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Introduction

This issue of *THE ICAC RECORDER* presents a review by Professor Dick Davis of New Mexico State University, USA, of an FAO Regional Expert Consultation on Hybrid Cotton Production which was held in Nagpur, India, October 21 to 25, 1990. The Meeting was organized by Dr. R. B. Singh of the FAO Regional Office in Bangkok, Thailand, and hosted in Nagpur at the Central Institute for Cotton Research (CICR) of the Indian Council of Agricultural Research (ICAR). The views expressed in the review are those of Professor Davis. An official report of the meeting is available from Dr. R., B. Singh, FAO Regional Office for Asia and the Pacific, Maliwan Mansion, Phra Atit Rd., Bangkok 2, Thailand. Professor Davis attended the consultation as one of three ICAC-sponsored experts from outside the Asian region.

Also included are two papers which were presented at a Cotton Forum held in Santa Marta, Colombia, August 30 to September 1, 1990, to celebrate the Tenth Anniversary of CONALGODON. The Secretariat of ICAC assisted CONALGODON, a confederation of associations and cooperatives of cotton farmers in Colombia, with the planning for the forum, which was held in conjunction with an exposition of machinery and agricultural inputs.

Everett Backe's paper reviews the history and current state of progress in using high volume instruments (HVI) to test cotton fiber samples for selected physical properties both rapidly and accurately. Beginning with the 1991/92 crop, the harvest of which will begin in July 1991, all U.S. Government classing of upland cotton will be by HVI. John Price's paper presents the spinner's viewpoint regarding desirable fiber properties, given today's technology in the production of yarn.

Other papers presented at the Forum include "High Quality Cottons" by Kamal El Zik of Texas A&M University (USA); "Cotton Response to Subsoiling and Fertilizer Placement" by Gordon R. Tupper of the Delta Branch Experiment Station, Stoneville, MS (USA); "Plant Mapping and Managing Modern Cultivars of Cotton" by Johnie N. Jenkins, USDA Crop Science Research Laboratory, Mississippi State, MS (USA); "Methods and Techniques in Efficient Irrigation of Cotton" by Jeffrey Silvertooth, University of Arizona, Tucson, AZ (USA); "Cotton Integrated Pest Management: A Focus on the Boll Weevil” by R. E. Frisbie of Texas A&M University, College Station, TX (USA); and “Weed Control in Cotton" by R. M. Hayes, West Tennessee Experiment Station, Jackson, TN (USA). The complete proceedings of the Forum will be published at a later date in Spanish by CONALGODON, Carrera 7[a], No. 33-42, Piso 6, Bogota, Colombia, Fax 287-6820.

FAO - ICAR Regional Expert Consultation on Hybrid Cotton Production

CICR, Nagpur, India, October 21-25,1990

A Special Report to the International Cotton Advisory Committee by Professor Dick D. Davis, Department of Agronomy and Horticulture, New Mexico State University, Las Cruces, New Mexico 88003, USA

Dr. R. B. Singh shaped the meeting into the form of an “expert consult-ation" rather than a symposium, and exerted his influence to urge the par-ticipants to avoid lingering on past achievements, and to make a realistic evaluation of the world situation in the development of hybrid cotton.

Tour of Rural India

The first and last days of the meeting were devoted to extended field tours. These were fatiguing, but gave a perspective that symposia can never pro-vide. As might have been expected, a random panorama of the countryside revealed fields at all levels of management, particularly with reference to tillage and weed control. Closer inspection of selected fields revealed considerable insect damage, and ample room for improvement in management techniques. We can only imagine what it was like when, only a few years ago according to published data, yields were much lower. Seen from the bus, nearly all of the fields seemed to be planted in the 90 cm X 60cm planting pattern advocated by the Central Institute of Cotton Research (CICR), indicating that extension outreach has permeated through the countryside to a considerable extent.

A highlight of the first day tour was a visit to a remote village where Gandhi’s "Free India" movement took shape. I was impressed, as our Indian hosts intended we should be, by the way in which such great events could be shaped in such humble, even backward, surroundings. It was Gandhi’s maxim that men ought to make use of the resources that are available locally, and not rely upon resources and technology drawn from outside source. The Indian achievement with hybrid cotton is an ideal realization of Gandhi’s tenet.

Commercial Hybrid Production

The Indian Council of Agricultural Research went all out in hosting the delegates from other nations. Dr. R.S. Paroda, Deputy Director of ICAR, laid emphasis on the importance of cotton to the infrastructure of India in labor and commerce, and lauded the contribution of the Indian researchers who pioneered the development of hybrid cotton. Cotton has been an economic growth area for India that might serve as a model for other underdeveloped countries. India has the largest area planted to cotton of any country in the world. Now production continues to increase despite the fact that area is now declining slightly. The productivity growth rate is 3.7%, significantly above the population growth rate of 2.3%, underscoring the importance of cotton in raising the standard of living. Maharashtra state, where the meeting was being held, has the largest area of hybrid cotton in the world (2.7 million ha.) The government has recognized the importance of these developments by earmarking $120 million for hybrid cotton research. The American contribution of cytoplasmic and genetic male sterile technology was acknowledged as an example of the importance of international cooperation in making progress in productivity.

Dr. Basu, director of the CICR, noted that productivity had doubled in the last decade, and that hybrids now constitute over 28% of the nation’s 7.6 million ha. of cotton. These gains in productivity have enabled India to supply the domestic market and to move into the export market. Some 39 million labor units have been generated by hybrids. Despite the extremely low wages (15 rupees, slightly less than $1 per day), hybrid production has generated a source of income for rural women that previously did not exist, raising the standard of living in one of the most disadvantaged sectors of the economy. It is scarcely believable to Westerners that a 90 cent (U.S.) per day income could raise the standard of living, but having toured a large section of Maharashtra state, one can see how it could be a significant benefit to unemployed women in destitute rural families.

Dr. Bhale (India) emphasized how the "white revolution" of hybrid cotton has benefitted the small farmers in rainfed areas as contrasted to the "green revolution" in wheat which benefitted the more prosperous areas of the nation.

The success of hybrid cotton in India was given its impetus by the development of Hybrid 4 by Dr. Patel, who was given special recognition as the

"Father of Hybrid Cotton." His Hybrid 4 was a clear historical breakthrough in yield and fiber quality. Hybrid 4 spread to 200,000 ha. in 1973 and 2 million ha. by 1986, and despite the requirement for hand emasculation, is still a major variety today.

Mr. Patil (Akola) reported on the CICR production of hybrid cotton seed. Hybrid 4 is still being produced but is being phased out. CMS hybrids make possible a 10-fold reduction in pollination costs for hybrid cotton. It is anticipated that overall seed costs can be reduced from 170 to 120 rupees/kg, primarily due to the lower labor requirements. This will allow each producer to produce more seed, and hybrid acreage will be rapidly expanded.

China probably has the second largest area devoted to hybrids (2,000 ha., projected to increase to 20,000 ha. in 1991). Pakistan appears to be poised to move into hybrids. Dr. Zahoor reported heterosis of about 20% over the check, using seeding rates of about 2.5 kg/ha. Dr. Soomro confirmed that several hybrids have given 20% or more heterosis above the check. On the negative side, introduced CMS and restorer lines have not proven to be good parents. However, Dr. Chaudhry stated that there was a systematic scheme in place to exploit hybrids using genetic male sterile parents.

Hybrid Development in High Tech Nations

The most technologically advanced countries have not been able to make the requisite breakthrough in F1 hybrid seed production. Davis (USA) noted that under optimal cultural conditions, where yields were normally 1250 kg/ha. or more, it was hard to find hybrids that would give enough yield heterosis over the newest and best American pure line cultivars to justify the extra cost of F1 seed production. American labor costs nullify the hand-pollination option.

Soviet scientists reported that commercial production has been stymied due to the high cost of seed production. Only 150 ha. of hybrids were in production now, but this was expected to increase in the near future. The Soviets have shelved work on the cytoplasmic-genetic system of hybrid production due to inadequate fertility restoration. To an American, this is an indication of the long isolation of the communist world. Fertility restoration in interspecific hybrids was never a problem in America, and restoration of upland hybrids has been gradually improved over the years until now these are fully fertile also.

Hybrid Development in the Tropics

Cotton is a difficult crop in the humid tropical regions. Dr. Jinda of Thailand found interspecific hybrids *(G. hirsutum* X *G. barbadense)* to be high yielding, but too rank in growth habit. He is trying to transfer *G. barbadense* characteristics into hirsutum, rather than working for F1 hybrids. On the other hand, the Philippines and Vietnam appear to be moving toward hybrids for special applications. Dr. Cabangbang of the Philippines is seeking to develop a program for the use of hybrids in a sustainable agricultural regime.

Dr. Tho (Vietnam) reports that they have identified a high yielding interspecific hybrid. However, they have experienced severe insect problems in the Mekong Delta, a humid tropical region. Furthermore, blackarm has been very serious on interspecific hybrids. Hybrids are very useful in specialized applications as garden crops or as bund crops. Dr. Hasnam (Indonesia) expressed the view that F1 cotton hybrids are too expensive to produce because the labor cost is too high.

Prospects for Interspecific Hybrids

Lively discussion ensued about the merit of interspecific hybrids. Dr. Zahoor (Pakistan) asked if expanded interspecific hybrid research is not necessary for the continued commercial success of hybrids as a crop. Dr. Patel (India) raised the question of the neppiness of interspecific hybrids. Dr. Weaver (USA) replied with the prevailing American view that the problems inherent in interspecific hybrids, particularly immaturity and neppiness, probably rule out any extensive use of them as a commercial crop. Davis (USA) countered that a wide range of variability exists in interspecific hybrids for these properties, and that measured introgression of upland germplasm into the *G. barbadense* parent might be the means of providing a true solution for the problem. Drs. Basu and Sundaramurthy of India agreed that it was possible to reduce motes. However, no one indicated that the reduction of motes in species hybrids would be done without continued intensive research effort.

Northern India does not have hybrids at present, for reasons similar to those retarding development in the first world nations. Since yields there are already very high, it is difficult to develop hybrids that are significantly better. Also, the low seeding rates used in the rain belt are not acceptable in the intensive irrigated culture of the Punjab and N. Rajastan. However, Dr. Randhawa (Ludhiana, Punjab, India) reports that recent hybrids have shown a 10-20% increase above the checks, and feels that the next jump in productivity will likely be due to hybrids. This scenario is confirmed by Dr. M. Singh (New Delhi, India) who predicts interspecific hybrids for the Northern zone. He reports that very high yielding, early interspecific hybrids are being developed for N. India. The premium fiber quality of these hybrids may make them acceptable elsewhere.

Interspecific hybrid research, as elaborated by Dr. Katarki, has been extensively pursued in India. The Indian interspecifics are inferior to the best Egyptian cottons (Giza 45, Giza 70) and are only grown to a limited extent. Green seed fuzz and increased neps are major problems in interspecific hybrids. Motes seem to be the major source of neps. It was emphasized that breeders need to adhere to stricter standards for maturity and fiber strength, and more attention should be given to trash and seedcoat fragments in the lint. Seedcoat fragments may possibly be reduced by selecting for lower fiber attachment strength.

Mr. Akhmedov (USSR) reported that interspecific *hirsutum* X *barbadense* crosses have high heterosis for yield, which is related to boll number. Mr. Rahimjanov reported adequate levels of crossing when an unemasculated female was crossed with pollen collected from a red marker male and cooled overnight. Yield of the hybrid was almost 50% higher than the *G. barbadense* check. Mr. Simongulian reported that the parents 'Karshy' and 'Karshy 2' were excellent hybrid parents. Semidwarf hybrids gave the best performance. Although interspecific hybrids may yield more, Dr. El Gohary reported that Egypt is attempting to develop hybrids between *G. barbadense* strains. Davis (USA) is also devoting some effort toward *G. barbadense* hybrids.

Use of Male Sterility

India is considering the possibility of more expensive labor costs in the future. In this regard Dr. Patil demonstrated the various means of field production, contrasting hand emasculation with GMS and CMS lines. Already CMS lines show a 33% reduction of labor cost per kg of F1 seed.

Dr. Bhale opened the discussion on the relative merits of the two types of male sterility in hybrid production. He reported on hundreds of test hybrids produced by using genetic male steriles (GMS) and cytoplasmic male steriles (CMS), and found the CMS hybrids to be really handicapped in yield, possibly due to the restricted range of male parents used. This hypothesis is to be extensively tested this year. Bee pollination of hybrids is also being considered, and Dr. Shroff (Indore, India) reported on research findings in this area.

Dr. Mishra, Research Director for Maharashtra Hybrid Seed Company (MAHYCO), reported how GMS has been used since 1973. He confirmed Dr. Bhale's report that, on average, GMS hybrids were significantly superior to CMS hybrids. In spite of this, however, Mech 25 may possibly be the best of the new MAHYCO hybrids, so the controversy about the relative merits of GMS and CMS hybrids seems destined to continue for some time. MAHYCO has undertaken the massive effort of converting 900 lines to GMS and an additional 300 to CMS. Dr. Weaver (USA) advised developing countries to move into hybrids by making fertile X fertile crosses, and testing to find the best performing F2's. Then one parent of the elite crosses should be converted to GMS to facilitate hybrid production. He recommended use of the genes ms5 and ms6, noting that many Indian varieties already carry one of the loci, and give a 3:1 ratio in testcrosses. In this regard, it was noted that China reported an elite F2 hybrid with heterosis of 20%, and already had 2000 hectares in production.

Use of Germplasm Resources

Dr. Narayanan reported that the cotton research institute has about 7000 accessions of cotton germplasm, classified for about 65 useful characters. He estimates that another 6000 entries are needed in order to make the collection reasonably complete. About 20 CMS lines are now available for hybrid research.

There were two reports made that challenged conventional wisdom in cotton breeding. Breeding work with the wild germplasm is being conducted by Dr. Tayyab. He showed many exotic crosses at Akola, and demonstrated a wide array of flower colors, and reported exotic crosses with ginning percentages above 60% and resistance to bollworm. He advised the transfer of dominant markers into the best varieties and the subsequent conversion of these into CMS lines.

Dr. Rao of India presented a case to show that Asiatic (Desi) cottons were being replaced by American tetraploid or hybrids that were actually far inferior to them in yield stability and pest resistance. This was obviously a minority view, and not being familiar with the issue, I could not even comment on its merits.

However, it is probably true that, for several reasons, the Desi cottons are in danger of virtual extinction. At present it is very expensive to produce Desi hybrids, because of the lack of good male steriles and small boll size which drives up pollination expense. Because of their extreme resistance to stresses, including drought and pests, it is probably in the best interest of the nation to continue their improvement. Selections for improved staple length (27mm) have been reported, but hybridization research needs greater emphasis.

Role of Improved Management

Hybrids with improved yield potential require concurrent improved management. Although the details are beyond the scope of this report, it should be noted that attention is being given to many aspects of crop management in India, such as soil classification, water relations and plant diseases (particularly the perplexing malady called "new wilt" and insect management).

Several participants indicated strong interest in integrated pest management (IPM), and this concern was second only to means to increase crop yields. Dr. Sundaramurthy reported that IPM in cotton can reduce the number of insecticide applications with attendant reductions in environmental impact and costs. Cotton is in real difficulty in the Sudan, as acreage has been reduced by almost 50% in the last few years. Sticky cotton (due to whitefly) is the major problem, but fusarium wilt is also on the rise, and better resistance to blackarm is needed.

Chinese researchers feel confident that Pix treatment provides considerable protection against bollworm, an effect partially due to high gossypol. According to data presented by Dr. Cao (China), gossypol was 60-75%

higher in the treated squares, and bollworms were suppressed by 60-77%. Dr. Patel reported a hard carpel wall variant that had bollworm resistance. Scientists at Dharwad in southern India also reported that they had a strain with very hard carpel wall that was resistant to bollworm.

Dr. Patel sees the possibility of transferring insect resistance to high yielding cotton. This is a goal that is shared by most of the delegates. Its importance is underscored by the desperate plight of the Sudanese industry as reported by Dr. Fadlalla. There is at present no means of developing simultaneous resistance to attack by whitefly and jassid.

New Projects Engendered by the Meeting

Dr. Paroda asked why the USA did not have seed produced in India or another developing nation where labor costs were low. Davis responded that, in his opinion, this was primarily a regulatory problem, and that Americans would be open to using inexpensive seed produced elsewhere. Mr. Barwale, board chairman for MAHYCO, the largest private firm in India, commented that government policy had changed and that such arrangements can now be made. Dr. Paroda confirmed this statement, noting that the only exception would be restriction of export of a specific hybrid in short supply in India.

Dr. R. B. Singh (FAO, Bangkok) presented an excellent report of the proceedings which was adopted as official with minor discussion on the final afternoon of the meeting. This report is highly recommended to those who would like an independent report of events.

Dr. Singh suggested that in order to continue the excellent spirit of cooperation generated by the meeting, that the group might form an International Hybrid Cotton Association with a view toward future cooperative projects, meetings, and publications. FAO could serve as the umbrella organization and foster transfer of technology through a visiting scientist program.

There was a clear sentiment among the majority to form an association that was regional (Asian) rather than worldwide in scope, and this view was supported by Dr. Pineda (FAO, Rome).

In the ensuing discussion, India agreed to become the host country and to facilitate communication with at least minimal office staff, and coordinate the publication of a quarterly newsletter. At the same time it was made clear that contributions and cooperation from the USA and other countries outside the region would be welcome. Dr. A. K. Basu of CICR was named to serve as liaison for the group.

Summary

In conclusion, there are several pertinent points that should be reiterated and underscored.

(1) The Indian program has made a significant positive impact upon the national economy, and could serve as a model for other third world countries. Basic researchers, breeding researchers, developmental researchers, crop production researchers, and extension outreach personnel seem to be working together to continually expand and strengthen the hybrid cotton program. There were signs that the ties between state researchers and private industry were not as close and synergistic as their counterparts in the United States. Closer cooperation between the public and private segments of the industry should result in more rapid gains.

(2) One is impressed with the competence of the Asian scientists, even in those countries that have no traditional cotton industry. They will undoubtedly benefit from sharing experience and expertise with their colleagues if the proposed Asian Association becomes functional.

(3) Good rapport developed between scientists from the USSR and USA. However, the long isolation of the two groups was very evident, and neither group was aware of the major research initiatives of the other. A program to foster extended scientific visits between the two countries should be very productive.

(4) Apparently the regulatory mechanisms to allow for large scale seed exportation from India are now in place. We are aware that potential hybrid seed production in India has already been explored by at least one American firm. Probably the first target would be to produce fertile X fertile F1's in India that would be used to produce F2 hybrid planting seed in the USA. However, there is an outside chance that cytoplasmic genetic systems could be used to produce F1 planting seed directly.

(5) The establishment of an Asian Cotton Association and the provision for a regular newsletter should benefit the entire region, but particularly the smaller nations that have only a small research staff.

(6) The western nations might do well to explore Indian germplasm. Several Indian researchers report exotic crosses with significant resistance of *Lepidopteran* species. The collection and crosses of Dr. Tayyab at Akola are a case in point. Only a few minutes were available for inspection of his array of interesting exotic crosses. A postdoctorate grant to study this largely uncatalogued group of material could prove very profitable to all concerned.

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Cotton Property Classifications Past, Present and Future

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A little over 20 years ago, the idea of rapidly and accurately testing cotton fiber samples for selected physical properties became a reality when the first high-volume test instrument (HVI) was delivered by Motion Control of Dallas, Texas to Texas Tech University in Lubbock. Six months later two units were delivered to Plains Cotton Co-op, also located in Lubbock. From this beginning, interest has been such that by early 1990, there were over 400 high volume systems, or various components of them located worldwide. Over 200 of these units are being operated in the United States. Included in the 400 or so systems are elements from another instrument builder besides Motion Control, i.e. Uster/Spinlab of Knoxville, Tennessee. Both companies are extremely active in the HVI arena, and both hold excellent reputations as builders of the equipment.

Replacing stand alone instruments, which were quite slow and very operator sensitive, with essentially one unit for quickly determining such properties as length, strength, elongation, fineness, color, etc. made a lot of people nervous. Some felt that the accuracy of measurement would suffer tremendously, but time has shown that the accuracy of the results from HVI measurements are as good as, or even better in some cases, than stand alone instruments. Couple this with a speed in excess of 150 times faster, and HVI very quickly looked attractive and began to assemble its followers. These disciples of HVI are strongest in the United States Department of Agriculture, but a great number of adherents can be found among producers, ginners, merchants, shippers, and spinners. One of the main thrusts behind its acceptance is the notion of knowing more about the fiber one is buying. This means that the producer is rewarded for growing good quality cotton and having it ginned in such a way as to preserve its quality, and the spinner purchases the fiber on his needed fiber properties, and handles the bales in a manner such that consistent running conditions result, with predictable yarn quality. Optimization of bale laydowns in terms of quality and cost is certainly attractive to spinners.

Most recently, new technologies in textile processing, for example the move to shorter cleaning lines, and open-end and air jet spinning, have made HVI information a necessity if maximum use is to be made of these expensive machines to produce quality products at the lowest possible cost. Bale selection to accomplish this is only feasible through HVI.

It is believed that, in the final analysis, if a company is to survive in today's competitive textile market, the new technologies in manufacturing must be employed, and HVI must be used to maximize the quality of the products.

High volume instrumentation (HVI) for testing staple fiber was first thought to be feasible in the middle 1960s. Twenty years later approximately 300,000 bales of cotton were tested in one of the United States Department of Agriculture's classing offices. In 1989, nearly 50 percent of the 15.4 million bale cotton crop was tested at a number of classing offices, with classing of the entire crop by HVI scheduled to being in 1991.

Prior to the successful development of HVI, textile manufacturers had relatively little information about the actual cotton fiber they were using. Cotton was mainly evaluated using subjective techniques by a classer. In the

1940s and 50s a number of instruments were developed to determine some of the more important, at that time, physical properties, e.g. the Fibrograph for length, the Micronaire for fineness, and the Pressley for strength. Each of these instruments contributed valuable information about the sample being tested, but the time required to perform these tests was such that only a small percentage of the total crop to be consumed was tested.

In the early days of stand alone instruments and testing as much of their incoming cotton as practical, some plants still experienced difficulty in maintaining satisfactory inplant performance. Whenever these unfortunate experiences happened, supervision usually pointed the finger at the cotton buyer inferring that he did a less than acceptable job of selecting cottons that would perform satisfactorily. Now, with HVI, it is possible to accurately and rapidly evaluate a number of properties of a cotton sample in less than one minute, providing many advantages over the evaluation procedures using stand alone instruments. After calibration of the instrument and proper conditioning of the samples to be tested, two things that are extremely important if reliable information is to be expected, it is common to test approximately 100 samples an hour, with each sample representing a bale. The tests performed by an HVI system, whether it be a system manufactured by Uster/Spinlab in Knoxville, Tennessee or Motion Control in Dallas, Texas are: micronaire fineness, color, trash, upper half mean length, length uniformity, strength, and elongation.

As I mentioned previously, early on in HVI there were many who worried about the reliability of the test data. Let's take a look at where we are with respect to the individual measurements from HVI. For micronaire, the actual measurement is the same as it has been since it first became part of the cotton classing system almost 30 years ago. The only thing that HVI has done to this test is to improve its repeatability and the ease of performing the test by eliminating the necessity of having to accurately weigh the test specimen prior to testing. Microcomputers are used to adjust the micronaire reading for a range of test specimen sizes. It has been found that for a bale of cotton that reads 4.2 micronaire on an HVI system, over 68 percent of the readings will be between 4.1 and 4.3, and 95 percent between 4.0 and 4.4. With only one or two tests per bale, a very precise measurement of average micronaire can be obtained. In terms of reproduceability, the USDA, in a 77,000-bale test, found that HVI measurements of micronaire performed in different laboratories agreed with each other within 0.1 micronaire on 77 percent of the bales checked. In research work done by various institutions, including the Institute of Textile Technology, micronaire has been found to be influenced by both fiber fineness and fiber maturity. Dr. Preston Sasser of Cotton Incorporated in the United States has mentioned many times that for a given growing area, the cotton variety generally sets the fiber fineness, and the environmental factors control or influence the fiber maturity. Thus, within a growing area the micronaire value is usually closely related to the maturity value. However, on an international scale, it cannot be known from the micronaire readings alone if cottons with different micronaire are of different fineness, or if they have different maturity levels.

Some textile companies in the U.S. believe that the micronaire fineness of United States cotton should decrease so that yarns of higher quality, primarily in strength, can be obtained more efficiently on the newer spinning technologies, that is open-end and airjet. For the record, there is a small downward trend in the average micronaire value of the United States crop, so evidently the producers are reacting to the spinner’s needs.

Length, as measured by HVI, is in terms of upper-half-mean length. This is defined as the average or mean length of the longest one-half of the fibers in the test sample. Even though the two popular HVI systems use a different means and procedure for preparing the sample for length testing, they both comb to straighten and parallel the fibers to be tested, and then brush them to remove crimp. The instruments then scan the fiber beard to determine the length information. Each instrument is calibrated to read in staple length, for example a one-inch USDA staple standard would read 1.00 inch or 25.4 millimeters on the instrument.

Again, referring to Dr. Preston Sasser of Cotton Incorporated, he has stated that the length obtained from the HVI instrument is more repeatable than the staple length as determination by a classer. In a comparison test, the instrument obtained the same length determination 44% of the time while the classer repeated his determination only 19% of the time. Also, the instrument repeated to 1/32 inch on 76% of the samples while the classer agreed on 71 % of the samples to within 1/32 inch.

The precision of the HVI length measurement has been improved over the last few years. Taking the same bale of cotton used in the micronaire example and repeatedly measuring length with an HVI system, over 68 percent of the measurements will be in a range of only 1/32nd of an inch. Ninety-five percent of the individual readings will be within ± 1/32nd of an inch of the bale average. In the 77,000 USDA bale test mentioned earlier, the length readings were repeated within 0.02 inches on 71% of the bales.

While the HVI systems are looking at the upper-half-mean length, they also give an indication, at least in the eyes of some, of fiber length distribution. This measurement is called the Length Uniformity Index and is a calculated number obtained by dividing the mean length by the upper-half-mean length and expressing it as a percentage. Dr. Sasser points out that a reading of 80 is considered average length uniformity. Higher numbers equate to better length uniformity and lower numbers to poorer length uniformity. A cotton with a length uniformity index of 83 or above is considered to have very good length uniformity and low short fiber content, while a cotton with a length uniformity index below 78 is considered to have poor length uniformity and high short fiber content.

Repeated measurements on a single bale of cotton show the length uniformity index measurement to have good repeatability, but relatively low precision. About two-thirds of the measurements occur within one unit of length uniformity. Thus a bale with an average length uniformity index of 80 would have 68 percent of the readings occurring between 79 and 81, and 95% of the readings occurring between 78 and 82. This doesn't seem too bad until one considers that most United States upland cottons will have a length uniformity reading within a relatively narrow range, 75 and 85. In the USDA test of 77,000 bales, the results showed that different laboratories agreed only 68% of the time to within one length uniformity index unit.

Strength measurements made by HVI systems differ from the traditional Pressley and Stelometer in a number of ways. First, the sample preparation is quite different. In the traditional tests, a sample of fiber is selected by an operator/technician, combed, and aligned in a set of law clamps that fit into the tester itself. For the HVI, the fibers to be tested are randomly selected and automatically prepared for testing. In the HVI, the clamped specimen is combed and brushed to remove loose fibers and crimp.

A second difference is that in the traditional method the mass of the broken fibers is determined by weighing. In the HVI systems, the mass is obtained by measuring light absorption or resistance to air flow. In the HVI, the mass is obtained at the exact point that the sample will break.

A third difference is the testing speed. The HVI operates at a speed ten times faster than the stand alone instruments for measuring fiber strength.

Because of these three differences, HVI test systems show grams per tex data 3 to 5 percent higher than the traditional testers, and it has been found that some varieties produce differences of up to 8 percent higher on HVI.

Of all the measurements that can be made on HVI systems, strength is the least precise. When performing repeated tests on a single bale, it has been found that 68 percent of the values obtained will be within one gram per tex of the bale average. Ninety-five percent of the time the individual readings will be within two grams per tex of the bale average. This relatively high range has caused HVI users to increase the number of tests per sample, most use between 2 and 4, and average the results. When they do this within a laboratory, the averages repeat to within one gram per tex approximately 80 percent of the time. Between laboratories, agreement on the same bale samples is within one gram per tex only 55 percent of the time. Most of the discrepancy between laboratories is related to the difficulty laboratories have in maintaining a constant relative humidity. Cotton Incorporated has found that a three percentage point change in laboratory relative humidity about an average 65 percent can cause a one gram per tex shift in fiber strength.

Cotton color, which is a measure of the grayness and yellowness of a fiber has long been measured, but mostly shunned because of a lack of understanding of what it affects. Nevertheless, both HVI systems incorporate its measurement. In terms of color repeatability on a single bale of cotton, 68 percent of the reflectance or grayness readings will be within 0.5 units, and 95 percent of the readings within 1.0 unit. For yellowness these values become within 1/4 of a unit 68 percent of the time, and 1/2 of a unit 95 percent of the time.

In the USDA test of 77,000 bales, the measurement of color was the most repeatable. Eighty-seven percent of the bales repeated within one grayness unit, and 85 percent within one-half of a yellowness unit.

Both of the HVI systems available to the world today have the capability of measuring trash or non-lint content by use of a video camera. As the camera scans the sample surface, a signal is processed by a microcomputer to determine the number of dark spots encountered and how much area they take up in the total sample "window".

These data are expressed as count and area. Reported is a two-digit number that pertains to the area taken up by trash on the sample surface. In the U.S., trash meter readings have been assigned to six classifications of cotton, i.e. Strict Middling to Good Ordinary. The repeatability of trash measurement has been found to be good, for when a sample is retested, nearly 81 percent of the readings agree within 01 trash units. For reference, a 41 grade cotton, Strict Low Middling, has a Trash Meter reading of between 03 and 04.

With this review then of what the systems can do with respect to measurement, their accuracy, and their precision, what lies ahead in the area of HVI testing? First and foremost, there are a number of public and private organizations working both separately and jointly to improve the present measuring systems. The use of robotics will allow an increase in test speed, because of reduced labor at a more economical operating cost. At the USDA research laboratories, a large effort is being placed on improving the precision of measurement, primarily for length uniformity and strength. The use of improved and more exact calibration cottons should help between laboratory repeatability, realizing of course the significant effect that relative humidity has, especially on the strength results. With these improved calibration cottons, new machine calibration procedures will be developed to assure the same operating level between machines and laboratories.

But these things are auxiliary. What about additional measurements? A great amount of effort exists in trying to find a fast measurement for maturity, one that could be operated at the speed of an HVI system. Shirley Developments of Manchester, England has a unit that is said to approach HVI speed, but it requires one minute per two determinations on a sample, still too slow for optimum HVI use. We at the Institute of Textile Technology have pioneered and developed a maturity measurement using near infrared technology that can be performed on a cotton sample in less than 20 seconds. Does the method really measure maturity? To prove or disprove this we had four varieties of cotton planted and grown in the mid-

South. At the time of the pink flower, hundreds of hang tags were placed on these potential bolls in a single day. Later, these bolls were hand harvested at five-day intervals and hand ginned. The exact age of the cotton being known, a definite measure of maturity, the samples of lint were then placed into a near infrared measuring unit for maturity measurement. The results showed a curve similar to Dr. Lord's maturity curve of many years ago where he showed the relationship between maturity and fiber age during the growth cycle. Since this indisputable proof that near infrared can measure fiber maturity, many of our member companies have purchased units to measure it, and are using the information in a way similar to other HVI data.

An extremely valuable measure of cotton quality is short fiber content. We have performed trial-after-trial on its effect, and it goes down in our research ledgers a property requiring immediate attention by all, HVI system builders, producers of cotton, ginners, and spinners. Many in the textile industry point the finger at the ginner as the primary producer of short fiber in a cotton bale. Our work substantiates this thinking. Also contributing though, is the archaic system being used to market cotton, that is grade, staple, and micronaire. Good grades are mostly achieved at the gin, and more often than not, high grades and higher short fiber content go hand-in-hand, since they are mainly attained by higher ginning temperatures and the use of lint cleaners. Our system of marketing cotton rewards high grades, regardless of short fiber content. Presently, work by Uster Technologies of Knoxville, Tennessee and the USDA in Clemson, South Carolina, cooperatively, has shown a great deal of promise in measuring short fiber content, and length and length distribution. The unit presently being studied is one that carries fibers aerodynamically at a high velocity into an accelerating nozzle assembly where the force of acceleratlon aligns and straightens them. After being aligned, they are injected into a carefully tuned ribbon beam of light where high speed electro-optical sensors provide responses that the computer turns into length measurements. In a little less than one minute, 10,000 fibers can be tested using this principle of measurement. As you can imagine, this technology holds promise for HVI systems.

Research is also underway by the USDA to develop video trash meters that can recognize the types of trash that can be present in cotton, e.g. grass and bark.

With Cotton Incorporated, the USDA has supported research by Shaffner Technologies (now Uster Technologies in Knoxville, Tennessee) on their already famous AFIS series of instruments. AFIS stands for Advanced Fiber Information System, and the research work thus far has centered around measuring individual fiber properties, and measuring non-lint content in cotton samples. In a prototype, the sample presented is mechanically opened, and the lint, dust, trash and neps are separated. The amount of dust, and the micron size of the dust, can be determined. The amount of trash is measured and a determination of its type made, e.g. bark, grass, etc. The neps are then counted and their size determined. The cleaned lint is then measured for length and fineness. Presently, strength and elongation is being looked at for addition to the unit. The cleaned fibers can be collected on a batt for color measurement, etc.

Future HVI systems will measure the fiber properties that are important to the spinner, as well as the producer and ginner, for the manufacture of world class quality cotton yarns and fabrics. The main purpose of the measurements though, will be to predict the processing and dyeing performance, and the final product quality of each bale of cotton. How will this be done considering the marketing system we now operate in? Well, it will not. As long as our system continues to use only grade, staple, and micronaire to price cotton, the use of HVI data will be minimal. Presently, some textile companies are paying a premium for strength, and some even for length Uniformity Index, but at this time the market itself doesn’t recognize HVI properties. This is going to change, however. In 1988, the United States Secretary of Agriculture appointed a fifteen-member committee to advise him on how the cotton marketing system should change in response to the technological changes that are occurring in cotton production, ginning, cotton quality evaluation, and textile manufacturing. In August of 1989, this committee, which was made up of producers, ginners, merchants and shippers, marketing cooperatives, warehousemen, textile manufacturers, and researchers, recommended the following to the Secretary of Agriculture:

1. That HVI data (length, length uniformity, strength, color, and trash) be made mandatory for the 1991 crop.

2. That a premium and discount schedule be established for strength and that it apply to the 1991 crop.

3. That a premium micronaire range be established for cottons between 37 and 42 micronaire (premium not to apply to certain lower grades) and that research to develop a rapid method to measure maturity and fineness be given a high priority.

4. That grade be divided into its component parts of lint color and non-lint content; that the classer use the HVI color meter to guide his determination of color grade and use the HVI trashmeter to guide his determination of trash grade; and that as soon as the technology and the market will allow, use only the instruments to set these values.

5. That the USDA determine the feasibility of using the length uniformity index readings to indicate short fiber content.

6. That new fiber properties be added to the price schedule in such a way that the base price of U.S. cotton does not change.

7. That these changes be incorporated into the Congressional farm bill that will apply to the 1991 crop.

These recommendations were fully approved by the Secretary of Agriculture in December 1989. What a momentous occasion, for now the foundation has been laid for using present HVI data, and later being able to use data on properties not now being measured, for example, maturity, short fiber content, neps, etc., to establish the true value of a cotton bale. The new system of premiums and discounts will reward the farmer and ginner for producing quality cotton fiber such that the textile manufacturer can efficiently process it into world class quality cotton yarns and fabrics.

Cotton Breeding Directions: The Yarn Producer's Viewpoint

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Introduction

Over the past twenty years, staple yarn production has undergone considerable change. New principles of yarn formation have been successfully introduced. Other methods have not achieved fruition.

In order to achieve the maximum benefit from these processes, either in production speed, yarn quality, or both, the demands placed on staple fibers have changed to some degree. For cotton in particular, it has been necessary for breeders to become more aware of the needs of industry so that the cottons under development will allow full exploitation of available technology.

A review of these processes will be made with the object of determining the reasons why there are differences in fiber requirements for different spinning methods. This will be followed with a review of progress with particular reference to American (US)-grown cottons.

Modern Yarn Production Methods

Yarns composed entirely of staple fibers may be spun by one of several methods. Those which have been most successful are

(a) ring spinning

(b) open-end spinning

(c) air-jet spinning

Ring Spinning

Ring spinning continues to be the yarn production method which generally provides the highest efficiency of conversion of fiber properties into yarn strength. While other methods of yarn production have become more popular in certain yarn number ranges, more interest in the ring spinning process has been apparent in the last few years.

The increased interest has arisen because of the feasibility of using higher speeds. Ring frame development was retarded because higher spindle speeds required the use of rings of smaller diameter. Smaller rings meant that lighter packages were produced which, in turn, increased the frequency of knots per unit length of yarn. Knots are undesirable, for they are potentially detrimental to high weaving efficiencies and fabric quality.

The break-through occurred with the advent of splicing. The imperceptible union of two pieces of yarn overcame the problems associated with knots and the production of smaller packages could be tolerated. Consequently, spindle speeds of about 20,000 rpm are now being offered by machinery manufacturers compared with about 14,000 rpm several years ago. The economics of the ring spinning process have been further enhanced by labor-saving devices such as automatic doffing (which has been established for some time now), the union (or linking) of ring frame to winder, and the automatic creeling of roving bobbins.

In ring spinning, fiber attenuation is realized by means of the roller drafting system. Despite the introduction of aprons, alteration of the hardness of the top roller covering, etc., the problem of controlling the movement of short fibers still remains. In theory, a fiber should be gripped by the next, faster moving pair of rollers supplying the bundle of fibers. A fiber greater in length than the distance between the nip points formed by the two rolls will be broken; a fiber shorter than this distance will "float" uncontrolled until it is entrained by a gripped fiber.

To avoid fiber breakage, rolls are set according to the length of the longer fibers. Control of shorter fibers has to be sacrificed and less even yarns are produced. For processes involving roller drafting, therefore, it is most desirable to have fibers of minimum variation in length in order to ensure the most regular product. This fact is borne out by the existence of the combing process which, in addition to achieving greater fiber parallelization, removes short fibers resulting in yarns which are more even and, therefore, stronger.

Simple considerations of yarn structure reveal that it is desirable to incorporate as long a fiber as possible. The use of longer fibers within a yarn implies that there will be greater overlapping between fibers, allowing loads to be transmitted and shared between fibers more readily. Stronger, more even yarns are produced.

The requirement of the ring spinner will continue to be the provision of longer cottons of improved length uniformity. The supply of cottons of greater strength is also desirable but not essential for the production of yarns on modern ring spinning machines. The use of smaller rings has permitted an improvement in production rates without substantial increases in the load imposed on the yarn during formation.

Open End Spinning

Of the several systems of producing open-end spun yarns, only two have achieved commercial reality. Friction spinning has had limited success in that a small proportion of 100% staple fiber yarns are produced using DREF machinery. Hollingsworth’s Masterspinner was designed for the production of finer yarn and has been withdrawn from the marketplace, unfortunately.

Rotor spinning has proved to be the most successful form of open-end spinning. First demonstrated by the Czechs in 1967, this method of yarn production has rapidly increased in utilization. Ring spinning capacity has tended to remain constant, however.

Since the introduction of the first generation of rotor spinning machines into the United States in 1973, considerable progress has been made. Rotor speeds have increased at the average rate of 3,500 rpm per year, and it is now commonplace to hear of speeds in excess of 100,000 rpm being used. Together with increased rotor speeds, improvements in the transportion of fibers by air, rotor profile and navel (doffing tube) design have improved the translation of fiber strength into yarn strength. The application of automation to the rotor spinning process and the elimination of rewinding by electronic monitoring and waxed conical package formation, have permitted finer yarns to be produced economically. Whereas the break-even yarn number for rotor spinning compared to ring spinning used to be about Ne 24/l (25 tex) in 1973, it is now believed to be about Ne 50/l (12 tex).

Modern examples of the rotor spinning process do not employ roller drafting to achieve attenuation of the fiber bundle. Fibers are teased from the feedstock as they are released by a feed roller and transported individually to a collecting surface (the rotor) by contact with the teeth of an opening roll and subsequently, an air stream.

Transport of the fibers in the airstream does not guarantee that all fibers are completely straightened. As fibers arrive at the surface of the rotor, some buckling is inevitable. During yarn formation, the fibers are incorporated into the yarn in the manner in which they lie in the rotor groove. Consequently, relatively large changes in fiber length will be required to provide significant increases in yarn quality when compared to ring spinning.

The opening roller system is also aggressive. The action of the saw teeth of the opening roller moving at about 1500 m/min on fibers delivered at the rate of 1 m/min is likely to incur some fiber damage. The tendency to shorten fibers further reduces the opportunity for longer fibers to contribute to improved yarn quality. The fact that the opening roller system is so efficient at individualizing the fibers ensures that yarns are produced which are superior in regularity to comparable ring yarns.

The process also suffers from another defect. Fibers can attach themselves prematurely to the yarn bundle. These attachments are referred to as wrapper fibers which contribute little or nothing to yarn quality. Furthermore, unlike ring spun yarns, the rotor yarn structure is such that the twist varies from the core to the surface.

The loss of useful fibers as wrapper fibers, the reduced extent of the fibers assembled in the yarn and the fact that the core fibers bear most of the loads imposed on the yarn, are manifest in a lower yarn strength. In addition, these factors explain the need for more fibers in the yarn crosssection in order to achieve satisfactory production performance. The rotor spinner therefore seeks primarily strong, fine fibers.

Air-Jet Spinning

Commercially available air-jet spinning machinery of which the models produced by Murata have been the most successful, rely on roller-drafting to attenuate the fiber mass, followed by a process known as false-twisting to achieve the necessary inter-fiber cohesion for a useful yarn structure.

The bundle of fibers issuing from the front rollers of the drafting system are twisted in one direction, then in the opposite sense by a pair of air vortices generated by compressed air flowing through two nozzles. The complex action causes fibers at the extremities of the bundle offered by the front rollers to be wrapped around the body of the yarn. In this spinning system, therefore, the wrapper fibers are useful and necessary for the yarn.

This system of yarn formation has achieved considerable acceptance in the United States since its introduction in 1981, particularly in the production of relatively fine polyester/cotton yarns at high speeds. Industrial experiences have confirmed the need for well-prepared sliver, in other words a regular assembly of long, parallel fibers. Attempts to produce air-jet yarns purely of cotton have not been successful on a commercial scale and have appeared to prefer combed materials. There may be a possibility that Murata's Twin Spinner or Suessen's Plyfil machine in which two air-jet yarns are produced and taken up side-by-side, (to be plied together in a subsequent process) could be successfully applied to the production of an all-cotton air-jet yarn.

The inference is that air-jet spinning, in utilizing roller drafting, requires long fibers of high length uniformity. Since a number of fibers are also used to bind the structure together, there may be a requirement for finer and, perhaps, stronger fibers to make up the resultant deficiency.

To summarize, spinning systems involving roller drafting will continue to require long fibers of consistent length. Open end systems are less sensitive to length variation but need finer fibers, probably of increased strength, in order to exploit fully the productive potential of the process. This should not be interpreted to mean that improved length characteristics will not improve rotor yarn quality and that ring yarns will not benefit from the use of finer, stronger fibers. Improvement in fiber strength, fiber length, fiber uniformity and the provision of finer fibers will benefit all spinning processes but some spinning systems will show greater responses than others, depending on the fiber property in question.

Trends in Fiber Quality Improvement

In the United States, the trends in fiber breeding have been directed primarily toward improving yield. For example, from 1920 to 1985, there has been a three-fold increase in yield. This can be attributed to increased use of irrigation water, chemicals for both fertilization and pest control, and some genetic improvements.

While industry recognizes the necessity of increasing yield to enhance the farmer's profitability, provision of larger quantities will reduce the cost of cotton to the mill. At the same time there is a need to increase the supply of higher quality fiber in order to improve the economics of yarn production.

The well-established ring spinning process has long been recognized as requiring longer fibers. Not surprisingly, therefore, the U.S. Department of Agriculture's statistics show that the average staple length of American Upland cottons has increased by more than 10% over the fifty-year period from 1935 to 1985.

The development of the long staple cottons grown in California since 1939 has produced a 33% increase in yield and a 22% increase in fiber tenacity. The increase in fiber length has been modest and there has been little change in Micronaire.

For the medium staple cottons grown in the Mississippi region, data for a recent forty-year period shows an increase in yield of 30% and an improvement in strength of 6%. Micronaire values have also increased over this period and may be one of the prime reasons for the increased yields.

For the shorter staple cottons grown in West Texas, a comparison of obsolete and contemporary varieties has shown that yields have increased as well as fiber tenacity and Micronaire index. The Micronaire values are lower than those obtained elsewhere, yet the fiber strengths were greater than those of the Delta-grown cottons.

The extra long staple cottons grown in Arizona have been improved in terms of yield. This has apparently been achieved by increases in Micronaire index, similar to the developments in Mississippi.

These trends indicate that the needs of the modern spinning processes have been ignored to some extent. The increase in Micronaire value particularly for the Delta and Pima cottons is probably not so much an indication that the new varieties are maturing more rapidly, as that they are intrinsically coarser. On the other hand, the trend in the development of the

West Texas cottons is probably more desirable to the spinner, with the increase in Micronaire value probably being the result of the introduction of earlier-maturing varieties. The increased fiber strengths achieved in both California and West Texas have to be favorably considered, also.

Fiber Development

The trend toward increasing yield by introducing cottons which probably yield intrinsically coarser cottons should be reversed. The demand is for fine cottons which are mature to avoid problems of uneven dyeing and the presence of undyed specks called neps on dyed fabric.

Unfortunately, a fundamental inverse relationship seems to exist between yield and fineness. Finer cottons tend to have lower yield than coarser cottons. Certain cotton breeders, however, are making significant efforts to alter this relationship. If this change does not occur, finer fibers may not be available to the spinner at a satisfactory price, and cotton will lose its position to the finer polyester fibers which are now being introduced in Europe and the United States in particular.

A further deterrent to the introduction of a naturally fine fiber lies in the lack of instrumentation accepted by the USDA to permit fineness and maturity to be measured separately. The Micronaire test fails to differentiate between a fine, mature cotton and one which is coarse and immature. Consequently, there is a danger within current classing systems to wrongfully reject a very good cotton on the basis of it having a low Micronaire value. Possible solutions to this problem lie in the use of the Shirley Developments Ltd. Fineness/Maturity Tester (F/MT III) or even the application of Near Infrared spectroscopy in conjunction with High Volume Instrumentation.

Contamination

The demand for cottons of improved quality involves cleanliness to reduce waste at the mill and ensure high efficiencies in the spinning process. At present, grading systems for cotton reward producers for providing white cottons of low trash content. The ginner is empowered to achieve cotton of maximum value for the farmers. The result is that whiteness and freedom from those particles which are readily seen, is obtained at the expense of fiber quality, particularly short fiber content and neps. The problem is that larger particles are reduced in size to trash fragments which are more difficult to remove, even with modern mill cleaning equipment.

Until cotton classification systems become more tolerant of the presence of larger trash particles, in other words when new standards of cleanliness can be established, cottons will risk being "overginned." In the meantime, breeders' efforts to improve yield by ensuring that plants are tolerant to adversity and are capable of maturing rapidly, will assist in reducing the likelihood of cottons having high trash content.

Another problem in cottons is stickiness, which, in American cottons like those of other areas, appears to be growing. Adhesion of fibers to machine surfaces cause unevenness and frequent, costly interruptions in processing. There are many difficulties to be overcome, mostly involved with the establishment of a rapid test method whose results are indicative of mill performance. Until such information is forthcoming, it is unlikely that cotton breeders will be given the guidance they may require in order to develop varieties which are less susceptible to this problem.

Summary

In conclusion, it is desirable for breeders to develop longer, stronger, finer and more regular cottons. In particular, the provision of finer fibers should not be at the expense of maturity or yield.

Other problems remain to be overcome. Ways and means of avoiding the inclusion of non-lint in harvested cotton are desirable. Similarly, the development of cottons which are guaranteed to process without sticking is a very important goal.

Clearly, the difficulties encountered in the spinning industry are influenced by decisions made in all facets of the cotton production industry - not only the farmer and the breeder, but also the entomologists, chemical manufacturers, etc., with whom they interact. Consequently it is necessary that there be an understanding of everyone's role in cotton production, from field to fabric, in order that cotton may continue to retain its position and provide a livelihood for all.

Notes

- The Third Meeting of the Latin American Association for Cotton Research and Development is planned for May 27-31, 1991, in Campina Grande, PB Brazil, under the sponsorship of Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA). The Regional Association last met in Ica, Peru, in October 1988. Additional information is available from Orozimbo Silveira Carvalho, EMBRAPA/CNPA, Rua Osvaldo Cruz 1143, Caixa Postal 174, Campina Grande, Paraibo, Brazil.

- The Federación Nacional de Algodoneros, Colombia, announces the publication of the fourth edition of *Bases Técnicas para el Cultivo del Algodón en Colombia* (Technical Bases for Cotton Growing in Colombia, available in Spanish only). This book, which is a complete compilation of all the agronomic aspects of cotton cultivation in Colombia, is available at a cost of US$35 (including airmail costs) from the Federación Nacional de Algodoneros, Carrera 8ª, No. 15-73, Bogotá, Colombia.

- Copies of two documents from the 49th Plenary Meeting of the ICAC have been mailed to recipients of *THE ICAC RECORDER.* These documents are *Current Research Projects in Cotton,* a compendium of ongoing research projects on cotton in 27 countries, and the papers from the Technical Seminar on Cotton Production Research from a Farming Systems Perspective, with Special Emphasis on Stickiness (mailed separately).