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Contents

	Page
Introduction	3
Cotton Breeding in the USA	4
Zero Insecticide Pest Control System in Syria	9
Update on Genetically Engineered Cotton	12
A DIALOG Search of Agricola and CAB Abstracts Databases	16

Introduction

Most research on cotton in the world is conducted in the field of breeding for development of superior varieties. All countries that have active research on cotton have a program to develop high yielding and better quality varieties. Developing a new variety is a lengthy process. Most breeding programs, where hybridization is employed as means of creating variability followed by selection take 10-12 years to develop a new variety. A good variety could be lost easily if the breeding process is not properly backed by a good seed production system. In the USA, the cotton-breeding program started in the early 1800s with individual farmers selecting better performing plants and using them to produce planting seed. However, private seed companies were established in the early 1900s. Now, almost all cotton area in the USA is planted to varieties developed by private seed companies. The public sector is responsible for development of germplasm. Varieties are sold under various brand names like Deltapine and Stoneville. The data from the Cotton Program of the Agricultural Marketing Service of the USDA shows that varieties belonging to more than 22 brands were planted in 2003/04. The first article on breeding of cotton in the USA provides extensive detail on variety development, promotion and adoption in the USA.

Insecticides have become an integral part of production practices in most countries. Insect pressure is so high under most conditions that if cotton is not sprayed, yields could be reduced by more than 50%. Syria adopted insecticides in the 1970s, but decided to reduce the use, realizing that the long-term consequences were not in favor of cotton production. The area treated with insecticides increased to almost 50% in late 1970 but in 1979 researchers provided an alternative to increasing of insecticides and successfully managed to grow cotton with almost no insecticides. Area treated with insecticides decreased to 25% of the total area by 1985/86 and since 1999/00 less than 1% of the area has been treated with insecticides. The average yield in Syria was 1,364 kilograms of

lint per hectare in 2003/04, and less than 1% of the total cotton area was sprayed with insecticides. Syria has managed to control insects, particularly bollworms, through enhanced biological control systems in the field and also through lab rearing and release of *Trichogramma principium*. Herbicide use is common but diseases are managed through resistant varieties. How Syria has managed to eliminate the need for insecticide spraying in cotton is one of the most successful stories of cotton in the world. You can learn more about the Syrian cotton production system in the 2nd article on zero insecticide pest control system in Syria.

Genetically engineered (GE) cotton was grown on a commercial scale in nine countries in 2003/04. All GE crops were planted on 67.7 million hectares and GE cotton formed 11% of all the GE crops area in 2003/04. GE soybean and maize occupied the most GE crop area. It is estimated that 21% of world cotton area was under GE varieties in 2003/04. For the last four years, GE cotton area in the USA has been more than 70% of the total area. In 2003/04, GE cotton was planted on 76% of the total area. In China (Mainland), GE cotton increased to 58% of the total in 2003/04, as against 51% last year. Colombia planted GE cotton for the first time on 6,000 hectares in 2003/04. GE cotton is expected to increase in Colombia in 2004/05. Australia still has a limit of 30% of the total area to be planted to GE varieties, but this condition will be lifted in 2004/05. India has approved more Bt hybrids for commercial planting. Four new GE products have been extensively researched in the last few years, but only LibertyLink has been approved for commercial use. Three other technologies VIPCot, WideStrike and Roundup Ready Flex are near approval. An update on the GE technology is given in the third article.

A DIALOG Search of the Agricola and CAB Abstracts Databases using the key words cotton and fineness is also a part of this issue of the *RECORDER*.

The International Cotton Advisory Committee has published a book *COTTON FACTS* that is available from the Secretariat at the following address. The price of the 158 page hardbound book, including shipping and handling, is US\$20. For more details and to place orders see the enclosed flyer or visit the ICAC web page at <http://www.icac.org>.

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The International Cotton Advisory Committee constituted an

expert panel on biotechnology in cotton in early 2000 with the mandate to prepare a balanced science-based report on cotton biotechnology written in language understandable to most people. Dr. Phillip Wakelyn of the National Cotton Council of America chaired the nine-member expert panel. Other members were from Australia, Brazil, Egypt, CIRAD-CA of France, Greece, India, UK and USA. The panel prepared a report in November 2000, which is available free on the ICAC web page under cotton biotechnology. The 62nd Plenary Meeting of ICAC held last year in Poland decided to revive the panel and update the report published in 2000. Dr. Gary Fitt of CSIRO, Australia, is the chairman of the current panel. The panel is communicating through email but will meet once before finalizing the report. Final report will be presented to the 63rd Plenary Meeting of the ICAC in India from November 28 to December 3, 2004. The report will also be available free on the ICAC web page.

Cotton Breeding in the USA

Breeding for high yielding varieties was taking place even before genetics was born as a science. Producers have always tried to find the best varieties for their area/region, and in this effort they selected not only the best variety but also the best plants within varieties. Selection, a process of developing new varieties, was being practiced long before organized hybridization began. Hybridization became popular as a common method of developing new varieties only after inheritance of characters was found to follow certain scientific principles and patterns. The reasons for and the basis of inheritance of characters are far better understood now than they were a century ago, but introduction and selection are still practiced.

The three methods of developing varieties—introduction, selection and hybridization—are used in most countries, but it is very rare for one breeding program to practice all three methods. Introduction of germplasm and selection within the germplasm are less used in developing new varieties compared to hybridization, followed by various selections and testing approaches that in 8 to 10 years culminate in a new variety. Commercial cotton hybrids are popular in India and portions of China (Mainland) because labor to emasculate and pollinate by hand is readily available. Commercial cotton hybrids are not commercially produced to any extent in the USA. The introduction of new genotypes has been limited to enhancing genetic diversity in most countries, although a few countries directly import varieties from other countries. There are not many varieties widely grown in the world today that have been developed directly from selections from within an approved variety or registered germplasm. Hybridization has recently become the dominant method for developing new varieties. The need for and emphasis on combinations not existent in the available genotypes has stimulated a focus on hybridization.

Scientific breeding of cotton started simultaneously in most countries. In the USA, the cotton-breeding program started in the early 1800s with individual farmers selecting better performing plants within populations and using them for seed production. The US public sector cotton breeding program started in 1898. Since then, significant progress has been made to improve yield and fiber quality. The average yield of cotton in the USA in 1900 was 216 kg/ha of lint and increased to 813 kg lint per hectare in 2003/04. The nearly four-fold increase in yield can be attributed to many factors, but undoubtedly the development of varieties suitable for growing conditions throughout the cotton belt has played a major role in increasing yields.

When Mendel's work on the two fundamental laws of inheritance was recognized, private companies rightly foresaw the role of the private sector in developing new varieties and started to establish businesses. In the USA, private seed companies that started developing new and unique varieties were established in the early 1900s. Other countries, where cotton was already produced but private seed companies were established much later, definitely strengthened their programs on cotton breeding in the early 1900s. The public sector breeders competed with private seed companies for decades in the USA until the US government changed the mandate of public breeders in the country. Now, except for the few remaining state supported breeding efforts that have a mandate to develop varieties, the public breeders are limited to development and maintenance of germplasm. The USDA-ARS Southern Crops Research Lab, Crop Germplasm Research Unit at College Station, Texas, maintains a large inventory of cotton germplasm collected from around the globe, including obsolete varieties in the USA.

Private Sector Takes over Breeding

China (Mainland) has the largest cotton-breeding program in the world, with close to 100 cotton breeders at national and state levels. Private breeding is limited to transgenic varieties from multinational companies under a joint venture with local companies. India has the largest area under cotton in the world, and might be expected to have an even larger program, but the exact number of breeders is not known, as most hybrid cotton work is in the private sector. The number of cotton breeders in Egypt and Pakistan ranges from 50-60 and private cotton breeding does not exist yet. All other breeding programs are smaller than these. According to Bowman (1999), the number of full-time cotton breeders (public and private) in the USA has increased from 38 in 1974 to 45 in 1999. It is estimated that there has been a more than six-fold increase in private breeding efforts in the last 25 years because private companies have not only hired more breeders but also have employed a lot more people to promote varieties and manage research programs.

While private programs are on the rise, public sector breeding in the USA is shrinking in number and size. According to Bowman (1999), the Agriculture Research Service (ARS) of the USDA had 20.5 full-time-equivalent researchers working in 1974; this number decreased to 17.2 in 1992 and to 10.8 in 1998. Of the 10.8 in 1998, one full-time-equivalent was engaged in maintenance of germplasm, one in a national variety testing program and four in genetic studies, leaving only four others working on breeding of germplasm, one of which is dedicated to Pima (*Gossypium barbadense* L.) germplasm enhancement. Moreover, since 1998, USDA-ARS has closed more positions. The state level breeding programs were cut by half between 1974 and 1999. The number of state cotton breeders decreased from 16.5 full-time-equivalent positions in 1974 to 11.5 in 1992 and to 9.3 in 1998. The number has gone down further as some senior breeders have retired from state universities and no new breeders were hired in their places. Accordingly, funding for federal and state research programs also fell, and now variety development is only in the private sector.

The Role of Private Seed Companies

Whereas in almost all countries, variety development and seed production are separate, in the USA both are in the hands of private seed companies. Putting them together ensures that once a successful variety has been developed, it is not lost in the seed production process. In contrast to the public sector breeding programs, private companies have to be more cautious in promoting their varieties. It is easy to earn a good name by developing one good variety, but it is hard to maintain a reputation as a quality seed supplier in a quality-conscious market like that of the USA. Companies follow their own quality standards and observe strict self-assessment to remain reliable suppliers of better varieties and quality seed.

Almost all cotton area in the USA is planted to varieties developed by private seed companies. The varieties developed by state breeders (at universities) are grown on only a limited area, mainly in Texas. However, the seed companies develop varieties, test them throughout the cotton belt, advertise them, multiply them for seed purposes, produce and process planting seed and market seed under their own brand names. Thus, varieties in the USA are sold under various brand names such as Deltapine and Stoneville. The data from the Cotton Program of the Agricultural Marketing Service of the USDA showed that varieties belonging to more than 22 brands were planted in 2003/04.

Some brands have dominated the market for a long time; however, the newest addition is the FiberMax varieties from Bayer CropScience, a joint venture between Bayer CropScience and Cotton Seed International. Bayer CropScience started the cotton-breeding program in the USA in 1999. All FiberMax varieties currently planted are imported from Australia, except those bred on the High Plains of Texas, which originate from a Bayer-owned seed company. Germplasm of Australian origin from the Commonwealth Scientific and Industrial Research Organization (CSIRO) is used in the FiberMax varieties. FiberMax varieties are popular in Oklahoma and Texas, where they were planted on 28% of area in 2003/04. FiberMax varieties claim higher yield potential and superior fiber properties. Delta and Pine Land varieties account for most cotton area in the USA.

Share of Seed Companies in Cotton Area in the USA - 2003/04	
Seed Company	Area (%)
Delta and Pine Land Company	33.04
Paymaster (Owned by Delta and Pine Land)	21.33
Bayer CropScience (Fibermax varieties)	15.61
Stoneville Pedigree Seed Company	13.55
Sure-Grow	5.44
All-Tex	3.07
PhytoGen Seed Company	2.07

Attributes of Public Versus Private Breeders

The priorities of public and private sectors are different. Private breeding programs are motivated by potential income in the short as well as long term, while public sector programs are more viewed as a service to the community, with the exception of public breeding programs whose products are owned by university research foundations. Such foundations actively seek corporate partners, through which the publicly bred varieties can be marketed, providing access to popular transgenic traits. Bowman (2000) undertook an interesting survey of programs and activities of breeders in the USA and concluded that two approaches are quite different in many respects. Some data from the paper are reproduced in the following table.

Attributes of Private and Public Sector Breeding Programs in the USA		
Attributes	Private	Public
No. of breeders (Full-time equivalents)	27.0	20.1
Breeding objectives		
Germplasm development	0%	55%
Cultivar development	100%	45%
Average time devoted to		
Transgenic breeding	35%	1%
Conventional breeding	65%	99%
Breeding methods used		
Pedigree	82%	71%
Backcross	6%	28%
Reselection	29%	14%
Bulk	18%	14%
Single seed descent	6%	0%
Source of parental material		
In-house	56%	40%
Commercial cultivars	28%	32%
Public germplasm	15%	25%
Other	1%	3%
Average number of genetic combinations yearly	105	102
Parental selection criteria		
Yield	100%	86%
Stability	87%	71%
Disease resistance	73%	43%
Insect resistance	53%	57%
Pubescence	53%	43%
Nectariless	20%	28%
Fiber properties	47%	57%

The survey was undertaken in 1999, and the number of public sector breeders has fallen since, but the data show that all-out efforts are made in the private sector to develop new varieties and no time or resources are spent to enhance/develop germplasm which could be used in future breeding programs. In contrast, more than half of the emphasis in the public sector is to develop new germplasm and deliver it for utilization in breeding programs by all breeders. Almost no work is going on in the public sector to develop transgenic varieties, except where university research or experiment stations have executed licensing agreements with technology providers. The broad based patent on all genetically engineered cotton jointly held by private companies like Bayer and Monsanto essentially enjoins public entities from commercializing their own proprietary transgenic technologies, except through the agreement of these companies. The data shows that in 1999, almost one-third of the private sector breeders' time was consumed on breeding transgenic cotton and transferring available insect- and herbicide-resistant genes into existing or new varieties. It is assumed that the trend has changed in the last four years and now even more time is spent on developing transgenic varieties. All breeders employ some form of pedigree method of selection to develop improved germplasm whereby performance history of the finally selected progenies can be traced. Back-crossing was used more by public sector breeders, but it is also assumed that by now transgenic cotton must have enhanced the use of back crossing in the private sector. Back-cross incorporation of transgenic traits remains the norm,

except where forward-crossing is permitted using a transgenic variety as the donor parent of the transgenic trait(s). Private breeders to a considerable extent used reselection from the existing population and bulk methods, but it is assumed that that their use should have decreased by now. Eighty-four percent of the parents used by private breeders were either their in-house breeding material or commercial varieties that are supposed to be their own varieties. This is negatively affecting the genetic base of varieties developed in the USA. The genetic base is even narrower within specific brand varieties. Yield is no doubt a number-one priority among all breeding programs, but 87% preference for adaptability limits utilization of new and out of brand germplasm, further contributing to the narrow genetic base. The necessity to broaden the genetic base of cotton has been pointed out by many researchers in the USA. Meredith (2003) in his paper presented at the 16th EFS® System Conference held from June 9-11, 2003 said that the genetic progress is directly dependent on the amount of genetic variability available for breeders and the instrumentation and technology available to identify that variability. The narrow genetic base could have long-term consequences.

Impact of Transferring Breeding to the Private Sector

Public sector breeders are responsible for development of varieties in almost all countries except India and the USA. Private companies do exist in some other countries and are making efforts to develop new varieties, but tough competition against public breeders and the variety approval process are limiting their efforts. In the USA, responsibility has been transferred to the private sector, but in India it is successful because of the hybrid cotton program. The change in the USA has had both positive and negative effects on the development of varieties:

- The number of breeders in the private sector has increased significantly compared to the public sector, and more funding has become available for breeding programs.
- The public sector is not producing trained cotton breeders. USDA and state universities produce geneticists, but in contrast to when breeding was in the public sector, only limited applied breeding training is now available. Though some companies have initiated some training programs for young people, it is not their primary objective.
- All companies prefer to use their own breeding germplasm and varieties in their hybridization programs; consequently the genetic base of the breeding material used in crossing has narrowed in the USA. The three reasons usually cited are reliance on selections from within adopted varieties, repeated use of same parents and a reluctance to use un-adapted genotypes. The immense pressure for commercial breeders to develop cultivars does not allow for wide-crosses because this type of work

requires a long-term commitment. Breeders' tendency to use only accepted high-yielding varieties in their breeding programs has also increased because it is easier to improve existing yield potential than to combine characteristics from more than two varieties. Consequently, varieties have become more specific for cultivation in specific areas.

- While cotton breeding has become more challenging due to competition in the private sector, better utilization of genetic principles, and more recently, the introduction of genetic engineering, the total time spent on developing new combinations has decreased significantly.
- Private companies work directly with growers; hence, better feedback is available to breeders for meeting the needs of industry.
- The private sector is able to release new varieties at a faster rate. The Plant Variety Protection Act of 1971 also encourages private breeders/companies to better focus on variety development. However, 1994 amendments to the Plant Variety Protection laws have negatively affected the free exchange of germplasm.
- It is inferred that the public sector breeders were spending most of their time on development of new varieties rather than developing new germplasm. However, now that the public sector does not have the obligation to come up with new varieties every few years, it can better focus on new combinations and the development of better germplasm. Thus, better germplasm would probably have become available if the number of breeders in the public sector had not been reduced.

Varieties Planted in 2003/04

There is no formal variety approval process in the USA, except for quality assurance standards that must be met for transgenic varieties. Based on their own judgment, companies decide whether a variety is ready and suitable for release in commercial cultivation. The new variety will not only compete against varieties from other companies, but also will compete against varieties from the same company.

Thirty-one varieties of Deltapine and 21 varieties of Paymaster, both belonging to the Delta and Pine Land Company, were planted on a commercial scale in 2003/04. It is estimated that in total, about 150 varieties belonging to 22 brands were planted on a commercial scale, though only four varieties were planted on at least 5% of US cotton area. Only a single variety was planted on more than 8% of US cotton area. The data in the following table show that 13 varieties covered 59% of the total area, while about 137 others were planted on 41% of the total area.

Genetically engineered (GE) varieties were planted on 77% of the total US cotton area in 2003/04. GE varieties have accounted for more than 70% of the total in the USA since 2000/01. Further increases are not expected because of refuge requirements

Main Cotton Varieties Planted in the USA - 2003/04

Variety	Area (%)	Genetic Status
DP 555	8.7	Bt + Herbicide resistant
ST 4892	7.9	Bt + Herbicide resistant
DP 451	6.5	Bt + Herbicide resistant
PM 1218	5.9	Bt + Herbicide resistant
DP 458	4.6	Bt + Herbicide resistant
FM 958	4.5	Non-transgenic
PM 2326	4.3	Herbicide resistant
SG 215	3.4	Bt + Herbicide resistant
FM 832	3.1	Non-transgenic
DP 5415	3.1	Herbicide resistant
FM 989	2.3	Bt + Herbicide resistant
ST 4793	2.2	Herbicide resistant
FM 989	2.1	Herbicide resistant

and because the pest complex in some areas does not necessitate the use of transgenic cotton. Of the total area planted to GE varieties, 28% was planted to herbicide-resistant GE varieties, 47% to stacked gene insect-resistant plus herbicide-resistant varieties, and less than 2% was under transgenic Bt varieties. Although it is not popular among growers, the same variety could be available in four different forms in the USA; conventional form, herbicide-resistant form, Bt form and Bt plus herbicide-resistant form. More choices could become available when Bollgard II becomes widespread, and newer forms of GE products such as VIPCot, WideStrike and Liberty Link also become available for commercial production.

Pima Research Program

Experiments to grow Pima on a commercial scale started in the USA in the early 20th century. Some extra-long staple varieties were introduced from Egypt and the Caribbean Islands in the 1700s, but no variety was formally released until 1949. The varieties from Egypt had good quality fiber but they grew very tall, produced low yields and matured late. As with upland cotton, early breeding work started with selection from within existing populations, but hybridization was also attempted. However, it took five decades to develop a prominent variety due to the narrow genetic base.

The first and most successful Pima variety released in the USA is Pima S-1. Released in 1951, Pima S-1 was developed from a series of crosses involving Sea Island, Pima, Tanguis and Stoneville varieties. The success of Pima S-1 sent breeders back to the original interspecific crosses, resulting in the release of a series of other varieties such as Pima S-3 and Pima S-6.

The main objective of the Pima breeding program has been to develop heat-tolerant genotypes. The USDA breeding program was located in Phoenix, AZ because Arizona was the main *G. barbadense* producing state until the mid-1980s. Then, in the mid-1980s, some growers started experimenting with Pima

cotton in the San Joaquin Valley of California. The trials proved successful, but farmers were restricted and could not grow Pima due to legal requirements in California, where the “one-variety” law was passed in 1925 permitting only the Acala type to be grown in the San Joaquin Valley. It was easy to market quality Acala cotton, and maintenance of quality could be better managed under the one-variety law. The “one-variety” law was modified in 1978 to allow any approved variety to be grown. The first Pima cotton varieties were approved for planting in 1991. The “one-variety” law was repealed in 1999, opening the San Joaquin Valley to any variety. Nevertheless, California growers can only grow varieties approved by the San Joaquin Valley Cotton Board or by the San Joaquin Valley Quality Cotton Growers Association.

At present, about 90% of USA Pima is produced in California. Pima S-6 was the major variety grown when Pima production became popular in California. Pima S-7 was released by the USDA in 1991, which was the last variety released before the program was closed in 1993. Since then, private companies like PhytoGen and Delta and Pine Land Company have developed Pima varieties. PHY 76 was planted on 56% of the Pima area in the USA in 2003/04. The Pima breeding program has been very successful, and many special characters like frego bract, nectariless, glandless seed, cytoplasmic and genetic male sterility have been successfully transferred from *G. hirsutum* to *G. barbadense*.

Commercial Cotton Hybrids

A lot of work has been undertaken on commercial cotton hybrids in the USA, particularly at the University of New Mexico, Las Cruces and the University of Georgia, Athens, but there have been only limited efforts by the private sector. The hybrid breeding research at the universities of Georgia and New Mexico were abandoned when faculty members retired in the 1980s. Hybrid cotton is a two-fold issue: 1) identification of suitable parents, which when crossed, express sufficient hybrid vigor over commercial varieties, and 2) economical production of F_1 hybrid seed. Cotton, behaving like a largely self-pollinated species, does not harbor favorable dominant alleles required for the expression of hybrid vigor at the same frequency as outcrossing species such as maize. A number of varieties were converted into cytoplasmic male sterile lines and restorer lines. An ‘enhancing factor’ was also identified and inserted into potential male parents. Bumblebees were used for pollination to avoid the expensive work of manual pollination. But it was concluded that their populations greatly varied from year to year, resulting in a mixture of hybrid and self-pollinated seed, and accordingly, the same hybrids produced different yields. Experiments were conducted to enhance the honeybee population by releasing additional bee colonies in cotton fields. It was observed that the native bees visited fertile flowers more frequently than sterile flowers, whereas honeybees visited sterile flowers more frequently. The genetic male sterility system was also tried, but elimination of fertile plants remained an issue.

While most work was focused on intraspecific *hirsutum* crosses, interspecific crossing between *G. hirsutum* and *G. barbadense* was also tried, but pollination remained an issue. Bees visited the yellow colored *G. barbadense* male parent more frequently than the *G. hirsutum* parent. Perfect pollination could not be achieved and seed production remained a problem.

Three-way crosses were tried, but hybrid vigor was lost and an economical increase in yield could not be retained. A private company, Chembred, discovered a gametocide in 1978. Chembred was followed by other companies with different gametocides. Gametocides were desirable due to the absence of fertile plants in F_2 and no yield loss due to *G. harknessii* cytoplasm, but private companies soon concluded that it was not economical to produce hybrid seed for commercial cultivation using the gametocide technology. Although some hybrids were approved by the Cotton Board of the San Joaquin Valley in 1992, in real terms the technology never took off, and now no work is going on in hybrid cotton in the public or in the private sector.

The Difficult Task of Breeding and Testing New Varieties

Breeders face the big challenge of improving yields and quality at the same time. Because lint is an outgrowth of the seed coat, yield is difficult to improve. The fact that fiber quality characteristics are measured in various forms (length, strength, micronaire, maturity, color, brightness and spinability) makes the task of quality improvement more difficult. Meeting the needs of growers and the demands of the textile industry becomes even more complicated when certain desirable characters are negatively correlated with each other or are linked to undesirable characters. Only one out of four plants will be a desirable target plant if a single gene controls a character. Only one in 16 will be a target plant if only two genes are involved in the genetic control of a character. If a character is influenced by ten genes/alleles, the chances of getting a single target plant are one out of every one million plants. The area needed to grow one million plants and the care and vision needed to identify and select the right plant suggest the importance and the difficulty of developing improved varieties. Genetic engineering of cotton has not eased the process of developing new varieties, but it has the potential to provide at least some relief when gene transfer through recombinant DNA becomes routine within and among species, and characters are molecularly marked.

Once a variety has been developed, it is sometimes tested in the National Cotton Variety Testing Program (NCVT). This program, conducted since 1960, is a uniform system of reporting data from trials conducted across the US cotton belt. The trials take place annually, and yield, boll size, seed index, fiber quality and spinning performance data are recorded. NCVT data are not used for recommending or rejecting any variety for commercial cultivation; no doubt the data provides unique information on performance and quality of varieties grown in

the USA. The private sector volunteers varieties in NCVT and has successfully supplied improved varieties in the USA. The program could be copied in other countries and public sector resources could be utilized on more focused research in other disciplines.

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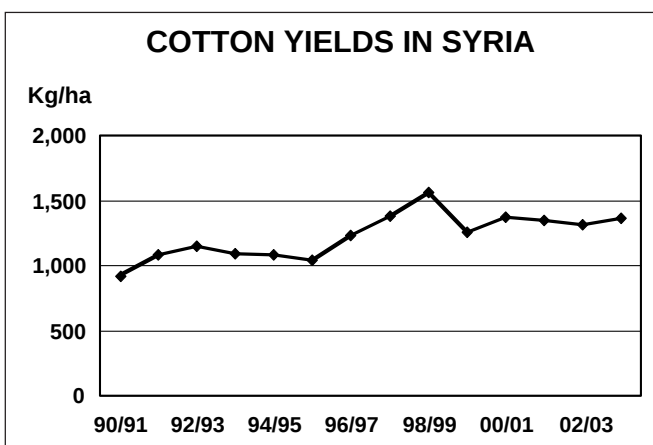
Zero Insecticide Pest Control System in Syria

Cotton is an important cash crop in Syria. In 2003/04, Syria's average yield was 1,364 kilograms of lint per hectare, and insecticides were used on less than one percent of the total cotton area. Cotton production in Syria is unique with respect to the yield and use of pesticides. In this article Syria's approach to growing cotton without the use of insecticides is described. Cotton production in Syria, centralized under the Ministry of Agriculture, is divided into three regions: Central North, covering the Aleppo and Hama provinces; Eastern, covering Rakka and Deir ez Zore provinces, and; North Eastern, covering the El Hassaka province. Cotton production has centralized planning because inputs such as seed, fertilizers, and pesticides are supplied by the government owned Agriculture Cooperative Bank. Although farmers have the option of buying these products from the open market, the Agriculture Cooperative Bank offers them for lower prices.

In consultation with its subordinate offices, the Ministry of Agriculture prepares a cotton production plan every year. The plan is approved by the government and conveyed to the provinces for implementation. The provinces then distribute the plan to local authorities and allocate the areas in which the cotton is to be grown. The El Hassaka province is responsible for almost one fourth of the country's cotton production. In Deir ez Zore, only one variety Deir ez Zore 22 is planted and the yield is lower than in other regions due to hot summer temperatures (often exceeding 40°C during peak flowering season). The Cotton Marketing Organization (CMO) of Syria is the only provider of planting seed set at a price determined by the government. Most of the cotton is picked by end of September and ginning begins on October 1 and continues until end of April. The Cotton Marketing Organization has its own gins and storage facilities for handling all cotton in the country, and has recently installed two new ginning factories. These factories have the ability to handle a total of 300,000 tons of seed cotton - one gin can handle 180,000 tons of seed cotton and the other 120,000 tons. The addition of these new

gins will help to shorten the ginning season. Furthermore, some of the old gins are not running efficiently and decrease the quality of the cotton. The new gins have also been designed to cover cotton bales with cotton cloth. Ties will be put around the cotton wrap, while the bale will be put into a jute bag for protection against handling in the warehouses and during shipping. The old gins will continue to operate under the old system of wrapping the cotton in jute.

Syria has constructed additional cotton storage facilities which will allow for comfortable handling of ginned cotton before it is exported or sold in the local market. Only one-third of the total cotton production is bought locally. Additional storage facilities will reduce pressure to enhance the ginning process. Although there is no official training school for ginning, the Cotton Marketing Organization organizes training courses in which the senior staff provides training to the new and less experienced staff. Training is provided in all areas related to ginning operations, including accounting. The Cotton Marketing Organization owns all ginneries in Syria, and has recently intensified the training of their ginning staff.



Insecticide Usage

The advent of insecticides attracted Syria to use chemicals for pest control, and in the beginning, Syria embraced their usage to control bollworms. Consequently, approximately 50% of the total cotton fields were being sprayed with insecticides by the late 1970s. In 1979, the Government of Syria decided to reduce the use of insecticides and adopt a different form of pest control - not due to environmental concerns, but rather, the exorbitant cost of insecticides. This logic has become one of today's most serious criticisms of the cotton industry. While many other large cotton producing countries such as India and Pakistan were struggling with how to best promote the use of insecticides, researchers in Syria trusted their abilities to tackle the pest problem through non-chemical means. As cotton production was under government subsidy, the researchers were assured that a good science-based idea would be implemented. Thus, for the first time in 1979, the various predators and parasites that feed on the pests in cotton fields were examined. The researchers discovered 13 species of predators and 6-7 species of parasites that were very active in cotton fields. Unfortunately, the spraying resulted in the decline of the population of beneficials (predators and parasites). However, it was also observed that if the population of predators and parasites was increased, the pest population became overpowered. Therefore, the researchers increased the threshold levels (number of pests observed for initiating insecticide use) for various pests and correlated the number of pests with the predators and parasites at various stages of crop development.

The threshold for the American bollworm *Helicoverpa armigera*, the most persistently serious pest in Syria, was 1 larva per 100 fruiting parts. In other words, when 1 larva was found on a minimum 100 fruiting parts, insecticides were utilized. In an attempt to decrease insecticide use, the researchers revised their recommendations to higher a threshold level - 10 larvae per 100 fruiting parts - an amount that is rarely reached. Experienced farmers, observing early insect appearance and damage to their crops, were very uneasy with the revised recommendations. Regardless, the government discontinued the supply of insecticides to farmers when experts did not recommend them. As the researchers continued to make the predator/parasite populations equivalent to the pests' increasing threshold levels, pests were being eliminated naturally and cotton growers were encouraged to delay their use of insecticides.

Through their investigation, the researchers concluded that the population of beneficials and pests in cotton fields follow a specific trend. Specifically, if cotton is planted during end of April, field observations demonstrate a higher proportion of pests than beneficials until mid- or late-June. However, if no insecticides are used against the early season population, the beneficials will eventually overpower pests by end of June or early July - pushing the bollworm population to low levels and

eliminating the need for insecticide applications. In a further attempt to control pests, particularly bollworms, cutworms, and sucking insects, researchers and breeders began to emphasize the use of short stature varieties of cotton plants. Short stature and smaller leaves allow higher light penetration into the plant canopy and better aeration, thus avoiding the bacterial blight and decreasing pest damage. Under normal conditions, all plant varieties will grow no more than 90 centimeters tall.

An important step for establishing the biological control system is to monitor the lepidopteron moth population through the use of moth traps (pheromone traps). Studies conducted in various countries do not provide a direct correlation between pheromone traps and field infestation. However, large numbers of moths caught in pheromone traps indicate a higher expected bollworm population at early stages. Early planting is also strongly recommended despite the fact that soil temperatures are low in April. Although low temperatures may affect germination, early planting provides temporary protection from insects. Insects usually appear late in the season, and by then, the plants have developed their volume and bio control agents.

Biological Control

Biological control is an environmentally friendly alternative to conventional chemical control for eliminating pests, and involves the use of beneficials such as *Trichogramma*, a parasite. *Trichogramma principium* parasites invade bollworm eggs, in which the adult *Trichogramma* females lay their own eggs. In Syria's search for effective methods to control pests, researchers tried to rear and release many species of *Trichogramma*. It was concluded that *Trichogramma principium* is the best suited for Syrian conditions, as all the other species had some limitations. For example, *Trichogramma brassica* was found to become ineffective at temperatures over 28°C, and the eastern region of Syria often exceeds 40°C.

Experiments with commercial release of *Trichogramma principium* in cotton fields began in 1995, and the parasite has been available in abundance to cotton growers since. Presently, 28 species of *Trichogramma*, imported from other countries and collected locally, are maintained in Syria. The Biological

Cotton Area sprayed with Insecticides in Syria	
Year	Area Sprayed (%)
1985/86	25.0
1986/87	15.0
1987/88	29.0
1988/89	4.0
1989/90	8.0
1990/91	2.0
1991/92	5.0
1992/93	5.0
1992/94	3.0
1994/95	3.0
1995/96	3.7
1996/97	3.0
1997/98	1.2
1998/99	1.9
1999/00	0.5
2000/01	0.1
2001/02	0.6
2002/03	0.3
2003/04	0.4

Control Lab of Aleppo University and the Plant Protection Section of the Cotton Research Department (previously known as Cotton Bureau and also located in Aleppo) are the two labs that routinely rear *Trichogramma principium* capsules for commercial release. Each capsule carries approximately 1,000 *Trichogramma principium*. The capsules (100 per hectare) are placed 10 meters apart in fields.

Trichogramma principium is used when pest populations reach levels at which potential crop damage might result in losses greater than the cost of the treatment. The economic threshold for *Trichogramma* release is 5-10 eggs of *Helicoverpa armigera*, *Earias insulana* and *Pectinophora gossypiella* per 100 plants. The need to release *Trichogramma* usually arises at the end of June or during July, but if the threshold is not reached until August, *Trichogramma* may be released at 2 eggs per 100 plants. The *Trichogramma* technology in Syria is commonly known as "TR SYR." Recommendations regarding the use of TR SYR are as follows:

- At least 100 capsules, each carrying 1,000 *Trichogramma*, should be applied per hectare if the economic threshold has been reached (5-10 eggs of *Helicoverpa armigera*, *Earias insulana* and *Pectinophora gossypiella* were discovered on at least 100 plants).
- The capsules should be placed in the middle of the plant and should not face direct sunlight. Capsules are preferably placed in the shade of the cotton plants' leaves.
- *Trichogramma* capsules should be transported from the production lab under refrigerated conditions or as advised on the label from the producer. Capsules should not be exposed to direct sunlight during transportation to the fields.
- *Trichogramma* must be released according to the dates given on the capsules.
- Capsules should not be placed on the plant when temperatures are high. The recommended time of day is after 5:00 pm.
- A proper amount of time must be allotted for the parasite to develop, find its enemy and attack. Each capsule contains inactive *Trichogramma* that require 7-15 days to resume their activity, at which point the *Trichogramma* exit the capsules and search for bollworm eggs. The parasites are active for 7-10 days under Syrian conditions.

Numerous studies show that *Trichogramma principium* is capable of tolerating higher temperatures (those exceeding 34°C) than any other species of *Trichogramma* (the optimum temperature for most *Trichogramma* species is 25°C). Additional advantages of *Trichogramma principium* are a high fecundity (parasitized eggs per female) and longer lifespan than most other species of *Trichogramma*. The delivery system for field release is also very well suited to Syrian conditions in all cotton regions.

Other commonly used predators and parasites are *Encarsia formosa* (parasite), *Orius laevigatus* (egg predator), and *Eretmocerus mundus* (parasite). *Encarsia formosa*, *Orius laevigatus*, and *Eretmocerus mundus* were first used when whitefly became a problem in 1986 and cotton growers didn't want to use insecticides. The whitefly infestation was particularly severe in the eastern region where hot, dry conditions are suitable for whitefly survival and multiplication. *Encarsia formosa* parasitizes inside the whitefly pupae and comes out after 10 days. *Orius laevigatus*, reared in labs only when needed, has been found to be very effective against whitefly in Syria. Both adults and nymphs feed by inserting their proboscis-like mouthparts into the pest and sucking out its body juices. The best results are achieved when the *Orius laevigatus* are released in the early morning or late afternoon. *Orius laevigatus* also attack the larvae of *Helicoverpa armigera*, *Heliothis* spp., *Earias* spp., *Spodoptera* spp., and *Littoralis* spp. *Orius* spp. is commonly known as the "minute pirate bug" - adults are active fliers, are about 3mm long, and have dark brown with black, brown or grey patterns on their wings. The females lay up to 130 eggs over 2-3 months in plant tissue. Its life cycle from egg to adult is about 3 weeks, and adults live for up to 3 months in the summer. *Orius* spp. are known parasites of thrips, spider mites, aphids, leafhoppers, and soft skin worms.

Economic Threshold for Various Pests

<i>Helicoverpa armigera</i>	10 live larvae per 100 fruiting parts
<i>Spodoptera exigua</i>	15 larvae per 100 plants
<i>Earias insulana</i>	10 live larvae per 100 fruiting parts
<i>Pectinophora gossypiella</i>	10 live larvae per 100 fruiting parts
<i>Thrips tabaci</i>	30% of plants with all leaves infested except terminal
<i>Bemisia tabaci</i>	No threshold, as pesticides are not recommended against whitefly
<i>Aphis gossypii</i>	10% of plants are infested
<i>Tetranychus</i> spp.	10-20% of leaves are infested per plant

Control of Diseases

Verticillium wilt, caused by *Verticillium albo-atrum*, is a serious disease throughout cotton production regions in Syria. All varieties of cotton plants must have a natural resistance to verticillium wilt - no other control measures are available or used. The following five varieties were planted during 2003/04 and will be planted again this year. Aleppo 118 is ready for planting and will slowly replace Aleppo 90. All plant varieties have good resistance to verticillium, except for the plants in Deir ez Zore, which have a lower tolerance to verticillium.

Variety	Estimated Area 2003/04
Aleppo 90	53%
Rakha 5	28%
Deir ez Zore 22	12%
Aleppo 33/1	5%
Aleppo 40	2%

Bacterial blight, caused by *Xanthomonas campestris* pv. *malvacearum*, is also common in Syria. The bacterial blight is known by various names throughout the world, based upon the parts of the plant infected, including “angular leaf spot,” “vein blight,” “black arm,” and “boll rot.” In Syria, the bacterial blight is known as the “black arm disease” in cotton production. Bacterium can affect all of the plant’s above-ground-parts during any stage of its growth, but in Syria, damage is particularly serious during the seedling stage, especially if more than two of the first irrigations are applied with sprinklers. Angular spots on the full-grown leaves appear first as water-soaked areas, and the spots later turn dark brown to black in color and are covered with a glazed film. Often, the surrounding tissue becomes yellow, giving a halo effect. Leaf spots are limited in size by leaf veins, which result in an angular shape. Black spots or cankers may occur on the stems or branches (black arm) causing girdling and the death of some branches. The disease can also affect bolls if humid conditions exist. However, this situation does not develop in Syria, as sprinkler irrigation is shifted to furrow irrigation after the first two irrigations. The bacterium over winters in crop residue. Therefore, plowing under the stubble immediately after harvest and practicing crop rotation helps to reduce inoculum in the field.

In Syria, specific steps are taken in an effort to prevent the aforementioned diseases. First, the cotton is planted at a row-to-row spacing of 70-74 centimeters with 8-10 plants per square meter. Approximately 70% of the area is planted by hand by dibbling 20-25 seeds per dibble. The seed is dibbled on the ridges’ sides and the first two irrigations are applied with

sprinklers to make sure there are no empty spaces on the ridges. If required, the farmers will fill any gaps where seed did not germinate due to dry soil or some other reason (there are more chances of the need for gap filling if the cotton is planted by a tractor rather than by hand). The number of seeds planted is high, but farmers are willing to pay the additional expense in order to ensure optimum plant population (the fundamental prerequisite for high yields of cotton). The high seed rate is also used to prevent damping off (seedling disease) risk caused by *Rhizoctonia solani*. Farmers also utilize thinning, or the process of removing immature fruit that is crowded or blemished, to prevent disease and ensure optimum plant growth. When the crop is thinned twice, three plants initially remain, and are finally thinned to one plant 30 days after planting. Most farmers thin twice per season in an attempt to avoid the loss of any single plants left after the first thinning.

Weed Control

Syrian cotton growers are very conscious about weed control, fertilization, and irrigation, as there is very little need for insect control operations. Some weeds are found in cotton fields throughout the cotton growing areas in Syria. Farmers in Syria apply herbicides twice per season to make sure cotton fields are free of weeds. Farmers can buy herbicides from the Agriculture Cooperative Bank, based upon the area they’ve planted to cotton. They can buy more if the chemicals are available in abundance with the bank. Otherwise, farmers may buy herbicides from the open market. Weeds are also removed mechanically and manually.

Common Weeds in Cotton Fields in Syria

Narrow leaf weeds	Broad leaf weeds
<i>Setaria</i> spp.	<i>Xanthium</i> spp.
<i>Digitaria</i> spp.	<i>Amaranthus</i> spp.
<i>Cyndon dactylon</i>	<i>Solanum</i> spp.
<i>Sorghum halepense</i>	

Update on Genetically Engineered Cotton

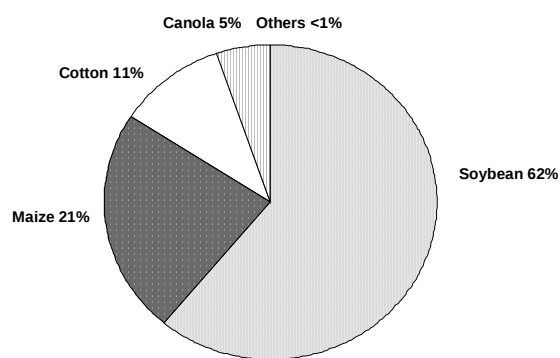
Genetic engineering technology is spreading, and more countries are adopting genetically engineered (GE) cotton varieties. Nine countries have commercialized GE cotton, and a few more are experimenting with the technology. However, a lack of national biosafety regulations and the cost of the technology are slowing adoption. Genetic engineering, as an additional tool for breeders to develop new varieties, has tremendous applications. The technology allows breeders to insert a specific gene or genes for specific traits. With conventional breeding, it is not possible to transfer only one gene at a time. Genes are linked, and in some cases, the linkage is very strong. So, if the desirable gene is close to a gene controlling an undesirable character, it is often not possible to

break such a linkage and transfer only the desirable character. Moreover, conventional breeding is a long-term process, and genes can be moved within species or among species but not across genera. Some times even interspecies crosses are not possible. On the other hand, new characters can be acquired through transfer of non-cotton and non-related genes into cotton through genetic engineering.

The first transgenic cotton with a Bt gene, extracted from the soil bacterium *Bacillus thuringiensis*, expressing the protein at an economically viable level was developed in 1989. Bt cotton was commercially planted for the first time in 1996/97 in Australia and USA. According to the International Service for Acquisition of Agri-Biotech Applications (ISAAA), all

transgenic crops were planted on 67.7 million hectares in 2003/04. A number of crops have been transformed, but soybean, maize, cotton and canola occupied about 99% of total GE area in 2003/04. Other crops that have been transformed include squash, tomato, papaya and others that were planted on less than 1% of the transgenic area in the world. Soybeans account for 61% of total area, followed by maize on 23% and cotton on 11%. Efforts have been made to improve a number of traits in various crops. But, insecticide and herbicide resistance are still the only two traits used on a commercial scale, apart from virus resistance and others planted on less than 1% of the total transgenic area.

TRANSGENIC CROPS AREA - 2003/04

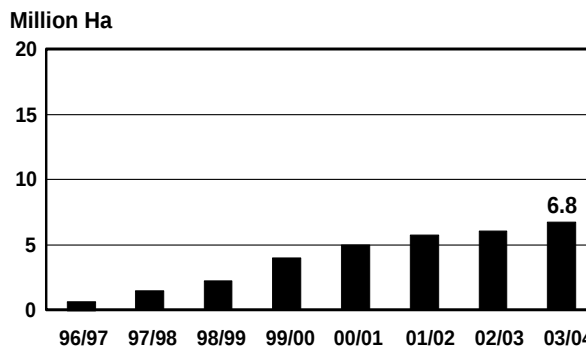


GE Cotton Area in the World

Transgenic cotton was planted on 6.8 million hectares in 2003/04, accounting for 21% of world cotton area and responsible for almost 30% production and 34% international trade. In December 2002, Monsanto received full U.S. regulatory clearance for its Bollgard II insect-protected cotton technology for large-scale use of a second Bt gene. 2003/04 was the first year that the proteins Cry2Ab and Cry1Ac were available in the form of Bollgard II for protection against bollworms. The purpose of Bollgard II is to have a dual gene resistance mechanism. The technology fee in the USA for Bollgard II is \$99/ha, as against \$79/ha for Bollgard only. Bollgard varieties will continue to be available, but plans are to replace them with Bollgard II varieties.

The US Department of Agriculture (USDA) and the Food and Drug Administration (FDA) have already confirmed the food, feed and environmental safety of Bollgard II. The Bollgard II technology has used the same soil bacterium as in the case of Bollgard, but it has two genes working at the same time. The primary objective remains the same, which is to control target insects that damage cotton bolls. However, the Bollgard II technology has some additional advantages over the Bollgard technology, some of which are long lasting and some are short-term.

TRANSGENIC COTTON AREA - WORLD



- The basic objective of finding the 2nd Bt gene is to delay the development of resistance to the Bt toxin. Insects can develop resistance to one gene faster than to two genes working in the same genotype.
- The Cry1Ac in Bollgard causes much damage to tobacco budworm (*Heliothis virescens*), and the American bollworm (*Helicoverpa armigera*) but it provides comparatively less resistance to other worms. The 2nd most important objective of inserting the 2nd gene was to extend the spectrum of bollworms and budworms controlled by Cry proteins. The Cry2Ab gene in Bollgard II provides equally good control of fall armyworm (*Spodoptera frugiperda*), beet armyworm (*Spodoptera exigua*), cabbage looper (*Trichoplusia ni*), and soybean looper (*Pseudoplusia includens*) in addition to bollworms and budworms already controlled by Bollgard. The latest information from West Africa shows that Bollgard II has performed quite well against the red bollworm (*Diparopsis watsoni*) in Burkina Faso in 2003/04.
- Some bollworms and budworms survive on Bollgard varieties, particularly towards the end of the fruit formation stage. The phenomenon, which occurs due to a smaller amount of toxin in flowering parts, brings some loss in yield. The Cry1Ac levels are usually expressed 1 to 3 parts per million, while Cry2Ab is expressed from 7 to 19 parts per million. The higher dose of toxin in the plant in the form of Bollgard II technology will save the plant from late-season losses.

Cry1Ac (in Bollgard or Bt cotton elsewhere and Ingard in Australia) and Cry2Ab (in Bollgard II along with Cry1Ac) are protein toxins and can interact with each other and affect the performance of one or both toxins. However, studies have proved that there is no interaction between the two Cry proteins. Three isogenic lines of a variety having Cry1Ac only, Cry2Ab only and Cry1Ac+Cry2Ab were used to examine the relative contribution of each toxin to the total efficacy of Bollgard II, in addition to studying the nature of the interaction between the individual toxins in the 2-gene cotton. No interaction was

proved. In 2003/04, Bollgard II was planted on a commercial scale in Australia and USA, and no negative results have been reported.

Area under Transgenic Cotton in Various Countries

GE cotton is commercially planted in Argentina, Australia, China (Mainland), Colombia, India, Indonesia, Mexico, South Africa and the USA. Indonesia planted only a few thousand hectares for the 2nd year in 2002/03 and there is no increase in area in 2003/04. In India, the Bt gene (Cry1Ac-Bollgard) has been introduced only through commercial cotton hybrids, and the three Bt hybrids were planted on 101,174 hectares in 2003/04. More hybrids have been approved in India for planting in 2004/05. Herbicide-resistant transgenic varieties are permitted for commercial cultivation in Argentina, Australia, South Africa and the USA. In other countries, only Bt cotton has been approved for commercial production. Estimated transgenic area in nine countries is as follows:

Transgenic Cotton Area 2003/04

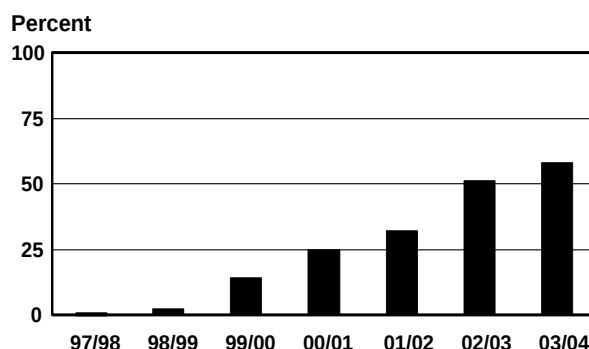
Country	Percent Area
Argentina	5-7%
Australia	30%
China (Mainland)	58%
India	1%
Indonesia	< 1%
Mexico	62%
South Africa	70-75%
USA	77%

GE cotton was planted on 77% of the total cotton area in the USA in 2003/04, and GE cotton occupied more than 70% of cotton area in the USA during the last five years. It seems that GE cotton has reached its peak in the USA, and increases should not be expected in 2004/05. Bollgard II was planted on small area but in the next few years most Bollgard will be replaced with Bollgard II varieties. Herbicide tolerance is the most popular character in cotton in the USA. Over four million hectares were planted to transgenic cotton varieties in the USA in 2003/

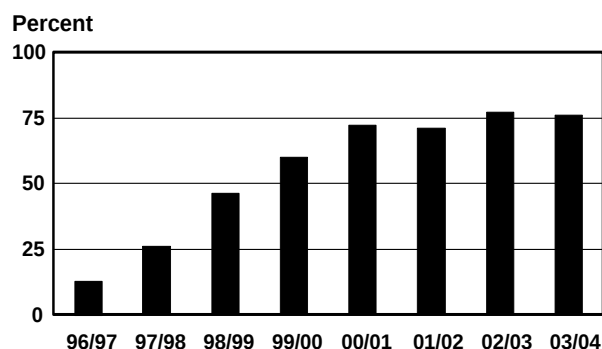
04. Of the total GE cotton area in 2003/04, 37% area was planted to herbicide resistant varieties, 61% to stacked gene herbicide and insect resistant varieties, and only 2% was planted to insect resistant Bollgard or Bollgard II varieties.

GE cotton continues to gain popularity among farmers in China (Mainland), and insect resistant transgenic cotton area increased to 58% in 2003/04 from 51% last season. If the Yellow River Valley had not been hit by insect resistance to insecticides in the early 1990s, transgenic cotton may not be as popular today. China (Mainland) continues to expand insect resistant GE cotton developed domestically. It is estimated that 46% of the total GE cotton area in China (Mainland) in 2003/04 was from Monsanto and 54% was planted to a Bt cotton developed in China. No detailed and comparable data are available on the two genes. However, the popularity of the local gene indicates that it is equally effective against bollworms, particularly *Helicoverpa armigera*, which is the main pest in the Yellow River Valley and the Yangtze River Valley. The Xinjiang region does not grow GE cotton.

TRANSGENIC COTTON AREA - CHINA (M)



TRANSGENIC COTTON AREA - USA



In India, Bt cotton is approved for use only in those states where commercial cotton hybrids are approved, and that does not include the North. Yields are higher in the North due to irrigation and better management practices, but hybrids have not been grown on a significant amount of area. Farmers in Haryana, Rajasthan and Punjab states that form the North cotton zone are impressed from the performance last year of Bt hybrids in other regions, and they are anxious to grow Bt hybrids. Last year Mahyco-Monsanto had applied to the Genetic Engineering Approval Committee for approval of a Bt hybrid in the north of India but their request was rejected on the ground that the hybrid was susceptible to the leaf curl virus disease. This year, Rasi Seeds has received approval from the Genetic Engineering Approval Committee for large-scale trials of a Bt hybrid (RCH 2) in 2004/05. Although some farmers in the North may be experimenting with Bt hybrids on their own, Bt hybrids could be officially approved for commercial adoption in 2005/06. RCH 2 has been approved for cultivation

in Madhya Pradesh, Chhattisgarh, Andhra Pradesh, Karnataka and Tamil Nadu. It was expected that 300,000 packets of 450 grams each will be sold in 2004/05. In India, the price of each packet of Bt hybrid seed is US\$35.5, compared to the price of US\$10 per packet in case of non-Bt hybrid seed. The packet includes seed for the refuge crop and, is enough to plant half a hectare.

New Technologies

Since the initiation of Bt cotton in commercial use in 1996/97, Bollgard II was the first new product to be approved as a replacement for Bollgard cotton. Three other products have been extensively researched for commercial release in the last few years, but only one has been approved so far. LibertyLink® cotton from Bayer CropScience was approved for commercial use. Three other products are close to approval, two insect resistant and one herbicide resistant. A lot of work is going on to improve many other features of cotton, including salt tolerance, stress tolerance and improved fiber quality, but no field tests have been reported on any of these products, indicating that they are years away from adoption.

LibertyLink® Cotton

LibertyLink® was approved for commercial adoption on March 10, 2004. The LibertyLink® herbicide's active ingredient is glufosinate-ammonium, commonly known as Ignite. Glufosinate-ammonium inhibits the enzyme glutamine synthetase in plants, leading to a rapid disruption of photosynthesis. LibertyLink® cotton will survive when Ignite is sprayed over the top of the crop. Ignite has low toxicity and is highly biodegradable. Ignite can be used to control grass weeds and broadleaf including troublesome weeds, such as morning glory, pigweed and Johnson grass. LibertyLink® cotton has a longer application window, up to the 10th leaf, and doses can be adjusted depending on the size of weeds, not the growth stage of the cotton. LibertyLink® cotton has been approved in the USA for use in most cotton growing states in 2004/05. LibertyLink® cotton will be available in FiberMax varieties. LibertyLink® cotton is not available with Bollgard or Bollgard II genes yet, but plans there are to produce stacked gene varieties in the future. LibertyLink canola and LibertyLink corn have been available commercially for several years.

Vegetative Insecticidal Protein (VIP) Cotton

VIP cotton is an alternate to Bollgard or Bollgard II that has been developed by Syngenta to control insects. The difference is that VIP cotton contains a vegetative insecticidal protein that controls target insects through a novel mode of action. Bollgard and Bollgard II utilize proteins from the *Bacillus thuringiensis* bacterium known as d-endotoxins. Bt d-endotoxins were discovered in the early 1900s, and have been used in many insect control applications other than cotton. The VIP protein is an exotoxin derived from the same soil

bacterium *Bacillus thuringiensis*. As an exotoxin, the VIP protein is structurally, functionally and biochemically different than Bt d-endotoxins. The VIP protein is expressed in the entire cotton plant, including the floral parts, to provide protection against target species. When pest larvae feed on VIP cotton, the protein is ingested and causes the larvae to stop feeding and die. VIP is not approved for commercial use yet.

Wide Strike Cotton

WideStrike™ cotton from Dow AgroSciences is a combination of the Cry1Ac and Cry1F *Bacillus thuringiensis* proteins. Dow AgroSciences has field tested WideStrike™ for several years and is expecting approval from the government for planting in 2005/06. WideStrike™ delivers season-long protection against a broad spectrum of lepidopteran pests such as cotton bollworm, tobacco budworm, pink bollworm, beet armyworm, fall armyworm, southern armyworm, cabbage loopers and soybean loopers. WideStrike™ cotton was also tested in Australia in 2003/04.

VIP cotton and WideStrike™ have completed experimental stages and are awaiting government approval for commercial use. It is not known if the approval will come this year or next year. But, when approved, two new kinds of genes will become available to tackle bollworms.

Commercial Name	Bt Genes
Bollgard	Cry 1Ac
Bollgard II	Cry 1Ac + Cry 2Ab
VIPcot	VIP3
WideStrike	Cry 1Ac + Cry 1F

Roundup Ready Flex

Roundup Ready Flex™ from Monsanto is an improvement over the Roundup Ready® technology already in use singly and in conjunction with insect resistant genes in cotton. Some reports indicate that Roundup Ready applications caused reductions in yields due to boll abscission, because of a negative impact on anther development, pollen production, pollen morphology, pollen viability, and flower morphology. Monsanto's new Roundup Ready Flex™ (RR Flex) technology has been designed to enhance reproductive tolerance to glyphosate. The development of Roundup Ready Flex cotton varieties with a lengthened post-emergence-topical application window provides improved flexibility to treat past the 4-leaf growth stage when due to some reasons it was not possible to control weeds at an early stage. Experiments have shown that late application of Roundup Ready on the Roundup Ready transgenic cotton results in significant losses in yield due to direct damage to the plant. The Roundup Ready Flex can be sprayed as a post-emergence-topical application and will not cause any damage to the crop. Roundup Ready Flex can be sprayed on the Roundup Ready Flex cotton up to the 14 leaf stage and in two to three times higher quantities to control tougher weeds. The technology is close to approval.

A DIALOG Search of Agricola and CAB Abstracts Databases

The key words used in the search are **cotton** and **fineness**.

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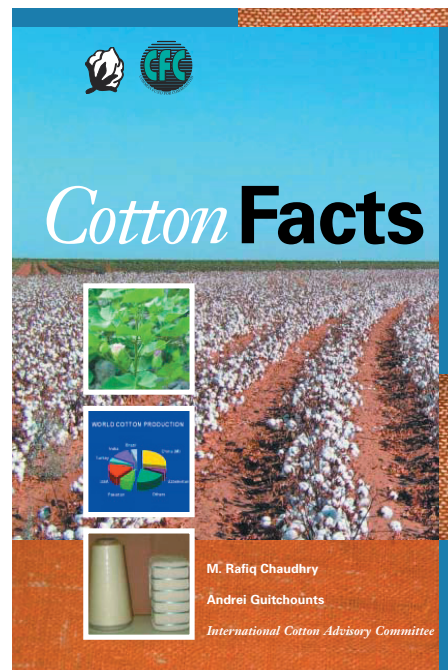
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