and soybean, the absolute global acreage of transgenic cotton is far less and the adoption rate is relatively low.

1.2 Transgenic traits

Herbicide-tolerant cotton grown almost entirely in the U.S. was the most important transgenic trait with an approximate share of 55% of transgenic cotton in 1999 and very high adoption rates. *Bt*-cotton acreage has slightly decreased worldwide in favour of stacked varieties (i.e. herbicide-tolerant and insect-resistant). High adoption rates for herbicide-tolerant traits and substitution of insect-resistant crops by stacked varieties are common trends for all transgenic crops.

1.3 Change in pesticide use

Current statistical data for the U.S. provided by the National Agricultural Statistics Service (NASS) reveal no correlation between transgenic cotton adoption rate and change in the overall amount of insecticides or herbicides.
From 1996 to 1998 the acreage of *Bt*-cotton steadily increased reaching 17% of the total cotton acreage in the U.S. in 1998, while insecticide use per acre remained more or less at the same level. However, according to the claims by agri-biotechnology firms, a decrease in insecticide use should have been expected. Data that will be published next year will give more information on this issue.
From 1997 to 1998 no substantial reduction in herbicide use for cotton farming occurred. Data on specific herbicides show a substitution by glyphosate and bromoxynil, the corresponding herbicides to the herbicide-tolerant traits for other herbicides. Whether current herbicides are replaced by less harmful chemicals cannot be answered in this study.

Insects which are resistant to the *Bt*-toxin due to the widespread use of transgenic crops with the same *Bt*-toxin have not been reported in the field, yet. But from experience in development of insecticide resistance previously in the U.S. one can assume that resistance against the *Bt*-toxin is highly probable in the near future. In the past, overuse of insecticides have led even to insecticide resistance to a broad spectrum of different insecticides at the same time. Furthermore, the incorporated *Bt*-toxin which is produced in the plant over the whole growing season is not sound with current integrated pest management (IPM) ideas in which pesticides are applied only on an economical threshold level.

1.4 Experience in transgenic cotton farming

Four years of cultivation of transgenic cotton is a short period for a proper environmental impact assessment, assuming that adaptation of new agricultural practices to transgenic cotton requires several years. Therefore, it stands to reason that current trends should be interpreted with caution.
But the most reliable data for the past two years provides little evidence that transgenic cotton may contribute to a more sustainable and environmental-friendly cotton

farming. It should be borne in mind that herbicide tolerance in combination with the interest to sell the corresponding herbicides can be interpreted as the key-driving force for the adoption of transgenic cotton in the U.S.

1.5 Outlook

In the near future, more statistical data provided by the National Agricultural Statistics Service (NASS) in the U.S. will help to assess the “environmental performance” of *Bt* and herbicide-tolerant cotton varieties. Field trials collected by the OECD will give an idea on what will be approved next: **Major traits are multiple gene insect-resistance and tolerance to other herbicides.**

2 Introduction

2.1 Background

The WWF international Factreport (Draft) and the Workshop “Cotton and Freshwater” revealed that cotton is one of the most relevant cash crops with severe impacts on freshwater ecosystems on a global scale. In fact, cotton farming uses more pesticides than any other area of agricultural production. Freshwater pollution due to high inputs of fertilisers and pesticides, wasteful water use and salinisation are the major problems.
Some representants of cotton industry and policy institutions promote transgenic cotton (GM-Cotton) as a possible solution to fight high production costs due to pesticides and to increase the cotton yield per area. In contrast, WWF International seeks a moratorium on release of genetically modified organisms (GMOs).

2.2 Objective

The current report is the first step towards an answer to the following project objectives:

- The report provides an updated study on cultivation of transgenic cotton varieties and accessible results of the releases (e.g. benefits by lower pesticide use, resistance problems).
- The case study on transgenic cotton serves members of the Freshwater Programme and the FWAG with facts and scientific data on biodiversity impacts of transgenic cotton cultivation with special emphasis on water relevant (quantitative and qualitative) aspects.
- The relevant stakeholders related to transgenic cotton and their driving forces to introduce transgenic cotton are assessed (e.g. relevant seed suppliers, relevant policy makers, cotton industry, institutions (e.g. NGO’s) with campaigns against transgenic cotton, FAO, World Water Vision Thematic Panel on Biotechnology).
- The study provides well-founded arguments regarding ecological impacts and risks as well as potential benefits of GMO-varieties as a basis to find consent on recommendations for policies and the best management practice for cotton cultivation.
- The study gives a good background to find a consent for recommendations on transgenic cotton and best management practice for cotton, e.g. in the WWF int. Project “Cotton and Freshwater”.

3 Breeding targets for cotton varieties

3.1 Overview

The **emphasis of cotton breeding** is put on the following features given in Table 1 [after Bajaj, 1998].

Table 1:Main targets in conventional and genetic engineered cotton breeding [after Bajaj, 1998]

Objectives	Conventional cotton breeding	Genetic engineering in cotton breeding (For details see Appendix I)
Increased yield	Yes	No
Early maturing types	Yes	No
Fibre-modification	Yes (i.e. upgrading the quality of fibre)	Yes (i.e. colour in cotton fibre)
Gossypol-free cotton seed	Yes	No
Insect-resistance (IR)	Yes (i.e. resistance to various insects, nematodes, and diseases but with an emphasis on increased yield and early maturing types of cotton varieties).	Yes (i.e. insect- resistance)
Herbicide tolerance (HT) or resistance (HR)	No	Yes
Environmental stress-resistance (salt, drought)	No	Yes
Production of male sterility (useful in cotton breeding)	No	Yes

Comments: Today breeding targets in gene technology are strongly limited (e.g. by the molecular transfer techniques). Most of the properties such us early mature, resistance to drought or a higher yield are of a complex nature. They are relied on several genes which are often unknown or not properly understood. Therefore, it is very unlikely that such traits are incorporated in transgenic plants by genetic engineering. Although more than 10 years of transgenic cotton breeding have gone by, today only three different cotton traits (i.e. insect-resistance (*Bt)*, herbicide-tolerance and a combination of both properties are marketed and cultivated.

Outlook:
In the next few years no new traits in transgenic cotton will be commercialised [Biotechnology Industry Organisation, 1999]. An analysis of field trials registered at the OECD database showed an emphasis on herbicide tolerant cotton in 1998 [OECD, 1999a]. In the near future *Bt*-cotton varieties with multiple insect resistance will be marketed to face other than lepidopteran insect pests.

Breeding targets that may have impacts on the environment in terms of water are evaluated and summarised in the following list in Table 2.

It should be borne in mind that there are no inherent differences in water use between transgenic and conventional cotton. According to *Monsanto* a great deal of agronomic testing is done to determine if there are differences in the performance of the plants as a result of inserting the new genes. However, improved water use can be brought about by different agricultural practices such as increased levels of crop residues on the soil surface and reduced moisture loss through repeated cultivation: If such indirect effects are attributed to the adoption of transgenic varieties cannot be answered in this study.

Table 2: Breeding targets with potential environmental impacts

Goal	Water-relevance	Status in transgenic engineering	Outlook	Comments
Early maturing types	Reduced water-use by shorter growing season.	No current research in genetic engineering.	Using techniques of molecular genetics such as DNA markers may speed up traditional breeding.	Early maturing types are achieved by traditional breeding since the beginning of this century in the U.S. and other countries. For instance the Central Cotton Research Institute has developed several varieties with such characters in Pakistan [CCRI, 1999].
Gossypol-free cottonseeds	Increase in insecticide use is probable.	No current research in genetic engineering	There are wild cotton species with these characters. Gossypol-free seeds will be achieved by intra- or interspecific hybridisation.	Cotton breeders try to eliminate the chemical ingredient Gossypol that has low toxic effects on humans, since cotton oil is used as food ingredient. Gossypol has also an insect repellent effect [Thomas, 1998].
Insect resistance	Reduced insecticide use.	*Bt* insect-resistance is commercialised	Other genes will be evaluated to prevent yield losses by insect pests: • Protease inhibitors, lectins (Feeding deterrents) • Neuropeptides (Kill or paralyse feeding pests) • Gossypol	Plant-insect interactions are somewhat unpredictable. For instance, when Gossypol was tested in combination with Bt- toxin, larval growth was not inhibited [Thomas, 1998].
Herbicide resistance	Reduced herbicide use.	Several herbicide resistant cotton varieties are already commercialised or approved for field trials	In the near future other herbicide resistant traits will be introduced in cotton (e.g. glufosinate)	Herbicide resistance is easily to achieve by genetic engineering. Commercial interests for these traits are based on herbicide producing firms.
Salt and Water Stress tolerant cotton	Extension of cotton acreage to dry area with increasing irrigation.	Genetic engineering on stress-tolerant cotton is still on a molecular level.	Progress in obtaining stress-tolerant cotton will still be made by exploiting existing cotton varieties by interspecific hybridisation. This progress may speeded up by using techniques of molecular genetics such as DNA markers [*Leidi et al.*, 1998].	**Cotton is considered rather tolerant to salinity and yield may be increased even by low salinity.** **Cotton itself should not be regarded as heavy water user.** In fact, cotton crops compare favourably with many other agricultural land uses in terms of water use. Most crops use only less water than cotton because they grow for a shorter period.

3.2 Herbicide tolerance (HT or HR)

Herbicide-tolerant (HT) cotton is a cotton variety which is resistant to a herbicide (HR). As a result these specific herbicides can be used for post-emergent weed control, whereas conventional cotton would have been destroyed. Herbicide tolerance can be an inherent character of a plant, but can also be introduced by selection, mutation, or genetic engineering. Currently, there are two types of herbicide-tolerant cotton, introduced by genetic modification available on the market:

- BXN cotton (tolerant to the herbicide bromoxynil).
- *Roundup Ready cotton* (tolerant to the herbicide glyphosate).

Roundup ready cotton is expected to provide superior broad-spectrum weed control, especially in the critical early growth-stage of cotton [Monsanto, 1999].

> The environmental impact with respect to water is assumed to increased use or overuse of the herbicide glyphosate and its toxic effects to organisms.

Outlook: In May 1998, the Environmental Protection Agency (EPA) approved the use of bromoxynil on cotton, including genetically modified cotton. In 1999 *BXN cotton* was planted in the U.S. for the first time. Intensive field trials for the herbicide glufosinate (synonym: phosphinotricin) were conducted in 1998 by the biotechnology firm *AgrEVO*. Both traits are expected soon to be available for commercial cotton farming worldwide.

3.3 Insect-resistance (IR)

Bacillus thuringiensis (Bt) derived insecticides are widely used to control insects susceptible to the *Bt*-Toxin. Researchers have inserted the gene encoding for the *Bt*-toxin from a bacterium into cotton plants, called *Bt*-cotton. The currently available plants produce their own *Bt*-insecticide during the whole growing season[1]. The principal pest insects of cotton are those that attack the bolls or the flower buds.
Commercialised *Bt*-cotton which incorporate the *Bacillus thuringiensis* gene cry1Ac are effective primarily against:

- Tobacco budworm (*Heliothis virescens*, *Heliothis sp.*)
- Cotton bollworm (*Helicoverpa zea*)
- Pink bollworm (*Pectinophora gossypiella*)

The adoption of *Bt*-cotton varieties **is expected** [Gianessi and Carpenter, 1999]

- to reduce the amount of insecticide used in cotton production
- to reduce insecticide costs
- to increase yields

[1] All current genetic cotton varieties have a constitutive 35S promoter from cauliflower mosaic virus.

> The environmental impact with respect to water is presumably attributed to reduced use of insecticides as growers may face reduced pressure from budworm, bollworm and pink bollworm.

For experience and results in transgenic cotton farming in terms of water-relevant impact see chapter 6 to 8.

4 Countries

4.1 Share of global area of transgenic cotton by country in 1999

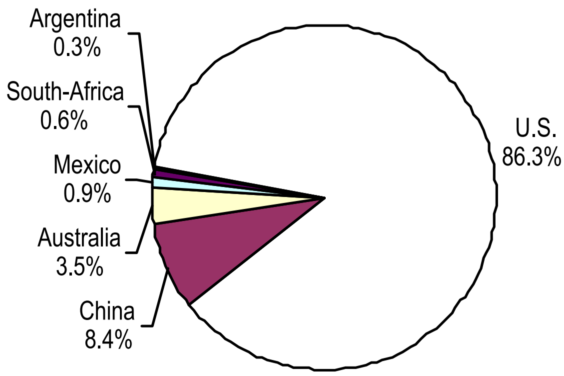

Figure 1: Transgenic cotton producing-countries and their share of the total transgenic cotton market in 1999 [Barton, 1999; Fitt, 1999; FAO STAT, 1998; Cotton and Wool yearbook, 1999] (For data, please refer to Appendix II)

Highlights:
Only two (i.e. China and U.S.) of the six top producing countries of the world were cultivating transgenic crops in recent years.
By 1998 the number of countries which have grown transgenic cotton had increased to six including China, Argentina and South Africa. In 1999 no new countries approved transgenic cotton. Today, the U.S. is clearly dominating the transgenic cotton market, accounting for over 85% of the global transgenic cotton acreage (see Figure 1). The share of transgenic cotton by other countries is minor. China as one of the biggest cotton producers grew approximately 300'000 hectares of *Bt*-cotton in 1999 which comprised 100'000 hectares of *Monsanto/ Delta & Pine Land* products and 200'000 hectares of a cotton variety developed by the Chinese [Barton, 1999; James, 1999].

Outlook:

- Growth of transgenic cotton acreage will continue in the mentioned countries within the next years, but with lower adoption rates. For instance, Australia and China had relatively strong extensions of transgenic cotton areas in 1999 [James, 1998; 1999]. One reason for this expansion is the increasing availability of transgenic cotton varieties adapted to the specific climate conditions.
- The adoption in developing countries will go in hand with the protection of developer's intellectual property (Agreement on Trade Related Aspects of Intellectual Property TRIPS and WTO conditions) and the acceptance/ability to pay the demanded licensing fees to the seed companies. For instance, licensing problems are slowing down the adoption of transgenic crops in India [Jayaraman, 1999].

Comments: Transgenic cottonseeds are relatively expensive compared to conventional cotton varieties. Therefore Texas, by far the largest producing state in the U.S. has adopted *Bt*-cotton on a small scale only, accounting for 5% of total acreage in 1998 [Gianessi and Carpenter, 1999]. One reason is that *Bt*-technology is considered too expensive under the specific growing conditions in Texas [Gianessi and Carpenter, 1999]. No data were available for herbicide-tolerant cottonseeds.

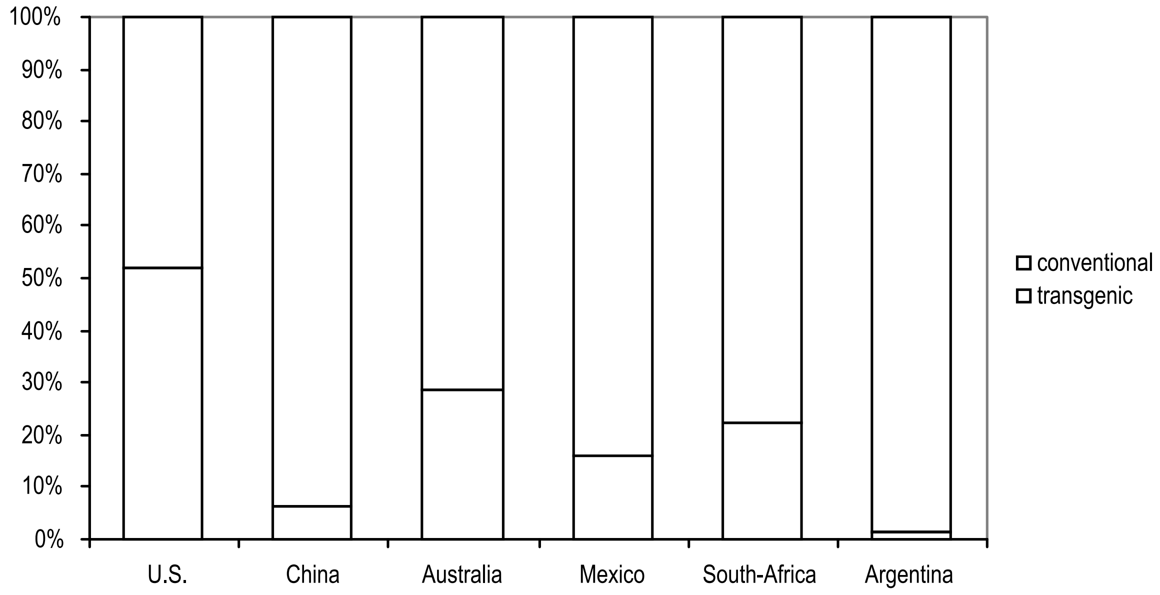

Figure 2: Approximate share of transgenic cotton on national cotton acreage in 1999 [Barton, 1999; Fitt, 1999; James, 1999; FAO STAT, 1998; Cotton and Wool yearbook, 1999]

Highlights: Figure 2 shows that U.S. farmers grew transgenic varieties on more than half of the cotton acreage in 1999. China as one of the biggest cotton producers in the world cultivated only on minor acreage transgenic cotton; whereas in small cotton producing countries such as Australia, Mexico and South-Africa approximately one quarter of the total acreage is already covered by transgenic cotton, especially *Bt*-varieties.

Comments: With the acquisition of *Delta & Pine Land* a leading producer of cottonseeds, *Monsanto* got access to countries like South-Africa or Australia where *Delta & Pine Land* has good marketer positions.

Outlook:
The number of countries where transgenic cotton varieties were cultivated did not change between 1998 and 1999. Thus, it can be expected that the number of countries that adopt transgenic varieties for the first time will increase slowly in the next years.

4.2 Global area of transgenic cotton by trait

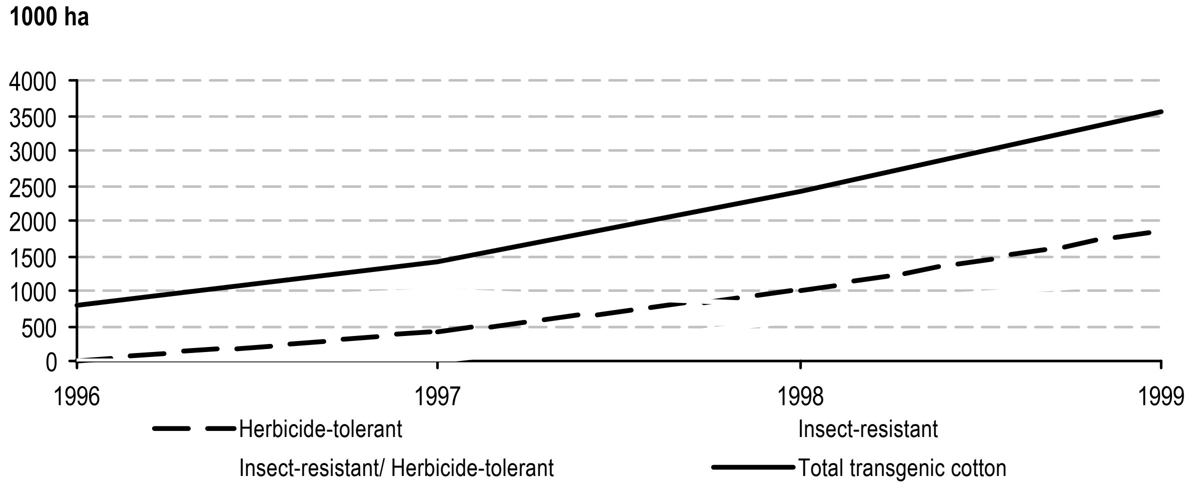

Figure 3: Global area of transgenic cotton by trait [Barton, 1999; James, 1997, 1998, 1999]

Highlights:
Insect-resistant *Bt*-cotton with solely one trait decreased slightly in the last years. This can be explained by the substitution with varieties with "stacked" modified genes in it (i.e. two genes). The adoption rate of *Bt*-cotton is almost constant.
The adoption of herbicide-tolerant cotton is directly related with the use of this specific herbicide (compare Chapter 7). Herbicide-tolerant cotton (i.e. *Roundup Ready cotton*) is marketed only in the U.S., whereas *Bt*-cotton is currently sold in all other countries (For details compare Table 3).
The increase of transgenic cotton acreage in the last two years is mainly due to an increase of herbicide-tolerant cotton in the U.S.

> **Comments:** Herbicide-tolerant cotton is strongly correlated with the approval status of its corresponding herbicide. For instance, after bromoxynil was approved by the Environmental Protection Agency (EPA) in the U.S. in 1998, *BXN*-cotton varieties were planted on large areas in the next growing season.
> The high adoption rate of herbicide-tolerant cotton in the U.S. is due to the high use of herbicides in U.S. cotton farming. No such herbicide-tolerant traits are adopted in other countries where weeding is done by hand.

Outlook:
Within the next years mainly the acreage of insect and herbicide-tolerant cotton will increase [James, 1998]. In the near future there will be other herbicide tolerant cotton varieties which are marketed by multinational companies (e.g. *Du Pont's* sulfonylurea cotton).

Table 3:Adoption and development of different traits in the world

Trait	1996	1997	1998	1999
Herbicide tolerance	-	U.S. farmers have started in 1997 to grow the so-called *Roundup Ready* transgenic cotton which is herbicide-tolerant. Herbicide tolerant cotton was grown almost entirely in the USA, with a small area of 0.3 million ha in Mexico.	Herbicide tolerance becomes the most important trait in transgenic cotton farming.	*BXN*-cotton was planted entirely in the U.S. on 0.3 million ha for the first time. *BXN*-cotton was sold by *Stoneville Pedigreed Seed*.
Insect resistance	Transgenic cotton carrying the insect-resistant *Bt* gene was commercialised in 1996. Two varieties of *Bt*-cotton were planted on 0.7 million ha in the U.S.	Insect-resistant cotton was grown mainly in the USA but with smaller acreage in Australia (29000 ha) and Mexico (1900 ha). In 1997/98 Australian cotton growers planted 60,000 hectares of insect protected cotton containing the INGARD® gene by Monsanto.	The *Bt*-cotton area in the U.S. in 1998 was approximately the same as 1997 at 1.0 million ha but in 1998 the area was split into 0.6 million ha with the single *Bt*-trait and 0.4 million hectares of transgenic cotton with stacked genes for *Bt* and herbicide tolerance [James, 1998]. New Comers: Argentina (8'000 ha) and South Africa (12'000 ha) grew insect-resistant cotton for the first time in 1998.	China has the highest adoption rate regarding *Bt*-cotton.
Insect resistance/ Herbicide tolerance	-	Farmers have cultivated transgenic cotton varieties which are herbicide and insect-resistant, called *Bollgard* on small scale trials.	Multiple gene expression like insect resistance and herbicide tolerance is getting more important: Mexico was growing an introductory area of about 1000 ha of the multiple trait *Bt*/herbicide tolerant cotton for the first time in 1998. In addition 400‘000 hectares of cotton with both herbicide tolerance and insect resistance were planted in the USA in 1998, up from 20‘000 hectares in 1997.	-

5 Companies

5.1 Transgenic cotton varieties approved for commercialisation

Table 4: Transgenic cotton varieties

Technology proprietor/ Company	Seed selling company	Cotton Variety	Trademark of the cotton variety
China (no company name)	local	Bt	-
Du Pont	n.d.	sulfonylurea tolerant cotton	n.d.
Monsanto Co.	*Delta & Pine Land*	Bt/glyphosate tolerant	Bollgard, Ingard, Roundup Ready
Rhône poulenc (Aventis)	*Stoneville Pedigreed Seed*	bromoxynil tolerant	BXN

Source: Krattiger, 1997; James, 1998

Highlights: One of the most significant features to impact on agri-biotechnology in the last three years is the number of mergers and alliances that has resulted in a **strong consolidation** of technology proprietor (compare Table 4) and their seed selling companies. *Delta & Pine Land*, the world largest supplier of cottonseeds is in the process of being acquired by *Monsanto*. *Delta & Pine Land* trades cotton seed under its original name in the USA and in other countries, including China. It sells *Monsanto's* transgenic varieties in all countries where transgenic cotton has been sold in the past. *Monsanto* was also proprietor of *Calgene's* bromoxynil tolerant cotton sold by *Stoneville Pedigreed Seed* until this year. In September 1999 *Monsanto* sold its cotton seed units from *Stoneville Pedigreed Seed to Hicks and Muse/Emergent Genetics*. As shown in Table 4 China had its own transgenic seed supplier for 10'000 hectares cultivated in 1998.

> **Comments:** Data on all local seed suppliers of transgenic cotton around the world are not available. But Table 4 shows clearly that *Monsanto* dominates transgenic cotton Research and Development. *Monsanto* which has also incorporated *Agracetus*, a company which has been very aggressive in obtaining patents covering transgenic cotton plants [Bijman, 1994], has a monopoly position in transgenic cotton lines.
> The monopoly position by Monsanto has led to difficulties in gaining access to new technology by countries through extraordinary licence fees demanded by the technology proprietor *Monsanto* for their transgenic cotton variety [Bijman, 1994].

5.2 Stakeholder and driving forces

The following section presents a choice of stakeholders, which are important in the discussion about benefits and threats of transgenic cotton and the further adoption in the near future.

Stakeholder	Name/Who is who	Policy Status to cotton	Driving force	Comments	Reference
NGO	IFOAM (International Federation of Organic Agriculture Movement)	General policy on genetic engineering	Genetic engineering with its unprecedented danger for the entire biosphere is an isolated view of nature and it is a contradiction to the principal aims in organic agriculture.	IFOAM has official consultative status with FAO. It includes also ethical notions.	http://ecoweb.dk/ifoam/gmo/ge2.htm
	Rafi (Rural Advancement Foundation International)	No explicit policy	Impact of transgenic crops on genetic diversity and intellectual property on agriculture.	Rafi set up the discussion about the "Terminator" technology, making seeds sterile.	http://www.rafi.org
	Pesticide Trust	No explicit policy	Concerns about increasing pesticide use due to adoption of transgenic crops.		http://www.gn.apc.org/pesticidestrust/
	FoE (Friends of the earth)	No explicit policy	Concerns about impacts of transgenic crops on biodiversity.		http://www.xs4all.nl/
	• PAN (Pesticide Action Network) • PANNA (Pesticide Action Network North America)	No explicit policy	Concerns about impact of transgenic plants on pesticide use.		http://www.panna.org
	UCS (United Concerned Scientists)	Policy on genetic engineering	No general objection to genetic engineering. Weigh the benefits of the technology against the risks. Until now, insufficient benefits by genetic engineering.		http://www.ucsusa.org
Farmers		No explicit policy	Higher net-return.	If *Bt*-cotton shows a bad yield performance in the next years, growers will abandon cultivating *Bt*-cotton.	-
Swiss government	SDC (Swiss Agency for Development and Cooperation)	No explicit policy	Multi-lateral development cooperation.	No special activities in the area of transgenic crops.	http://194.230.65.134/dezaweb2/home.asp
Industry	NCC (National Cotton Council of America)	No explicit policy	Speeding the transfer of new technology to U.S. cotton producers.	NCC coordinates the *Beltwide Cotton Conference* . The Conference is the global platform for technology transfer in cotton farming.	http://www.cotton.org http://www.cotton.org/beltwide
	Monsanto		Commercial interests	Monsanto is providing the corresponding herbicide *Roundup*	http://www.monsanto.com

Stakeholder	Name/Who is who	Policy Status to cotton	Driving force	Comments	Reference
	ICAC (The International Cotton Advisory Committee)	No explicit policy	Adoption of transgenic cotton line is considered to reduce the production costs and to lower the prices.	Breeding targets should be achieved through conventional breeding and by developing transgenic cotton.	http://www.icac.org
International Organisations	World Bank CGIAR (Bank's Consultative Group on International Agricultural Research)	No explicit policy	Benefit for developing countries from biotechnology.	CGIAR is a small but influential player in agricultural research. CGIAR is critical against multinational biotechnology cooperations for their little interest to researching plants, pest and diseases common to tropical zones and small scale farming in developing countries.	Press release by http://www.oneworld.org
	WTO	No special policy	Commercial interests	WTO represented a major effort by developed countries to force developing countries to protect intellectual property.	http://www.wto.org
	World Water Council Thematic Panel on Biotechnology and its Implications for Water Resources.		Biotechnology can help to address Problems as water scarcity, increased soil-salinisation. WWV promotes research collaboration on drought and salinity research.	The Commission is sponsored by FAO, UNEP, WHO and the World Bank and has been convened by the World Water Council.	http://www.watervision.org/clients/wv/water.nsf
	FAO	No explicit policy	Sustainable agriculture.	FAO has no explicit policy but general concerns about the loss of biodiversity in modern agriculture.	http://www.fao.org/sd
	ISAAA (International Service for the Acquisition of Agri-biotech)	No explicit policy	Augmenting conventional agricultural production, while protecting the environment and biodiversity	The ISAAA promotes the distribution of transgenic crops to overcome significant biotic stresses that constrain crop productivity in the developing countries of the world.	http://www.isaaa.org

According to *Monsanto* the key drivers for the adoption of transgenic varieties can be identified as the following [Voth, 2000].

- For *Bt*-cotton economics is the key driver, based on two facts: First, there is a reduction in total insect control costs. Second, *Bt*-cotton yields higher than conventional cotton because of “subtreshold protection”, a damage level which does not trigger an insecticide application.
- The primary driver for herbicide tolerant cotton is improved weed control and the overall convenience of the herbicide tolerant system.

6 Change of yield

6.1 *Bt*-cotton

There are various controversial reports about the change of yield. Yield data were gathered mainly in the U.S. In the USDA survey of cotton producers (1997), no yield difference was found for growers using *Bt*-cotton varieties compared to other growers [Gianessi and Carpenter, 1999]. In a survey of Australian cotton growers Hancock reported for the first season that 5 out of 19 growers indicated equal or better yield from INGARD® compared to conventional cotton varieties. However, some growers sustained significant losses by growing INGARD® [Hancock, 1999].

Similar results revealed the study conducted by the Economic Research Service (ERS) in the U.S. over a period of 3 three years: In 1997 farmers stated an yield increase with respect to change in the adoption of *Bt*-cotton, whereas in other years *Bt*-cotton contributed to lower cotton yields compared to conventional varieties [ERS, 1999].
A survey presented at the *Beltwide Cotton Conference* showed a yield increase in 1998 [Mullin *et al.*, 1999 cited after Gianessi and Carpenter, 1999].

6.2 Herbicide-tolerant cotton

The survey published by the Economic Research Service (ERS) in 1999 reports relatively small increases in yield during the growing season of 1997 in the USA. In some regions herbicide tolerant cotton contributed to yield losses up to 10% for herbicide tolerant cotton according to the estimations by the authors [ERS, 1999].

> **Comments:** Yield performance of cotton varieties is depending on a large number of factors , such as irrigation, weather, soils, nutrient and pest management practices, other cropping practices, operator characteristics, pest pressure of each cotton field. Therefore, it should be borne in mind that *Bt* or herbicide-tolerance is only one (minor) factor influencing yield performance and it is difficult to generalise and to attribute lower or higher yield of *Bt*- and herbicide-tolerant varieties to the specific genetic modification. That means: No clear tendency or indication of a trend can be drawn so far.

7 Change in herbicide use

Herbicides have high water relevance due to their toxicity and persistence in the environment. Herbicide-tolerant cotton is supposed to affect highly the use of herbicides and are therefore assessed.
Databases on detailed herbicide usage for cotton farming are available for the U.S. The National Agricultural Statistics Service (NASS)[2] provides a detailed list of chemical ingredients used in cotton farming in the major cotton producing states since 1991 [NASS, 1992-1999]. The information presented in Figure 4 is a result of data collected from sample surveys conducted each year in the U.S.

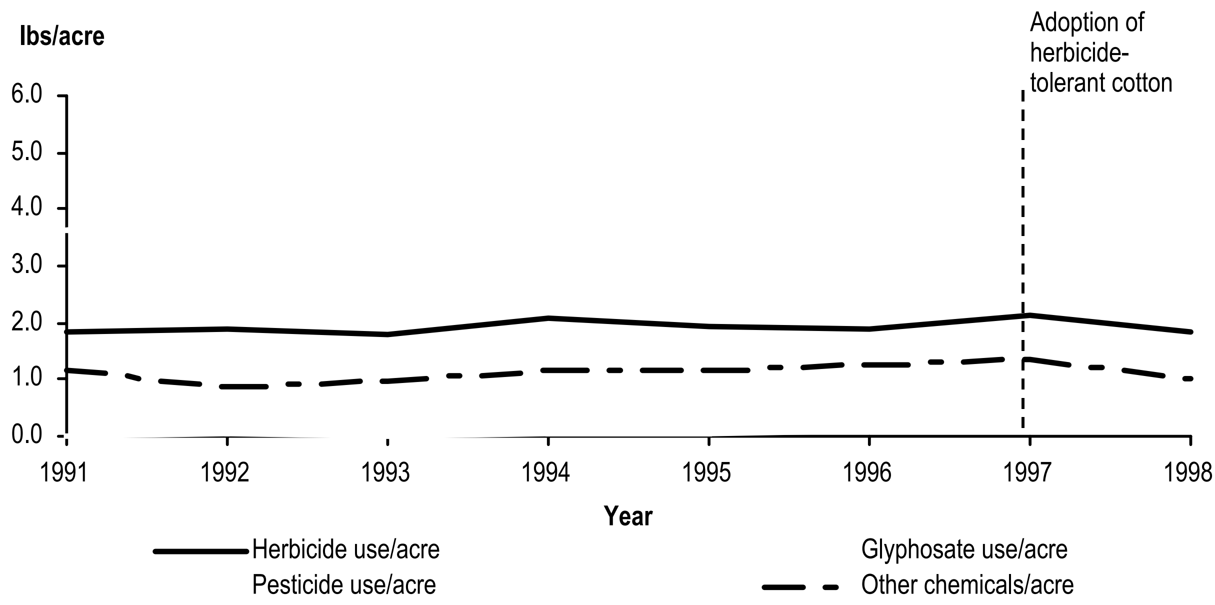

Figure 4: Herbicide use per acre in U.S. cotton farming [NASS, 1992-1999]

Highlights:

Figure 4 shows that almost half of the overall pesticide[3] use in cotton farming can be attributed to herbicide usage, whereas the world's average is only 22% [AWA, 1995 cited after WWF, 1999]. The overall applied amount of pesticides decreased slightly last year [NASS, 1999]. This can be explained by less use of "other chemicals" (compare Figure 4). The adoption of herbicide-tolerant cotton (e.g. *Roundup Ready*) did not basically change the herbicide use practice in the past, however the use of glyphosate (e.g. *Roundup*) increased highly. This shows a trend towards substitution of other herbicides by glyphosate.
These observations are partially sound with the survey conducted by the Economical Research Service (ERS)[4] in 1997: They observed no statistically significant change either for the use of the herbicide group *Triazine* and other synthetic herbicides or glyphosate (e.g.

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[2] NASS is responsible for collecting on-farm agricultural chemical use information to support the evaluation of water quality and food safety issues.

[3] **Pesticides** are divided in four classes: **herbicides** for weeds; **insecticides** for insects, nematodes and mites, **fungicides** for fungi, and **other chemicals** for soil fumigants, growth regulators, defoliants, and desiccants [NASS, 1992-1999].

[4] The ERS conducts research on the impact of alternative pesticide regulations, policies, and practices.

Roundup) for transgenic cotton farming [ERS, 1999].

> **Comment:** The ERS study indicates that the substitution of other herbicides by glyphosate cannot only be attributed to transgenic cotton varieties, but they helped at least to push glyphosate. The curve in Figure 4 indicates remarkable growth-rates for glyphosate since 1996, becoming one of the three top active herbicide ingredients used in U.S. cotton farming in 1998 with a growth rate of over 50% a year (compare Figure 4) [NASS, 1992-1999].

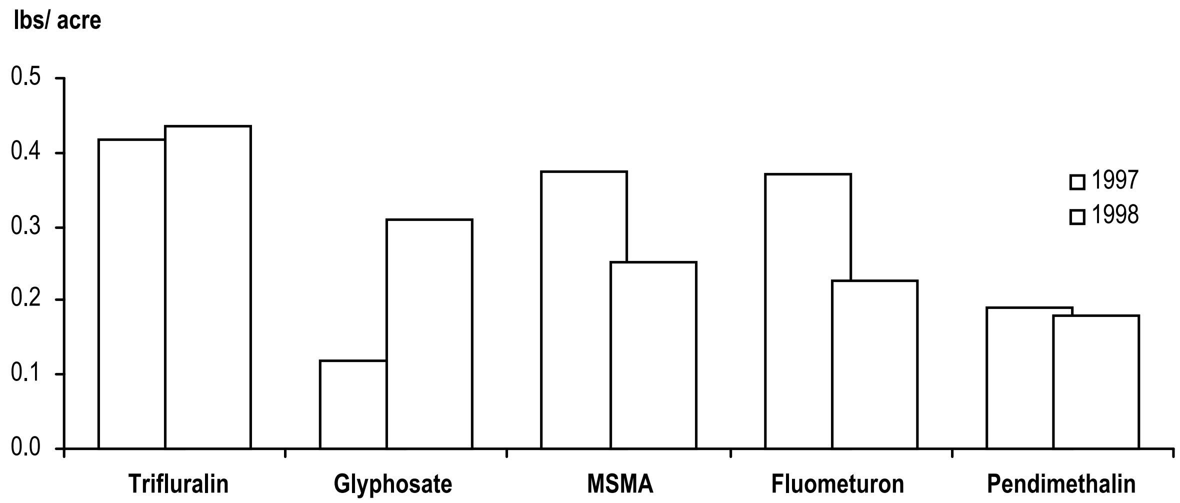

Figure 5: The five top herbicides in U.S. cotton farming (use per acre)

The observations in cotton farming are partially sound with the ERS observations for herbicide-tolerant soybean [ERS, 1999]: As adoption of herbicide tolerant soybean increased, use of glyphosate herbicide, such as *Roundup* also increased. By contrast, to a larger extent other synthetic herbicides diminished and a net decrease of herbicide use was reported for the investigated year (no quantitative data available) [ERS, 1999].

> A time frame of three years is too short to show clear trends in herbicide usage and to estimate the water relevance of the ongoing herbicide substitution. But it can be expected that the adoption of herbicide tolerant cotton will further increase the use of glyphosate (e.g. *Roundup*) and also other herbicides as bromoxynil and glufosate (phosphinotricin). The data shown in this chapter are for the U.S., as an example for a highly industrialised agriculture. Therefore, it is difficult to generalise for other countries.

Open questions:

1. It is not the focus of the study to evaluate which herbicide are replaced by the group of total herbicides, but it would be of interest for future assessments.
2. Are the results from the U.S. comparable to other countries with other agricultural techniques?

8 Change in insecticide use

Data on specific insecticides used by cotton producers are available for the U.S. [NASS, 1992-1999]. According to Gianessi and Carpenter, pest management experts recommend about twelve insecticides for the *Bt*-cotton targeted insect pests [Gianessi and Carpenter, 1999]. For these insecticides, which comprise to a large extent pyrethroids one could expect a decrease.
The assessment of these twelve insecticide would draw only an uncompleted picture mainly for the two following reasons:

- In practice a proper identification of insecticides and their corresponding target insects is difficult since many ingredients have activity on more than one insect.
- With a decrease of the targeted pests other pests may increase and require further spraying of other insecticides that are not comprised in these twelve insecticides.

To exclude the mentioned problems the overall insecticide use is assessed in Figure 6:

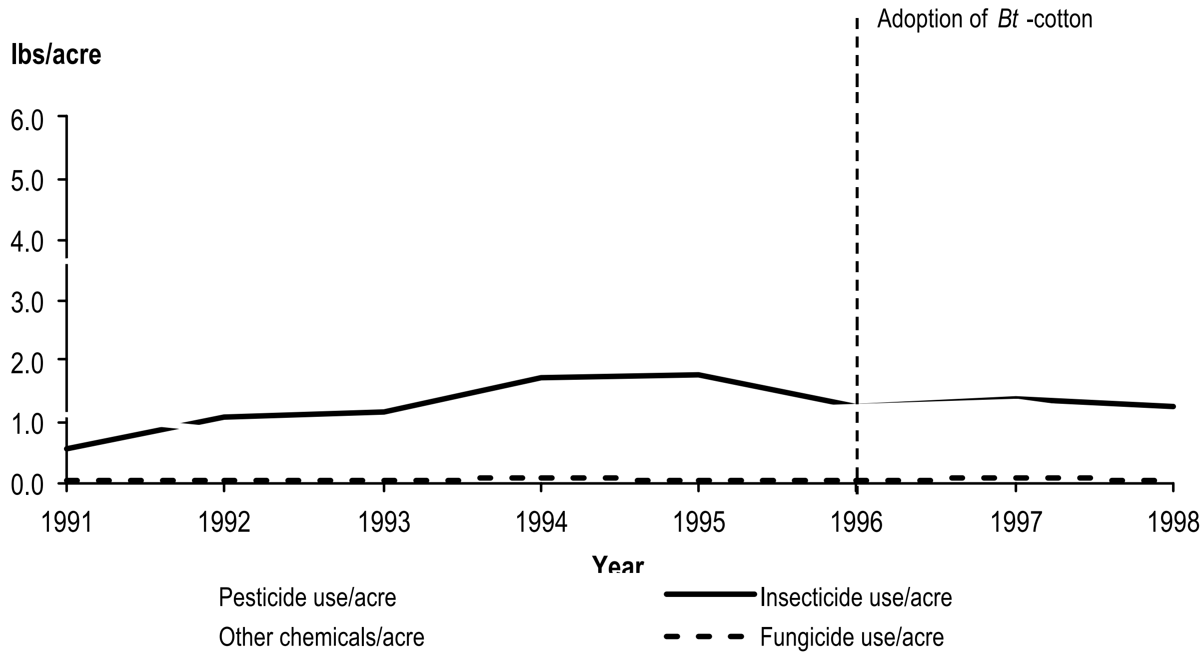

Figure 6: Insecticide[5] use in U.S. cotton farming

[5] **Pesticides** are divided in four classes in this report: **herbicides** for weeds; **insecticides** for insects, nematodes and mites, **fungicides** for fungi, and **other chemicals** for soil fumigants, growth regulators, defoliants, and desiccants [NASS, 1992-1999].

Highlights:

Insecticides are applied on about two third of the U.S. cotton acreage and have a share of pesticides of about one third [NASS, 1992-1999], whereas the worldwide average is 67% [AWA, 1995].

Low insecticide use in 1991 is primarily due to bad statistically data. In most states 1995, the year before *Bt*-cotton was introduced, high insect infestations required high amounts of insecticides [Gianessi and Carpenter, 1999]. In 1996 a lot of farmers faced high yield losses due to ineffective control by *Bt*-cotton varieties. Consequently insecticide use in 1997 slightly increased.

Reported damage on *Bt*-cotton in the introductory year by cotton bollworm [UBA, 1997] underlines reduced efficacy against the targeted insect cotton bollworm (*Helicoverpa zea*). Plants producing these *Bt*-Proteins are capable of providing effective control of tobacco budworm, pink bollworm and only of moderate levels of bollworm (*Helicoverpa zea*) [Moore *et al*., 1999 cited after Gianessi and Carpenter, 1999].

In the period from 1996 to 1998 the acreage of *Bt*-cotton increased up to more than one sixth of the U.S. cotton acreage in 1998. In the same period insecticide use remained more or less at the same level, although a decrease should have been expected (compare Figure 6).

> **Comments:** Pests patterns and infestation levels are different for each region and each year, requiring different insecticides and amounts of insecticides. Consequently, analysed data often draw controversial situations for different regions and years.

For instance in *Alabama* where growers faced serious damage from bollworm in *Bt*-cotton fields in 1996 the adoption rate increased from 1997 to 1998 by 10%, while insecticide use also increased from 0.6 in 1997 to 08 lbs./acre in 1998. In contrast, in other states reductions were reported by increasing adoption of transgenic *Bt*-varieties.

Generally, other factors than the introduction of transgenic cotton may also have contributed to changes in insecticide usage in U.S: in many cotton producing areas the return of beneficial insects that naturally control bollworm/budworm pests have reduced insecticide usage after eradication programs for the boll weevil (*Anthonomous grandis*) have been pursued, with high insecticide usage in the early nineties [Gianessi and Carpenter, 1999].

It stands to reason that three years are a short period to draw a definitive picture in insecticide usage in the U.S., however there are several features which should be mentioned and can be summarised as following.

- From 1996 to 1998 *Bt*-cotton acreage reached one sixth of the U.S. cotton acreage, in the same period insecticide use was more or less constant.
- Most farmers growing *Bt*-cotton still uses insecticides for the *Bt*-targeted pests (i.e. bollworm, pink bollworm and tobacco budworm).
- Gianessi and Carpenter calculated an approximate reduction of 10% of the overall insecticide use after the introduction of *Bt*-varieties. They compared the insecticide use of five states in the U.S. in 1995 (a high infestation year) and 1998 [Gianessi and Carpenter, 1999].
- A study conducted by the Economic Research Service (ERS) revealed that

the use of organo-phospate and pyrethroid insecticides did not change due to adoption of *Bt*-cotton [ERS, 1999]. Reductions were reported for the insecticide *aldicarb*[6] (Temik®) which is not recommended as a cotton Bollworm/Budworm insecticide after Gianessi and Carpenter [Gianessi and Carpenter, 1999].

- *Bt*-sprays were not included in the presented timeline. The application of *Bt* has generally declined during the last years. But if the production of *Bt* in plants is regarded as a permanent insecticide application, *Bt*-cotton might have contributed to an increase of insecticide use in the last years. This fact is excluded in any statistical data.
- In years with low infestation levels *Bt*-cotton is a rather expensive method compared to traditional pest managment solutions where sprayings were applied only after reaching economical thresholds. The average technology fee for *Bt*-cotton was approximately $32 per acre in 1998 [Gianessi and Carpenter, 1999]. The pricing of the technology fee is calculated on the alternative cost for spraying and is different for every country [Barton, 2000].

According to *Monsanto* insecticide usage significantly decreases when a grower switches to *Bt*-cotton. Since *Bt*-cotton is grown on only a portion of the acres (just over 20% in 1998) it is not astonishing that the pesticide use across all of the acres and all pesticides would not show a strong correlation. “This is especially true for insecticides which are used at very very low application rates compared to herbicides” [Voth, 2000].

> **Comments:** The picture drawn in this chapter points out that the influence of *Bt* can hardly be isolated in a complex system as agriculture. It is a matter of fact that many factors are influencing infestation levels and subsequent insecticide use. The analysis of nation-wide data is an attempt to show the net benefit for the environment nation-wide and to overcome isolated approaches that showed controversial benefits in the past. It is evident that this is a rather rough approach which cannot elucidate what is happening on a specific cotton field.

6 *Aldicarb* is a carbamate and is commonly used to control nematodes in cotton farming.

9 The situation in Australia

In 1999 Australia is expected to cultivate 125‘000 hectares of *Bt*-cotton. This represents about 25% of the overall cotton acreage. Herbicide tolerant cotton varieties are not registered for use, yet. Transgenic cotton lines are provided by *Monsanto*. Table 5 shows the list of organisations that are related with the approval of transgenic cotton varieties in Australia.

Table 5:Organisations dealing with transgenic cotton in Australia

Organisations	What they do
GMAC (Genetic Manipulation Advisory Council)	regulates the research with transgenic cotton
NRA (National Registration Authority)	regulates commercial registration of *Bt*-cotton Details of pest management strategies are recommended to the NRA by TIMS. NRA includes the strategy as part of the registration and the label for Bt-cotton, making it legally binding.
TIMS (Transgenic and Insecticide Management Strategy Committee)	TIMS develops recommendations about use and management strategies for *Bt*-cotton. TIMS has representation from industry, researchers, funding bodies, technology providers.

9.1 Change in insecticide use

According to the WWF Australia pesticide use is one of the main issues that affects the industry’s public acceptability in Australia [Handley, 1999]. In Australia a broad range of insecticides are used to face *Helicoverpa sp.,* the main lepidopteran pest: Endosulfan, synthetic pyrethroids, organo-phosphates, carbamates, *Bt*-sprays and virus sprays. Data collected over the last three seasons by the *Cotton R&D Corporation* shows reductions in specific insecticide applications of **50-60%** on *Bt*-cotton [Fitt, 1999].

> These reductions have been almost all for sprays targeting *Helicoverpa sp.*, the main target of the *Bt*-proteins. There has been no change in sprays for other pests [Fitt, 1999].

9.2 Change in land use

According to WWF Australia transgenic cotton does contribute to more irrigated cotton in the near future by driving the expansion of cotton acreage in the northern parts of Australia [Handley, 1999]. The previous attempt to cultivate conventional cotton in this area failed due to high infestations from insects. *Bt*-cotton is supposed to overcome these problems.

> **Comment:** In fact, any prospects for cotton production in northern Australia depend on far more than *Bt*-cotton and according to the WWF irrigation is the primary threat to Wetlands in Australia [Handley, 1999].

10 Environmental impact of transgenic cotton releases

10.1 Potential for out-cross

One concern about the risks of transgenic cotton is the escape of transgenes through pollen dispersal (via wind, insects) from transgenic crop plants to their relatives. Dispersal of pollen from transgenic cotton plants to surrounding non-transgenic plants has been observed, although cotton is mainly self-pollinating [Umbeck et al., 1991; Llewellyn and Fitt, 1996]. *Biothai* for instance has reported that conventional farmers found transgenic cotton in their fields last year [Bangkok Post, 1999].

10.1.1 Out-cross of herbicide-tolerant genes

The escape of transgenes through pollen is regarded as a environmental concern in the case of herbicide resistance genes, resulting in "superweeds" which are resistant even to broad-spectrum herbicides.
According to the list published by Keeler *et al.*, 1996 cotton (*Gossypium hirsutum*) is likely to hybridize with wild congeners. However, no member of the genus *Gossypium ssp.* is known as a weed worldwide.

> **Comments:** The danger that the genes for herbicide tolerance from the transgenic crops could be transferred to closely related cotton plants growing nearby, can give rise to labelling problems for conventional or organic cotton produces. The ecological impact through pollen dispersal in cotton farming can be regarded as less important than for other crops, such as canola, which has several weedy relatives. Recently, the resistance of a weed to three herbicides has been reported which derived from transgenes in canola[7].

10.1.2 Selection of herbicide tolerant weeds

A more indirect but not less adverse effect in transgenic cotton farming is due to repeated application of herbicide on the same area contributing to naturally developing herbicide resistance. Herbicide resistant weeds can be observed within a short period as a result of high selection pressure. For instance, overuse of the herbicide group *Triazine* has led to resistance in more than 55 weeds [UBA, 1999]. This phenomenon is also well known for the herbicide *glyphosate* (*Roundup*) [Anken, 1999; UBA, 1999].
Hence, it can generally be assumed that arable weeds develop a specific herbicide resistance after intensive application of one herbicide.

> **Comments:** Higher herbicide dosage will be needed to control weeds in the future, raising higher impacts on the environment by herbicides.

10.1.3 Side-effects by broad-spectrum herbicides

There is little knowledge about long-term use and subsequent side effects of broad-spectrum herbicides for non-target species and for biodiversity. This feature is getting more important when these herbicides are used intensively. A recent review from the German

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7 http://www.producer.com

government gives strong evidence that harmful effects on arthropods can not be excluded [Pesticides Trust, 1999].

10.1.4 Compensation by other pests

Whilst introducing *Bt*-cotton to reduce the most damaging pests in cotton farming, increasing populations of other pests (i.e. tarnished plant bug (*Lygus hesperus*), boll weevil (*Anthonomous grandis*)) have been reported in several areas. For instance, *Bt*-cotton in *North Carolina* sustained less damage from bollworms compared to conventional fields, while damage from other pests (e.g. stink bug) was approximately four times higher than in conventional fields [Bacheler, 1999 cited after Gianessi and Carpenter, 1999]. An other survey conducted in 1998 revealed an increasing number of insecticide treatments for pests not controlled by *Bt*-varieties on *Bt*-cotton fields than on conventional fields [Mullin *et al.*, 1999 cited after Gianessi and Carpenter, 1999].

> **Comments:** These field experiences back the facts stated in chapter 8. No overall insecticide reduction in current statistical data can be seen as a strong evidence that growers increase the number of treatments targeting these (secondary) pests, even though three years of experience in *Bt*-cotton farming are a (too) short period to prove changings in pest patterns due to the new *Bt*-technology. These tendencies should be assessed in more details. Insect-pests in cotton farming have shifted over time in the past as well without transgenic cotton.

10.1.5 Resistance of target insects

The development of insecticide resistance is a naturally occurring phenomenon. For instance, in *Arkansas*, pyrethroid resistance by the tobacco budworm has progressed to the point of basically no control in 1998 [Williams *et al.*, 1999 cited after Gianessi and Carpenter, 1999]. The resistance spectrum can also encompass many of the newer organo-phosphate and carbamate insecticides. Even broad-spectrum resistance to these synthetic insecticides has been reported.

The occurrence of resistance in *Arkansas* has led to the development of resistance management plans to reduce selecting pressure on insects for *Bt*-cotton. They are currently in place for the U.S., where selection pressure for resistant insecticides is particularly high due to monocultures and missing crop rotation practice: cotton growers who plant *Bt*-cotton varieties are required to plant a portion of non-transgenic cotton as a refuge for insects in order to avoid the development of resistance to *Bt* in insect populations.

According to the USDA's *Cotton Research Laboratory* this insect management plan does not properly fulfil its intentions at least for the Pink Cotton Bollworm (*Pectinophora gossypiella*) after preliminary results from laboratory work [Liu *et al.*, 1999].

> **Comment:** If one looks at the history of pest resistance it is very likely that resistance to the *Bt* incorporated in cotton will occur within the next years. When conventional *Bt* control agents have been used intensively in cotton farming in the past insecticide resistance was observed. Thus, insecticide use will increase again and an easily biodegradable insecticide such as *Bt* won't be effective anymore.

Opinion: As *Bt* represents a good larvicide that does not target the non damaging moth stage of Pink Cotton Bollworm (*Pectinophora gossypiella*), it seems to be reckless to risk insecticide resistance by large scale farming of *Bt*-cotton.

10.1.6 Side-Effects on non-target species

Several laboratory studies have revealed strong evidence that the *Bt*-Protein Cry1Ac (also incorporated into *Bt*-cotton) expressed by transgenic plants may harm more non-target species than assumed before [Losey *et al.,* 1999]. Moreover Hilbeck et al., (1998) reported in a laboratory based study that predatory larvae of green lacewings (*Chrysoperla carnea*) – an important beneficial insect in cotton fields – were fed on caterpillars that had in turn been feeding on maize leaves expressing a *Bt*-toxin. The lacewings given the *Bt* fed caterpillars to eat died in higher numbers (62% mortality) than those given *Bt*-free caterpillars (37% mortality).
Even though, the results of the cited research are based on laboratory studies and were not confirmed yet on farm they indicate some adverse effects by *Bt*-technology and it should be kept an eye on these findings in the future.

11 General outlook in transgenic crops

The preview released this autumn by the organisation ISAAA shows further linear growth of transgenic crops in 1999 but with slow adoption rates for transgenic cotton compared to other crops (compare
Figure 7 and Figure 8). For the next year the total transgenic crop acreage is expected to decrease basically due to consumer concerns to transgenic crops in food in Europe.
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Figure 7:Transgenic crops and transgenic cotton worldwide

Transgenic cotton had an adoption rate approximately linear during the last years and is now on position three under the most important transgenic crops throughout the world, but far behind corn and soybean (compare Figure 8).
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Figure 8:Acreage of transgenic crops and their development between 1996 and 1999 worldwide

> **Comments:** There is some uncertainty what happens with transgenic cotton acreage in the near future. Consumer concern about GMO-food is focussed primarily on corn, soybean and canal but not on cotton, seeing that it is generally not used as food ingredient in Europe. Therefore, a decrease in transgenic *Bt*-cotton acreage could be interpreted as insufficiency of the incorporated *Bt*-trait in transgenic cotton against insect pests and subsequently in insufficient net-return to the farmers.

The tendency in cotton and other crops show that herbicide-tolerant traits are the most powerful among all transgenic traits transferred to plants (data not shown, compare chapter 4.2). For instance, in the U.S. 50% of the soybean acreage are covered by herbicide-tolerant soybean.

Therefore, herbicide-tolerance in combination with the interest to sell the corresponding herbicides can be interpreted as the key-driving force for the adoption of transgenic crops.

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12.1 Further Websites

12.1.1 Biotechnology related

Biotechnology Knowledge Centre
http://www.biotechknowledge.com

Biotechnology Industry Organization (BIO)
http://www.bio.org

12.1.2 Cotton related

Cotton on the net
Cotton on the net seeks to serve the cotton community worldwide. It is a place where one can view information on the cotton industry
http://www.cotton-net.com

King Cotton Links
Various cotton related links
http://cotton.net

Pesticide trust
http://www.gn.apc.org/pesticidestrust

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13 Glossary

Bacillus thuring.	Bacillus thuringiensis (*Bt*) occurs naturally in the soil and on plants. Different varieties of this bacterium produce a crystal protein, called *Bt*-toxin that is toxic to specific groups of insects. *Bt* has been available in the U.S. as a commercial insecticide since the 1960s. The *Bt*-toxin Cry 1Ac is incorporated in *Bt*-cotton.
Bt	See *Bacillus thuringiensis*
***Bt*-cotton**	is a local cotton variety in which the trait *Bt* has been introduced by cross-pollination and which is supposed to be resistant to lepidopteran pests. See transgenic cotton.
Economic thresholds	Levels of pest population that, if left untreated, would result in losses in revenue that exceed treatment costs. The use of economic thresholds in making pesticide treatment decisions requires information on pest infestation levels from scouting.
Foliar pesticide application	Applying the pesticide to the foliage of the plant.
Gene expression	The process of producing a protein from its DNA- and mRNA-coding sequences.
Gene flow	The exchange of genes between different but (usually) related populations.
Gene	A locus on a chromosome that encodes a specific protein or several related proteins. It is considered the functional unit of heredity.
Genetic engineering	The manipulation of an organism's genetic endowment by introducing or eliminating specific genes through modern molecular biology techniques. A broad definition of genetic engineering also includes selective breeding and other means of artificial selection.
Genotype	The structure of DNA that determines the expression of a trait. See Phenotype.
Genus	A category including closely related species. Interbreeding between organisms within the same category can occur.
GEO	Genetically engineered organism.
GMO	Genetically modified organism.
Herbicide tolerance	Herbicide tolerance is a trait or characteristic that makes plants unsusceptible to specific herbicide applications.
Herbicide	Any substance that is toxic to plants, usually used to kill specific unwanted plants (e.g. weeds). Weeds compete with cotton for moisture, nutrients, and light. The greatest competition usually occurs early in the growing season. Late-season weeds, while not as competitive as early season weeds, may interfere with insecticide applications and may cause harvesting difficulties.
Herbicide-tolerant	See herbicide tolerance

Hybrid The offspring of two parents differing in at least one genetic characteristic (trait). Also, a heteroduplex DNA or DNA-RNA molecule.

Insecticide Insecticides are chemicals used to control insect. They are commonly applied as spray and granular formulations.

Insect-resistance Insect-resistance is a characteristic or trait of a plant, which has an insect repellent effect. This characteristic can be achieved by conventional breeding or genetic engineering. For instance, *Bt*-cotton is local insect-resistant cotton varieties derived by genetic engineering.

Insect-resistant See Insect-resistance

Integrated Pest Management (IPM): „A pest control strategy based on the determination of an economic threshold that indicates when a pest population is approaching the level at which control measures are necessary to prevent a decline in net returns. In practice, IPM is an ecologically based strategy that relies on natural mortality factors, such as natural enemies, weather, crop management, and seeks control tactics that disrupt these factors as little as possible." *Alternative Agriculture*, National Academy of Sciences (1989).

Invasiveness Ability of a plant to spread beyond its introduction site and become established in new locations where it may provide a deleterious effect on organisms already existing there.

Open pollination Pollination by wind, insects, or other natural mechanisms.

Pest scouting The inspection of a field for pests (insects, weeds, or pathogens). A basic component of IPM programs, scouting is used to determine whether pest populations have reached levels that warrant intervention for control and to help determine the appropriate method of control.

Pesticide A substance that kills harmful organisms (for example, an insecticide or fungicide). As defined by the Federball Insecticide, Fungicide, and Rodenticide Act (FIFRA) in the U.S., pesticides include any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any pest, and any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant.
In this report four classes of pesticides are used: Herbicides, Insecticides, Fungicides and other chemicals such as soil fumigants, defoliants and growth regulators.

Pests Insects, diseases, and weeds or uncultivated plants that naturally exist in the environment. Agricultural pests cause damages to crops, resulting in reductions in yield, crop quality, or both.

Phenotype The observable characteristics of an organism, the expression of gene alleles (genotype) as an observable physical or biochemical trait. See Genotype.

Postemergence herbicide: Herbicides that are applied after weeds emerge. Postemergence herbicides are considered more environmentally sound than preemergence herbicides because they have little or no soil residual activity.

Preemergence herbicide: Herbicides that are applied before weeds emerge. Preemergence herbicides have been the foundation of row crop weed control for the past 30 years.

Promoter A region of DNA extending 150-300 bp upstream from the transcription start site that contains binding sites for RNA polymerase and a number of proteins that regulate the rate of transcription of the adjacent gene.

Self-pollination Pollen of one plant is transferred to the female part of the same plant or another plant with the same genetic makeup.

Species A classification of related organisms that can freely interbreed (e.g. upland cotton *Gossypium hirsutum)*

Trait The phenotype or characteristic of transgenic plantSee Phenotype.

Transgene See Transgenic.

Transgenic cotton Transgenic cotton are local cotton varieties in which a transgen (e.g. a gen from a bacteria) is incorporated into its genome.

Transgenic plant Genetically engineered plant or offspring of genetically engineered plants. The transgenic plant usually contains material from at least one unrelated organisms, such as from a virus, bacterium, animal, or other plant. See Transgenic

Transgenic An organism in which a foreign DNA gene (a transgene) is incorporated into its genome early in development. The transgene is present in both somatic and germ cells, is expressed in one or more tissues, and is inherited by offspring in a Mendelian fashion. See Transgenic plant.

Weed An undesirable plant

Weediness Unwanted effects of a plant

Appendices

Appendix I: Genetic engineering in cotton breeding

Target genes	Potential application
Insecticidal genes	
Bacillus thuringiensis (Bt) toxins	Control of *Helicoverpa zea, Heliothis viescens, Pectinophora gossypiella*
Protease inhibitors, lectins	Feeding deterrents
neuropeptides	Kill or paralyze feeding pests
Herbicidal genes	
5-Enolpyruvylshikimic acid 3-phosphate	Glyphosate tolerance
Nitrilase	Bromoxynil tolerance
Acetolactate synthase	Sulfonylurea tolerance
2,4-Dichlorophenoxyacetate monooxygenase	2,4-D tolerance
Phosphinothricin acetyltransferase	Bialaphos tolerance
Environmental stress-resistance genes	
Superoxide dismutase	Free-radical quenching
Thermal and water stress-tolerance genes	Heat, cold, and drought tolerance
Fiber-modification genes	
Cotton genes	Modification of existing fiber properties
Other plant genes (extensins, peroxidase)	Modification of existing properties
Bacterial genes (e.g., hormone genes)	Modification of existing properties
Genes for hybrids	
Pollen-specific antisense genes	Production of male sterile plants
Cytotoxic genes (e.g., Rnases)	Protection of proprietary seeds

Source: Bajaj, 1998

Appendix II: Global acreage of transgenic cotton

Country	Approx. share of transgenic cotton acreage on national cotton acreage	Transgenic cotton acreage				National cotton acreage		Approx. share of national transgenic cotton acreage on total cotton acreage worldwide	Cotton production	Total acreage	Transgenic crops in 1999
	1999*	1996	1997	1998	1999	1998	1999	1998	1998	1998	1999
	%	thousand ha	thousand ha	thousand ha	thousand ha	thousand ha	thousand ha	%	thousand tons	thousand ha	thousand ha
U.S.	56.8	600	1300	2400	3079	5423	5909	1.3	3970	189915	28700
China	6.3	0	0	63	300	4750	n.d.	0.1	4000	96115	300
Australia	28.4	30	60	85	125	440	n.d.	0.2	577	48934	100
Mexico	16.2	0	15	40	32	200	n.d.	0.2	179	24710	<100
South-Africa	22.5	0	0	12	20	90	n.d.	0.1	63	13174	100
Argentina	1.6	0	0	8	12	764	n.d.	0.0	419	35750	6700
India	0.0	0	0	0	0	9070	n.d.	0.0	2711	168990	0
Pakistan	0.0	0	0	0	0	2930	n.d.	0.0	1859	20730	0
Uzbekistan	0.0	0	0	0	0	1530	n.d.	0.0	1200	n.d.	0
Turkey	0.0	0	0	0	0	700	n.d.	0.0	799	27885	0
Total of transgenic cotton for these countries	10.1	630	1375	2608	3569	25897	5909			626203	35900

*Coloum "Transgenic cotton acreage1999" divided by coloum "National cotton acreage" 1998 or 1999 where available

Source: Fitt, 1999; Barton, 1999, James, 1997, 1998, 1999; FAO STAT, 1998; Cotton and Wool yearbook, 1999