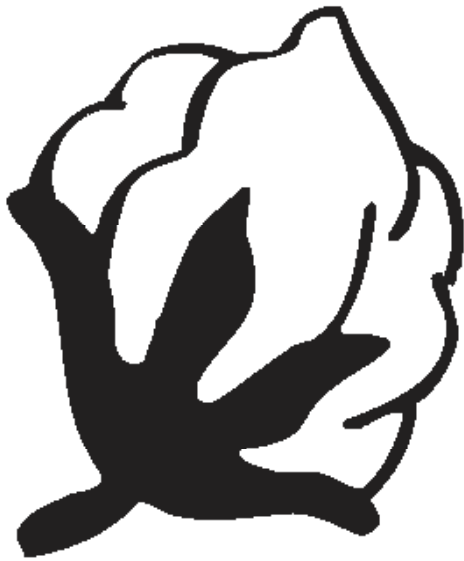




THE ICAC RECORDER

International
Cotton
Advisory
Committee

Technical
Information Section

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Update on Cotton
Production Research

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Introduction

The first article in this issue of the *ICAC RECORDER* is a progress report from a project titled 'Utilization of Cotton By-produce for Value-added Products CFC/ICAC20' in India. The project is sponsored by the ICAC and funded by the Common Fund for Commodities. It is known that cotton stalks are rich in cellulose, hemicellulose and lignin akin that are found in most hard woods. The Central Institute for Research on Cotton Technology (CIRCOT), Mumbai, India has developed a technology for manufacturing composite boards, paper and material for raising edible oyster mushrooms from cotton stalks. Among these options, the manufacture of particle-boards has been found to be economically feasible, and under the project, a demonstration has been set up at Nagpur, India. The project has also looked at the feasibility of compacting stalks in the field and transporting them to the factory for processing. The work done so far indicates that it is not economically feasible to process cotton stalks in the field and bale them for transportation to the factory. However, chipping the stalks in the field then transporting the chips directly to the board factory is feasible. Two types of cotton boards are being manufactured in the project. The cotton stalk supply chain model clearly showed that farmers could earn an additional income of US\$12.5 per ton of dry biomass (10-12% moisture). Uprooting, cleaning, chipping and transportation of cleaned chips could fetch an additional income of US\$50 per ton if the industry is located within a radius of 50 kilometers. On the average, 2-3 tons of cotton stalks are produced per hectare in India. The project is scheduled to conclude on September 30, 2008 when a final report, including full details on the economics and quality of particle-boards, will be available.

The Technical Information Section of the ICAC undertakes a survey of the cost of production of cotton every three years. The current survey was published in October 2007 and contains data from 31 countries. The average of 31 countries showed that farmers spent US\$717 to produce one hectare of cotton in 2006/07. This does not include the cost of land rent but includes all inputs and operations up to harvesting of seedcotton. The average cost of producing a kilogram of seedcotton comes to US\$0.34, which is only one cent higher

than the cost in 2003/04. Addition of ginning, economic and fixed costs determine the total cost per hectare and per kilogram of lint. The gross cost (Including land rent and without excluding seed value) per kilogram of lint in the world averaged US\$1.64 in 2006/07. The net cost (excluding land rent and seed value) of producing lint came to US\$767/ha. The net cost of producing a kilogram of lint averaged US\$1.04 compared to US\$1.01 in 2003/04 and US\$0.83 in 2000/01. It is most expensive to produce a kilogram of lint in North America, followed by West Africa. It is least expensive to produce a kilogram of lint in Other Africa, US\$0.80/kg. The average cost of insect control is 14 cents per kilogram of lint. The cost of fertilizers is on the increase, and in 2006/07 averaged 23 cents per kilogram of lint. The cost of weed control operations, which comprised hoeing, inter-culturing and herbicides, was 11 cents/kilogram of lint. The cost of harvesting averaged 14 cents per kilogram of lint. The cost of ginning came to 11 cents per kilogram of lint. The article also discusses the data on cost of producing a kilogram of lint by country. The full report that contains complete data for 31 countries can be ordered from the ICAC Secretariat at <publications@icac.org>. The report is available in hard copy or in electronic form.

The third article is on global warming and its impact on cotton production. Ground and atmospheric temperatures are increasing, and the processing is speeding up due to deforestation and industrialization. The ozone layer is thinning and greenhouse gases are increasing. One of the most common sources of gas emissions is the combustion of fossil fuels in cars, factories and power generation. According to the UN's International Panel on Climate Change, the gas responsible for most of the warming is carbon dioxide. Other contributors are methane from landfills and agriculture, nitrous oxide from fertilizers, gases used for refrigeration and industrial processes, and the loss of forests that would otherwise consume carbon dioxide. Greenhouse emissions and global warming will have multifarious impacts on cotton production. Higher levels of carbon dioxide and higher temperatures could benefit cotton production as far as plant growth is concerned. But, growth

could be just vegetative growth if technology fails to maintain a balance between vegetative and reproductive growth. Similarly, global warming will also impact the pest situation and fiber quality. All these issues are discussed in the third article.

The World Cotton Research Conference-4 was held in Lubbock, Texas, USA from September 10-14, 2007. 590 researchers from 37 countries attended the conference with more than half from outside the USA. The theme of the WCRC-4 was 'Nature's High-Tech Fiber.' The program, available at <<http://www.wcrc4.org>>, comprised of plenary speeches and a number of breakout sessions. In total, there were 21 plenary speakers and 201 breakout session speakers during the 4-day period. There were 118 poster papers, with one special interaction session for the posters. Two field visits were also a part of the Conference. Participants visited the experiment station of the Texas Tech University in Lubbock, the Agriculture Research Service facility of the USDA, a research station of the Texas A&M University near Lubbock, a ginning factory and a dairy farm. The U.S. Organizing Committee after considering various options has decided to publish the proceedings on a CD. Proceedings will also be placed on the ICAC web page at <<http://www.wcrc4.org>> for free access to everybody. The CD will be mailed to all participants. There may be a nominal fee for non-participants to buy the CD from the ICAC.

The World Cotton Research Conference-5 will be held in New Delhi, India in September/October 2011.

The Technical Information Section of the ICAC in collaboration with the U.S. Agency for International Development (USAID), the Common Fund for Commodities (CFC) and the Economic Community of West African States (ECOWAS) organized an Expert Consultation on Biotechnology Applications in Cotton in Ouagadougou, Burkina Faso from October 29-31, 2007. The USAID sponsored the meeting through the West Africa Cotton Improvement Program (WACIP) together with the Common Fund for Commodities. The Technical Information Section of the ICAC in consultation with the USAID prepared the program, invited speakers and participants and implemented the meeting. The Institut de l'Environnement et de Recherches Agricoles - INERA (Institute of the Environment and Agricultural Research) of Burkina Faso served as the primary host. Over one hundred participants from all cotton producing countries in the region attended the Consultation, with visits to a field trial site where participants observed Bt cotton growing under field conditions alongside conventional cotton. The decision on whether to adopt biotech cotton depends on a range of issues related to agronomic factors, environmental concerns, farming systems, economic considerations and long-term sustainability of the technology. The Consultation discussed all these aspects of biotech cotton. Burkina Faso has conducted trials on biotech cotton for many years now and is very close to making a final decision to commercialize biotech cotton. If so, Burkina Faso will be the second country to commercialize insect resistant biotech cotton in Africa after South Africa. All the papers presented at the Consultation and their PowerPoint presentations are available in English and French on the ICAC web page at <<http://www.icac.org>> under 'Cotton Biotechnology.'

Utilization of Cotton Plant By-produce for Value Added Products

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The work reported in this article is part of a project titled 'Utilization of Cotton By-produce for Value-added Products CFC/ICAC20' in India. The project is sponsored by the International Cotton Advisory Committee and funded by the Common Fund for Commodities. It is currently in progress and is scheduled to conclude on September 30, 2008. The project proposal is available at <http://www.icac.org/projects/CommonFund/20_ucbvp/cfc20_proposal.pdf>. Additional information on project activities may be obtained from <circot@vsnl.com>.

Abstract

The biomass available after the harvest of seedcotton is rich in cellulose, hemicellulose and lignin akin to that found in most hard woods. Thus, it is an excellent raw material for the manufacture of composite boards, pulp and paper, as

well as for raising edible oyster mushrooms. Among these options, the manufacture of particle board has been found to be economically feasible. The Central Institute for Research on Cotton Technology (CIRCOT), India has standardized methods to manufacture composite board from cotton stalks collected and processed after the cotton harvest. Under the project, CIRCOT has designed models for the logistics of supplying cotton stalk to the particle board industry, and has installed a pilot plant at the CIRCOT Ginning Training Center in Nagpur, India. The cotton stalk supply chain model clearly showed that farmers could earn an additional income of US\$12.5 (equivalent to Indian Rupees 500) per ton of dry biomass (10-12% moisture). Uprooting, cleaning, chipping and transportation of cleaned chips could fetch an additional income of US\$50.00 (Rs. 2000) per ton if the industry is located within a radius of 50 kilometers.

The cotton stalks may be cleaned of boll rinds and adhering residual lint manually by beating the stalks gently on a wooden mallet. The cleaning process is laborious and labor intensive, so a mechanical device was developed to remove the unwanted materials by running the uprooted stalks through a set of rollers. Mechanical cleaning may be a feasible alternative wherever labor is expensive or in short supply. In India, cotton stalks are uprooted manually and/or by a mechanical device in rainfed areas; they are usually cut flush with the ground in irrigated tracts.

Remnants of boll rinds and roots can definitely affect the quality of the end product, i.e., particle board, hard board, soft board and medium density fiber board. Stalks must be processed in compliance with the required specifications. In the USA and other places where seed cotton is picked mechanically, the presence of boll rinds in the stalks is minimal and the biomass may be sent directly to the chipping stage.

A great effort has been put into developing a machine to compact the stalks and transport them in baled form to a centralized chipping center. The work done so far indicates that it is not economically feasible to process cotton stalks in the field and bale them for transportation to the factory. However, chipping the stalks in the field then transporting the chips directly to the board industry has been found to be feasible. Considering the above, operation of a 20-ton-per-day particle board plant in countries like India and other African and Asian countries have been found to be feasible and sustainable.

Introduction

India has the distinction of growing all four cultivated species of cotton, in addition to commercial hybrids. India can also take pride in growing cottons that meet the quality requirements for spinning a wide spectrum of yarn counts ranging from 6s to 120s. An alternate strategy for improving farm income is to use cotton by-products economically and feasibly. Cotton stalks are one of the important by-products of the cotton crop.

Some 23 million tons of cotton stalks are produced annually in India. On average, about 2 to 3 tons of cotton stalks are produced per hectare, though the actual volume will depend on crop height and plant density. Most of the stalks in India are treated as waste and approximately 15% is used for fuel. The bulk of the stalk is burnt in the fields after the harvest of the cotton crop, although it is not a desirable practice, since it causes air pollution. Additionally, cotton stalks piled up in fields tend to harbor pests and disease causing organisms. The cotton stalk has a fibrous structure comparable to that of most of the common species of hard wood; hence it can be used to manufacture particle board, pulp and paper, hard board, corrugated cardboard and boxes, as well as micro-crystalline cellulose to grow edible mushrooms.

CIRCOT has been engaged over the course of many years in the development of cost effective technologies to produce

Table 1: Availability of Cotton Stalks - 2007/08

States	Area* (Million ha)	Availability of Stalks (Million tons)**
1 Andhra Pradesh	0.96	2.4
2 Gujarat	2.39	7.17
3 Haryana	0.53	1.6
4 Karnataka	0.37	0.74
5 Madhya Pradesh	0.63	1.26
6 Maharashtra	3.12	6.24
7 Punjab	0.59	1.76
8 Rajasthan	0.35	0.7
9 Tamil Nadu	0.13	0.27
10 Orissa	0.06	0.12
11 Others	0.04	0.07
Total	9.18	22.33

* Cotton Advisory Board estimate (March 09, 2007)

** Cleaned Stalks

Table 2: Chemical Composition of Cotton Stalks

Species	Holo-Cellulose (%)	Lignin (%)	Ash (%)
<i>G. arboreum</i>	67.3	25.8	7.0
<i>G. herbaceum</i>	69.1	28.1	8.3
<i>G. hirsutum</i>	70.0	27.1	6.7
<i>G. barbadense</i>	69.2	28.2	8.1
Desi Hybrids	67.3	27.6	6.8
<i>Hirsutum</i> hybrids	68.6	24.3	5.9
Mean Value	68.6	26.8	7.1
Range of values	67.3 to 70.0	24.3 to 28.2	5.9 to 8.3

value added products (such as particle board and hard board) from cotton stalks with a view to providing cotton growers with an additional source of income, as well as to help develop entrepreneurship in rural areas. A brief summary of the economic potential of cotton plant stalks is given above.

In India, most cotton is cultivated during the period from February to July and the crop is harvested from October to March. Table 1 contains information about the cotton area and production, as well as the availability of stalks in various parts of the country.

The biomass yield varies from species to species; the highest yielders being the hybrids, and *G. arboreum* the lowest. On average, about 3 tons of cotton plant stalks can be harvested from one hectare of land during a normal growing season. However, according to estimates, after the leaves, boll rinds and twigs are removed in the collection and cleaning process, only some 2 tons of field cleaned stalks are available per ha. Depending upon the variety and the crop conditions the stalks will be 1 to 1.75 meters high and their diameter just above the ground may vary from 1 to 2.5 cm. The specific weight of short-chopped stalks is about 160 kg/m³. The calorific value of cotton stalks is equivalent to poor quality wood and is about 17.40 (MJ/kg).

As an average, the stalk of the cotton plant contains about 68 % holocellulose, 26% lignin and 7% ash. The following table contains the chemical composition of stalks from different species of cotton.

It is interesting to note that in contrast to some other agricultural crop residues, cotton stalks possess fiber dimensions comparable to those of most commonly available species of hardwood. This is what encouraged CIRCOT to use cotton stalks to make various kinds of boards, paper and microcrystalline cellulose.

Logistics of Cotton Stalk Collection

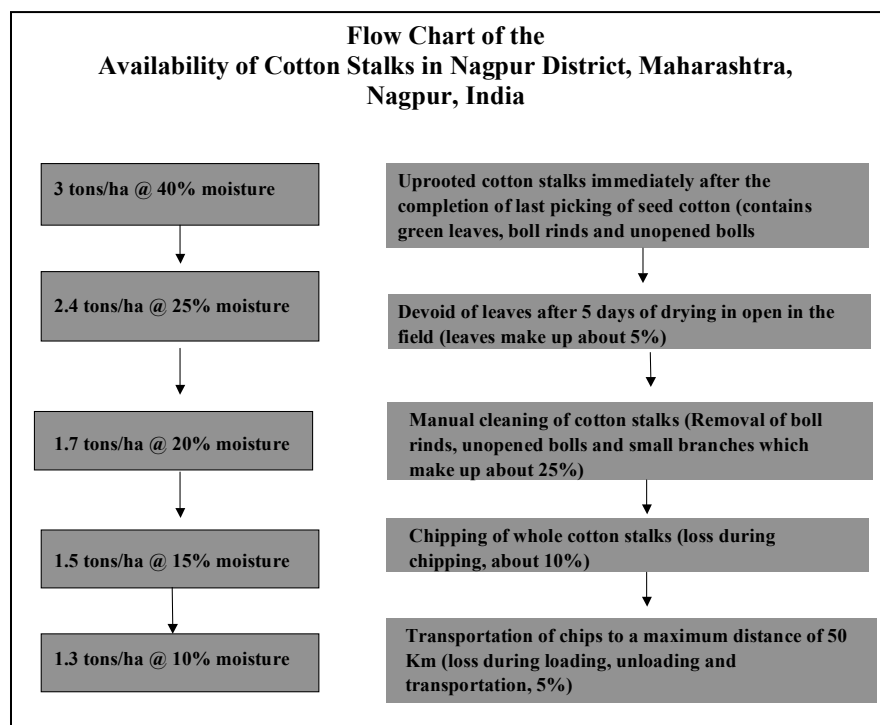
The following three models were tested to identify the most suitable and economical way of collecting and processing cotton stalks.

- Transportation of cotton stalks directly from the field to factory for chipping in the factory.
- In-field chipping of cotton stalks by farmers and transportation to the factory.
- Collection of cotton stalks by farmers in the field, transportation to a chipping center, chipping, and subsequent transportation to the factory.

In the first year, the stalks were transported directly to the factory where they were chipped in a drum chipper (Klockner chipper). Alternatively the stalks were collected, chipped in a central location (chipping center) in the fields, and then transported to the manufacturing plant. The second option was found to be feasible.

The cotton stalks were uprooted following the normal practice of farmers in Central and Southern India, allowed to dry for 4-5 days and cleaned by beating the dried stalks on a wooden mallet to remove the remaining cotton, boll rinds and twigs. The clean stalks were then chipped in the field using a tractor driven mobile chipper. The chips thus obtained were transported to the factory using two modes of transportation: One, the chips were directly loaded in bulk and transported to the plant; second, the chips were packed in gunny bags and then delivered to the plant. The above flow chart depicts the availability of stalks and their conversion to chip form at the end of the process.

Experiments showed that the cost of cleaned chips transported a distance of about 50 km comes to US\$50.00 (Rs. 2000) per ton. This has been ascertained by some interested entrepreneurs who have come forward to supply cotton stalk chips. According to their experience, the rate quoted for cleaned cotton stalk chips comes to US\$37.5 (Rs. 1500) per ton at the site (field where the stalks are collected and chipped) and the transportation is extra. This study has already interested a number of entrepreneurs in Central and Northern India as evidenced by the responses received from the participants at the awareness meetings held by the project. Tractor driven



mobile chippers are currently available and could be hired for the purpose. Manufacturing drum chippers (driven by power tillers) and using small tractors has not been found to be a viable option for a number of reasons: first, the machinery is heavy and difficult to carry from field to field; second, a three phase motor is essential to run a drum chipper; and third, three phase power is not available in most of rural India. On the other hand, tractor driven mobile chaff cutters are ideal and economical because they can be easily moved from field to field and they can be run on single phase power which is easily available in rural areas.

A Model Cotton Stalk Supply Chain for 20-Ton-Per-Day Particle Board Plant

According to estimates, about 1.5 tons of chips are required to produce a ton of boards, and it takes 3 tons of biomass (including leaves, boll rinds etc) to produce 1.5 tons of ready to use cleaned chips. Thus, a 20-ton-per-day particle board plant would require a daily input of 30 tons of chips. Experience in the project has shown that in and around Nagpur it is possible to obtain 1.5 tons of ready to use chips from one hectare of land. A factory running exclusively on cotton stalks would require the raw material from 6,000 hectares, i.e., 9,000 tons per annum (for 300 working days).

Storage

The cotton stalks are normally uprooted in and around Nagpur when the plant is almost dry (devoid of leaves). If uprooted and left in the field for three days and manually cleaned to remove the boll rinds, those stalks can then be chipped with residual

Table 3: Performance Evaluation of Cotton Stalk Cleaning System*

Initial Weight of Cotton Stalks (Kg)	Moisture Content (%)	Weight of Stalks after Passing the system (Kg)	Moisture Content of Cleaned Stalks (%)	Weight of Removed Material (Kg)			Moisture Content of Peeled Material (%)
				1	2	3	
100	10.5	77	11	16.0	0.6	6.2	6.0

* Performance is based on 5 trials

1 Material collected in the first unit

2 Material collected in cyclone

3 Material collected at the end of conveyor

PS: Moisture content of stalk is around 11% whereas that of wastes (boll rinds, leaves, lint and twigs) is around 6%

Table 4: Effect of Removing Impurities on Board Quality

	Density (g/cc)	Thickness (mm)	Bending Strength (MOR) (kg/cm ²)	Internal Bind Strength (N/mm ²)	Water Absorption (%) 2 h
Dried cotton stalks with boll rinds	0.78	13.0	105	0.25	128
Dried cotton stalks with boll rinds partly removed	0.78	13.2	113	0.26	115
Cleaned cotton stalks (No boll rinds)	0.78	13.5	106	0.31	96
Debarked cleaned cotton stalks	0.78	12.8	181	0.60	77

moisture of approximately 12%. During transportation to the factory, the percentage of moisture stabilizes at about 10%. Considering that the factory would have to have a 30-day supply of chips on hand, about 900 tons would have to be stored on the mill premises and the rest would be stored in 9 decentralized depots by a group of farmers (say in 9 villages with effective connections to transportation services)

Chipping Stations

It has been estimated that about ten chipping stations would be needed. Each chipping station would be provided with one mobile, tractor-driven chipper (outsourced) capable of providing chips at the rate of about 500 kg/ha, i.e., about 3-4 tons per day or 90-120 tons per month. Each chipping station would have to store about 900 tons of chips. The chips would be stored in three stock piles about 3 meters high and each pile would be covered with a polyethylene tarp to prevent spoilage during the rainy season. These stock piles must be far enough apart from each other to facilitate loading of the chips into trucks. The density of cotton stalk chips is about 0.14g/cc. The average area occupied by a 3-meter high stock pile would be around 70 m² and the total area required at each chipping center would be around 1/10 of a hectare.

Cotton Stalk Collection for Each Chipping Station

About 100 tons of chips are to be stored in each chipping center, i.e., the stalk output from 70 hectares of land. Four people can uproot and collect the stalks from one acre in a day, so 10 persons will be required to uproot the stalks from

one hectare. This means the 10 people would get employment for one week just for the uprooting operation and an equal number of people would have to be employed to clean the material.

Cleaning System for Cotton Stalks

The presence of boll rinds and adhering lint affects the quality of the boards, so a cleaning system was designed and manufactured incorporating the following features: scratching system (peeler), conveyor system, air blowing chamber and an air suction chamber. Testing by the project has found that 90% of the boll rinds are removed in the first unit and about 5% are removed in the suction chamber. This indicates that the scratching system could be connected directly to a chipper to make the process more profitable. The results obtained are in the above-given Table 3.

A study was undertaken to establish the effect that removing either the boll rinds or the bark alone or both would have on the quality of the boards. The results presented in Table 4, showed that removal of bark reduced water absorption. Cleaning and bark removal enhanced both the modulus of rupture (MOR) and internal bond (IB) strength.

Storage Trials

Several trials were conducted to determine the effect of storage on cotton stalks. Stalks were stored in different forms, either as whole cotton stalks or as chips. Samples were collected at different intervals and analyzed for chemical composition to assess the deterioration in quality, if any, during storage. The material, in both stalk and chip form was kept in the open

Table 5: Chemical Analysis of Cotton Stalk Chips Stored Indoors or Outdoors

S. No	Month	Moisture (%)		Lignin (%)		Holo-cellulose (%)		Ether Extractives (%)	
		Stored in Shed	Stored Outside	Stored in Shed	Stored Outside	Stored in Shed	Stored Outside	Stored in Shed	Stored Outside
1	July	14.2	16.0	26.6	25.4	82.1	77.1	7.1	7.2
2	Aug.	14.0	15.9	26.1	25.0	81.4	76.4	7.0	7.1
3	Sept.	12.0	11.9	26.0	24.8	81.2	75.7	7.0	7.2
4	Oct.	11.2	12.9	25.9	24.5	81.1	75.4	6.5	6.8
5	Nov.	11.8	11.4	25.8	24.2	80.9	75.2	6.8	7.1
6	Dec.	11.1	11.2	25.5	24.1	80.7	75.2	6.7	6.5
7	Jan.	11.3	11.4	25.2	24.1	80.5	75.1	6.7	6.8
8	Feb.	11.3	11.4	25.5	24.7	81.1	75.0	6.5	6.3
9	March	11.2	11.4	25.5	24.6	80.9	74.7	6.9	4.5
10	April	11.0	11.1	25.6	24.5	80.5	75.1	6.6	6.4
11	May	10.1	11.5	25.3	24.7	80.4	74.9	6.5	6.4
12	June	13.2	14.4	25.2	24.4	81.0	74.8	6.4	6.3

as well as inside a shed. After 12 months of storage, there was no change in the chemical composition in the materials stored inside. However, there was discoloration/darkening of the surface layer of the material stored in the open. Trials were undertaken to identify any change in the chemical composition of the cotton stalks that were stored in the open. The trials included: 1) Stalks stored in the open on a stone-cemented platform, 2) Chips stored in the open, 3) Chipped stalks stored in a shed, 4) chipped stalks packed in gunny bags and stacked inside a shed, and 5) 35 tons of chips stored outdoors for 7 months in gunny bags at the factory, but covered with tarpaulins.

Chemical Analysis

The results for material indoors or outdoors are given in Table 5.

The chemical analysis indicated that there was not a significant change in the composition of chips stored indoors. However, there was a slight reduction in the holocellulose content of chips stored outdoors. This might be due to the exposure of chips to rain, but even this might be avoided by covering the chips with tarps made of polyethylene or other impermeable material. Analysis has shown that the samples stored outdoors at the factory, but covered, suffered no change in their chemical constituents even after 7 months.

Installation of Particle Board Pilot Plant

A one-ton-per-day pilot plant was commissioned at the CIRCOT Ginning Training Center, in Nagpur using domestically produced machinery. This plant was intended mainly to demonstrate to prospective entrepreneurs the feasibility of using cotton plant stalks and other related biomass to manufacture particle boards measuring 4 x 3 meter in area and in varying thicknesses, in a three-day light hydraulic press. Table 6 (below) shows the extent to which the properties of the boards satisfy the specifications set by the Bureau of Indian Standards (BIS).

Table 6: Properties of Three Layer Particle Boards

Parameters	Urea Formaldehyde Bonded Cotton Stalk Boards	BIS Specification
Thickness (mm)	18	-
Density (kg/m ³)	671	500-900
Bending Strength (MOR) (N/mm ²)	14.64	11.00
Internal Bond Strength (N/mm ²)	0.57	0.30
Screw Nail Withdrawal (Face – Newton)	2,118	1,250
Water Absorption (%)		
2 hour	28	40
24 hour	81	80
Surface Absorption (%)	2.8	9

Economic Analysis

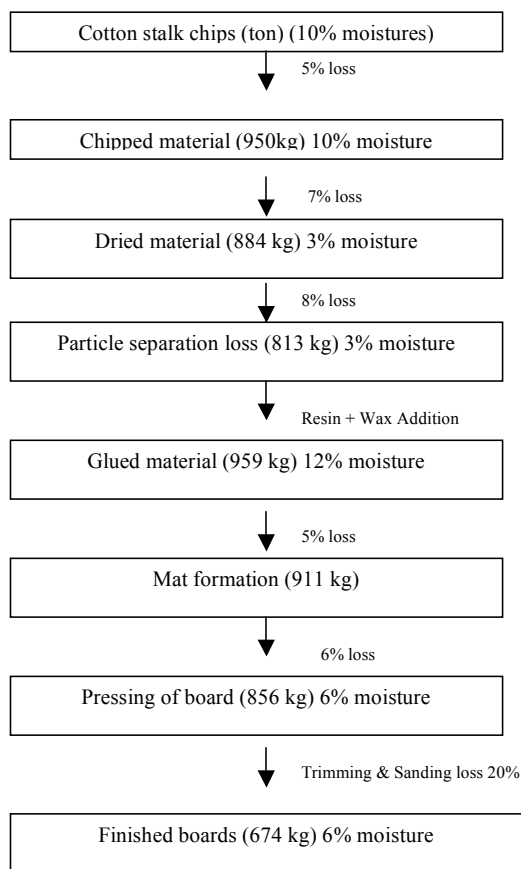
The economic feasibility analysis of a particle board manufacturing plant using cotton stalks as its raw material is based on the following fundamentals.

- The plant is to have a 20-ton-per-day capacity and be equipped with domestic machinery.
- The plant is to be located within a 50 km radius of the cotton production area.
- The cost of one ton of cleaned and chipped stalks delivered at the plant site is to be Rs.2, 000.

- The land and building costs estimated assuming that the plants are set up in cotton growing tracts in India.

Although CIRCOT scientists established the fact that cotton stalks are an excellent material for manufacturing particle boards back in the early eighties, cotton stalks have not been used commercially due to the abundant availability of forest material (timber), lack of legislation on ecological considerations, and uncertainty of the cotton stalk supply chain in dry land agriculture. But the fact remains that processing cotton stalks is not only good for the environment, but also creates jobs for rural workers, along with additional income to cotton growers.

Table 7
Material Balance for Manufacture of Particle Boards from Cotton Plant Stalks



- One ton of cleaned cotton stalk chips with 10% moisture yields 0.7 tons of plain boards with 6% moisture.
- Manufacture of one ton of plane board with 6% moisture requires about 1.4 tons of cleaned cotton stalk chips with 10% moisture.

Costs of Cotton Production in the World

The International Cotton Advisory Committee (ICAC) has been studying the cost of cotton production since the early 1980s. Since 1992, the same questionnaire has been used to collect data from countries and surveys have been undertaken regularly every three years. The ICAC Coordinating Agencies are the primary sources of information from most member countries. In some cases, data have been received from other government sources.

World Average

Fifty-four countries planted cotton on at least 10,000 hectares in 2006/07. Thirty-one countries that planted 30.1 million hectares, 88% of world cotton area in 2006/07, participated in the current survey. The data from all countries are for 2006/07.

The average of 31 countries showed that farmers spent US\$717 to produce one hectare of cotton. This does not include cost of land rent but includes all inputs and operations up to the harvesting of seedcotton. The average cost of producing a kilogram of seedcotton comes to US\$0.34, which is only one cent higher than the cost in 2003/04.

The addition of ginning, economic and fixed costs determine the total cost per hectare and per kilogram of lint. The gross cost (Including land rent and without excluding seed value) per kilogram of lint in the world averaged US\$1.64 in 2006/07. The value of seed sold after ginning may be significantly lower or higher than the cost of ginning. Thus, a net cost has been calculated excluding land rent and seed value from the total cost. The net cost of producing lint per hectare comes to US\$767/ha. The net cost of producing a kilogram of lint averages US\$1.04 compared to US\$1.01 in 2003/04 and US\$0.83 in 2000/01. The cost is only slightly higher in 2006/07 because of higher yields; the world average yield was 645/ha in 2003/04 and 756/ha in 2006/07.

Cost of Production by Region

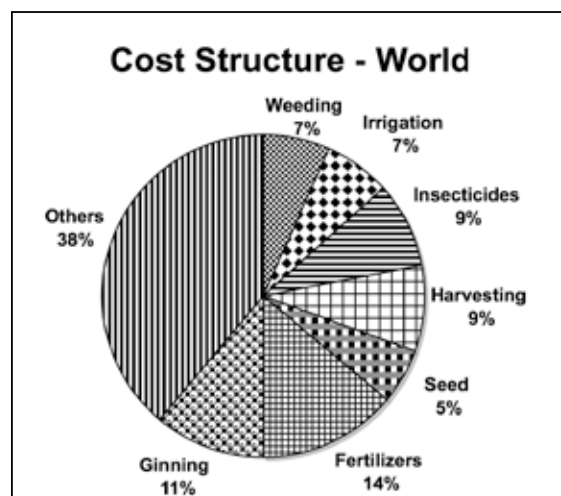
The thirty-one countries participating in the survey were divided into six groups: North America, South America, Asia, West Africa, Other Africa and Australia. The most money is spent in Australia to produce and harvest a hectare of cotton. Three West African countries participated in the survey, and on average, farmers spend US\$391 to produce a hectare of cotton. The expenses of producing one hectare of seedcotton are close to double West African costs in Asia, almost three times in Australia and 12% higher in other African countries. However, the average cost of production of seedcotton among regions is close, except in Australia, and ranges from 29-36 cents/kg of seedcotton. However, the cost of production of lint varies greatly among regions. It is most expensive to produce a kilogram of lint in North America, followed by West Africa. It is least expensive to produce a kilogram of lint in other Africa, US\$0.80/kg.

Cost of Production of Cotton by Region (US\$)		
Region	Cost/kg Seedcotton (Land Rent Excluded)	Net Cost/kg Lint (Excluding Land Rent & Seed Value)
North America	0.29	1.43
South America	0.31	1.01
Asia	0.36	0.94
West Africa	0.35	1.32
Other Africa	0.32	0.8
Australia	0.19	1.23
World Average:	0.34	1.04

Cost Structure

The four major inputs, not including field operations, are planting seed, irrigation water (if cotton is irrigated), insecticides and fertilizers. On average, farmers spend US\$69 per hectare to purchase planting seed. The cost of planting seed includes seed delinting and treatment with fungicides, if any. The average cost of planting seed comes to 9 US cents per kilogram of lint. Almost half of the world cotton area is grown with assured irrigation water. The cost of irrigation is US\$110 per hectare, or 11 cents per kilogram of lint. Insecticides are used in almost every country, and the only exception seems to be Syria.

The average cost of insect control is US\$101/ha or 14 cents per kilogram of lint. The cost of fertilizers is on the increase, and in 2006/07 averaged 23 cents per kilogram of lint. The cost of weed control operations, which comprise hoeing, inter-culturing and herbicides, was 11 cents/kilogram of lint. The cost of harvesting averaged 14 cents per kilogram of lint. The cost of ginning came to US\$0.11/kilogram of lint. The share of individual inputs/operation in percentage of gross cost is given in the chart above. A major portion of 'others' comes from land rent, economic costs and fixed costs.



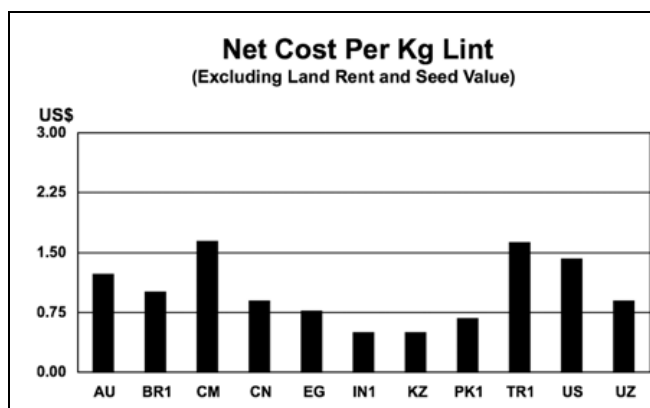
Inter-country Comparisons

Some countries provided data for more than one set of production practices. Thus, the total number of entries in the data is 56 from 31 countries. It is not possible to compare 56 entries, so a limited number of countries have been more extensively compared in this article. The countries/entries are Australia (Irrigated upland - AU), Benin (BJ), Brazil (Central West/Cerrado - BR1), Cameroon (North and Extreme North - CM), China (Mainland - CN), Egypt (EG), India (North Irrigated - IN1), Kazakhstan (KZ), Pakistan (Punjab - PK1), Syria (SY), Turkey (Southeastern Anatolian Project/GAP - TR1), USA (National average - US, Fruitful Rim - US3), Uzbekistan (UZ) and Zambia (ZM).

Although there are not many differences among regions, the cost of producing a kilogram of seedcotton varies greatly among countries within regions. The cost of producing a kilogram of seedcotton is as low as 12 cents/kg in Ethiopia and 14 cents/kg in Tanzania and as high as 76 cents/kg in Nigeria. The cost of producing a kilogram of seedcotton is over 55 cents/kg in Israel, Mexico (Sonora), Myanmar, Sudan (irrigated Barakat and Acala) and Turkey (GAP, Ege and Akdeniz). It was not possible to estimate the cost of producing a kilogram of seedcotton in the USA.

The data shown below from 12 major cotton producing countries representing various regions and production systems indicated that it is most expensive to produce seedcotton in Turkey 57 cents/kg, followed by Syria, 53 cents/kg. It costs 36 cents, 25 cents and 29 cents to produce a kilogram of seedcotton in China (Mainland), India (North) and Pakistan (Punjab), respectively.

The net cost (total cost less land rent and income from seed sold after ginning) of producing a kilogram of lint also showed differences among countries. It is most expensive to produce a kilogram of lint in Bulgaria. The cost of producing a kilogram of lint is over two US\$ dollars in Bulgaria and Israel (Pima). It was not possible to calculate the net cost per kilogram of lint for all 31 countries that participated in the survey. The net cost per kilogram of lint in the USA is US\$1.42/kg, US\$0.90/kg in China (Mainland) and US\$1.63 in Turkey (GAP). The net cost/kg is only US\$0.67 in Pakistan. Assuming the ginning

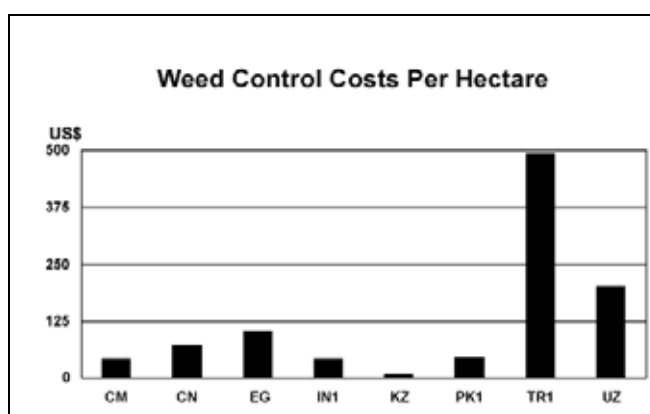
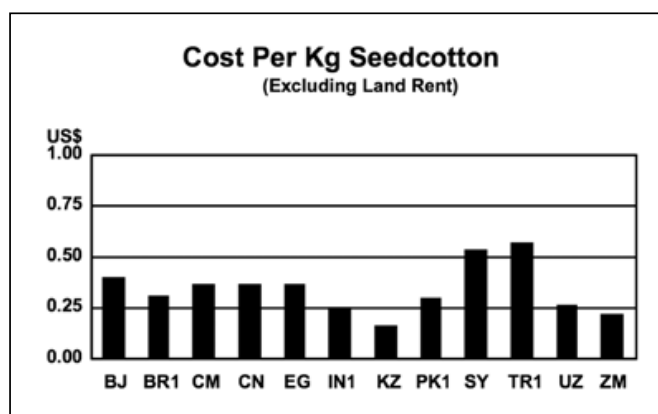


cost in India equivalent to the cost in Pakistan, the net cost in the North region of India equates to US\$0.50/kg of lint. Net cost per kilogram of lint is lower in India due to recent increases in yields and also higher values for cotton seed after ginning. The cost of production data from Kazakhstan, Tajikistan and Uzbekistan showed that the cost of producing a kilogram of lint is the lowest in the Central Asian countries as a region.

Costs of Individual Inputs

The data on structure of cost of production showed that a cotton grower spends the most on fertilizers, even more than insecticides. The survey includes information/costs of all inputs and operations starting from land rent and pre-sowing operations to economic and fixed costs on the farm. However, in this report only cost of weed control, insect control, fertilizers, irrigation, picking and ginning of cotton have been discussed.

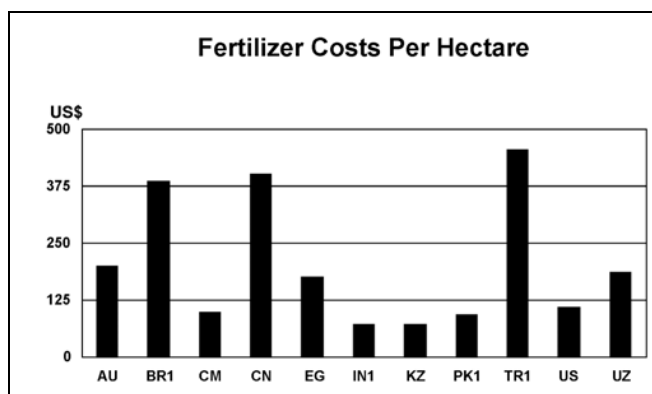
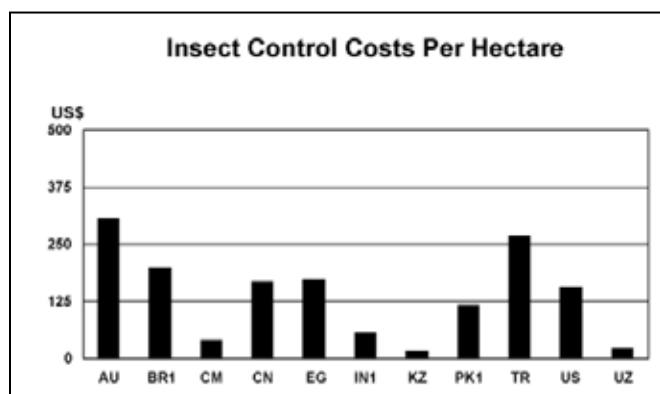
Experiments in some countries have shown that the benefits of good insect control and optimum fertilizer use can best be achieved only if weeds are properly removed from the field. Weeds harbor insects and share inputs if the fields are not properly cleaned. Weeds can be removed manually, mechanically or chemically with the use of herbicides. Biological control of weeds has not progressed well, and it is yet not popular in any country. Herbicide resistant biotech cotton is approved in Argentina, Australia, Colombia, Mexico,



South Africa and the USA. Weed control costs per hectare were the highest in Turkey in 2006/07. Higher cost per hectare on weed control could be due to high weed infestation, high cost of labor/mechanical operations and also the high cost of herbicides. In Turkey, herbicides are used on over 90% of the cotton area but the high cost weed control due to the high cost for manual/mechanical weed control. Weed control costs are also comparatively high in Uzbekistan where herbicide use is still not popular. Weeds may not be a serious problem in Kazakhstan where the least amount of money is spent on weed control. Herbicides are not used in Kazakhstan.

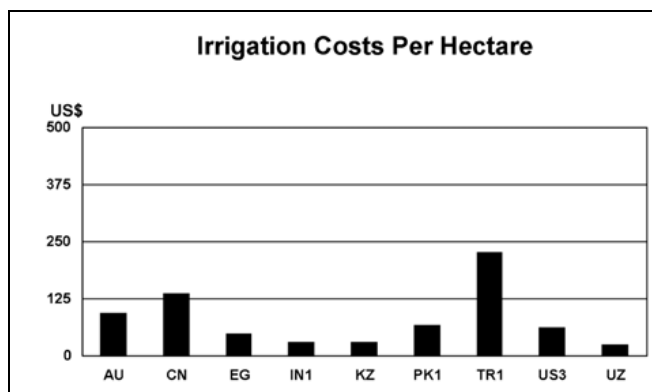
The world average of insect control costs should be viewed in the light of the fact that 36% of the world cotton area was planted to biotech varieties in 2006/07, and most of the biotech area was under varieties with insect resistant gene/genes. Otherwise also, it seems that insect pressure is decreasing in most countries. India and Pakistan are the only major cotton growing countries where more recently a new pest has been noticed on cotton. The mealy bug was on increase for the last two seasons in Pakistan, and the bug has also been noticed to affect significant area in India. The mealy bug is sucking insect that feeds mostly on branches and the main stem. The affected plants remain stunted, and the shoot tips develop a bushy appearance. A mealy bug attack results in retarded growth and late opening of bolls, thus, affecting the yield. Otherwise no new insect has been observed on cotton in other countries. Countries/governments are encouraging non-chemical control measures, which along with better insecticides is reducing the use of insecticides. Insect control costs are the highest in Australia, followed by Turkey and Brazil. Among 11 countries discussed extensively with regard to input costs, the least amount of money is spent on insect control in Kazakhstan and Uzbekistan. It is long known that cotton growing countries in the Central Asian region have good biological control systems and severe winter also help to break the insect lifecycle.

Fertilizers are used in all cotton producing countries of the world. The quantity of fertilizer and price will make the difference in the cost of fertilizers. Nitrogen is a must and is almost applied, partly before planting but most of the time before and during flowering. Phosphorous is applied before planting, and potassium is not applied in all countries. Fertilizer

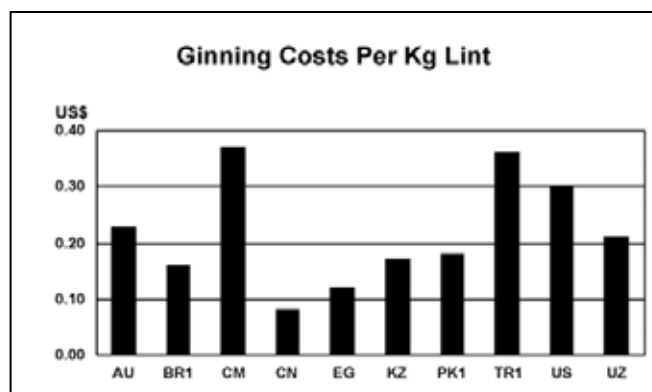
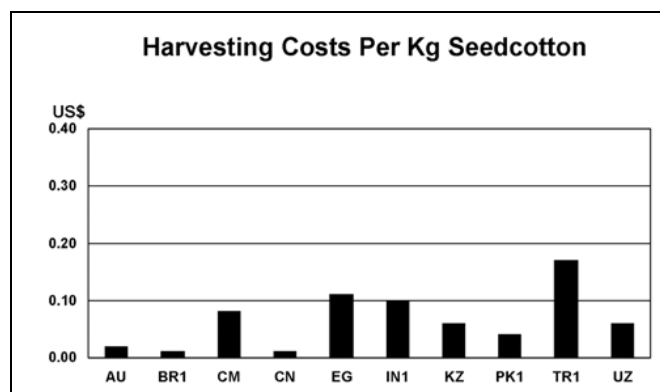


costs are the highest in Brazil, China (Mainland) and Turkey, where US\$400-450 is spent on fertilizers. Fertilizer costs are the lowest in the Northern region of India because of no use/need of potassium in areas where cotton follows wheat.

Almost half of the world cotton area is irrigated. Out of the 11 countries extensively discussed in this article, Brazil (Central West-Cerrado region) and Cameroon produce cotton under rainfed conditions. Irrigation of cotton is most expensive in Turkey and least expensive is Kazakhstan and Uzbekistan. The data from the USA (US3) is for the Fruitful Rim region. The Fruitful Rim region comprises most of Arizona and California and the southern parts of Texas. Cotton in some other regions is also irrigated, but not as frequently as in the Fruitful Rim region.



The cost of harvesting has been calculated per kilogram of seedcotton. It is already known that machine picking is less expensive compared to hand picking. On the average 17 US cents are spent to pick a kilogram of seedcotton in the GAP region of Turkey. High picking costs, due to non-availability of rising labor and labor costs, are forcing cotton growers in Turkey to move to machine picking. Hand picking of cotton in China (Mainland) is the same cost as machine picking in Brazil, because of the abundance of labor in China. Hand picking is expensive in Egypt because of the fact that picking is done more carefully in Egypt compared to most other countries. Labor costs are high, but because of fiber quality, Egypt is not considering moving to machine picking.



Ginning costs have been calculated per kilogram of lint. Ginning costs included transportation of seedcotton to the gin and classing and grading charges. Ginning costs are the lowest in China (Mainland), as ginning is subsidized by the government. Ginning costs are the highest in Cameroon and the GAP region of Turkey. Otherwise, there are small differences in ginning costs compared to other inputs and operations.

Caveats

There are a number of caveats that compromise the data presented in this report. It would have been best if all countries had provided data on all applicable items included in the survey questionnaire. Unfortunately, this is not the case and net cost comparisons become less reliable. But, ICAC's

survey is the only source of cost of production data in the world. There are certain inherent limitations, e.g., seedcotton yield is not estimated in Australia and the USA, inputs may be subsidized, and custom ginning is not available in many countries. Production systems are different and the method of collecting the data in various countries is not the same. Data on certain inputs/operations are not available from some countries because they do not collect data in the ICAC format. Countries estimate cost of production in local currencies, while ICAC data are compared in US\$, thus, exchange rates have an impact on cost comparisons. Also, differences in cotton quality among countries, and even farmers, paying the same cost of production would have an impact on cost comparisons, so a low cost of production would not mean a higher income for growers in every case.

Global Warming and Cotton Production – Part I

Global warming is defined as an increase in the average temperature of the ground and atmosphere of the whole planet. Long term historical records show that the average ground and air temperatures have increased by one degree Fahrenheit in the last century. The rate of increase is believed to have speeded up because of deforestation and industrialization in the half century or so since World War II. The current rate of increase in temperature is dangerous, and the process is considered to be accelerating with the increased use of machinery, deforestation, greenhouse gas emissions, natural calamities (like volcanic eruptions) and the thinning of the ozone layer in the upper atmosphere.

Global Warming and the Ozone Layer

Global warming and ozone depletion are two phenomena going on at the same time in our world, and although they are different, they are interrelated. The sun's rays are capable of producing very harmful radiation if they are not slowed before reaching the earth. Researchers have found that while we are warming the world with daily activities, we are also depleting the ozone layer in the atmosphere. Ozone depletion is the

thinning of the ozone layer, which is believed to extend from 15 to 50 kilometers above the ground surface. Sunrays are interrupted by ozone, and thus radiation is minimized before it hits the earth. Radiation can be useful, but most radiations are harmful. Good or bad, changes due to radiation—artificial or natural—are permanent.

Global Warming and Greenhouse Effects

Researchers have found that the earth's temperature has been going up and down for ages, but has average temperatures have been fairly constant over the last few thousand years. The "greenhouse effect" is warming that takes place when certain gases in earth's atmosphere trap heat and retain it. These gases allow light to penetrate, but they prevent heat from escaping, just like the glass walls of a greenhouse, commonly used to raise crops under extreme or unfavorable weather conditions. Sunlight shines on the earth's surface, where it is absorbed and then radiated back into the atmosphere as heat. Greenhouse gases trap some of this heat. The greater the amount of greenhouse gases in the atmosphere, the more heat is trapped. Thus, depletion of the ozone layer and an increase

in greenhouse gasses complement each other in raising the temperature of the earth.

Factors Responsible for Global Warming

There are a number of factors that are working together at the same time to increase the temperature of the planet. There are some natural phenomena, like volcanic eruptions, El Niño and others that are also adding to the warming of the Earth, but firstly, their effects are comparatively minimal, and secondly, they do not last long. Unfortunately, the biggest problem is human activity in various forms. Recent estimates suggest that the amount of carbon dioxide (CO₂) in the atmosphere has increased by more than one third since the start of the industrial revolution. The United Nations formed a group of scientists called the International Panel on Climate Change, which meets every few years to review the current situation and publish its report on the status of global warming. Scientists have learned that there are several human-related activities that are directly responsible for the greenhouse gasses that increase the planet's temperature. The most common source of gas emissions is the combustion of fossil fuels in cars, factories and power generation. According to the UN's International Panel on Climate Change, the gas responsible for most of the warming is CO₂. Other contributors are methane (CH₄) from landfills and agriculture, nitrous oxide (N₂O) from fertilizers, gases used for refrigeration and industrial processes, and the loss of forests that would otherwise consume CO₂.

The UN Panel has observed that different gases have different heat-trapping capabilities. For example, a molecule of methane produces more than 20 times the warming of a molecule of CO₂. Nitrous oxide is 300 times more powerful than CO₂. And other gases, such as chlorofluorocarbons (which have been banned in much of the world because they also degrade the ozone layer), have heat-trapping potentials thousands of times greater than CO₂. But, because their concentrations are much lower than that of CO₂, none of these gases add as much warmth to the atmosphere as CO₂ does. In order to understand the effects of all the gases together, scientists tend to talk about all greenhouse gases in terms of the equivalent amount of CO₂.

Consequences of Global Warming

According to Jordan (2007), atmospheric CO₂ levels have increased from about 280 parts per million at the beginning of the industrial age to more than 375 ppm today. The process is accelerating, and according to other estimates, yearly emissions have gone up by more than 20% since 1990. In its latest report, issued on November 17, 2007, the fourth in the series, the UN International Panel on Climate Change (<http://www.ipcc.ch/>) stated that CO₂ already in the atmosphere could result in a rise in sea level of up to 1.4 meters over the next one thousand years. As early as 2020, millions of people in Africa will face water shortages and many large coastal cities in Asia will be at risk of river and coastal flooding.

Global warming will cause more rain, floods, storms and hotter weather. A general rise in the temperature of the ground and air could have both desirable and undesirable effects. For example, a rise in temperature where winter temperatures are too low may have a desirable impact, compared with conditions where winter is not that harsh. However, the long-term consequences of global warming are serious, and they could trigger the onset of a series of reactions that will ultimately harm our world. Once they have taken place, the changes brought about as a result of global warming are impossible to be reversed. There are certain other changes that will be harmful, even for places with severe winter conditions. However, the theme of this article is not to consider all the reactions that may occur or might be triggered as a result of global warming, but to analyze how the rise in temperatures will impact cotton production.

In that connection, the important changes that will take place will be: changes in rainfall patterns, the rise in sea level due to melting of ice, higher levels of CO₂ in the air, drought conditions, impact on flora and fauna, effect on nutrient availability in the soil and pest populations.

Living things, including agricultural crops, naturally attempt to adapt to climate changes, in spite of the fact that certain changes are clearly negative. However, the underlining problem is the fact that greenhouse gases or climate changes are happening faster than some living things are capable of adapt to them. Some changes have already occurred; others are expected to happen.

Cotton's Role in Greenhouse Gas Emissions

According to a short note published in the April-May 2007 issue of *The Australian Cottongrower*, methane and nitrous oxide are among the main contributors of emission gases in Australia. This is contrary to what is happening in most other countries where CO₂ is the main source of global warming. In Australia, the main source of methane is livestock production, while nitrous oxide comes from nitrogenous fertilizers. So, the situation is different in different countries, but there is a common denominator linked to cotton production.

Irrigated conditions produce more greenhouse gas emissions than dryland farming. This might be due to the comparatively lower use of nitrogen fertilizers and lower methane emission in dryland farming, as opposed to the more intense use of these chemicals in heavily irrigated crops like rice. Almost half of world cotton area is irrigated, and nitrogen fertilizer is an indispensable component of current production practices. It is usually recommended that slow-release nitrogenous fertilizers be applied at the preflowering stage, and that nitrogen forms be made readily available at flowering. There are at least 16 different sources of nitrogen that can be used in agriculture, and most can be used on cotton. ICAC undertakes a survey of cotton production practices every three years, and data show that the most commonly used form of nitrogen in cotton is

urea followed by ammonium nitrate and ammonium sulphate. Nitrogen requirements depend on a great many factors, and so does the yield obtained from any set of production practices and the levels of inputs used to grow cotton. But, in general it is assumed that about 115 kilograms of nitrogen is needed to produce a ton of lint cotton on medium textured soils. Clay and clay loam soils require another 40-50 kilograms of nitrogen, particularly if cotton is not being planted after leguminous crops or shallow rooted crops like corn. Sandy soils result in greater loss of nitrogen through leaching and evaporation.

It is generally believed that cotton-based farming systems are potentially high-risk agricultural systems with respect to losses of nitrogen in the form of nitrous oxide. Cotton is a summer crop, and nitrogen losses are higher if urea fertilizer is left on a dry soil surface for days at a surface temperature of more than 24°C, which is common in cotton growing countries at the time of application of nitrogen fertilizers. Work done at Mississippi State University in the United States showed that up to 30-50% of nitrogen is lost if the fields are not irrigated within 5-7 days after applying Urea and the day time temperature is over 24°C. An average rainfall of about five centimeters adds approximately 10-12 kg of nitrogen per hectare from the atmosphere. Water run-off from fields also amounts to a loss and to an inappropriate use of nitrogen that adds to global warming. Although it has not been scientifically proven, there are many who believe that some of the gaseous products that result from the transformation of nitrogen fertilizers may also be responsible for depletion of the ozone layer.

Most of the remainder of the nitrogen applied to cotton is in the form of ammonium nitrate (NH_4NO_3). Ammonium (NH_4) is a positively charged ion and does not leach readily. Nitrate, on the other hand, is the principal form of nitrogen used by plants. Thus, as a negatively charged ion nitrate is not attracted by soil particles (clay) and is thus liable to be leached or lost into the air rather quickly. The cotton plant is capable of taking up nitrogen in the form of nitrate rather quickly, thus leaving little time to evaporate in gaseous form as nitrous oxide. The nitrification process using ammonium is more likely to release nitrous oxide into the atmosphere.

Another way in which cotton contributes to global warming is through its nature as a C3 plant. Like all other plants that photosynthesize in the open, cotton cleans the environment by absorbing CO_2 from the air. During the photosynthesis process carbohydrates are formed from CO_2 and water is absorbed from the air. Some crop plants are able to consume most of all of the carbohydrates formed during the process of photosynthesis; such plants are called C4 plants. Plants that are not capable of utilizing all the carbohydrates formed in the photosynthesis process are known as C3 plants. Cotton belongs to the C3 type, and its photorespiration rate is almost 1/3 of its photosynthesis rate. C3 plants tend either to burn a given percentage of their carbohydrates or release them into the atmosphere in different forms. Photorespiration, in real terms, is a loss of oxygen, CO_2 and light utilized during photosynthesis. This may not be desirable but it is what cotton does.

Methane gas is lighter than air, colorless, odorless and flammable. It is produced by the decomposition of organic matter. There are many sources of methane production; it is released from swamps, rice paddies, garbage in landfills, and burning forests. Animals, such as cows, also produce methane as a byproduct of their digestive process. Fortunately, cotton is not a major contributor of methane to the environment.

Cotton Production in the Changing Environment

Global warming will affect cotton production mainly as a result of higher concentrations of CO_2 and increases in temperature. However, both these changes will set off a series of other actions that will have a direct and indirect impact on cotton production. Although ginning waste and other subsequent aspects of cotton processing will also be affected, and they too are currently having their own impact on global warming, this article will focus on production practices and other factors that have an impact on the growth of the plant.

Higher CO_2 levels in the immediate surroundings of the cotton plant will increase photosynthetic activity, which in general should have a positive impact on fiber yield. This was the object of the work done in the US with the CO_2 enrichment program that was developed over many years, particularly during the 1980s. Higher photosynthetic rates increase water use efficiency by the cotton plant, thus increasing productivity per unit quantity of water applied to grow cotton. However, increased photosynthesis might also result in greater vegetative growth. There is no doubt that vegetative growth will take place before there is any effect on fiber yield. Thus, it will become more important to preserve a balance between vegetative and reproductive growth.

Keeping this balance so that it will work to the benefit of the grower by fostering higher yields requires a full understanding of the crop and its proper management. On the other hand, higher levels of photosynthesis expressed in the form of greater growth might also lead to an increased demand for inputs, including water and soil nutrients, particularly if the balance is inclined toward vegetative growth. If this should happen, especially in marginal production conditions where water is not available in sufficient quantities, the result could be quite negative. Thus, production technology will become more important and its value will become evident in successive revisions.

Boll retention is more sensitive to high temperatures than any other condition, except for nutrient deficiency, which is easy to correct. It is not possible to avoid the effects of high temperatures, so this is a condition that can produce bud shedding, which is the most common reason for loss of fruit forms (Reddy *et al.*, 1999). Reddy *et al.*, (1999) observed that the temperature regime and CO_2 enrichment altered boll development and fiber properties. The conducted experiments under controlled conditions where temperature was based on ambient outdoor temperatures. The actual mean daily

temperature to which each boll was exposed from flowering to maturity was averaged over the fiber developmental period. They found that boll size and the maturation period both decreased as the temperature increased. Boll growth increased as average temperature increased up to a maximum of 25°C; beyond that they declined with the highest temperatures. Boll maturation period, size, and growth rates were not affected by atmospheric CO₂ with treatments at 360 µL L⁻¹ (ambient) and 720 µL L⁻¹. At 720 µL L⁻¹ atmospheric CO₂ there were 40% more squares and bolls than at 360 µL L⁻¹ CO₂ at all temperatures. There is abundant literature available from a great many countries showing that when bolls grow at less than the optimal boll growth temperatures they tend to produce longer fibers. Optimal is a relative term and it varies depending on locations and varieties. Reddy *et al.*, (1999) also observed that as temperature increased, fiber length distributions were more uniform. Fiber fineness and maturity increased linearly with the increase in temperature to a certain limit (26°C and 32°C respectively in their experiments) after which they decreased.

Higher temperatures in cotton producing areas and regions already suffering from high temperatures could have a negative impact as a result of increased bud shedding. The rise in temperature could have a positive effect on yields in certain areas and regions where the effective fruiting period is squeezed between two phases of lower temperatures: one early in the season to start effective flowering/boll formation and one at maturity that results in termination of fruit formation. Thus it becomes evident that higher temperatures could affect different regions in different ways.

Higher temperatures could also result in heat stress for certain areas. In work not specifically addressing the impact of global warming, Kater *et al.*, (1996) found that heat stress that is not associated with water stress can damage cotton when plant tissue temperatures remain warm throughout the day and night cycle. As mentioned previously, heat stress can result in excess shedding, reduced boll size and weight, and fewer seeds per boll.

Given the findings above, rising temperatures will have a complex effect on plant growth, yield and fiber quality. Moreover, the effects on growth and yield could have their own impact on fiber quality. For example, a review of the literature reveals that increased temperatures could result in higher micronaire values, stronger fiber and more mature fibers. While higher micronaire values are not a desirable characteristic when they are already close to the upper limit, higher micronaire values could have a desirable effect in areas characterized by low micronaire and low maturity cotton.

Reddy *et al.*, (1998) conducted an experiment in sunlit chambers where temperature was maintained at 30/22°C (day/night) throughout the experiment. CO₂ was maintained at subambient level (178.5 ± 0.36 µmol CO₂), ambient (360.8 ± 0.79 µmol CO₂) and elevated level (718.7 ± 0.70 µmol CO₂) from emergence to harvest. Reddy *et al.*, 1998 found

that growing cotton in environmental growth chambers with elevated CO₂ levels enhanced leaf area by 20%, while it increased the leaf area of the whole plant by an average of 47% at all the temperature used for treatments. CO₂-enriched leaves also had greater specific densities (mass per unit area) than leaves grown at ambient CO₂. As a result, plants grown in elevated CO₂ concentrations had 31% to 78% more biomass than plants grown at ambient CO₂. Atmospheric CO₂ enrichment also increased the number of fruiting sites per plant at all temperatures. However, at temperatures greater than 30°C, most of the fruit aborted, regardless of the CO₂ concentration. These results indicate that cotton will grow more vigorously as the amount of CO₂ in the air increases. Leaves will likely be larger, thereby giving plants greater photosynthetic surface area to produce more carbohydrates and thereby facilitate growth. With more atmospheric CO₂, greater numbers of branches and fruiting sites will likely develop, and this, in turn should ultimately provide for higher lint yields.

Low soil temperatures at planting time often hamper timely planting of cotton in many cotton-producing countries. For example, ideally cotton should be planted only when the five-centimeter soil temperature is at least 14°C for four consecutive days. Planting seed in soil whose temperature is below 14°C leads to poor germination, weak seedlings and poor plant stand, all of which are conducive to lower yields. Low soil temperature is an issue throughout the central Asian cotton growing area where farmers have no choice other than to wait until the soil warms before they can start planting their cotton. Similarly, the cutout date is also fixed in all production systems. A study of cotton growing practices shows that the cutout date is more common across the board than the planting date. Rising temperatures resulting from global warming will benefit those regions and countries that have to deal with low soil temperatures because they will be able to plant cotton much earlier than they can plant it now. It is also assumed that higher temperatures will also delay the cutout date for a number of days. Consequently, getting a headstart on the planting season and a postponement of the cutout date will effectively extend the growing season and benefit a great many countries. Conversely, higher temperatures during the middle of the season or in the hottest months in regions where temperatures are already close to the upper threshold could lead to negative impacts on yields.

The sun emits ultraviolet radiation continuously in three different forms (in the UV-A, UV-B, and UV-C bands). But, some estimates suggest that 95-99% of the radiation is stopped by the ozone layer in the stratosphere before it reaches the surface of the planet. Ozone is continuously formed and destroyed so that its ultimate volume remains almost stable unless the process is perturbed by anthropogenic activity on earth. Scientific observations show that since 1978 the ozone layer over the northern countries has thinned by 4-5%. This increase in the amount of ultraviolet radiation reaching the earth will have many consequences on cotton production.

Zhao *et al.*, (2003) tested cotton with UV-B radiation at 0, 7.7 and 15.1 kJ m⁻² d⁻¹ -- the latter levels being twice the current maximum observed in the United States. They found that UV-B radiation at 7.7 kJ m⁻² d⁻¹ did not affect cotton growth and development, but higher levels of UV-B radiation, i.e., in the vicinity of 15.1 kJ m⁻² d⁻¹, significantly reduced stem elongation rate, leaf area and dry matter accumulation. Forecasters predict that a 30% depletion of the ozone layer will enhance UV-B radiation from 7.7 to 15.1 kJ m⁻² d⁻¹. Zhao *et al.*, (2003) also observed that elevated atmospheric CO₂ could not counterbalance the detrimental effects of high UV-B radiation, net photosynthesis and growth in cotton. This is something, which is more menacing than just a rise in temperature or CO₂ levels.

Insects are a recognized threat to cotton production throughout the world. Global warming will have inevitable impacts on insect pests that already affect cotton. Most insects can adapt their body temperature to the temperature of the environment. The effect of global warming on living organisms is so slow that cotton insects have ample time to adjust to rising temperatures and other changes accruing from global warming. Thus, despite the effects of global warming, the insects current plaguing cotton will continue to be major pests affecting cotton production. In fact, many fear that global warming will affect insects' metabolism allowing them to increase their multiplication rate. Rising temperatures will open new areas for colonization by insects and more of them will spread to newer areas. Increases in the populations of currently important insects may also take place as a result of higher multiplication rates, along with the elimination of the need to go into diapause during winter to avoid the colder temperatures. The effects could be further amplified under conditions where alternate host plants are already available for wintering.

Global warming could impact disease control mechanism in three ways: through its effect on pathogens; by creating disease-propitiating environments; and by affecting host tissues. It is feared that a rise in temperature will affect some disease control methods as a result of changes in the pathogen emergence time. It is also feared that chemical control methods may become less effective due to the possibility of faster decomposition of chemicals under higher temperatures. According to Chakraborty *et al.*, (2002), higher CO₂ levels will increase the severity of diseases, induce fungal growth, spore formation and will destroy more plant tissue. In general the disease problem will become more important.

Weed control programs will also be affected in the same ways as disease pathogens. Most weeds belong to the C4 plant type category and will show less reaction to CO₂ enrichment. Stem thickening, however, is one of the most prominent effects that are expected as a result of global warming. This means that

weeds will become established with a stronger stem more quickly. Work done in Turkey has shown that climate change will be beneficial to weeds due to the fact that genetic variations and selective ecological adaptation are more developed in weeds than in cultural plants (Grenz and Uludag, 2006).

Additional aspects of global warming and their impact on cotton production, along with a limited number of options, will be discussed in coming issues of *THE ICAC RECORDER*.

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