INTERNATIONAL COTTON ADVISORY COMMITTEE

1629 K Street NW, Suite 702, Washington, DC 20006 USA

Telephone (202) 292-1687 • Fax (202) 463-6950 • e-mail: rafiq@icac.org

http://www.icac.org

Cotton Research: World Situation[1]

M. Rafiq Chaudhry
Head
Technical Information Section

Cotton Production

Although cotton is produced in over 60 countries in the world, only five of them, China (Mainland), India, Pakistan, USA and Uzbekistan, share 75% of production, 71% of area and 70% of consumption. The five large producers have been the same for decades, though production and consumption have shifted a lot among them. The most significant changes have been reduced consumption in the USA, expanded production and use in China (Mainland), high local consumption in Pakistan and more than 50% increase in yields in India. Production in Uzbekistan has experienced different changes but with minimum or no impact at an international level. So, at the mega level, most international scenarios can be attributed to the changes in four countries, though influences from some other producing countries also have impacts at the international level.

On average 33-34 million hectares are planted to cotton every year, almost 90% in the Northern Hemisphere and 10% in the Southern Hemisphere. India is the largest cotton growing country in the world with 9.1 million hectares planted to cotton in 2006/07, almost 3.4 million hectares more than the USA and 3.8 million hectares more than China (Mainland). It is estimated that cotton was planted on 34.5 million hectares in 2006/07 as against 34.2 million hectares the previous year.

ICAC forecasts that 24.7 million tons of cotton will be produced in the world during 2006/07, 94,000 tons less than produced in 2005/06. While production in most countries will be equal to, or slightly higher than in 2005/06, the U.S. crop is expected to be 14% lower than in 2005/06. The ICAC estimates indicate that severe drought in Texas will lower U.S. production from 5.2 million tons to 4.5 million tons in 2006/07. Higher production in Brazil, China (Mainland), India and Pakistan will compensate for lower production in the USA.

According to the latest ICAC estimates, the average cotton yield during 2006/07 is expected to be 716 kg/ha. The wide gap in yield among countries continues to grow. Average yield in some countries planting as much as close to three hundred thousand hectares in 2005/06 was as low as 139 kg/ha compared to a yield of 1,806 kg/ha in a country planting almost fifty thousand hectares more than the poor yielding country. The five highest yielding countries in 2005/06 in descending order were Israel, Australia, Syria, Turkey and Spain. The average cotton yield is also more than one ton of lint per hectare in Brazil, China (Mainland), Greece and Mexico.

Compared with production of 24.7 million tons, consumption is expected to be 25.9 million tons during 2006/07, an increase of 858,000 tons. Exports are expected to be at the same level of close to 9.5 million tons but ending stocks are expected to be lower by 1.2 million tons at 9.8 million tons compared to 10.9 million tons in 2005/06. Lower ending stocks are expected to have a favorable

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effect on prices and push the Outlook A Index to 64 cents/pound in 2006/07 as against 56 cents in 2005/06 and a long term average of 70 cents.

Why Yields Increase and What is Next?
The world average yield did not increase from 1992/93 to 1999/2000: 596 and 598 kg/ha, respectively. The world has seen such periods of no growth in the past. The long-term trend in world cotton yields shows that yields increase, then they stagnate and then they increase again. Such periods of slow or no growth followed by consecutive increases for a few years are common in cotton. Yields are limited by constraints and if a constraint is eliminated, yields start to increase. Increase in yield is proportional to the depressing effect of that constraint. The increase in the average yield within a region or country and thus at the world level depends on how quickly or efficiently a particular limitation factor is eliminated. There could be high increases in the national average yield if a particular limitation to the yield is eliminated suddenly and by all or most growers in the country. Similarly, a slow increase in the world average yield shows the speed of adoption of a solution to the limiting factor.

The nature of limiting factors may or may not be the same among countries. Solution to the common limiting factors across countries and regions could bring significant increases in world average yields. However, countries can identify local limiting factors, eliminate those limiting factors and increase yields within a country. It is not uncommon that a constraint was identified and eliminated in some countries but not in another. This is an instance where countries can learn from others' experiences.

Thus, there are two fundamental issues: identification of a constraint and developing a technology to overcome that constraint. It is usually easier to identify a weakness in the system but hard to find a solution/technology to correct that weakness. However, inadvertently more efforts and resources are spent on finding solutions without properly identifying and pinpointing constraints. Consequently, results are not proportional to the efforts made to achieve those results. There is no doubt that perfection in the adoption of existing technologies will also have a positive effect on yield.

World average yields started to increase in 2000/01 but once again, they seem to be slowing down: 733 kg/ha in 2004/05, 724 kg/ha in 2005/06 and 716 kg/ha (ICAC forecast) in 2006/07. Even if yields would continue to increase for a few more years, ultimately they are going to stagnate. Once again, it will be a challenge for everyone working in the field of production research to find ways and means to improve yields. Such efforts have to be different from the traditional approaches aimed at developing high yielding varieties, agronomic management practices and insect pest control. Improvements in traditional cultivation practices would affect yields positively, but a sustained increase in yields requires a non-traditional technological innovation. It has always been a challenge for researchers to develop such a technology.

Biotechnology and its Applications
Biotechnology is a new science with tremendous potential for application. Application of biotechnology could produce various products and the products could be good or bad. Improper or wrong use of any technology, just like insecticides, could have serious consequences and the same is true for biotechnology applications. However, as in the case of other technological developments, there is a need to separate technology from products. One may or may not like the currently available biotech insect and herbicide resistant cottons but no one can disregard biotechnology as a science. Currently available biotech products in cotton are not the only applications of biotechnology; rather it is just the beginning.

The impact of biotech insect resistant cotton has been different in different countries. The benefits range from lower cost of production without any impact on yields to higher yields with or without increases in cost of production, or none of the two but an environmental benefit. Some of the earlier apprehensions are also coming true in the form of resistance to the toxin and herbicide and the issue of secondary pests. Reports from Australia and China (Mainland) show that mirids populations have increased in both countries and insecticide spraying against mirids has become necessary. So, there is a need to use the technology wisely.

The use of biotech cotton is only going to expand and cover more than half of the world cotton area in the next few years. But, it depends, among other factors, on Monsanto's and other companies' willingness to share technology and governments' official approval of biotech cotton. New traits are going to come even without any expansion of the existing technologies. The technology is expensive and it takes 8-10 years to bring a new trait to the market. The product development cycle seems shorter but in fact it is much longer and driven by a complex approval process. Monsanto estimates that development of a new trait costs on average about 100 million U.S. dollars.

Research is continuing on many aspects for the improvement of cotton. Monsanto's new biotech cotton products in the pipeline include Bollgard®III, containing an additional gene that will increase toxicity to insects. It is also expected that Bollgard®III will extend the toxicity effectiveness through to the boll maturing stage. Similarly, a third generation of weed technology control includes herbicide tolerant cotton with alternative modes of action to Roundup Ready® cotton, allowing the pre and post emergence use of alternative herbicides that do not persist in the soil. Work is also going on for a more efficient water use cotton that could have a positive effect on yield. Water use efficient cotton could improve water utilization and benefit dryland areas, lower water costs and potentially expand cotton to new areas.

Most research on biotechnology applications is in the private sector. Thus, it is evident that much more is being pursued than what is known to the public. The long-term products could cover fiber quality, oil quality, drought and salt tolerance, cold tolerance, yield enhancement and non-Bt resistance to insects.

One of the most interesting traits to be improved is yield enhancement, which can be achieved by many ways using biotechnological applications. One way of enhancing yield is to improve photosynthetic efficiency of the plant that combined with efficacious insect control could increase yields. Photosynthetic efficiency can be improved by a possible recovery of chloroplast genes or chloroplast transformation. The objective is to keep the leaves green and photosynthetically active for a longer time. Yield enhancement can also be achieved by delayed leaf senescence. Delayed aging of leaves with sustained photosynthesis during peak boll maturation can definitely enhance yields.

The U.S. Patent and Trademark Office have granted a patent for enhancing fiber yield by changing the composition of oils in cottonseed. A paper on the patent was presented at the 2006 Beltwide Cotton Conferences held in San Antonio, Texas, USA in January 2006, but the paper did not appear in the proceedings of the conferences. The technique is based on the inhibition of oil synthesis in cottonseed in order to reduce the energy-intensive incorporation of sucrose-derived carbon into stored oil so as to increase the supply of sucrose available for sustained fiber and vegetative plant growth. To achieve this, researchers must produce a transgenic plant by regenerating a whole plant from a plant cell that has been transected with DNA sequences comprising a gene capable of suppressing the biosynthesis of oil in the developing seed. Plants made according to these specifications exhibit increased production of fiber.

The current system of expression in the whole plant, while satisfactory for the current transgenic traits, may be replaced by regulated expression for other transgenic traits. Methods of regulated expression include: tissue specific, temporal specific, generation specific, etc. The tissue specific transgene expression derives from the use of tissue specific promoters that allow gene expression in specific tissues. These will be highly useful with output traits such as fiber, oil or protein modification that improve the value of the harvested product, since gene expression in non-seed tissue could be superfluous and may be even deleterious.

Plant Protection and Pesticide Use

According to Cropnosis (A private company dealing with crop protection and biotechnology sectors), pesticides valued at US$32.35 billion were used in the world in 2004. The pesticide sales were static for almost two decades until 2003, increasing almost at the same rate as inflation. The reasons for stagnation were lower consumption, lower cost of herbicides as a result of older products emerging from their patent-protected period, lower commodity prices, increased use of lower-cost generic pesticides and lately, the use of insect-resistant biotech cotton. Pesticide sales increased by 13% in 2004 compared to 2003. Most of the increase came in Latin American countries, where sales increased by 26%. Despite the fact that the region has an active generic pesticide industry, sales still increased significantly in Argentina and Brazil. North America accounted for 27%, Western Europe 24%, Asia Pacific 25%, Latin America 14% and the rest of the world 10% of all pesticide sales. Herbicides accounted for 45.9% of the pesticide market, followed by insecticides (26.7%), fungicides (22.6%) and other products including growth regulators and crop desiccants (4.9%). The share of herbicides is increasing due to high labor costs and the reduced use of insecticides.

Six large companies dominate the pesticide market and accounted for 77% of all pesticide sales in the world in 2004. The six companies accounted for 73% of sales in 2002 and 81% in 2003. The pesticide industry has experienced increased concentration, and the number of major pesticide companies has reduced by half between 1984 and 2003. It is estimated by Cropnosis that 8.5% of all herbicides, insecticides, fungicides and other chemicals used in agriculture by value in 2004 were used on cotton. Fruit and vegetables consumed almost 29% of all chemicals (by value), followed by cereals with 16%. Cotton accounted for almost 19% of all insecticides used in 2004.

Plant Protection Chemical Use in the World (Sales in Million US$)

Chemical Group	2000	2001	2002	2003	2004
All Crops					
Herbicides	13,796	13,386	12,475	13,348	14,849
Insecticides	8,206	7,744	7,314	7,738	8,635
Fungicides	5,818	5,467	5,450	6,055	7,296
Others	1,364	1,347	1,322	1,374	1,569
Total:	29,184	27,944	26,561	28,515	32,349
Cotton					
Herbicides	675	740	685	673	777
Insecticides	1,548	1,467	1,351	1,423	1,618
Fungicides	57	58	57	60	70
Others	282	266	254	252	280
Total:	2,562	2,531	2,347	2,408	2,745

Source: Cropnosis, Limited, Edinburgh, UK.

Is this pesticide dependent production technology sustainable, certainly not! It was a wrong decision on the part of researchers, managers and everybody else involved, including governments, to adopt pesticides. Long-term consequences of pesticide use in cotton and other crops were not properly weighed and pesticides were aggressively promoted in agriculture. Promotion was so aggressive that governments provided subsidies, and a higher use of pesticides was considered to be a credit. The industry has realized the lapses and is now striving to correct the situation.

Cotton could be grown successfully without the use of insecticides. Syria provides the best example for such a successful cotton production system. Syria planted cotton on 218,000 hectares in 2005/06 and the average yield was 1,512 kg/ha lint and the cotton area sprayed with insecticides was less than 1%. Is it too late to get rid of insecticides, No it is not? Syria used to spray almost half of the cotton area in the late 1970s and then decided to eliminate insecticide use and they successfully achieved it. If Syria can do it, other countries can do it too.

Breeding for New Varieties Will Change

Breeding should be a science-based practice but, so far, it has been generally employed as an art of selecting the most suitable plant that ultimately becomes a variety for any set of growing conditions. With the advent of genetic engineering becoming more accessible, the art of breeding is going to change and become more scientific. Conventional breeding will continue to play a dominant role, but specific changes through insertion of specific genes, molecular marking of characters, enhancing the expression of a particular gene, blocking the expression of a particular gene, etc., will be so prominent that breeding will have to acknowledge contributions from biotechnology applications. Breeding for new varieties will change from a fieldwork to field plus lab work.

The other major change, which is going to happen, is the privatization of breeding for suitable varieties. Breeding has already been privatized in the USA and USDA breeders are responsible for only developing germplasm material. Private breeding is also practiced in India where commercial cotton hybrids are developed and distributed by many private companies. Almost four million hectares were planted under hybrid cotton in India in 2006/07 and all the planting seed was developed, multiplied and distributed by private companies. Breeding must go to the private sector and countries that are in the process of strengthening their breeding programs should not make the mistake of nationalizing their breeding programs.

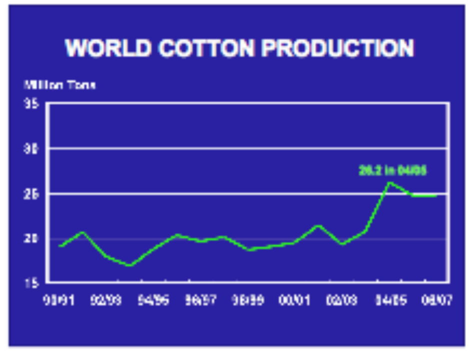
Future changes in breeding also require working closely with seed production systems. The latter may be successful without the former but breeding cannot stand-alone. Good varieties developed by breeders are easily lost in the poor seed production system. This fact is better realized today than it was yesterday. The privatization of breeding will automatically take care of the amalgamation of both disciplines. It is going to happen, and the sooner we do it the better.

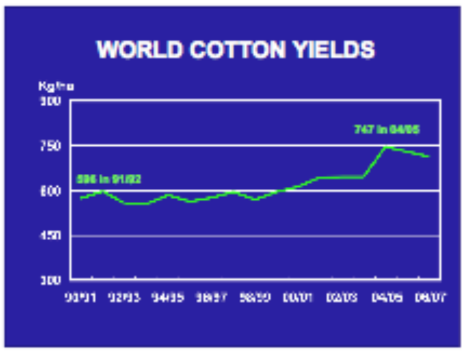
Fiber Quality Testing

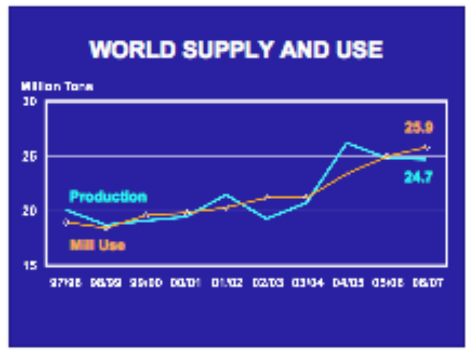
Best quality fiber must be authenticated through better testing. But, unfortunately, fiber quality testing is the least developed area in cotton. Lately, the emphasis has increased and it is expected to increase further. The ginning system has not changed since the invention of the saw gin by Whitney in 1793. Higher efficiency and cleaning were no doubt achieved, but the process remains the same– harsh pulling and beating action. Many efforts have been made including differential ginning, cage ginning and Templeton ginning, but none of these could be commercialized. The need is there but changes are not expected for many years to come. The soft fiber has to bear the harsh treatment of sharp metallic saws.

Measurement of fiber quality characteristics is slow, stickiness has no standards, maturity and fineness are not separated, short fiber content, is not defined, interlaboratory variation for many characters is poor, repeatability of the data also needs improvement, and so on. Machine testing of quality characteristics is improving and sooner or later all cotton in the world will be tested on rapid testing machines like the High Volume Instrument. Five companies produce rapid testing instruments but most of the close to 2,000 instruments come from Uster Technologies, Inc. Premier Evolvics Pvt. Ltd. has produced over 100 machines, only a few come from Lintronics, and two other companies have produced even lower number of machines.

The need for a real qualitative value of fiber is becoming recognized and fiber quality testing has become one of the fastest growing areas in cotton. Not only the measurements on the currently measured quality characters need to improve, but also the industry should start measuring new characters that have an effect on processing and products.







WHY YIELDS INCREASE?

Yield Potential Huge

Yield is limited by "constraints"

Eliminate a "constraint" and yield automatically increases.

WHY YIELDS INCREASE?

Increase in yield is a two fold issue:

1. **Identification of a constraint**
2. **Develop a technology to eliminate the constraint**

It is easy to identify a constraint but difficult to develop a technology for eliminating the constraint

WHY YIELDS INCREASE?

It is easy to identify a constraint but difficult to develop a technology for eliminating the constraint

What if constraint is not rightly picked?

Resources could go waste

and
this is what is happening

YIELD CONSTRAINTS

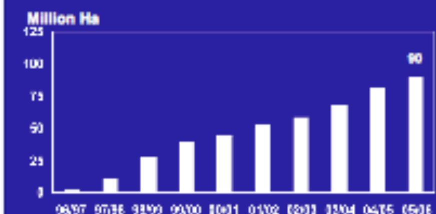
Constraints could be same across countries and regions or could be different

Limiting effect of a constraint could be small or huge

Increase in yield is proportional to the limiting effect of a constraint

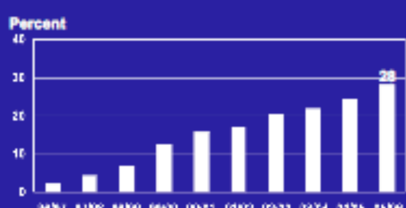
If you cannot deal with a bigger constraint deal with a smaller constraint

BIOTECH CROPS AREA - WORLD



TRANSGENIC CROPS AREA 2005/06

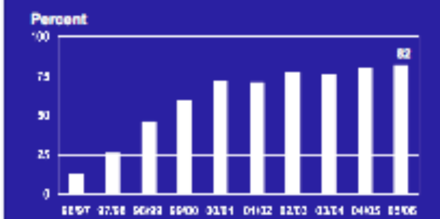
BIOTECH COTTON AREA - WORLD



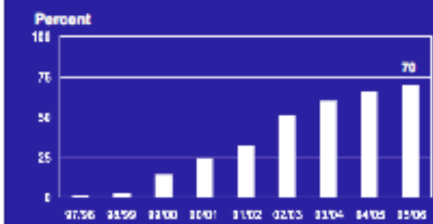
BIOTECH COTTON - 2005/06

World Area	28%
World Production	37%
World Exports	38%

Biotech Cotton Area - USA



Biotech Cotton Area - China (M)



BIOTECH COTTON - 2005/06

Argentina	Bollgard + Herbicide
Australia	Bollgard + Bollgard II + Herbicide
China (M)	Bt (Local + Monsanto)
Colombia	Bollgard
India	Hybrids
Indonesia	Bollgard
Mexico	Bollgard + Herbicide
South Africa	Bollgard + Herbicide
USA	Bollgard + Bollgard II + Herbicide

BIOTECH COTTON - Major Benefits

- Lower cost of production without impact on yields
- Higher yields with or without increases in cost of production
- None of the two but an environmental benefit

BIOTECH COTTON - New Trait

Period 8-10 year

Cost $100 Million

Process is complicated compared to conventional traits

Bollgard III
Third generation of herbicide resistance

BIOTECH COTTON - Future Traits

- Regulated expression, tissue/generation specific
- Fiber quality
- Oil quality
- Drought tolerance
- Salt tolerance
- Cold tolerance
- Non-Bt resistance to insects
- Yield enhancement

FUTURE TRAITS - Yield Enhancement

- Improve photosynthetic efficiency (combined with efficacious insect control)
  - a. Recover chloroplast genes
  - b. Chloroplast transformation
- Delayed leaf ageing
- Change oil composition in the seed

PESTICIDE USE ON COTTON - 2004

Pesticides	9%
Insecticides	19%

PESTICIDE SALES - 2004

Chemical Group	All Crops	Cotton
	(Million US$)	
Herbicides	14,849	777 (5%)
Insecticides	8,635	1,618 (19%)
Fungicides	7,296	70 (1%)
Others	1,569	280 (18%)
Total	32,349	2,745 (9%)

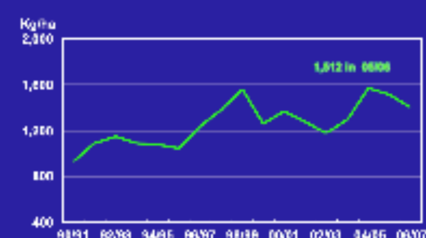
PESTICIDE USE BY REGION - 2004

North America	27%
Western Europe	24%
Asia Pacific	25%
Latin America	14%
Rest of the world	10%

PESTICIDE DEPENDENT TECHNOLOGY

Is it sustainable?	No
Was the decision right or wrong?	Wrong
Is it possible to eliminate them now?	Yes

COTTON YIELDS IN SYRIA



BREEDING FOR NEW VARIETIES

Breeding is like a central pivot in the production chain

Breeding has successfully contributed to production by

- Developing short stature early maturing varieties
- Improving quality
- Improving tolerance against pests
- And, in many more ways

BREEDING FOR NEW VARIETIES

The cotton plant is indeterminate in nature

Carries huge genetic potential

Breeding has not improved the genetic ability to produce more yield but has produced plants that are more suited to the conditions and thus produce more yield

BREEDING WILL CHANGE

Conventional breeding will not be independent

Change from fieldwork to field + lab work

Genetic engineering will become an integral part

Breeding will go to the private sector

Breeding and seed production will merge

FIBER QUALITY TESTING

Least researched area in cotton

Ginning system not changed since 1793

(Cage ginning, Templeton ginning, etc.,)

FIBER QUALITY TESTING

Automation in testing is a must

Ginning will not change any time soon

Need to measure unknown properties of cotton