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Introduction

The real potential of high yielding varieties can only be achieved if plant growth is properly monitored in the field and if the needs of plants are met on time. Plant growth can be monitored visually by frequently visiting cotton fields or with computer aided plant-monitoring programs like COTMAN. A grower must have a target development curve from previous years to know if his crop is behind, even or ahead of the normal growth pattern for a high and early yield. COTMAN is a computer based growth modeling system that helps the grower to manage his crop for maximum yield at minimum cost. The University of Arkansas developed COTMAN almost 15 years ago, and it is the most popular modeling system among growers in the USA. Nodes Above White Flower (NAWF) is the base line used to assess the crop termination stage. The last effective boll formation stage or cutout/crop termination stage is considered to have been reached when the number of nodes above the top most white flower lowers to five. There are certain limitations to the use of COTMAN, but in general the use of COTMAN for monitoring plant growth and the application of inputs enhances the profitability of cotton production. More details on COTMAN are in the first article.

The 2nd article is on improving the sustainability of cotton production. Sustainability of cotton can be defined many ways. The World Commission on Environment and Development provides the following definition: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The five pillars of sustainability are 1) habitat management, 2) crop attributes, 3) growth and input use, 4) integrated pest management and 5) economics issues. National and international institutions have undertaken various initiatives to improve sustainability of agriculture, and the ICAC has undertaken projects and organized seminars. Various aspects of sustainability of cotton production are discussed in the second article.

Micronaire is measured in all countries, and micronaire value is considered an indication of fiber fineness and maturity. A

lower micronaire value could be due to finer fibers or also due to less mature fibers. Because of such confusion, researchers recommend that fineness and maturity should be measured separately. The Southern Regional Research Center in New Orleans, Louisiana, USA has undertaken interesting work on measuring fiber fineness and maturity. An article on improved instrumentation for measuring maturity and fineness was published in the December issue of the *ICAC RECORDER* in 1995. A lot of work has been undertaken at SRRC since, to improve measurements of maturity and fineness, which is reported in the third article of this issue.

Latin American Association for Cotton Research and Development (ALIDA)

The 10th Meeting of the Latin American Association for Cotton Research and Development (ALIDA) was held in Ibagué, Colombia from June 8-10, 2005. Close to 300 researchers from Argentina, Brazil, Bolivia, Colombia, Mexico, Nicaragua, Paraguay, Peru, USA and Venezuela attended the meeting. Representatives from Delta and Pine Land Company Ltd., Plato Industries Ltd., International Cotton Advisory Committee and many private companies in Colombia also attended the meeting. The meeting discussed all aspects of production research and the cotton situation in the region. The increasing population of whitefly in Colombia and cost of production in the region were of special interest to many researchers. The meeting elected a new President of ALIDA until the next meeting. The new President of ALIDA is as follows:

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The next meeting of ALIDA will be held in two years either in Mexico or Venezuela. ICAC will contact government authorities in both countries and the host country for the next meeting will be announced on the ALIDA web page at <http://www.alida-algodon.org>.

Asian Cotton Research and Development Network

The Third Meeting of the Asian Cotton Research and Development Network in conjunction with final workshop of the ICAC Common Fund for Commodities funded project on Sustainable Control of the Cotton Bollworm *Helicoverpa armigera* in Small-Scale Cotton Production Systems (CFC/ICAC 14) was held in India from June 27-29, 2005. The Central Institute for Cotton Research, Nagpur of the Indian Council of Agricultural Research hosted the meeting. Delegates from Bangladesh, China (Mainland), Pakistan, Vietnam, UK, Uzbekistan, CFC, ICAC and a large number of Indian participants from the public and private sector attended the meeting. The meeting noted the emerging problem of pink bollworm in the region particularly in India and decided to designate a lead researcher to review the pink bollworm situation. China (Mainland) and Pakistan have already done a lot of work on this pest. The meeting decided to continue holding the meetings every two years and elected Dr. B. M. Khadi of India as the new Chairman of the network.

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World Cotton Research Conference - 4

The World Cotton Research Conference - 4 (WCRC-4) will be held in Lubbock, Texas, USA from September 10-14, 2007. The US Organizing Committee has selected 'Nature's High-Tech Fiber' as the theme of the conference. The Texas Tech University's International Textile Center will serve as the primary host for the conference. Pre-registration is open now. Once you have pre-registered, you become eligible to receive all forthcoming information of WCRC-4. A package for full registration including hotel booking will be available at least a year before the conference and mailed to you. A copy of the pre-registration is given at the end of this issue but all information is also available at <http://www.icac.org>.

COTMAN: A Growth Monitoring System

Yield is the result of the interaction of a genotype with the environment, including climate conditions, soil fertility and input applications. Aside from weather conditions, which may be highly favorable or unfavorable, the doses and timing of input applications have a vital effect on yield. Varieties could be developed that are comparatively less sensitive to environmental conditions, but that might be at the cost of yield potential. Such hardy varieties could have a more consistent performance but at a comparatively lower yield level. Thus the role of growing conditions, including inputs, would vary from country to country and variety to variety. Currently, that kind of variation is not high because no significant efforts have been made to develop hardy varieties. There have been some attempts to develop varieties that are more responsive to fertilizers, insecticides and other growing conditions, including drought for rain-fed cotton, and irrigation water for cotton with an assured water supply. Yet, growing conditions have a lot to do with yield and some estimates suggest that 80% of the variation in yield is due exclusively to growing conditions, and only 20% is due to other functions, including input applications. This is why it is very important to monitor plant growth in the field rather than assessing yield only at the end of the season when nothing can be done to correct the situation.

Plant growth can be monitored visually by frequent visits to the cotton fields or with computer assisted plant-monitoring

programs like the COTMAN expert system. Cotton crop modeling started in the late 1960s and more than 15 simulation models have been developed and tested. The fundamental principle is the application of mathematical methods to biology for successful plant growth monitoring. The objective is to use data compiled over a number of years to make a quantitative assessment of the impact of cultural practices on cotton yield so as to plan future cultural operations. In addition to COTMAN, the following are among the more important systems developed so far: CottonPlus, GOSSYM-COMAX, PMAP, COTTON TALK, CALGOS, Texas Crop Monitoring System, University of Arizona Crop Monitoring System and California Cotton Manager.

The COTMAN System

The University of Arkansas, USA, developed COTMAN (COTton MANagement) almost 15 years ago with financial support from Cotton Incorporated, USA, and technical cooperation from Mississippi State University, Louisiana State University, Texas A&M University, Virginia Tech and Arkansas State University. In-season plant monitoring with the COTMAN system allows ample time to correct and improve contingencies. The COTMAN computer software makes it easy to enter data and generate reports to assist in making management decisions. The grower must have the target development curve derived from previous years to

determine that the crop is either behind normal development, too far ahead or following the normal growth pattern for a high and early yield. The system comprises two subsystems: SQUAREMAN and BOLLMAN. The former is used to monitor crop development up to the first flower with reports providing feedback on square retention and plant stress. BOLLMAN is employed when the crop is flowering and it is used to monitor boll-loading stress and help determine the end-of-season crop termination stage. Nodes Above White Flower (NAWF) is the base line used to assess the crop termination stage. The last effective boll formation stage or cutout/crop termination stage is considered reached when the number of nodes above the topmost white flower drops to five. In a normal healthy crop in the USA and other countries, there must be at least 8-10 nodes above white flower at the time of first flower and throughout the peak flowering stage. The number of nodes above white flower begins to decrease as the crop progresses toward maturity. Five nodes above the white flower is a clear indication that the crop is reaching a termination stage. There is a non-computer version of BOLLMAN, but it can be used solely for end-of-season termination decisions.

The use of COTMAN has the following benefits:

- Continuous monitoring of the crop provides square shedding information that alerts growers of the need to correct the situation. If square shedding is due to insects, growers will know that they must initiate plant protection measures, while if it is due to input stress, they will have time enough to take the appropriate steps.
- Crop modeling using COTMAN allows researchers/growers to determine if the crop is progressing according to the target development curve or if it is too slow or too fast.
- COTMAN helps determine the precise moment to terminate input applications in order to save on inputs and lower production costs. Savings on production costs will vary from location to location but in some studies undertaken in Arkansas, where the system was developed, savings ranged from US\$88 to US\$91/ha when inputs were adjusted using COTMAN monitoring (Benson *et al.*, 2000). Inputs saved as a result of using lower doses included: fertilizers, growth regulators, insecticides and defoliant. Other reports, however, indicate much lower input savings.
- Premature defoliation of the crop produces immature fiber, which has serious consequences in spinning and weaving. COTMAN helps determine the right moment for defoliation of the crop.
- COTMAN improves the yield of seedcotton when out-of-target-curve development is corrected in time.
- Breeders measure earliness in cotton in many different ways but COTMAN provides a research tool that is very useful in determining relative maturity differences among cultivars.
- COTMAN helps use plant growth regulators at the right time and its software also monitors the impact of plant growth regulators on the crop.

Software and Data Collection

COTMAN uses Windows 98 or later versions of Windows. In 2005/06, farmers in the USA will be using COTMAN III, which will replace COTMAN II. Farmers and researchers in other countries can develop similar systems for their own conditions and varieties. Farmers have to determine their own target development curves for their own cotton varieties and growing conditions because any single variety may have different target development curves if any of the growing conditions changes significantly. According to the findings of the University of Arkansas, the three basic interpretation standards that must be followed are:

Square Retention

High or low square retention can greatly influence the interpretation of a particular growth curve slope. SQUAREMAN summarizes the total number of squares shed and the shedding rate by main-stem nodal position for all first-position squares. Evaluation of square retention is not yet available in BOLLMAN.

Target Development Curve

The target development curve assumes that the first square appears at 35 days after planting (DAP), the first flower at 60 DAP, with NAWF = 9.25 (apogee) and physiological cutout (defined as NAWF = 5) at 80 DAP. Thus, the apogee indicates the number of main-stem nodes added from first square to first flower. The target development curve is assumed to represent the optimum combination of early maturity and high yield. Actual growth patterns measured in the field may then be compared to the target curve. The target development curve begins with the first square at around 35 days after planting and displays progressive increases in node development and fruit formation. Under Arkansas conditions, the target development curve is set at each node formed at 2.7 days until about 60 days after planting when the number of nodes/day starts to decline. According to Oosterhuis *et al.* (1996), in Arkansas, NAWF = 5 is supposed to be reached at 80 days after planting at an average 0.2125 nodes per day.

Latest Possible Cutout Date

Latest possible cutout date is the latest date at which a population of flowers has a high probability of developing into bolls of acceptable size and quality. COTMAN assumes that 850 heat units (DD60's) are needed for maturation of the last effective boll population. Based on historical weather data and user-defined risk levels, the latest possible cutout date is defined as the latest date at which 850 DD60's can be expected to accumulate prior to any given target harvest date. If a field reaches physiological cutout (NAWF = 5) before the latest possible cutout date, end-of-season management will be

based on crop maturation and heat unit accumulation will be calculated up to the physiological cutout date. Otherwise, end-of-season-management will be based on weather conditions and heat unit accumulation will be calculated up to the latest possible cutout date.

The data collection procedure for developing a growth curve requires entry of farm information, field information (variety, planting date, row spacing, stand count, etc.) and plant information. A T-shaped sampling stick should be used to count the number of plants in a 3-foot section in order to assess the plant stand. The first fruiting node should be determined by taking four samples of 10 plants each in a field. The first fruiting position should be determined from the cotyledonary leaves to the first sympodial branch. Data should be taken only when squares can be consistently seen in the field. The system assumes that the first square will appear at 35 days after planting and that it will take another 25 days to become a white flower. While plant height is the average of all plants in both rows at each site, the presence or absence of squares should be recorded on five consecutive plants in two rows at each location. Data collection on nodes above white flower should begin when the first flower appears. Data should be recorded on five plants in one row in the sample and similarly five plants in the adjacent row. Such data should be recorded at four locations within a field and be discontinued when the cutout is reached.

Use of COTMAN in the USA

Various crop-modeling systems have been researched, developed and applied since the development of COTMAN in 1994. However, COTMAN is currently the most-used system in the USA. COTMAN is used in 17 cotton-producing states. Its use, however, is more extended and popular in some states than in others. Insecticide termination based on nodes above white flower is a part of the Cooperative Extension Service recommendations in many states even if growers do not use all the software. It is most popular in the mid-southern cotton growing states, though the number of users may be highest in Texas. The system can be applied to any variety and all growing conditions but, according to the policy of Cotton Incorporated, COTMAN is supplied exclusively to U.S. clients, including growers, consultants and researchers, although growers make up the greatest number of users. Cotton growing conditions in California and Texas are quite different but the same version is used in both states, thus proving that the system may be used with any variety, in rainfed or irrigated conditions and in low yielding and high yielding conditions.

The only limitation is that COTMAN monitoring is based on the first position bolls and is less sensitive to other boll positions. This factor could make a difference if it is applied to varieties where the greatest yield does not come from first position bolls. Farmers can reap the greatest benefit from COTMAN modeling only if they have access to inputs, including irrigation water, so that they can schedule them adequately to improve productivity. COTMAN is provided

free of charge to cotton growers in the USA. The COTMAN modeling system is not supplied outside the U.S. and there is no indication that it is used anywhere except in the USA.

COTMAN vs. Remote Sensing

Many more techniques are being explored in the USA to monitor crop development, particularly crop maturity, in order to terminate insecticide use at precisely the right time and spray defoliant only when the proper stage is reached. Any additional unnecessary spraying adds to the cost while premature cutout could result in lower fiber maturity. Researchers have explored the use of multispectral imagery data to classify cotton fields on the basis of crop maturity. Harris *et al.* (2004) compared imagery data in an attempt to use remote sensing to classify a cotton field into two zones based on COTMAN spray termination rules. They used the Normalized Difference Vegetation Index (NDVI) as a decision support system to determine whether to spray ($NAWF = 5 + <350 \text{ HU}$) or not to spray ($NAWF = 5 + >350 \text{ HU}$) portions of the same big field. A GER 1500® spectroradiometer was used to obtain radiometry and/or multispectral imagery data to determine cutout in two varieties planted on three sowing dates in 2002 and 2003. Radiometry readings were made 15 times in 2002 between 26 June and 23 September with intervals ranging from 2 to 12 days. Radiometry readings were made 17 times in 2003 between 9 June and 17 September with intervals ranging from 2 to 11 days. Each reading consisted of a reflectance measurement of a standard white reference and two readings above the center of the furrow. The reflectance percentage was calculated as $T/S \times 100$, where T = reflectance of the target plant (row center reading) and S = reflectance of the standard. Data were averaged to obtain a single mean reflectance percentage per plot. Reflectance data were used to calculate the reflectance percentage from which various indices were calculated and analyzed for correlation with NAWF and the percentage of open bolls. Harris *et al.* (2004) concluded that the Normalized Difference Vegetation Index was not closely correlated to NAWF or to the percentage of open bolls. Two other indices, Visible Atmospherically Resistant Index (VARI) and Green Vegetation Index (GVI) were closely correlated to the maturity parameters, especially for 2002 data, and could be used to assess crop maturity instead of COTMAN.

COTMAN and Site-specific Management

The COTMAN management software package was developed to monitor field conditions but not variations within a field. Some fields, however, may be very large and there may be wide variations within fields. In such cases, averaging the data could result in lower yields. Variation within a field can be assessed more accurately in order to apply site-specific treatment, which could result in a more homogeneous yield among the different zones or plots within a field, and ultimately mean a higher yield for the field as a whole. Sharp

(2004) characterized variability within fields and found that COTMAN could be a useful tool in making site-specific management decisions. Studies were conducted on two farms having at least 35 hectares planted to cotton. Variable rate application techniques were followed on one farm and uniform applications on the other farm. Profitability increased on the farm with zone-based management combined with variable rate application of inputs. The farm also produced other crops, but cotton production costs were reduced by 25-38%. The combination of cost reduction and yield improvement resulted in an overall increase in income of \$250 to \$500 per hectare per year. According to Sharp (2004), both of these farms now employ the variable rate application system for lime, pre-plant fertilizer, seeding, in-furrow fungicide and insecticide, summer applications of insecticides and plant growth regulators and crop termination treatments. Other researchers have found that although COTMAN helped increase yield, it was too cumbersome to apply the system to variations within fields irrigated by central pivot systems.

Limitations to the Use of COTMAN

Some of the work done in the USA in the application of COTMAN to ultra narrow row production systems concluded that the last effective boll was set at a higher position on the plant than nodes above white flower = 5 in most, but not all states. The studies suggest that some adjustment will be needed if the system is to be applied under production conditions other than those set for the system since some researchers consider cutout at NAWF < 5 to be an indication of crop stress. The other limitation to the use of COTMAN under different conditions is that the SQUAREMAN component of the system uses a default square shed limiter of 19% despite the fact that actual shedding may be much higher under different production conditions. Excessive shedding at an early stage may result in higher boll set at 2nd, 3rd and other positions while the COTMAN system is tuned to higher boll set at the first position.

The COTMAN does not warn about insufficient weed control, something growers must be vigilant about in their fields or employ other systems to detect the problem and make herbicide application decisions. Price *et al.*, (2004) reported three such systems that assist in evaluating alternative strategies and tactics. The programs, called HADSSTM (Herbicide Application Decision Support System), Pocket HERBTM, and WebHADSSTM, all employ field-specific information to estimate the yield loss that may occur if no control methods are used to eliminate herbicide treatments that are inappropriate for specified conditions, as well as to calculate expected yield loss after treatment and expected net return for each available herbicide treatment. Each program has a unique interactive interface that provides recommendations for three distinct user audiences: desktop use (HADSS), Internet use (WebHADSS), and on-site use (Pocket HERB). According to Price *et al.*, (2004), using WeedEdTM, an editing program, collaborators in several southern U.S. states have created different versions of

HADSS, WebHADSS, and Pocket HERB that are tailored to conditions in different areas.

According to Stewart *et al.*, (2000) the COTMANTM system does provide a wealth of information on crop progress and may aid in scheduling the harvest. It is, however, a very time-consuming method of monitoring crop development. They found that it took 31.6 minutes to collect COTMAN data as against 4.9 minutes for extension recommendations. According to Teague *et al.*, (2000), working with COTMAN at one of the research stations of the University of Arkansas in 1998, it took 12 minutes per plot for a two-person mapping team to collect the COTMAN data.

Cotton is typically a small farmers' crop and the majority of growers in most countries (other than parts of Argentina, Australia, parts of Brazil and USA) produce cotton on less than 10 hectares. COTMAN can be used only in large-scale farming systems where fields are big enough to justify the time it takes to collect the data. The time required to sample and track individual fields should not be an excessive burden for the grower, extension worker or consultant, whoever is responsible for monitoring the crop.

To usefully employ the COTMAN system, growers should have a fairly good knowledge of computer use, something small growers in developing countries do not usually have. Program training and support are available free to U.S. growers, but it is doubtful that farmers in other countries can get such a free services from their governments or researchers.

The COTMAN system relies heavily on cutout being defined at NAWF = 5. Production systems in many countries have a variety of constraints that would not permit the use of COTMAN. Though target growth models may be developed for any number of production regions or culture conditions, seasonal variation in any specific stress could invalidate some of the basics of the COTMAN system, such as NAWF = 5.

COTMAN Updates

The COTMAN software has been continuously updated since its development. It has been improved from DOS to Windows and the latest version for 2005/06 was shipped to U.S. users in April 2005. Since the system is free, it is believed that most farmers will replace their old versions of COTMAN with the latest version. The University of Arkansas distributes the system and by April 2005 it had received almost 400 requests from growers, consultants and researchers for the newer version of COTMAN. It is believed that many others may still opt to continue using the old version.

References

- Benson, N. Ray, Mark J. Cochran and Greg L. Smith. 2000. Benefits of COTMAN—Consultant's perspective. *Proceedings of the 2000 Cotton Research Meeting and Summaries of Cotton Research in Progress*, Special Report 198, University of Arkansas, September 2000.

Danforth, Diana M., Mark J. Cochran and Patricia O'Leary. 2004. Overview and update of the COTMAN™ crop monitoring system. *Proceedings - Beltwide Cotton Conferences 2004*, National Cotton Council, Memphis, TN 38182, USA.

Danforth, Diana M., Tina Gray Teague, Ray Benson and William Robertson. 2004. Field guide to COTMAN™ data collection. *Proceedings - Beltwide Cotton Conferences 2004*, National Cotton Council, Memphis, TN 38182, USA.

Harris, F. Aubrey, J. English, Donald L. Sudbrink, Steve P. Nichols, Charles E. Snipes, and Gene Wills and James Hanks. 2004. Remote-sensing measures of cotton maturity – cutout and boll opening. *Proceedings - Beltwide Cotton Conferences 2004*, National Cotton Council, Memphis, TN 38182, USA.

Oosterhuis, D. M., F. M. Bourland, N. P. Tugwell and M. J. Cochran. 1996. *Terminology and Concepts Related to the COTMAN Crop Monitoring System*. Special Report 174, University of Arkansas, USA, December 1996.

Price, Andrew J., Gail G. Wilkerson and John W. Wilcut. 2004. Weed management with cotton –HADSS, A new computer-based decision aid. *Proceedings - Beltwide Cotton Conferences 2004*, National Cotton Council, Memphis, TN 38182, USA.

Sharp, Tim C. 2004. Relationships among full season crop inputs and productivity zones for total variable rate cotton systems management determined by aircraft and ground based imaging with the COTMAN system. *Proceedings - Beltwide Cotton Conferences 2004*, National Cotton Council, Memphis, TN 38182, USA.

Stewart, A. M., K. L. Edmisten, J. S. Bacheler, D. W. Mott and J. B. Coltrain. 2000. Comparison of COTMAN™ system with extension recommendations in North Carolina. *Proceedings - Beltwide Cotton Conferences 2000*, National Cotton Council, Memphis, TN 38182, USA.

Teague, T. G., N. P. Tugwell, Jr., D. Danforth and D. M. Oosterhuis. 2000. COTMAN in cotton research. *Proceedings of the 2000 Cotton Research Meeting and Summaries of Cotton research in Progress*, Special Report 198, University of Arkansas, September 2000.

Technical Information Section. 1998. Computer-base plant monitoring systems. *THE ICAC RECORDER*, Vol XVI, No. 1, 1998. International Cotton Advisory Committee, Washington DC, 20006, USA.

Improving the Sustainability of Cotton Production

The sustainability of cotton agriculture may be defined in many ways wherein conservation of natural resources and of biological systems forms the foundation of successful farming practices. Over the past 3-4 decades, particularly since the adoption of inorganic fertilizers and pesticides and their incorporation as an integral component of production practices, farmers and researchers both have tried their best to develop ecologically sound production systems for cotton and other crops. More insecticides than on most other crops, and thus cotton is a model crop on which to develop sustainable production systems. The systems have received an array of names, such organic, natural, biological, low-input, integrated crop management, integrated pest management (IPM), biodynamic, bio-intensive, conservation tillage, zero tillage, regenerative and many others. They do not all involve the same practices, but they are all thought to achieve sustainability in crop production. Conservation tillage and organic production are the most commonly cited as successful forms of sustainable production in cotton, but that may be only partly true.

What is Sustainability – The UN Initiative?

There are many operational definitions of sustainable production, but the World Commission on Environment and Development (the Brundtland Commission) in its 1987 report defined sustainable production in the following terms:

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” The emphasis goes on ‘needs of the present’ and ‘future generations.’ Current needs must be met in such a way that what we do now does not compromise the ability of future generations to produce and meet their own needs. The UN General Assembly debated the report in 1989 and decided to organize the UN Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil from 3-14 June 1992. The conference, which came to be known as the UN Earth Summit, had a comprehensive agenda and did not deal exclusively with agriculture. Commodity-specific initiatives were not the target at the summit. However, the Summit was very successful in raising awareness about environmental pollution and its consequences. The Summit noted that increasing population pressure added to the complexity of the problem. One of the significant impacts was that governments recognized the need to redirect international and national plans and policies to ensure that all economic decisions took environmental impacts fully into account. As a follow-up to the Rio de Janeiro Conference, the World Summit on Sustainable Development was held in Johannesburg, South Africa in the summer of 2002. At the close of the Summit, the global community adopted an action plan known as the Johannesburg Plan of Implementation, which covered the following topics:

- Poverty eradication
- Changing unsustainable patterns of consumption and production
- Protecting and managing the natural resource base of economic and social development
- Sustainable development in a globalizing world
- Health and sustainable development
- Sustainable development of small island states
- Sustainable development for Africa
- Other regional initiatives (Latin America and the Caribbean; Asia and the Pacific; the West Asia region; the UN Economic Commission for Europe)
- Means of implementation
- Institutional framework for sustainable development

FAO and Country Policies

Producers in most countries first moved aggressively to adopt high-input production systems. Very soon, however they began to attempt to minimize their reliance on expensive inputs. Serious consequences on human health, economic pressure and environmental pollution forced many countries to change their cotton production policies. Some countries adopted the new plans earlier than others and were successful in cutting their use of insecticides to almost half of the peak consumption levels reached many years earlier. Syria is the best example of successful insecticide reduction. Insecticides were used on less than 1% of the total cotton area, and the yield was 1,571 kilograms of lint/ha in 2004/05. Australia, too, managed to alleviate the insecticide resistance problems and lower insecticide use significantly. Later, Australia developed the Best Management Practices model covering all aspects of cotton production and ginning, including occupational health and safety in the cotton industry (ICAC, 2004). China (Mainland) also successfully implemented an integrated pest management program (IPM) and recovered cotton yields while reducing insecticide use. Pilot projects in many countries have proved that many alternative technologies and options are available to improve the sustainability of cotton production by cutting costs through reduced input use without a negative impact on yield.

The United Nations Food and Agriculture Organization (FAO) undertook extensive initiatives focused on reducing the use of agrochemicals, particularly pesticides. FAO organized regional consultations and sponsored a variety of other approaches. One of the latest initiatives in cotton is the EU-sponsored project in Asia, covering over 50% of the world's cotton area. The project, implemented by FAO, involved an ecological approach to plant protection using grassroots expertise on IPM. The program, called the Farmer Field School (FFS), entailed regular meetings with a group of farmers. Instead of just listening to lectures or watching

demonstrations by experts, these farmers observed, recorded and discussed what was happening in their own fields from the time of planting to the time of harvesting. This discovery-learning process generated a deep understanding of ecological concepts and their practical application, not from the top down but from the bottom up (ICAC 2003). Farmers were trained to identify insects, decide upon non-toxic control measures and pass on their training to other farmers. They were also taught to interact more effectively with government agencies. In 1997, FAO, the United Nations Development Program, the United Nations Environment Programme and the World Bank established the Global IPM Facility online at <<http://www.fao.org/ag/AGP/AGPP/IPM/gipmf/index.htm>>. The facility is based at FAO Headquarters in Rome and provides a wealth of information in the English, French and Spanish languages on the limited use of pesticides. The Global IPM Facility provides technical support for IPM field programs in a large number of countries. This includes assistance in project or program design, fundraising and facilitation of collaboration among IPM programs.

The US Initiative

For almost 20 years the Cooperative State Research, Education Extension Service (CSREES) of the US Department of Agriculture has operated a program called 'Sustainable Agriculture and Education,' which has helped foster sustainability in agriculture. Since 1988, the Sustainable Agriculture Research and Education (SARE) program has employed a nationwide research and education grants program to help promote farming systems that are profitable, environmentally sound and good for communities. The program funds projects and conducts outreach research designed to improve agricultural systems. It is a competitive program providing grants to researchers, agricultural educators, farmers and ranchers, and students in the United States for professional development, research and education. The following types of grants are provided:

- Research and Education Grants: These grants fund projects that usually involve scientists, producers, and others in an interdisciplinary approach.
- Professional Development Grants: These grants target agriculture professionals and their goal is to spread knowledge about sustainability concepts and practices.
- Producer Grants: Producers are helped to conduct research, marketing and demonstration projects and share results with other farmers.
- Other grant opportunities: Graduate students, community development activists and agriculture educators conducting on-farm research in some parts of the country are eligible for these grants.

Almost one-third of the total number of the projects approved so far involve crop production and pest management, the number of commodity-specific projects is not great. Cotton

projects have been undertaken, but mostly as one component of a general farming system. Out of over 2,000 projects undertaken so far, only 22 were directly related to cotton. Other projects may have included cotton among the research topics but not as the primary focus.

Five Pillars of Sustainability

The sustainability of cotton agriculture cannot be improved by focusing on any single aspect of the cotton production chain. There has to be an integrated approach, one that begins with plant nutrition in the soil and carries through to the harvesting and marketing of the cotton product. Ecologically-based farming tactics must also be continued during the off-season when other crops are in the field. Nutrient upgrading through recycling of plant material from a preceding crop could have an impact on cotton. Improvement of sustainability does not always mean higher yields or lower costs. Yields may be higher but costs might also be higher, and this is not desirable. Neither can a production system be regarded as sustainable if production costs per hectare are clearly lower but yields are also lower. Cotton sustainability may also be affected even if, despite higher yields and lower costs, the farmer gets a lower price for his produce as a result of a number of reasons, including lack of marketing information. There is so much diversity among farms and farmers within countries and among countries that sustainability cannot be improved through the implementation of any single package of guidelines. Decisions have to be made on the spot and must relate to the particular stage of crop development, before planting or after planting, as the case may be. The fundamentals of improving sustainability may be divided into following five pillars, of which some are more dependant on each other than others.

Habitat Management

Use of cover crops such as vetch, winter grains and, more particularly, legumes combined with conservation tillage to improve soil quality and fertility, provide alternate habitats, and increase stability in the cotton agro-ecosystem. This will also help to improve organic matter in the soil, lower dependence on synthetic fertilizers and minimize soil erosion and nutrient leaching. Cotton should be grown as a partner in the farming system and not as a stand-alone crop. Cotton should contribute to the healthy production of other crops, as other crops should do to cotton without sacrificing cropping intensity where land is scarce and there is pressure to produce food crops.

Crop Attributes

Only varieties approved for the area should be grown. The planting seed should be pure and have a high germination capability; cotton should be planted on time so as to achieve an adequate plant stand and the surrounding habitat should not undermine IPM management practices. Cotton stalks should be removed from the field or plowed back into the soil after harvesting.

Plant Growth and Input Use

The importance of plant growth monitoring has been extensively discussed in the first article in this issue of the *ICAC RECORDER*. Crops should not be overfertilized nor should they be underfertilized. This is also valid for other inputs. Growth regulators should be used only if needed and defoliation should be done only at the proper time. Input application must also take into account their effects on fiber quality rather than concentrate exclusively on higher yields.

Integrated Pest Management

An IPM approach must be developed that deals with the natural enemy/pest complex as a component of an overall system. All possible options (agronomic, biological and chemical) should be employed to make the crop less expensive, more environmentally affordable and more harmless in its long-term consequences. IPM has attained greater popularity because of the high cost of pesticides and unavoidable consequences of pesticide use.

Economic Pillar

Fiber quality is of great importance. Seedcotton handling, ginning and post-ginning storage must be designed to preserve as completely as possible the fiber quality produced in the field. The ginning process should be made to have the least-negative impact on quality. Fiber quality should be adequately assessed using proper high-speed equipment in compliance with the needs of the spinning industry. Cotton is sold as seedcotton in most countries, but where custom ginning is popular and land holdings are large enough, farmers may arrange for custom ginning and sell their lint and seed separately.

Biotechnology and Sustainability

The Division for Sustainable Development of the UN Department of Economic and Social Affairs has categorized sustainable development issues in 40 different groups and biotechnology is one of them. Biotechnology is considered as the integration of new techniques emerging from modern DNA technology with the well-established methods of traditional technology. It is a set of enabling techniques for bringing about specific man-made changes in the DNA, or genetic material, of plants, animals and microbial systems, to obtain useful products and technologies. The insect-resistant biotech cottons currently in use, offer opportunities to reduce dependence on insecticides substantially and improve the sustainability of cotton production.

However, internationally agreed upon principles must be developed to ensure the environmentally sound management of biotechnology, to win public trust and confidence, to promote the development of sustainable applications of biotechnology and to establish the appropriate enabling mechanisms, especially in developing countries. Developing countries with scant resources are unable to initiate their own biotechnology research and cannot afford to buy biotech

products from other countries. There is no doubt that the countries that have adopted biotech varieties have reduced the use of insecticides—the group of pesticides most used on cotton—but the greatest long-term pest management benefits from agricultural biotechnology may well be process- and management-based instead of product-based, which is the current situation. Future pest management systems could help bring out and strengthen the plant's natural defense mechanisms. The future of sustainable cotton production lies in a significant reduction in the use of pesticides, and more particularly, insecticides. Biotechnology could help achieve this goal if our ability to create natural and inbuilt self-defense systems continues to progress.

ICAC Initiatives

The World Commission on Environment and Development was mandated, among other things, to propose long-term environmental strategies for achieving sustainable development up to the year 2000 and beyond. It was also called upon to explore ways in which concern for the environment might be translated into greater cooperation among developed countries and between countries at different stages of economic and social development for mutually supportive objectives, taking into account the interrelationship between population, resources, environment and development. Since the 1992 Earth Summit, the ICAC has undertaken a number of initiatives to make cotton production a more sustainable operation. The initiatives are intended to foster policy changes in ICAC member countries, as well as technical support and financial help in the form of short-duration projects. The projects were sponsored by ICAC and funded by the Common Fund for Commodities. In this regard, two projects are of particular relevance in as much as 11 countries benefited directly, while many more will benefit indirectly from their achievements. The projects, supervised directly by the ICAC Secretariat, are:

Improvement of the Sustainability of Cotton Production in West Africa (CFC/ICAC 25FT)

Cotton production almost doubled every 10 years in the West African countries for the last four decades. Average yields increased primarily during the 1960s and the 1970s but there has been no increase in yields for over two decades. This indicates that production increases have come from increases in the area devoted to cotton. Stagnation in yields, plus continuous increases in production costs threatened cotton production in the West African countries. Many countries in the region are also going through drastic changes in the previously centralized cotton production and marketing systems and are looking for new directions through which to continue producing cotton. The United Nations Conference on Trade and Development (UNCTAD), Geneva, Switzerland implemented a project entitled 'Improvement of the Sustainability of Cotton Production in West Africa,' which involved Benin, Burkina Faso, Cameroon, Chad, Ivory Coast, Mali and Togo. The

project concluded with a final workshop held in Bamako, Mali, in February/March 2005, wherein the participating countries and many international organizations, along with private companies active in the region, discussed various options to improve the sustainability of cotton production in the area. In addition to critically analyzing weaknesses in the current systems, the workshop developed many recommendations for countries to follow. The workshop's recommendations provided an opportunity for participating countries to pursue a number of avenues with further support from international organizations. The recommendations of the workshop may be obtained from UNCTAD or from ICAC.

Sustainable Control of the Cotton Bollworm *Helicoverpa armigera* in Small-Scale Cotton Production Systems (CFC/ICAC14)

China (Mainland), India and Pakistan together accounted for 51% of world cotton area in 2004/05. The most destructive insect in the three countries is the American bollworm *Helicoverpa armigera*. Due to the intense use of insecticides in China (Mainland), the pest has developed full resistance to the insecticides available in the country. Farmers were using insecticides again and again without any success in controlling the pest. Consequently, cotton yields started to decline while production costs continued to climb. Despite the negative experience China (Mainland) had already suffered, insecticide use in India and Pakistan kept increasing. There was fear that the situation in China (Mainland) would repeat itself in India and Pakistan. Thus ICAC arranged for China (Mainland), India and Pakistan to work together on the above-mentioned project. Additional technical input and management provided by the UK helped to implement the project. The five-year project concluded in June 2005 and the final workshop to disseminate results was held in India on June 27-29, 2005.

The project was designed to enhance the ability of old-world, small-scale cotton farmers, particularly in Asia, to manage the key pest, the cotton bollworm, *Helicoverpa armigera*, in a more rational, effective and economic manner. Work focused on the appropriate use of chemical components within an IPM context, in particular, how to reduce the widespread problem of acquired resistance to chemicals. Key outcomes of the project are:

Insecticide resistance monitoring

The patterns of resistance to the major chemical groups was mapped and it was concluded that pyrethroid resistance is the most severe; organophosphate/carbamate resistance was generally moderate and there were variable levels of endosulfan resistance. It is clear that the precise pattern in any one place will be a function of the historical use and sequence of chemicals applied.

Resistance mechanisms

The project concluded that among metabolic mechanisms, enhanced oxidases are of considerable importance in

pyrethroid resistance in India and China and, to a lesser extent, in Pakistan. Esterases are of secondary importance for all four major chemical groups in the three project countries, whereas they are of primary importance in Australia but are not important in West Africa. Glutathione-S-transferases have been found to play only a minor role in any of the studied sites. Among the target site mechanisms, nerve insensitivity was found to be important for pyrethroid resistance in heavily sprayed parts of India, but of lesser importance in China. As a mechanism of resistance to organophosphates and carbamates, modification of the target acetylcholine esterase was of only moderate significance in India, China and Pakistan. Reduced cuticular penetration has been shown to be a mechanism in pyrethroids (and possibly other chemicals) in Pakistan and China and, in all likelihood, in India.

Insecticide mixtures

The project concluded that if resistance to pyrethroids is metabolically based (as in most cases), a mixture of phosphothiorinate organophosphates with a pyrethroid can restore its efficacy, but the newfound efficacy of the mixture may be short lived.

Laboratory measured resistance and its relation to field control

The project concluded that there is a reasonably constant and useable relationship between the mortality of 3rd instar larvae in laboratory assays (the standard resistance monitoring method) and the ability of that chemical to control *H. armigera* in the field, something that had not previously been demonstrated and was widely doubted.

Minimum effective insecticide application practices

Detailed work in northern India on patterns and rates of deposition of spray droplets on crop canopies of different ages have demonstrated what the minimum equipment specifications are for acceptable control of *H. armigera* larvae using a chemical (spinosad was used as a model) to which no resistance had been developed. These specifications (particularly for spray nozzles) have been disseminated to farmers through booklets and recommendations, as well as to manufacturers through a dedicated workshop in Northern India.

Insecticide quality kits

The project developed a kit for easy, economical and quick testing of insecticide quality. Patenting and commercialization of the invention is being pursued through the Indian Council of Agricultural Research in the best interests of small-scale farmers.

Resistance detection kits

Current assays for resistance depend on laboratory assessment of the average level of mortality in cotton bollworm

populations resulting from a particular chemical. The ELISA plate and dip-stick kits that have been developed allow for the detection of a specific resistance mechanism in single larvae in a field or office situation. Patenting of this achievement is also in process.

The project published a handbook covering all aspects of sustainable control of the cotton bollworm. Other results of the project were abundantly demonstrated to researchers in the project countries and even outside the region, particularly in the West African countries, where insecticide resistance has been an issue for some time. National institutions in the project countries made significant contributions, both financial and technical, to the success of the project. The project will reduce insecticide use and improve the economics of cotton production.

Technical Seminars

The Technical Information Section of the ICAC organizes a Technical Seminar on a selected topic each year at its plenary meeting. Since 1991, the selected topics have covered a wide variety of issues related to improving the sustainability of cotton production. Speakers, including farmers, from many countries have been invited to discuss various aspects of the selected topic. Papers are published after each meetings and are available from ICAC. The objective is to minimize reliance on expensive inputs and explore more environment-friendly production practices with the ultimate goal of improving farmers' income. Some of the related topics were:

- Growing Cotton in a Safe Environment – 1991
- Yield Constraints in Cotton and Producing Quality Cotton under Rainfed Conditions - 1993
- New Sources of Genetic Resistance to Cotton Pests - 1995
- Short Season Cotton: How Far can it Go? - 1996
- Cotton-Global Challenges and the Future - 2000
- Integrated Crop Management - 2001
- How to Improve Yields and Reduce Pesticides Use? - 2004

ICAC Plenary Meetings

In addition to the technical seminar, which usually lasts a full day, plenary sessions have also been organized on topics related to enhancing the sustainability of cotton production. Two such sessions 'Strengthening the input supply chain to small holders' and 'Facilitating adoption of best agronomic practices by small holders' were held at the plenary meeting held in India in November 2004. Nine papers from nine different countries were presented in the two sessions. A similar session in 1999 was devoted to reducing the cost of cotton production. All these papers were published and are available from ICAC.

References

- Anonymous. *Johannesburg Plan of Implementation*. Available at http://www.un.org/esa/sustdev/documents/WSSD_POI_PD/English/POIToc.htm
- Benbrook, Charles. 2001. Do GM crops mean less pesticides use? Pesticide Outlook 2001. The Royal Society of Chemistry, October 2001, Page 204-207.
- Brundtlan, Gro Harlem. 1987. Our Common Future, A/42/427. World Commission on Environment and Development (WCED), United Nations, Available at http://www.are.admin.ch/are/en/nachhaltig/international_uno/unterseite02330/
- Earles, Richard. 2002. Sustainable Agriculture: An Introduction. Appropriate Technology Transfer for Rural Areas. Available at www.attra.nact.org.
- Food and Agriculture Organization of United Nations. Global IPM Facility at <http://www.fao.org/ag/AGP/AGPP/IPM/gipmf/index.htm>.
- Technical Information Section. 2003. FAO-EU IPM program for cotton in Asia. *THE ICAC RECORDER*, Vol XXI, No. 3, September 2003.
- Technical Information Section. 2004. The Australian Best Management Practices program. *THE ICAC RECORDER*, Vol XXII, No. 1, March 2004.

Update On Cotton Maturity, Fineness and Micronaire Measurements

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Introduction

Micronaire is of practical importance for international cotton classers and spinners (Heap, 2000). It is an indication of both fineness and maturity and has been used as a substitute when these measures are not available. A relatively low micronaire is explained as a predictor of problems in processing due to immature cotton or as fine fibers with adequate maturity. Similarly, growers may receive a discounted price for high micronaire. This is predictable for coarse cotton and is undesirable from the point of spinning and yarn evenness or from fibers with adequate fineness and good maturity. These fuzzy assignments of a micronaire value to the corresponding maturity and fineness levels make it increasingly clear that the latter measures are needed in cotton trade.

On a more fundamental level, any one of the three properties (micronaire, fineness or maturity) is sensitive to changes in the other two. For any cotton, the unique combination of these fiber characteristics may influence the performance of a broad range of functions such as maturity, yarn strength and dye uptake. This is why the measured properties are of interest to breeders and in the manufacturing of cotton products.

An earlier report concentrated on improved instrumentation at the Southern Regional Research Center (SRRC) to measure cotton maturity and fineness (Montalvo, 1995). SRRC continues to be actively involved in advancing measurements of the three fiber properties through fundamental research, instrumentation and method development, and technology

transfer. In this report, we present an update of this work. The key topics discussed under each category are listed in Table 1 for ease of reference. To be included in this table, the research must have been published after 2000 or is in progress.

Fundamentals

Diagnostic Relationships

When studying the relationships between micronaire and maturity, micronaire and fineness, and maturity and fineness, variability in the coefficient of determination (R^2) is observed. A reduced R^2 may be due to errors in the data, no relationship between the variables, or some underlying phenomenon that increases the variance in fitting data to a least squares model.

To understand the variability in R^2 , models of the three fiber properties were computer simulated. An unexpected finding was that rather than single line plots, the different graphs of the simulation database all produced a family of lines, each at a fixed perimeter. For a data set comprising a series of lines, the R^2 value will be reduced. To enhance the R^2 values requires that better plotting models be developed. Several new plotting models were created and are called diagnostic models, because perimeter is included in the complex relationships in a way that collapses the family of lines into one line. As a consequence, the relationships can be studied independently of how the data was measured.

An example plot of one of the diagnostic relations is shown in Figure 1. Figure 1A demonstrates a conventional graph of

fineness (H) versus maturity (M) for a subset of 30 of over 400 worldwide cottons, with a poor correlation coefficient. The linear regression model in the conventional plot is $H = kM$, where k is the slope at a fixed perimeter. Examination of the perimeter values shows a range of perimeters. This results in an underlying family of lines and very poor R^2 . When the same 30 cottons are graphed using the diagnostic model ($H/P = 0.0698MP$) where P is the perimeter (μm), the correlation coefficient is excellent as shown in Figure 1B. Note also that the slope and intercept are close to the model values of 0.0698 and zero, respectively. H/P versus MP is plotted rather than H versus MP^2 since the latter gives large numbers.

This fundamental and applied work is being published in the same issue of the *Journal of Cotton Science* (Montalvo, 2005; Montalvo and Von Hoven, 2005b). Part three of the series on 'Added error' is in preparation. These are the first articles on using modeling to understand variability in R^2 between the three fiber properties of interest, testing derived models with a large dataset, and the effects of added error on model performance.

Instrumentation and Methods

Improve FMT Precision

The FMT (Shirley Developments Limited Fineness and Maturity Tester, Micromat model) measures fineness and maturity based on air permeability through a fixed mass of compressed fibers. Differential pressures are the quantities measured. The initial stage of compression is referred to as PL for low pressure and the second stage compression is referred to as PH for high pressure; units are in mm water. The mechanically cleaned cottons are placed manually in the sample chamber. Fineness, maturity, micronaire and perimeter are calculated from the instrument readings by appropriate empirical equations (Montalvo and Von Hoven, 2005b). The FMT was upgraded at SRRC and has produced more upgrading data (Montalvo *et al.*, 2001b). Additionally, the New Orleans researchers have developed two practical approaches to obtain considerably more precise data.

The focus of the first investigation was to learn how to minimize variations that occur when cotton is mechanically cleaned (prepared) for FMT analysis and when the operator puts the specimen in the sample chamber (Montalvo *et al.*, 2002). Sensitivity of the instrument to an operator is detected as random 'spikes' or outliers in the data and is caused by an air channel or tightly packed cluster of fibers in the sample chamber. Sensitivity to preparation is recognized as 'biases' or persistent shifts in the data. Correcting data (PL and PH repeat readings) for operator influence is achieved by using statistical software to strip the questionable points outside the '3-sigma limit' from the data set. Correcting the data for preparation effects on operator corrected mean data is achieved by checking for improper settings in mechanical cleaners or by avoiding the use of a specific cleaner.

The second study to improve FMT precision dealt with a novel sample insertion tool compared to an existing three-prong device (Figure 2) (Montalvo and Von Hoven, 2003). This new mechanical device is used with a carded sample that has been rolled into a cylinder about 2" diameter and 5" long and allows for retesting of a sample. Retesting is useful for research purposes, to understand the effects of compression, as well as for quality control purposes. Hysteretic effects due to compression in the sample chamber were avoided by allowing at least one week for a tested sample to "bloom" before retests were conducted. The original length of the cylindrical sample along with the initial PL and PH readings were fully recoverable. Between tests, the samples were stored horizontally in tubes to minimize the effects of gravity on the blooming process. Based on the reduction of the coefficients of variation (Table 2), the wire insertion method is a more precise means of presenting the sample to the FMT. Fiber property ratios of the retests compared to the original tests were not practically different from one and there is no operator effect on the results.

Calibrate Improved FMT

Historically, the FMT had been calibrated using one high micronaire, high maturity cotton. The New Orleans research team showed that this approach did not result in unequivocal calibration of the SRRC upgraded FMT. The differences between the observed and reference values for micronaire, maturity, and fineness increased with a decrease in micronaire (Montalvo *et al.*, 2001a).

For this reason, a set of twelve cottons with micronaires ranging from 2.3 to 5.5 was used to calibrate the instrument (Von Hoven *et al.*, 2001, 2002). For the reference or target values, maturity and fineness values were measured using two independent reference methods.

The first of these was the British Standard Methods for maturity and fineness, respectively (British Standard BS 3085:1981 and BS EN ISO 1973:1996). We used 1,000 fibers for analysis of maturity on swollen fibers and 2,000 for fineness by weighing cut fibers. Maturity was also measured by the Lord Micronaire equation (Heap, 2000), given micronaire by the FMT instrument and fineness by the British Standard Method.

The second reference method used was image analysis of the fiber cross sections (Boylston *et al.*, 1991). Images of the cross sections containing 300 to 500 fibers are then analyzed using the Fiber Image Analysis (FIA) system (Xu and Ting, 1996a, 1996b). The fiber perimeter, area and circularity, are measured. Circularity of the non-swollen fiber is then converted to maturity ratio using the constant 0.577, established by Peirce and Lord (1939). Fiber fineness is calculated from the data.

Averages of the fiber properties by the different reference methods are calculated to develop the reference or target micronaire, maturity and fineness values of the 12 calibration cottons for the FMT to match. From these fiber properties, the FMT double compression target readings at low and high

compression, *PL* and *PH*, respectively, were back calculated using Lord's FMT models (Lord and Heap, 1988).

With these target *PL* and *PH* values, the FMT can be calibrated by minimizing the differences between the FMT instrument readings and the target values. This is accomplished by altering the volume of the FMT chamber. The relationships between the observed and target values (mm water) can vary widely as indicated in Figure 3A, 3B, and 3C. In Figure 3C, a constant offset relationship is noted. Thus, by a simple subtraction that we easily automated, the difference in readings is removed from both *PL* and *PH* and then micronaire, maturity and fineness can be calculated. When utilizing the constant offset relationship and comparing the measured FMT values to the target values that were averaged from the independent reference methods, good correlations were noted for micronaire, maturity and fineness, Figures 3D, 3E and 3F, respectively.

Create Master NIR Sample Sets

The calibrated and updated SRRC FMT (Von Hoven *et al.*, 2001, 2002) is used as a reference method for calibrating newer, faster and user friendly instrumentation such as the NIRSystems Model 6500 near infrared unit in an HVI configuration. However, NIR requires many more samples to be calibrated than the 12 used to calibrate the FMT. The NIR must be calibrated with over 100 cottons to develop prediction accurate algorithms for micronaire, maturity and fineness.

Since US cotton is traded in a global market, we asked the question: "How many NIR calibration and validation cottons are recommended by the International Committee on Cotton Testing Methods of the International Textile Manufacturers Federation (ITMF) to create master NIR sample sets?" SRRC consulted with representatives of the ITMF Maturity and Fineness Working Group. The consensus was that the 300 and 100 cottons will be used for calibration and validation, respectively. Additionally, proper regard should be given to adequate diversity of the samples in area grown, variety and crop year. The actual number of samples in the SRRC master NIR sets is: calibration (305) and validation (99) or a total of 404 worldwide cottons spanning the micronaire range from 2.2 to 5.7. There are at least 40 varieties of cottons from seven crop years in the two groups of samples.

An overview of the FMT and NIR analysis procedures follows. After blending and cleaning the samples on the Shirley Analyzer, each was divided into two portions – one for the FMT to determine reference micronaire, maturity and fineness values and the other to establish the NIR calibration equations (Montalvo and Von Hoven, 2005a). Descriptive statistics of the calibration set is shown in Table 3. For NIR calibration, partial least squares (PLS) with cross-validation was used to check for outliers, to ensure a high correlation between NIR and the FMT values, and to establish the calibration equations. These algorithms were then used to predict the fiber properties in the independent validation set. Results were quite good as shown in Figures 4A, 4B and 4C, for micronaire, maturity

and fineness, respectively, indicating the viability of NIR to quickly, easily and accurately measure these fiber properties. Robustness of the calibration equations has been demonstrated with the master NIR sample sets and justifies NIR round-robin studies.

Develop Advanced NIR HVI

Building on the results of studies conducted with the 1st and 2nd generation NIR HVI (Montalvo and Von Hoven, 2004), an advanced NIR HVI has been developed. A 2D model of the unit is shown in Figure 5 and consists of a mechanically robust fast NIR spectrophotometer that is placed under and off center a large rotating quartz window. A rotating plunger presses the revolving sample cell against the quartz window and transports fibers over the NIR sensor. Also, the spectrophotometer moves in a linear motion parallel to the sample plane. As a result, both the sample surface area scanned and the amount of cotton in the test cell can be varied. The unit operates at either a constant sample volume or a constant plunger force that presses the fibers against the quartz window. Cleaned, raw and seed cotton may be analyzed. The physical standards port allows for high precision standards in the analysis protocol. Performance studies are in progress.

Explore NIR Probe Applications

The use of fiber-optic probes and hand-held or portable NIR analyzers continues to grow. Several of these probe and portable techniques have been applied to fiber measurements, especially in the synthetic fiber industry (e.g., Costello and Knepper, 1996; Rodgers *et al.*, 2001; Rodgers, 2002; Rodgers *et al.*, 2004; Rodgers and Beck, 2005). Investigations have been initiated with cotton fiber properties that will lead to the direct comparison of standard bench-top dispersive NIR and FT-NIR analyzers with a portable NIR analyzer. Initial trials on a small sample set indicated that the portable NIR unit's ability to measure cotton maturity was very good and comparable to the results obtained with the larger, more sophisticated bench-top units. However, the initial analysis of the micronaire on these samples by the portable unit yielded good overall results, but the portable unit's micronaire results were not as robust as those obtained with the bench-top NIR analyzers. Comparative studies are in progress and expanding.

Technology Transfer

Comprehensive Review and Tutorial

In the assessing of cotton fiber quality, almost all measurements are being made by destructive techniques with their limitations on accuracy, speed and ease of use. By contrast, analytical NIR networks based on nondestructive reflectance spectroscopy are already in place worldwide in the grain industry to ensure quality of data. To understand this discrepancy, the NIR literature on cotton fiber analysis was reviewed and a critical analysis of the published reports was conducted. This work showed that successful application of

NIR spectroscopy to cotton fiber quality measurements has generally been precluded by shortcuts in development and validation (e.g., use of small sample sets without proper regard to variety, crop year and geographic area). This research was the basis of a book chapter that serves as a tutorial to research administrators and to experienced and new scientists in how to avoid the limitations of the past in future cotton work (Montalvo and Von Hoven, 2004).

New FMT Analyses More Fibers

At the request of Cotton Incorporated, we provided specifications to the Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia to design and construct a new fineness and maturity tester that analyzes a 10 g specimen rather than the 4 g inserted into the SDL FMT. By comparison, 4 g is equivalent to about 400,000 fibers (Montalvo, 1995) and 10 g is 1 million. The contractor is building 3 units. Initial precision studies of the *PL* and *PH* readings will commence this fall with cotton provided by SRRC.

Image Analysis Tops a Million Cross-Sections

The image analysis reference method (Thibodeaux and Rajasekaran, 1999) for maturity is based upon embedding bundles of parallel cotton fibers in a polymer matrix, cutting thin sections of the embedding, and imaging the cross-sections with a light microscope. Digital images of the fiber cross-sections are analyzed to accurately measure the outer perimeter and cell wall area of each fiber in the section. With the support of Cotton Incorporated, this technique has been used to develop a set of cotton standards for fineness and maturity distributions and averaged values (Hequet and Wyatt, 2005). A total of 104 cotton bales were selected representing a wide range of fineness and maturity values. A minimum of 4,000 fiber cross-sections were measured for each of the bales and, in the case of seven of the 104 bales, 40,000 cross-sections were analyzed. The standards are available in sufficient quantities for use in standardizing high-speed instruments to measure fineness and maturity.

ITMF Maturity and Fineness Working Group

The functions of the Maturity and Fineness Working Group of the ITMF International Committee on Cotton Testing Methods are to select and recommend standards and test methods for maturity and fineness. Meetings are held in even-numbered years in Bremen, Germany. A prototype double compression fineness and maturity tester (FMT) was developed that incorporates a 10 g sample of cotton (Abbott et al., 2004; Naylor et al., 2005) (also, see New FMT Analyses More Fibers, above). In addition, an instrument dubbed Cottonscan has been developed to measure the average values of cotton fineness and maturity based on counting cut fibers (Naylor and Purmalis, 2005). Also, using interference colors transmitted

under polarized optics to measure the maturity of cotton has been demonstrated (Gordon and Phair, 2005).

Disclaimer

Mention of a trademark, warranty, propriety product or vendor does not constitute a guarantee by the U.S. Department of Agriculture and does not imply approval or recommendation of the product to the exclusion of others that may be suitable.

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References

- Abbott, A.M., S.R.Lucas, G.R.S. Naylor and C.R. Tischler. 2004. Design and implementation of an upgraded FMT incorporating a 10 gram sample. *Proc. Beltwide Cotton Conf.*, San Antonio, TX. 4-8 Jan. 2004. Natl. Cotton Counc. Am., Memphis, TN. p. 2335.
- Boylston, E. K., O. Hinojosa and J.J. Hebert. 1991. A Quick Embedding Method for Light and Electron Microscopy of Textile Fibers. *Biotechnic Histochem.* 122-124.
- British Standard BS EN ISO 1973:1996. Textile fibres-Determination of linear density-Gravimetric methods and vibroscope. British Standards Institution, London.
- British Standard BS 3085:1981. Method for evaluation of the maturity of cotton fibers (microscopic method). British Standards Institution, London.
- Costello, M. and S. Knepper. 1996. Identification of Post-consumer Carpets by NIRA. AATCC Textile Applications of NIR Technology Symposium, Ashville, NC.
- Heap, S.A. 2000. The meaning of micronaire. *Proc. Int. Cotton Conf. Bremen*, 1-4 March 2000. Faser Institute Bremen e.V., Bremen, Germany. p. 97.
- Hequet, E. and B. Wyatt. 2005. Analysis of cotton fiber cross sections. *Proc. Beltwide Cotton Conf.*, New Orleans, LA. 4-7 Jan. 2005. Natl. Cotton Counc. Am., Memphis, TN. p. 2312.
- Gordon, S. G. and N.L. Phair. 2005. An investigation of the interference colours transmitted by mature and immature cotton fibre under polarised light microscopy. *Proc. Beltwide Cotton Conf.*, New Orleans, LA. 4-7 Jan. 2005. Natl. Cotton Counc. Am., Memphis, TN. p. 2284.
- Lord, E. and S.A. Heap. 1988. The origin and assessment of cotton fibre maturity. Institute for Cotton. Tech. Res. Division, Manchester, UK.
- Montalvo, J.G., Jr. 2005. Relationships between micronaire, fineness and maturity. Part I. Fundamentals. *J. Cotton Sci.* 9:81-88.
- Montalvo, J.G., Jr. 1995. Improved instrumentation to measure cotton maturity and fineness. December, *The ICAC RECORDER*. 13(4):3-7.

- Montalvo, J.G., Jr., S.E. Faught and S. M. Buco. 2002. Sensitivity of the Shirley Developments Limited Micromat Tester to operator and sample population. *J. Cotton Sci.* 6:133-142.
- Montalvo, J.G., Jr. and T. Von Hoven. 2005a. Micronaire, maturity and fineness research. *Proc. Beltwide Cotton Conf.*, New Orleans, LA. 4-7 Jan. 2005. Natl. Cotton Counc. Am., Memphis, TN. p. 2206.
- Montalvo, J.G., Jr. and T. Von Hoven. 2005b. Relationships between micronaire, fineness and maturity. Part II. Experimental. *J. Cotton Sci.* 9:89-96.
- Montalvo, J. G., Jr. and T. Von Hoven. 2004. Analysis of cotton. Chapter 25, p. 671-728. In Near-Infrared Spectroscopy in Agriculture, Agronomy Monograph no. 44, American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, WI, USA.
- Montalvo, J.G., Jr. and T. Von Hoven. 2003. Improved FMT precision with new sample insertion technique. *Proc. Beltwide Cotton Conf.*, Nashville, TN. 6-10 Jan. 2003. Natl. Cotton Counc. Am., Memphis, TN. p. 1961.
- Montalvo, J.G. Jr., T. Von Hoven, S.S. Reed, D.L. Francois and S.E. Faught, 2001a. Cotton research planning meeting. Southern Regional Research Center, New Orleans, LA, Sept. 6-7, 2001.
- Montalvo, J.G., Jr., T. Von Hoven, S.S. Reed, D.L. Francois and S.E. Faught. 2001b. Organizational and Instructional Manual for the Upgraded Micromat Fineness and Maturity Tester. Southern Regional Research Center, New Orleans, LA.
- Naylor, G. R. S., A.M. Abbott, B. Aspros and S.R. Lucas. 2005. The between instrument performance of two upgraded FMT machines. *Proc. Beltwide Cotton Conf.*, New Orleans, LA. 4-7 Jan. 2005. Natl. Cotton Counc. Am., Memphis, TN. p. 2291.
- Naylor, G. R. S. and M. Purmalis. 2005. Update on Cottonscan: an instrument for rapid and direct measurement of fibre maturity and fineness. *Proc. Beltwide Cotton Conf.*, New Orleans, LA. 4-7 Jan. 2005. Natl. Cotton Counc. Am., Memphis, TN. p. 2302.
- Peirce, F.T. and E. Lord. 1939. The fineness and maturity of cotton. *J. Textile Inst.* 12:T173-210.
- Rodgers, J. 2002. Influences of Carpet and Instrumental Parameters on the Identification of Carpet Face Fiber by NIR. *AATCC Review* 2(6):27-32.
- Rodgers, J. and K. Beck. 2005. Rapid Determination by NIR of the Cotton Content of Blend Fabrics After Dyeing. *Proc. Beltwide Cotton Conf.*, New Orleans, LA. 4-7 Jan. 2005. Natl. Cotton Counc. Am., Memphis, TN. p. 2731.
- Rodgers, J., S. Ghosh and W. Cardwell. 2001. Measuring Nylon Carpet Yarn Heat History by Remote NIR Spectroscopy. Part II: Applying Remote Fiber Optic NIR Techniques to the Manufacturing Environment. *Textile Res. J.* 71(2):135-144.
- Rodgers, J., P. Sukpaladisai, R. Barraza and C. Horton. 2004. At-Line Process Control of the Moisture and Finish-On-Fiber of Textile Products by NIR. *J. Process Anal. Chem.* 9(2):64-71.
- Thibodeaux, D.P. and K. Rajasekaran. 1999. Development of new reference standards for cotton fiber maturity. *J. Cotton Sci.* 3:188-193.
- Von Hoven, T. M., J.G. Montalvo, Jr., S. Reed, D. Francois, S. Buco and S. Faught. 2001. Calibration of upgraded FMTs. *Proc. Beltwide Cotton Conf.*, Anaheim, CA. 9-13 Jan. 2001. Natl. Cotton Counc. Am., Memphis, TN. p. 1302.
- Von Hoven, T. M., J.G. Montalvo, Jr., S. Reed, D. Francois and S. Faught. 2002. Calibration of upgraded FMTs. Part II. Expansion of Results. *Proc. Beltwide Cotton Conf.*, Atlanta, GA. 8-13 Jan. 2002. Natl. Cotton Counc. Am., Memphis, TN.
- Xu, B. and Y.L. Ting. 1996a. Fiber-image analysis. I. Fiber-image enhancement. *J. Textile Inst.* 87(2):274-283.
- Xu, B. and Y.L. Ting. 1996b. Fiber-image analysis. I. Measurement of general geometric properties of fibers. *J. Textile Inst.* 87(2):284-295.

Table 1
Major Categories and Key Topics in This Report of Update of SRRC Research on
Maturity, Fineness and Micronaire Measurement Technology^a

Category	Topic
Fundamentals	Diagnostic Relationships
Instrumentation and Methods	Improve FMT Precision Calibrate Improved FMT Create Master NIR Sample Sets Develop Advanced NIR HVI Explore NIR Probe Applications
Technology Transfer	Comprehensive Review and Tutorial New FMT Analyses More Fibers Image Analysis Tops a Million Cross-Sections ITMF Maturity and Fineness Working Group

^aStandard units are maturity (maturity ratio), fineness (*mtex*), and micronaire (micronaire units).

Table 2
Insertion Methods Compared: CV (%) of *PL* and *PH*
(both mm water) of High and Low Micronaire Cottons

	Prong	Wire
Low Mic		
<i>PL</i>	1.60	1.17
<i>PH</i>	1.51	1.06
High Mic		
<i>PL</i>	1.47	1.10
<i>PH</i>	1.76	1.20

Table 3
Descriptive Statistics of the NIR calibration set
as measured by the FMT^a

Statistic	<i>H</i>	<i>M</i>	<i>Mic</i>
Minimum	111	0.486	1.96
Maximum	254	1.11	5.92
Mean	174	0.864	4.06

^aUnits: *H* (fineness, *mtex*), *M* (maturity ratio), *Mic* (micronaire)

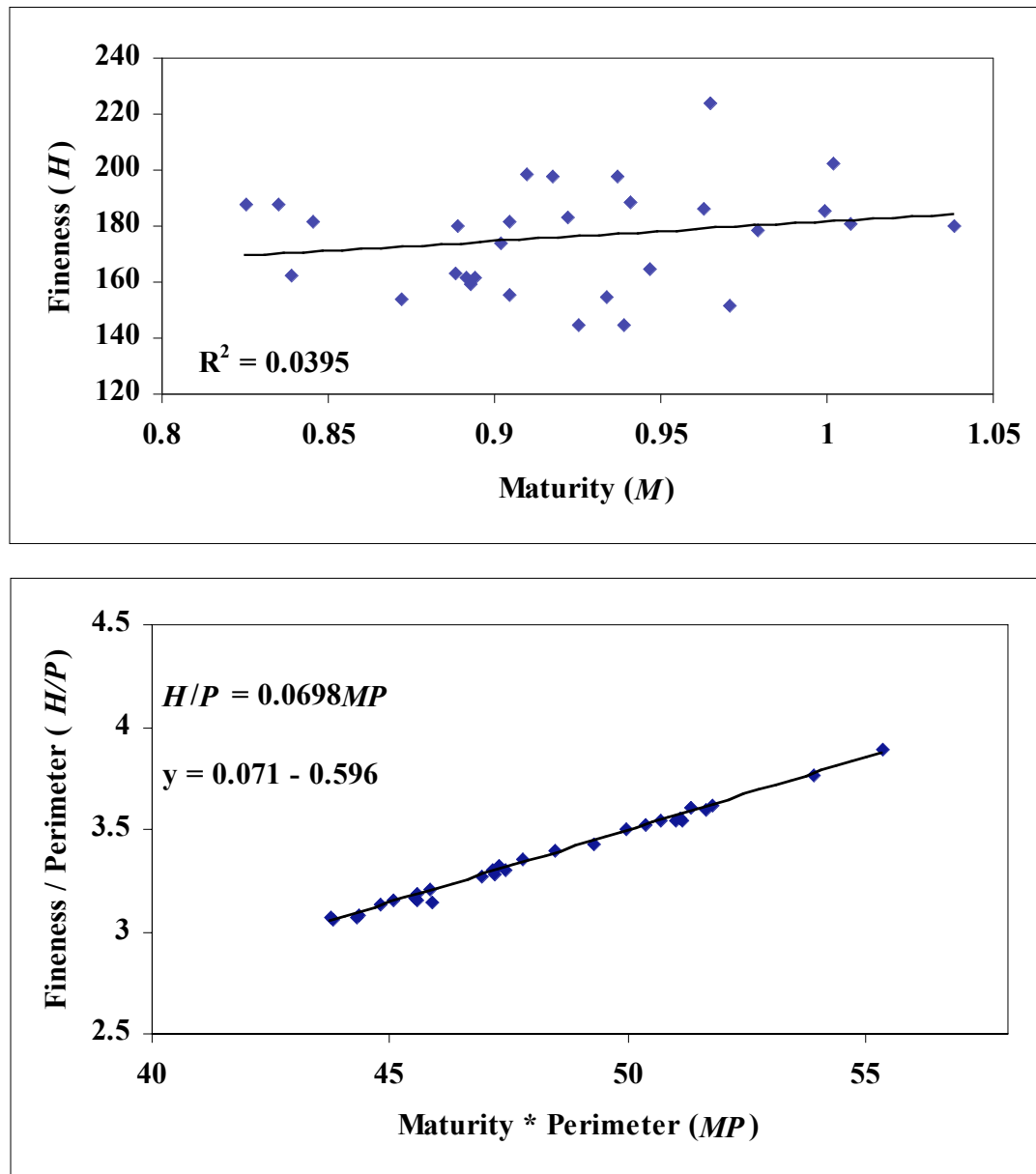


Figure 1. Plots of fineness and maturity data that were measured by the SRRRC improved FMT. Points represent mean values computed from six replications on 30 cottons. The scatter plot (A) shows the conventional graph of fineness vs. maturity; the new plotting model (B) illustrates collapsing the family of lines into one line.

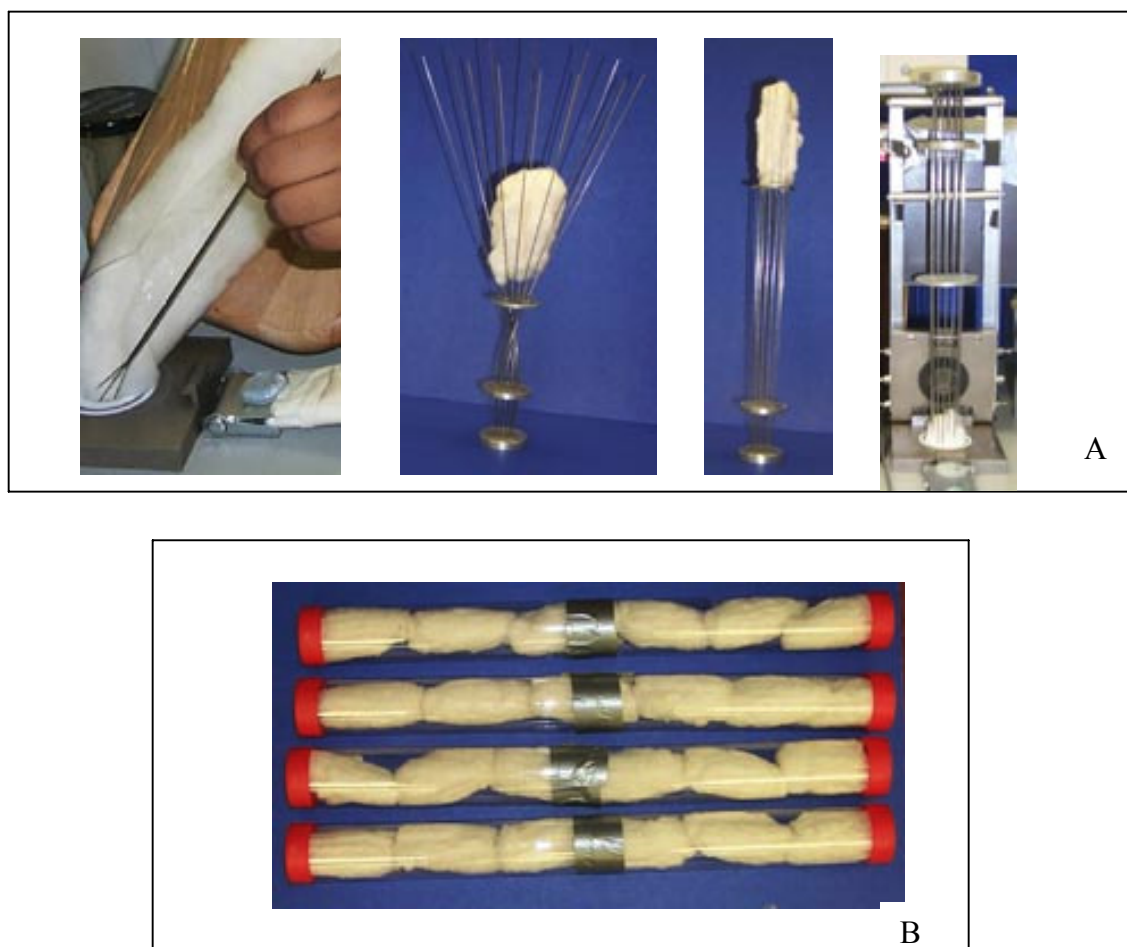


Figure 2. Mechanical tools to insert the sample into the sample chamber of the FMT. (A) Shows the pronged device, far left. Loaded wire tool left to right: opened, closed and inserted into sample chamber. (B) Six FMT replications stored in tubes after wire insertion and analysis

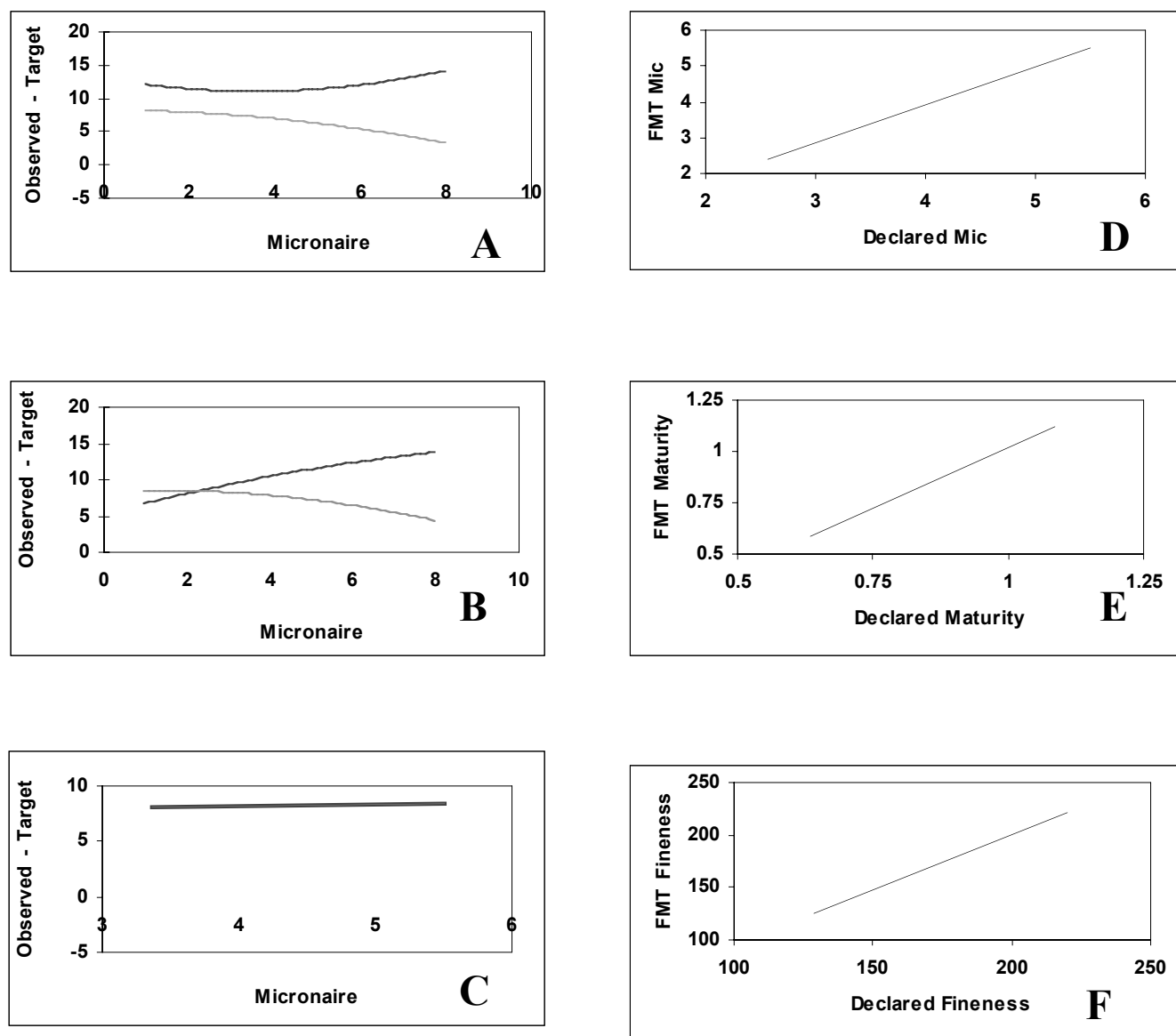


Figure 3. FMT relationships between observed and reference values for twelve calibration cottons spanning the micronaire range. Effects of varying the volume of the FMT sample chamber on differences between observed and target values for the instrument readings (mm water, PL – black line and PH – gray line): (A) Divergent polynomial relationship; (B) Crossing polynomial relationship; and (C) Constant linear offset relationship. Correlation between adjusted observed and reference property values: (D) Micronaire, $R^2 = 0.9914$; (E) Maturity, $R^2 = 0.9590$; and

(F) Fineness, $R^2 = 0.9553$. For clarity, all graphs are presented as smooth lines without showing the points.

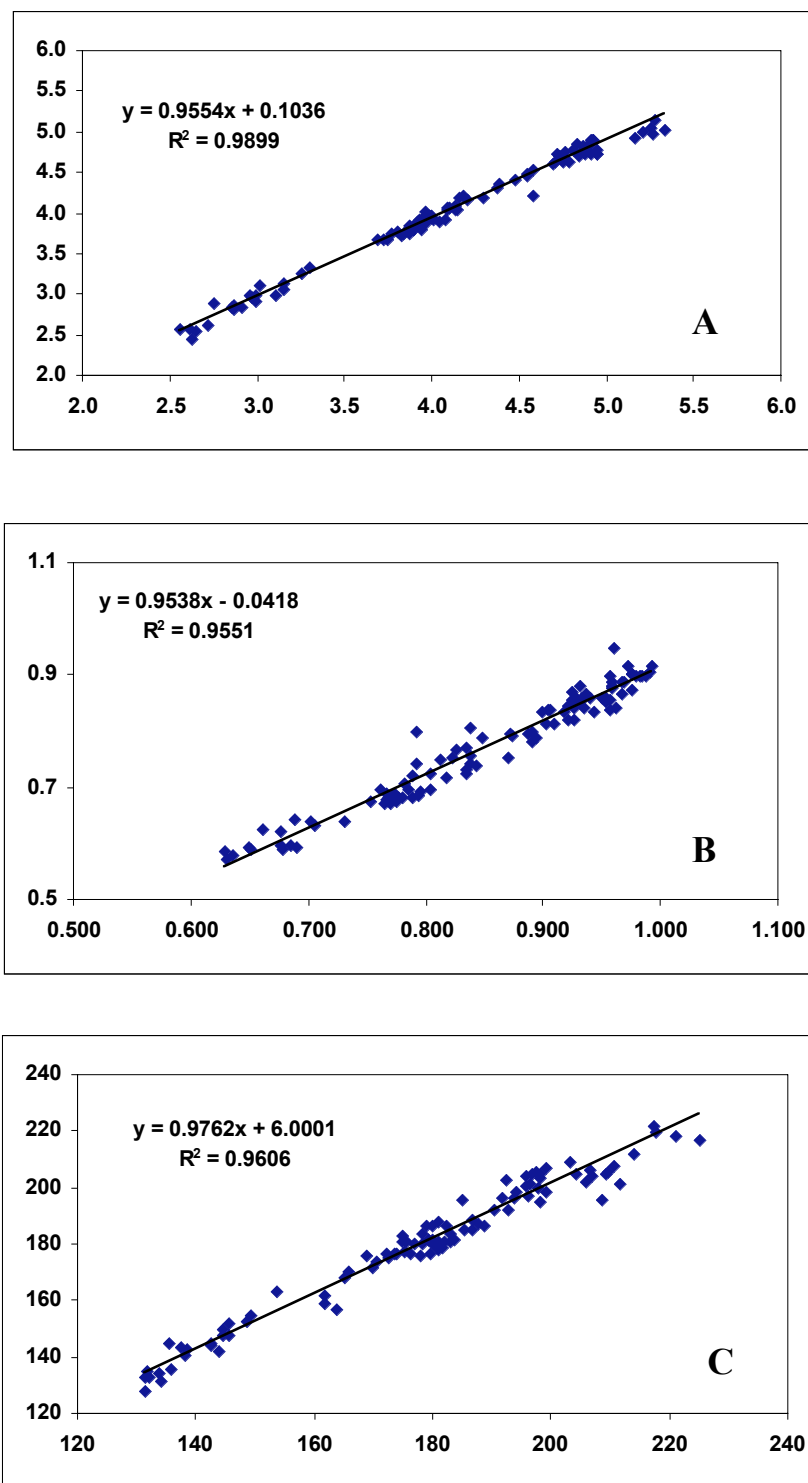


Figure 4. NIR Prediction (y-axis) of micronaire (A), maturity (B) and fineness (C) versus FMT values of an independent set of 99 cleaned cottons using the algorithms developed from 305 worldwide cottons.

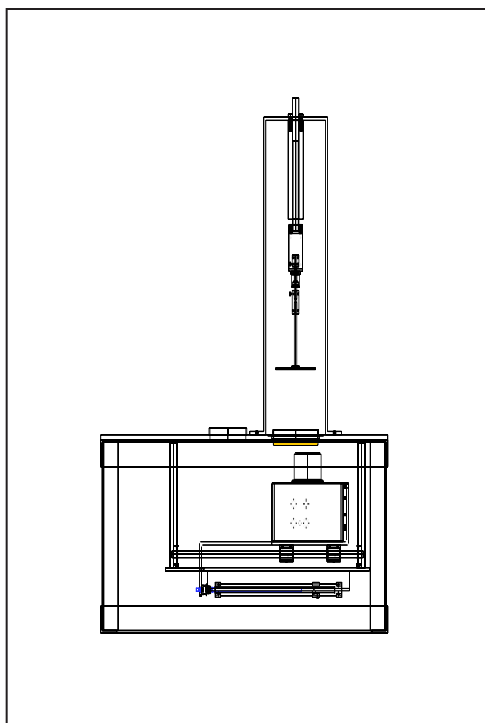


Figure 5. Advanced near infrared high volume instrument (NIR HVI). Front view of 2D wire-frame model; side panels, cotton sample cell, and physical standards are removed for clarity.

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