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Introduction

Extra-fine cotton comprises less than 3% of total world production but is very important because of its quality. *G. barbadense* is highly photoperiodic, which has restricted efforts to expand its production in Australia, Brazil, India, Mexico, Zimbabwe and many other countries. *G. hirsutum* varieties inherently lack the ability to produce extra-fine cotton. Differences in planting conditions in comparison to upland cottons are also included in an article on Extra-fine Cotton Production.

The second article is on Micronaire: Fineness and Maturity. Micronaire is a commonly measured and generally accepted fiber character among researchers and the industry. Quick and accurate methods are available for measuring micronaire, and breeders throughout the world rely on micronaire values to screen breeding material. However, micronaire values may be misleading. Why fineness and maturity should be measured separately and the availability of reliable fineness and maturity testing methods are reviewed.

The ICAC began sponsoring regional cooperation in cotton research in Latin America in 1986. The Latin American Association for Cotton Research and Development (ALIDA) was established in 1988. Since 1988, meetings of the ALIDA have been held every two to three years. The fifth meeting of ALIDA will be held in Nicaragua on the topic “Management of Varieties with Emphasis on Fiber Quality.” The Fundación Nicaraguense para el Desarrollo Agricola - FUNDA (Nicaraguan Foundation for Agricultural Research) will host the meeting on November 13-18, 1995. For more information on the meeting or to present a paper, contact the Technical Information Section of the ICAC or the coordinator of the meeting at the following address:

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Extra-Fine Cotton Production

Production of extra-fine cotton of long and extra-long length is restricted to a few countries as shown in the following table.

Production, Consumption and Export of Extra-Fine Cotton-1993/94

Country	1993/94				1994/95
	Production	Consumption	Exports	Export Share	Production
	000 tons	000 tons	000 tons	%	000 tons
China (Mainland)	28.3	25.8	12.0	4	30
Egypt	411.3	266.7	121.1	39	245
India	129.2	144.0	0.0	0	117
Israel	5.4	0.3	5.0	2	6
Peru	6.2	9.8	0.7	<1	6
Sudan	8.2	2.6	18.5	6	18
Tadzhikistan	25.0	5.0	16.5	5	26
Turkmenistan	25.0	5.0	19.4	6	5
USA	80.4	15.7	66.8	22	74
Uzbekistan	62.0	17.9	40.7	13	24
Others	9.4	5.3	8.1	3	11
Total	**790.4**	**498.1**	**308.8**	**100**	**563**

Most long staple cotton is produced from upland varieties. However, upland types inherently cannot produce extra-long staple cotton and are limited in producing low-micronaire, mature cotton. Extra-long cotton can only be produced from *G. barbadense* which includes Egyptian, Pima, Tanguis, Del Cerro and Sea Island cotton. *G. barbadense* is an allotetraploid cotton with (AD)2 genomes like upland (AD)1 but has absolutely different fiber characteristics.

Tanguis is a long staple cotton grown only in Peru but is usually not traded as extra-fine because of high micronaire (over 5.0). It is a *barbadense* type but was selected from an American upland variety in 1908. Tanguis was originally perennial but now has many annual varieties. Tanguis cotton moved from Latin American countries via Central America and the USA to West Africa. Present Egyptian types are the outcome of crossing Sea Island cotton with one of the derivatives of Tanguis cotton. Sea Island cotton was also developed in the USA. It is the longest and finest cotton produced in the world. It is grown in very small quantities in the West Indies under rainfed conditions. Pima was bred from an Egyptian variety Mit Afifi (*G. barbadense*) and is the extra-long staple cotton grown in the USA, Peru, Israel and Morocco. Del Cerro is an offshoot of the Pima breeding program undertaken in the USA many years ago. Del Cerro proved more successful in other countries and is currently grown in Turkey, Peru and Zimbabwe. In morphological characteristics, Del Cerro looks like upland cotton but has been extensively used in breeding programs throughout the world to improve the staple length of *G. hirsutum* varieties. Barakat and Shambat are *barbadense* cottons grown only in Sudan for the last many years.

Planting Conditions

G. barbadense varieties, like upland cotton, can be grown under a variety of soil conditions. The seed bed should be prepared to provide optimum moisture for seed germination. Adding nitrogenous fertilizers at the time of planting is usually not recommended. Highly fertile soils may sometimes result in undesirable vegetative growth, delayed fruiting and late maturity. *G. barbadense* varieties have lower seed indexes compared to upland varieties and thus require a lower seed rate per ha. Most of the viable seeds of upland varieties germinate five-six days after planting under optimum conditions. Because of a harder seed coat, it takes a longer period for *G. barbadense* varieties to germinate and to emerge from the ground. Cool, wet soil conditions slow down the process of germination to the extent that soil over the seed may start drying up. Soil temperature at the site of seed placement must generally be above 65° F for several days before the seed is planted. Planting at low temperatures results in slow and poor germination.

Egypt has the highest seed rate for planting per unit area of *G. barbadense*. The official recommendation is use of 75 kg/ha under optimum soil conditions. However, due to low seed viability, farmers usually use more than the government recommendation, sometimes up to 180 kg/ha. In most other countries, the same seeding rate as for upland cotton is recommended, though the lower seed index means a higher number of seeds per unit weight. In India, because hybrid seed is expensive to produce, utmost care is taken to plant the maximum area from a minimum quantity of seed without sacrificing the plant stand required for optimum yield. In case of interspecific hybrids, the official recommendation is half the seed rate recommended for other varieties grown in the area due to the larger plant size of interspecific hybrids. In Israel and Sudan, the same seed rate is recommended for *G. barbadense* and upland varieties, i.e., 16 kg/ha in Israel and 32 kg/ha in Sudan.

Effect of Atmospheric Conditions

G. barbadense is highly photoperiodic compared with the other three cultivated species of cotton. This characteristic has restricted its cultivation to only a few countries; expansion of its cultivation to other countries is not anticipated. India is one of the few countries which has been able to introduce *G. barbadense* on a small scale and also utilize *G. barbadense* in interspecific combinations for the production of extra-fine cotton.

G. barbadense is very sensitive to high temperatures, particularly at the early stage of plant development. High temperature conditions at the early stage of plant development, which generally do not have a significant impact on upland cotton, result in delayed fruiting and longer internodal distance in *G. barbadense*. Consequently, the effective boll formation period is shortened and crop maturity is delayed, resulting in vegetative growth and lower yield.

A high proportion of ozone in the air may be a major limiting factor to optimizing yield and fiber quality in *barbadense* varieties. Grantz and McCool (1992) studied the effect of ozone on Pima and Acala cotton and noticed significant effects on Pima varieties. Cotton was grown in carbon filtered and unfiltered air in Teflon-walled, closed-top field fumigation chambers. Target ratios were 0, 40, 60, 80 and 100% ambient air for Pima and 0, 50, 75 and 100% normal air for Acala. With the increase in ozone, the two cottons showed the following differences.

- Premature senescence of leaves was much more prominent in Pima compared with Acala.
- Seed size was significantly reduced with the increase in ozone in Pima while it was insignificantly affected in Acala.
- Lint yield was drastically reduced in Pima under high ozone conditions but not in Acala.
- Higher ozone in the air had many effects on fiber quality. Fiber length, length uniformity and micronaire were significantly reduced in Pima but not in Acala. Fiber maturity and fineness remained unaffected in both varieties. Fiber color (Rd) was the only character which was more negatively affected in Acala over Pima in high ozone conditions.

Irrigation and Fertilization

In the USA and Israel, where both *G. barbadense* and upland cottons are grown, it is possible to grow both species at the same plant population/ha and obtain optimum yield. In India, however, a lower plant population is recommended for *G. barbadense* because of the larger plant size. *G. barbadense* has a longer growing season compared with upland cotton. In Israel, *barbadense* varieties can be grown with the same amount of water as upland varieties. Experiments in the USA have shown that Pima can be successfully grown for optimum yield with one less irrigation than upland cotton (Kittock 1979). Generally though, *G. barbadense* has a higher delta of water compared with upland cotton because of its longer growing season. The first irrigation can be delayed without much sacrifice in yield but termination of the last irrigation is more important in *G. barbadense* than in upland cotton. Early termination of irrigation in *G. barbadense* will result in a deterioration of fiber characteristics. For proper fiber development, the water supply must be regular. Water stress is liable to have greater effects on fiber characteristics compared with upland cotton. Growing *G. bar-*

badense under rainfed conditions may result in the production of irregular fiber with a lower uniformity index.

As in upland cotton, nitrogen is the most important nutritional element required for normal growth in *G. barbadense*, but *G. barbadense* is very sensitive to excessive doses of nitrogenous fertilizers. At the same time, avoiding any N stress is very important for optimum yield. An excessive amount of N fertilizers applied to *G. barbadense* varieties can very easily lead to vegetative growth, and splitting N doses is desirable. Short stature and early maturing *G. barbadense* varieties capable of utilizing higher doses of N without rank growth have recently been developed (Silvertooth 1994).

Unruh et al (1994) conducted studies on N, P and K uptake which showed higher fertilizer requirements in Pima than in upland cotton. Trials were conducted on varieties DPL 90 and Pima S 6 for three years from 1990-1992 at six locations in Arizona. N, P and K soil fertility status was maintained throughout the growing period by in-season addition of fertilizers in flood irrigation. Nitrogen monitoring was based on petiole analysis, and additional doses were applied in the next irrigation as a need arose. Unruh et al found that total nutrient uptake in both upland and Pima cotton could be most reliably predicted using heat units after planting. Total N, P, and K uptake by upland and Pima was 199, 29 and 250 kg/ha and 196, 29 and 215 kg/ha, respectively. The pattern of nutrient partitioning was also similar in both varieties, and seeds were the major sink of nutrients. The nutrient requirement to produce 100 kg lint/ha for DPL 90 was 14, 2.1 and 19 kg/ha N, P and K, respectively, compared with 19, 3 and 21 kg/ha, respectively, for Pima S 6.

Insect Pests

G. barbadense leaves differ from upland leaves in color, size, shape, softness and hairiness. Accordingly, *G. barbadense* varieties also vary in their response to sucking insects. Experience in the USA (O'Neill 1995) has shown that the Lygus bug preferred Pima over upland varieties, while mites preferred upland varieties over Pima. According to O'Neill, in areas where mites are major pests, the cost of insecticides is 50% lower in Pima. One year's experience with aphids showed that they preferred Pima over upland. Because of leaf hairiness in upland varieties, whitefly prefer to live on upland varieties compared with *G. barbadense*. Other sucking insects like jassid, *Amrasca devastans,* prefer *G. barbadense* because its leaves are more succulent. Overall greater susceptibility to sucking insects may increase the cost of insect control in *G. barbadense*. In India, it costs 25% more to control insects in interspecific commercial hybrids compared with straight upland varieties. All different types of bollworms including leaf eating/chewing worms are found on *G. barbadense*. However, in the USA it has been observed that armyworms, *Spodoptera exigue*, prefer upland varieties. *G. barbadense* is also more susceptible to some leaf diseases like Alternaria leaf spot but less susceptible to others like virus-caused leaf crumple.

G. barbadense Yield

Obtaining a high yield from *G. barbadense* varieties is possible, but usually *G. barbadense* gives a lower yield than upland varieties. In the USA, Pima varieties usually give 85%-90% of the upland yields in the San Joaquin Valley. In Arizona, farmers get only 70% of the upland yields. Pima is an attractive crop when yield is only 10% lower and the premium for quality is at least 50% over upland cotton (Laughlin 1994).

From 1940-1985, many trials were conducted in Egypt to compare the performance of upland cotton against Egyptian varieties. The experiments were conducted at many locations without any solid conclusions. The primary objective was to replace long staple Egyptian varieties grown in Upper Egypt, particularly Ashmouni, with suitable upland varieties, if technically and economically feasible. The trials were conducted on a number of varieties including many DPL, Acala, Stoneville and McNair types. McNair 220 out-yielded Egyptian long staple varieties in some trials but the results remained controversial because of differences in growing conditions (Abdel-Salam 1993). Currently, Egypt imports medium and high-medium staple cotton if needed for the local industry instead of under spinning long staple, locally produced Egyptian cotton.

In Israel, conditions are favorable for growing *barbadense* varieties throughout the country. Because of a need to use more chemicals on barbadense varieties, it costs slightly more (3-4%) to produce extra-fine cotton in Israel. On the average, *barbadense* varieties yield 88% of the Upland varieties.

In Sudan, extra-fine varieties are grown in specific areas, usually away from upland varieties. *G. barbadense* varieties usually do not get any specific treatment and their yield is less than half of the upland varieties. Low yields have led to a drastic reduction in *barbadense* production since the early 1980s.

In India, it costs almost 25% more to produce one hectare of interspecific hybrids in the South compared with irrigated upland varieties in the Central South region. However, on average, hybrids produce over 30% more lint compared with upland varieties.

Interspecific Hybridization (*G. hirsutum* X *G. barbadense*)

In India, after the release of the first interspecific hybrid Varalaxmi in 1972, a number of interspecific commercial cotton hybrids have been developed for large scale cultivation. Some of them, like DCH 32, became very popular because of their high lint quality and high yields, without much delay in maturity. Interspecific hybrids are extensively grown in the South region in the states of Andhra Pradesh, Karnataka and Tamil Nadu. Interspecific hybrids involving *G. barbadense* as one of the parents are not grown anywhere else in the world. One limitation to growing interspecific hybrids (*G. hirsutum* X *G. barbadense*) is segregation in the F_2 generation resulting in a wide range of staple lengths. Of course, the segregation depends on how widely the parents differ from each other but closely related parents often result in less heterosis. Experience also shows that interspecific hybrids (*G. hirsutum* X *G. barbadense*) may also result in partially sterile plants in the F_2 generation.

Ginning

Longer and softer fibers are liable to be more entangled during ginning. Higher neppiness not only produces uneven yarn but also increases the cost of yarn production because of more frequent breaking during spinning and weaving. *G. barbadense* is grown for the sake of high quality, and it is important to preserve its quality premium. Thus, ginning all long and extra-long cotton on roller gins is recommended. Roller gins are slower (128 saw gins are almost three times faster than high-capacity roller gins) but better preserve the fiber characteristics of high quality cotton. Because of the slow process of ginning, on average, it costs 17 to 18 US dollars more per bale to gin Pima cotton than upland (O’Neill 1995). Pima cottonseed, on the other hand, is sold at a discount of US$10 per ton of seed because the seed must be cracked before feeding to livestock and a difference in its oil color.

G. barbadense Varieties Grown

In all extra-fine cotton producing countries except India and the USA, varieties are developed by breeders in the public sector. In India, interspecific hybrids are also developed by private companies and directly sold to farmers. In the USA, Pima variety development is done by the Delta and Pine Land Company under contract with the Supima Association. As in upland cotton, the main objectives of breeding *G. barbadense* varieties include high yield, high tolerance to insect pests and diseases, early maturity and better fiber quality characteristics. The following *G. barbadense* varieties are the most commonly grown:

Main *G. barbadense* Varieties Grown in the World

Variety	Country	Staple Length	Micronaire	Strength	GOT%
Giza 45	Egypt	36.0	2.8	33.4	
Giza 70	Egypt	36.0	3.7	33.8	
Giza 75	Egypt	31.5	4.1	29.7	
Giza 80	Egypt	31.5	3.5	27.2	
Dendera	Egypt	29-30	3.0	25.7	
MCU 5	India	29-30	3.5	22-24	33.0
MCU 32	India	32-34	2.7-3.0	25-27	36.0
SUVIN	India	30-33	3.0	28-32	29.0
F 177	Israel	32.8	3.9	32.5	35.3
Pima 67	Morocco	36-38	3.9-4.6	78*	29.0
Tadla 16	Morocco	34.0	3.1-3.5	98*	32.5
Tanguis	Peru	29.30.2	5.7-6.0	86-88*	
Pima	Peru	38.0	3.3-3.9	92-95*	
Del Cerro	Peru	33-36.5	3.3-3.8	92-95*	
Barakat	Sudan	34.2	3.8	27.9	
Barakat 90	Sudan	33.0	3.8	27.9	
Shambat	Sudan	32.1	3.8	24.0	
Del Cerro	Turkey	34-35.8	3.9-4.4	105-120*	
9871-1	Turkmenistan	31.8-32.6	3.3-3.4	98-110*	
Asch	Turkmenistan	31.8-32.6	3.3-3.4	98-110*	
Pima S7	USA	35-38	3.5-4.9	95-120*	
Pima S6	USA	35-36.5	3.5-4.9	95-115*	
C-6037	Uzbekistan	33.0	NA	35.5	31-32
9883-E	Uzbekistan	33.3	NA	33-34	32-32.5
Karshee	Uzbekistan	31.4	NA	32.2	32-33

*Thousand pounds per square inch

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Micronaire: Fineness and Maturity

Fiber maturity has a significant impact on yarn and fabric quality. Fiber maturity and fineness are usually measured by breeders in terms of micronaire. Varieties are selected or rejected based on micronaire value in addition to staple length and strength. The use of micronaire in evaluating cotton fiber does not allow for distinction between fiber fineness and maturity. Experienced breeders can distinguish different micronaire cottons from the feel of cotton in the field. High micronaire, which is usually a decision making point in selecting or rejecting a new breeding line, may result from high maturity, a desirable quality, or from a coarse fiber, an undesirable fiber quality. Similarly, low micronaire may result from immature fibers (undesirable) or finer fiber surface (desirable in many spinning applications). Objective separate measurements of fiber fineness and maturity that are fast, accurate and consistent would allow for a systematic means of avoiding these problems.

Micronaire, like length and strength, is a widely accepted fiber quality. Micronaire is a measurement of fiber mass and is an indirectly determined by air flow, as resistance to air flow through a bundle of fibers varies in proportion to the surface area of the fibers. It is not a very precise measurement of the fiber properties, but, as the results can be repeated with a high degree of confidence, it is one of the most popular and generally accepted characteristics of cotton. Micronaire is often used incorrectly to assess cotton fineness, although other promising fiber fineness testing methods are available. With the increase in spinning speeds, the importance of micronaire (representing fineness and maturity) has also increased. As seen from the table below, high speed rotor and air jet spinning requires finer and more mature cotton compared with ring spinning.

Importance of Fiber Properties for Different Spinning Systems

Rank	Ring	Rotor	Air Jet
1	Length	Strength	Length
2	Strength	Micronaire	Micronaire
3	Micronaire	Length	Strength

For efficient and smooth spinning in the case of ring spinning, micronaire must be in the range of 3.5 to 5.0 and maturity not less than 80%. Rotor or open-end spinning ideally requires cottons with maximum 4.0 micronaire and a minimum of 70% maturity. Within a cotton of any specific group, i.e., upland, extra-fine or short staples (*G. arboreum* and *G. herbaceum*), maturity is the major source of differences in micronaire value.

Fineness can be directly measured under a microscope as the mean diameter of a number of fibers in a cross section, but the secondary cell wall is so variedly developed in different fibers that immature fibers show drastically irregular shapes. Thus, a common measurement of fineness is the mean fiber weight per unit length. A bundle of fibers is held in clamps of known length, protruding ends are cut and fibers counted and weighed to calculate the weight of fiber per unit length. The Suter-Webb method also works on the same principle. Measurements are in micrograms per inch, micrograms per centimeter or converted to tex units of linear density as millitex, or micrograms per meter. These methods are rarely used, however, due to the speed and reliability of micronaire measurement on the air flow principle. Misleading results can result, as it is known that immature fibers weigh less and offer less resistance to air, thus lowering the micronaire value regardless of fineness. Thus, there are convincing reasons to measure fineness and maturity separately.

Effects of Immature Fibers

As long as the fineness value is within appropriate limits, more mature fibers are desirable. The problem in the industry is not high maturity but low maturity which results in complex problems, especially during spinning and dyeing. Immature fibers have a higher tendency to entangle with other fibers and form neps. Clotting of immature fibers starts in the picking process and continues up to yarn formation. Immature fibers not only form more neps and produce weaker yarn but also result in a larger number of sticky points if sugars are present. The immature fibers responsible for forming neps result in formation of uneven spots in the yarn and white specks on colored/dyed fabrics.

Factors Affecting Maturity

Cotton fibers are comprised of two walls called primary and secondary walls. The primary wall is comprised of cellulose but forms only 0.3% of the normal fiber weight. It does not contribute much to fiber strength but, along with the cuticle, has a significant role in fiber qualities such as dyeing, finishing, wettability, reactivity and attack by microorganisms. The secondary wall consists of cellulose deposited in the shape of tiny threads called “fibrils.” In fibers of normal maturity, the secondary wall is about 90% of the total weight of the fiber. It determines dye and moisture absorption. The amount of cellulose in the formation of the secondary wall or the degree of wall thickening primarily determines fiber maturity and strength.

Micronaire, fineness and maturity are primarily varietal characters but are greatly influenced by the environment. Growing conditions and quantity and time of input applications have a significant effect on fiber maturity. Undesirably high doses of nitrogenous fertilizers lower micronaire value and often affect the maturity ratio. Bolls formed under low temperatures, at the end of the growing season, usually result in immature fibers. Maturity is greatly influenced by the time of application of defoliants. Albers et al (1994) applied defoliants at various stages of crop maturity for three years and intentionally reduced the growing seasons. Cotton harvested from various treatments was evaluated for fiber characteristics including maturity. The only fiber parameter affected by early defoliation was micronaire. During 1991 and 1993, because of warmer conditions, delayed defoliation enhanced micronaire value. In the case of effective early control during 1992, micronaire value was reduced.

Vigil et al (1991) studied the effect of drought under greenhouse conditions on secondary wall formation (30-50 days after anthesis). They observed that drought conditions lowered micronaire value to 2.0 as against 5.0 in case of no drought.

Pettigrew (1994) tested three varieties under a variety of environmental conditions including shaded vs non-shaded plots. He observed that shaded plots gave 20% less yield due to fewer bolls. Strength was reduced by 3%, length by 2% and micronaire was reduced by 7% in the shaded plots over non-shaded plots.

Maturity Measurement

Two old methods are still in use to measure fiber maturity. Causticaire is the oldest method for measuring fiber maturity. Dead and immature fibers treated with caustic soda do not show proper swelling as in mature fibers. Treating cotton samples with caustic soda and waiting for a swelling reaction is a slow process, and the causticaire method does not measure the maturity ratio consistently, especially towards the extremes. The Arealometer was a machine used as a reference method prior to 1992. Its use is limited because of small specimen size and relative scarcity of the machine. Today, the only officially recommended reference method is the IIC/Shirley Fineness and Maturity Tester (FMT). Various other machines (AFIS, etc.) are in development, but none of them meets the requirements of the industry yet.

Pellow et al (1994) compared Arealometer, FMT and AFIS L&D to see if they could be used to distinguish differences in fineness and maturity. The Arealometer values for linear density were converted to correspond to fineness from the FMT in millitex (g/m). FMT millitex and AFIS L&D measurement of diameter were converted into perimeter to correspond to the Arealometer perimeter readings. They used cottons which could be separated into fineness and maturity groups and found that correlations among various instruments were good. They concluded that any of the three instruments could be used to detect differences of practical significance in fineness and maturity if enough replications are included in the test. They also observed that the lack of a standard method was a major difficulty in correlating values from various instruments. According to Pellow, image analysis of fiber cross sections may provide such a standard.

Ghosh (1994) reviewed the practical aspect of maturity measurement using the near-infrared spectroscopy method (NIR). At an early stage of NIR development, a commercial spectrophotometer was used. First, a scanning monochromat was used to identify spectral regions that are more sensitive to maturity changes. Then, a fixed filter instrument was utilized to develop a prediction model by correlating spectral data to causticaire values of the calibration set samples. A wide range of cotton samples was used to calibrate the machine, but, when calibrated cotton samples were used, it gave values equivalent to the causticaire method. Because causticaire maturity is considered biased by fiber fineness, at the second stage, the model was developed against FMT values. A wide range of samples characterized on the NIR spectrophotometer using a modified regression equation showed a strong correlation between the two measurements ($r = 0.94$). The NIR calibration curve was observed to be slightly skewed when the maturity value exceeded 85%; for instance, maturity measurement by FMT was difficult for fine cottons having 92% or higher maturity values. Fine cotton maturity measurement by FMT also did not correlate with microscopic maturity. The NIR prediction method was further modified using microscopic maturity values; once again, a strong correlation ($r = 0.97$)

was seen for value and dye uptake. Microscopic maturity is calculated from fiber cross-sectional wall area and wall thickness.

Maturity of Cotton from Different Growth Regions

Cotton Type	Microscopic Maturity	Near-IR Maturity
Pima	0.648	78.0
Israeli HQ	0.602	77.1
Russian PV2	0.610	75.1
Sudan X62 B	0.545	70.2
Pakistani	0.516	73.9
Sudan GB	0.495	70.4
India (Suvin)	0.493	68.1
Turkish	0.473	71.9
Sudan DG 6B	0.303	64.2

$r = 0.90$

After developing a satisfactory prediction model on a laboratory spectrophotometer, an HVI NIR maturity tester was designed. The prototype HVI NIR exhibited gradually increasing dye uptake with maturity as seen below.

Cotton Fiber Dye Uptake

Grade	Near-IR Maturity	Average Dye Uptake (K/S)	% Darker
Immature	70 or less	3.0230	
Low maturity	71-73	3.2458	7.4
Average maturity	74-79	3.4993	15.5
Mature	80 or greater	4.2200	39.6

Ghosh (1994) observed that accurate characterization of standards, sample presentation and instrument-to-instrument consistency were very critical in transferring calibration from a laboratory instrument to HVI-NIR instrument.

The fundamental measurement of fineness is the fiber's cross-sectional perimeter and measurement of maturity is the degree of fiber wall thickness relative to perimeter. Mature and fine cottons are ideal for today's high speed spinning. Cellulose in cotton fiber rather than any other chemical constituent is a cause of the correlation between wall thickness and NIR measurements. Experiments in 1982 showed that near-infrared reflectance spectroscopy (NIRS) can alone be used as an indicator of fineness and maturity.

The best reference method is the one based on image analysis of fiber cross sections. Although good progress has been made, there are a number of problems associated with image analysis of cross sections, including the lack of physical cross reference standards on which to base new instrument readings and an insufficient number of cross-sections to develop reliable data.

Earlier FMT models (1 and 1a) gave good results compared with FMT model 2. If NIR calibration is based on earlier models of FMT, better correlation can be found. Original NIR calibration was based on causticaire, but now it is based on an image analysis system made on only a few hundred cross sections on about 20 samples. According to Thibodeaux (1994), thousands of measurements are needed on samples representing the full range of variation in fineness and maturity. The latest FMT device, “Micromat,” is more reliable.

Dye Test in Fabrics

Another aspect of maturity is the measurement of immature neps which result in white specks in plain-dyed fabrics. Efforts have been made to explore image analysis techniques to detect and count the white specks. The work done on this line by Watson (1994) in the USA has shown that it is possible to count the number and measure the size of white specks with the help of a monochrome camera. The results have a high degree of reproducibility. However, when a very low micronaire cotton is used in spinning, difficulties are faced in dyeing the fabric and, accordingly, counting the white specks is impossible. Experiments have also been conducted with raw cotton.

ITMF Working Group on Maturity

The ITMF International Committee on Cotton Testing Methods has a Working Group on Maturity charged with the responsibility of bringing harmony among testing methods and recommending reference methods. The group has already recommended the IIC/Shirley Fineness and Maturity Tester (FMT3) as a reference method for estimation of average maturity. The group feels that no reliable method is presently available to evaluate the distribution of maturity or the proportion of those dead fibers which ultimately result in white specks in the dyed fabrics. Image analysis techniques are considered to have promise and, in the future, NIR and AFIS may be recommended as reference methods. The electromagnetic reflectance approach also appears to hold much promise for the future of cotton quality assessments. The availability of reference standards, preparation of high quality cross-sections for image analysis and the need for a large number of fiber sections are areas of critical importance in the future. The Working Group meets every other year to review the work done in their field and also outline the work plan for the next two years. The next meeting is scheduled for March 1996.

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Short Notes

- **Current Tendencies in Cotton Research**
  In Colombia, most farmers are associated with associations/ societies which are responsible for procuring inputs, marketing cotton and providing technical advice. The Confederación Colombiana del Algodón -CONALGODON (Colombian Federation for Cotton), a federation of associations representing about 70% of the cotton farmers in Colombia, organized a two-day National Cotton Forum January 26-27, 1995, in Bogotá, Colombia. 250 people from various sectors, including growers, consultants, researchers, associations, traders, spinners and government authorities responsible for providing research and extension services and credit to growers, participated in the forum which reiterated the need to strengthen research and to improve credit to growers, in addition to improving the marketing of cotton for a better return to growers.

  At the forum, Dr. M. Rafiq Chaudhry, Head of the Technical Information Section of the ICAC Secretariat, reviewed Current Tendencies in Cotton Research in the World. In reviewing current programs in biotechnology to develop cottons resistant to herbicides and lepidopteran insects, he said, it was likely that in the future

- Proteins toxic to other insects, sucking insects as well as bollworms, will be identified and incorporated into commercial varieties.
- Multiple resistance, the result of incorporating more than one resistant gene, will be available to farmers. More than one resistant gene at the same time will offer stronger and more reliable resistance and delay the process of development of resistance to Bt cotton by any insect.
- Transgenic cotton having genes resistant to a variety of insects will be available. It is also possible that a cotton variety will carry drought tolerance, insect resistance and other induced characters at the same time.
- Environmental contamination and the cost of cotton production will decrease.
- Colored cottons other than brown and green will be developed.

- Genetic or molecular manipulation of hormones related to the length of the fiber during its formation will contribute to producing more uniform and longer staple length and stronger cotton.
- Identification of genes resistant to adverse growing conditions like drought and soil salinity and their incorporation into new varieties will have a direct impact on the productivity of the plant.
- There will be improvement in the quality of proteins and oil in cotton-seed.
- Transgenic cotton resistant to viruses will be developed.

(A complete copy of his address is available in English from the ICAC Secretariat.)

- **Regulations on Plant-Pesticides in the USA**

One of the uses of biotechnology is to create a self-dependent defense mechanism within the plant to produce chemicals injurious to pests. Such chemicals inhibit multiplication of pest species within a commercial crop. The Environmental Protection Agency of the USA has proposed a number of actions to regulate plant materials to be used as novel insecticides. Novel pesticidal substances introduced into the plant to enhance its defense mechanism and the genetic material which required these substances have been designated as plant-pesticides and will be regulated under the proposed regulations. The proposed regulations will address plant-pesticides and not the plants themselves. The proposed program will ensure the safety of food and safeguard the environment but not restrict the use of self defense mechanisms which have great potential to reduce the use of toxic pesticide chemicals. Scientific developments to introduce deliberately into plants genetic traits to produce pesticide substances from many sources will continue to be utilized. The following three categories will be exempted from the proposed regulations:

- The plant-pesticides derived from close relatives, i.e., chemicals extracted from one variety of cotton and inducted into another variety of cotton.
- Those plant-pesticides which do not have or will not have a harmful effect on the non-target organisms.

- Coat proteins from plant viruses when produced in plants for virus-coat protein mediated resistance. (Source: *Biotech Reporter*, December 1994, Freiberg Publishing Company, 2302 W. 1st Street, Cedar Falls, IA 50613, USA)

- ***Helicoverpa* in China (Mainland)**
  For the third year, bollworm damage reduced cotton production significantly in China (Mainland) during 1994/95. The behavior of the American bollworm, *Helicoverpa armigera*, has significantly changed over a period of time, particularly in the North region during the 1980s. During the 1950s, aphids, spider mites and pink bollworm were major pests. Four generations of *Helicoverpa armigera* existed on cotton, but there was hardly a need for spraying against *Helicoverpa armigera*. During the 1960s and 1970s, the 2nd generation caused economic losses in yield and the 3rd and 4th generations appeared on cotton more frequently. During the 1980s, the 2nd, 3rd and 4th generations caused serious losses in yield. During the early 1990s, a 5th generation also appeared on cotton at the end of the crop, and insect pressure on the cotton plant further increased causing heavy losses in production. *Helicoverpa armigera* egg counts in the middle to the end of June, at the 2nd generation stage in the Shandong

province, showed that the average number of eggs per 100 plants increased from 200-300 in the 1950s to 925, 1351 and 2000 during the 1960s, 1970s and 1980s, respectively. Now, *Helicoverpa armigera* is the number one pest of cotton in China (Mainland).

Damage due to bollworms was lower during 1994 compared with 1992 and 1993. The fourth generation, recorded at the highest level than ever before, was mainly responsible for production losses during 1994. The reason for low densities of the 1st, 2nd and 3rd generations was the below-freezing mean temperature (-4.1° C which is lower by 7.4° C compared with normal) in the month of November 1993. Low mean temperature, coupled with high soil moisture, depressed the population of diapausing pupae. Rains at the peak fruit formation stage are also said to have reduced losses from the 3rd generation. *Helicoverpa armigera* has already shown high resistance to a group of insecticides particularly in the North.

The Government of China (Mainland) launched a project "Strategies and Tactics for Reducing Cotton Bollworm Disaster" in 1993 to control the situation. The project was extended to 100,000 ha in Shandong province during 1994. The key components of the program are as follows:

- Wheat is sprayed to control aphids and, at the same time, to kill the 1st generation *Helicoverpa armigera*.
- Second and third generations are controlled through moth trapping with sex pheromones and spraying with Bt insecticides.
- Fourth and fifth generations are controlled with two or three chemical insecticides.

It is estimated that, on average, in the highly infested area of Shandong, 1.13 pupae per square meter go into diapause at the end of the cotton growing season. This number is considered high and indicates that the insect will remain a major threat for cotton production in China (Mainland) for many years. An integrated approach including the problem of resistance management, suitable to the economic and agronomic conditions of the country needs to be followed each year to minimize the population density of the bollworm. (Source: Cotton Bollworm

Control in North China in 1994 by C. F. Sheng, 1995 *Proceedings of the Beltwide Cotton Conferences*, National Cotton Council of America, P. O. Box 12285, Memphis, TN 38182, USA)

- **Biotechnology News**
  The Patent and Trademark Office of the US Department of Commerce has completed the first stage of the reexamination of Agracetus, Inc.'s patent on cotton. Responding to a request made by the USDA, the patent office has now rejected the claims of Agracetus made in the application for the patent granted in October 1992. Agracetus claimed that its patent on cotton covered all transgenic cotton, no matter what methods or genes were used in the process of transformation. The broad spectrum patent caused an outcry among researchers and private companies who felt that the patent would impede research, possibly cause crop monopolies, negatively impact third world countries and result in loss of genetic diversity. In June 1994, the USDA and a law firm representing an unnamed client, submitted two petitions to the patent office for reconsideration of the broad spectrum patent. The patent office rejected the Agracetus claims because the development of transgenic cotton is prior art. Agracetus can counter-respond to the patent office and appeal to U.S.

Federal Courts. It may be up to two years before the issue is decided; the patent will remain valid during this period.

In the meantime, Agracetus, Inc. has received an award of US$ 1.1 million from the US Department of Commerce to develop transgenic cotton with biopolymers. Biopolymers are polyester-like compounds commonly produced by certain bacteria. Through genetic engineering it is possible to isolate the genes responsible for production of polymers from the bacteria and insert them into cotton. Agracetus had already demonstrated that one biopolymer, polyhydroxybutyrate, can be produced in cotton. It is expected that self production of biopolymers in the hollow centers (lumen) of fibers will improve appearance, enhance thermal characteristics, improve wrinkle resistance and reduce shrinkage and absorbency properties.

Transgenic cotton resistant to the herbicide bromoxynil and Lepidopteran insects at the same time will be tested under a variety of growing conditions during 1995 in the USA. Calgene, Inc., which plans to market its herbicide tolerant cotton (BXN) ----the first transgenic cotton to be grown on commercial scale---- for planting during 1995/96 season, has applied to the Environmental Protection Agency for a permit to test BXN and Bt cotton (tolerant to lepidopteran insects) in 12 states in the USA. Herbicide tolerance and resistance to a number of bollworms belonging to lepidopteran insects have been amalgamated in a Stoneville Pedigree Seed variety. (Source: *Biotech Reporter*, January 1995, Freiberg Publishing Company, 2302 W. 1st Street, Cedar Falls, IA 50613, USA)

- **Need for High Quality Fiber**
  At the 1995 Beltwide Cotton Conferences of the National Cotton Council of America, held in San Antonio, Texas, Mr. Chris Faeber, W. Schlafhorst AG & Company, Germany, presented a paper "Future Demands for Cotton Fiber Quality in the Textile Industry" emphasizing the need for improvement in quality characteristics. He said, because of technological advances in processing efficiency, higher quality raw material is needed to meet end-product quality requirements. In ring spinning, practical spindle speed has increased from 12,000 rpm in the early 1970s to 20,000 rpm at the present time. It is expected that, by the year 2000, ring spinning spindle speed will increase to 26,000 rpm. Rotor speed has risen from 25,000 rpm at the time inception of this system in 1967 to 130,000 rpm in

the early 1990s. At an average annual increase of 4,400 rpm in rotor spinning, it is anticipated that, by the year 2000, rotor speed will increase to 170,000 rpm. Knitting and weaving have also experienced similar technological developments. High speed spinning exerts greater spinning tension thus demanding finer, stronger and more uniform fibers.

Dyeing and finishing have also seen dramatic developments. In order to develop wrinkle-resistance, cotton fabric is treated with resin and oven-cured for some time, processes which reduce the strength of the finished fiber by 30-50%. Higher strength cotton and cotton yarn are needed to compensate for the loss in fabric strength occurring during finishing.

Holding down the cost of raw material is also important to the textile industry. Raw material accounts for about 40% of the total cost of a rotor spun yarn and is the largest single cost factor. (Source: 1995 *Proceedings of the Beltwide Cotton Conferences*, National Cotton Council of America, P. O. Box 12285, Memphis, TN 38182, USA)

- **An Alternate Weed Control Method**

  Fire has two uses in cotton cultivation. First, flames are used to remove fuzz from the seed coat for easy flow and uniform distribution of seeds during planting. Secondly, flames can be used to control weeds in cotton fields. Flame cultivation was tried as an alternative weed control method many years ago but did not prove economical because of the high cost of diesel oil. A paper was presented at the 1995 Beltwide Cotton Conferences on using low pressure gas instead of diesel oil to control weeds. Two applications provide effective control for optimum yield. The first treatment is applied when the stem reaches 5.75 mm in diameter. The second application is applied when needed. Burners are kept at least 20-25 cm away from the plants. The author stated that flame cultivation has the following advantages:

  - Compared with herbicide use, it is economical to use gas flames to kill weeds.
  - It is more environmentally safe to use the flame method compared with herbicide spraying and there is no need to observe a re-entry period into the field.

- Flame cultivation provides better control of perennial weeds.
- There is no fear of resistance development.

Disadvantages include the occasional need for more than two applications, the lack of a residual effect, hazards of pressured gas, the need to refill the tank and the potential threat of fire.