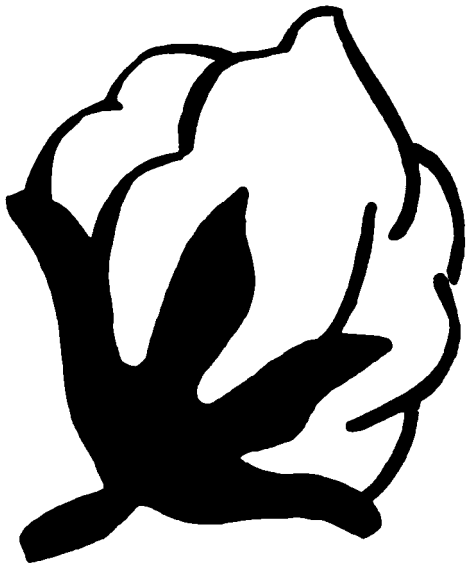




THE ICAC RECORDER

INTERNATIONAL
COTTON
ADVISORY
COMMITTEE

Technical
Information Section

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- **Update on cotton production research**
- **Nouvelles recherches cotonnières**
- **Actualidad en la investigación de la producción algodонера**

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Introduction

The Third Technical Consultation of the Interregional Cooperative Research Network on Cotton for the Mediterranean and Middle East Regions was held in Montpellier, France, from October 2-5, 1996. The Consultation hosted by the CIRAD was also sponsored by the ICAC and FAO Regional Office for Europe. The objectives of the meeting were to review the progress made in the last four years and consider possible changes in the structure of the Network. The meeting was attended by the chairs of various working groups and national coordinators from the member countries, in addition to representatives of the FAO and the ICAC. ICAC's financial support was utilized to bring resource people from as many countries as possible. The chairs of the working groups outlined their programs for the next four years. As much as possible, groups will meet jointly for better communication. Dr. Urania Kechagia of Greece was elected as the new Coordinator of the Network. More details are given in the report.

Dr. Ronaldo A. Sequeira of the USDA-ARS-CSRU, Mississippi State University, Mississippi State, USA, presented a paper on Cotton Modeling and Management at the Third Technical Consultation of the Interregional Cooperative Research Net-

work on Cotton for the Mediterranean and Middle East Regions. Dr. Sequeira discussed in detail the work of the cotton simulation model GOSSYM-COMAX which is commercially used in the USA. Two independent surveys indicated that the model brings additional income to farmers. The system can be run either by setting up the simulation component only (GOSSYM) or by using the automated decision support system, COMAX. His full paper is reproduced here. The ICAC also contributed a paper to the meeting, "Cotton Yields and Current Trends in Cotton Research," which is available from the ICAC Secretariat.

The transgenic Bt cotton resistant to lepidopteran insects was grown on a commercial scale for the first time in 1996/97 in the USA. The bacterial gene, trade-marked as Bollgard™ in the USA and Ingard™ in Australia, is capable of producing protein toxin in the plant throughout its life. This is the same toxin which is found in most biological insecticides. The insect pressure was unfortunately high in the USA during 1996/97 which turned Bt cotton into a test case for the technology. Australia is the second country to grow transgenic cotton on a commercial scale. Bt cotton resistant to herbicides was also grown on a significant area during 1996/97. The US Patent Office has granted a patent

to Calgene, Inc. for the expression of the pigmentation gene, melanin. The company owns Stoneville Pedigree Seed Company and claims that their scientists have developed blue and red colored cottons. They are now working to enhance the shades. Recently, a report was published which showed that Monsanto researchers have changed the thermal properties of cotton. More about these developments and how this technology works is given in the third article.

Organic cotton is produced in eighteen countries in the world. Since the reintroduction of growing cotton without synthetic insecticides, fertilizers, growth regulators and defoliants, over 50,000 tons of organic cotton has been produced in the world. A study carried out in the Netherlands showed that almost all the organic cotton produced in seventeen countries is utilized in mills in Europe. Organic cotton produced in the USA is usually spun locally. Statistics on organic cotton produced since 1990 are given in the fourth article.

In July 1996, the ICAC started an Internet facility for communications on boll weevil and its control strategies. The facility, called the Boll Weevil Mailing List, is available free of charge for exchanging views, observations and research results on any aspect of the boll weevil. More details on the List are included in this issue of *THE ICAC RECORDER*.

A DIALOG Search of the Agricola Database on Growth Modeling is also included at the end of the publication.

At the 55th Plenary Meeting of the ICAC held in Tashkent, Uzbekistan, from October 7-11, 1996, the Technical Information Section organized a one-day Technical Seminar on the topic of

“Short Season Cotton: How Far Can It Go?” Seven papers were presented in the Seminar on various aspects of short season cottons including availability and utilization of germplasm resources, impact of short season cottons on insect pest control, physiological implications of reducing crop duration, problems faced in breeding for short duration cottons and cost of production comparisons between short and long duration varieties. All the papers have been put together and published. Two papers on the introduction and development of short season cottons in Egypt which were not presented in the Seminar are also included in this report. The report is available from the ICAC at a cost of US\$75.00.

Since the recognition of the ICAC as an International Commodity Body with the Common Fund for Commodities, five ICAC projects have been approved. One project has been completed. Ongoing projects will be discussed at the Technical Seminar at the 56th Plenary Meeting of the ICAC in Asunción, Paraguay, from October 27-31, 1997.

Preparations for the World Cotton Research Conference—2 have started. The Conference to be held in Athens, Greece, from September 6-12, 1998, will be hosted by the Hellenic Cotton Board. Centre de coopération internationale en recherche agronomique pour le développement-Département des cultures annuelles-CIRAD-CA, of France, is also sponsoring the Conference. A brochure on the Conference is available from the ICAC Secretariat.

The proceedings of the World Cotton Research Conference—1 are still available. See the notice in this issue.

Third Technical Consultation of the Interregional Cooperative Research Network on Cotton for the Mediterranean and Middle East Regions

The Third Technical Consultation of the Interregional Cooperative Research Network on Cotton for the Mediterranean and Middle East Regions was held at the Centre de coopération internationale en recherche agronomique pour le développement-CIRAD (Center for International Cooperation for the Development of Agriculture) in Montpellier, France, from October 2-5, 1996. The Consultation was attended by fifty-five participants from Belgium, Bulgaria, Egypt, France, Greece, Iran, Iraq, Israel, Japan, Mali, Morocco, Paraguay, Poland, Spain, Sudan, Syria, Turkey, USA, the Food and Agriculture Organization of the UN and the International Cotton Advisory Committee. On behalf of CIRAD's Director General, Mr. J. Lefort, Director, Département des cultures annuelles-CA (Department of Annual Crops) welcomed participants to the Consultation. Mr. M. de Nuccé de Lamothe, President, Agropolis of Montpellier, also addressed the opening session. The Agropolis

of Montpellier is an association of over 2,300 teaching staff, researchers and technologists focusing on the European and Mediterranean regions and countries with tropical climates.

The Network was formally founded in 1988 and its structure was revised during the Second Consultation held in Thessaloniki, Greece, from June 16-19, 1992. Since 1992, the activities of the Network have increased in the form of more meetings of various working groups. The broad objectives of the Network are to facilitate communication among researchers and pool scientific knowledge for the development of cotton in the two regions. In the last four years, working groups organized joint meetings, contributing to frequent communication and exchange of ideas. A detailed directory of cotton researchers was prepared by the Coordinator of the Network and distributed in the regions.

Michel Braud, the outgoing Coordinator of the Network, presented the program of work for the Consultation: Reports of Working Groups on their activities; discussion of reorganization of Network activities, including elimination and addition of working groups and possible cooperation with the FAO European Cooperation Research Network on Flax; and plans for future Network activities.

Reports of the Chairs of Working Groups

The chairs of the working groups in the field of Cotton Breeding, Growth Regulators, Cotton Nutrition, Cotton Technology, Variety Trials and Biotechnology presented their reports. In the last four years, no activities were carried out by the working groups in the field of Weed Control, Water Management and Integrated Pest Management.

Cotton Breeding

The Group on Cotton Breeding contacted members in various countries to determine research priorities. A survey showed that most members want the Group to work on breeding for earliness, exchange and utilization of cultivated and wild species for incorporation of desirable characters, improvement in fiber quality and pest resistance. There is also some interest in joint experiments and exchange of information regarding colored cotton. While seed could not be procured for joint trials, exchange of modern breeding methods and other important scientific topics was realized through a meeting held in Turkey.

It was agreed that the Group should amplify its efforts on exchange of germplasm. Since the last meeting of the Working Group in Adana, a list of germplasm collection having 206 accessions along with their morphological and fiber quality characteristics was prepared and circulated among members of the Group. The issue of a centralized germplasm bank, with CIRAD-CA as custodian of the centralized gene pool was discussed but there was not enough support for such a proposal. The Group will continue revising its list of accessions at frequent intervals. Iran noted its need for very early maturing germplasm, which Greece promised to provide. Egypt proposed undertaking new studies on the efficiency of fertilizer use by different genotypes.

Work in Israel to develop commercial cotton hybrid seed for general cultivation was discussed. The Group noted that cytoplasmic male sterility, genetic male sterility and gametocide methods, in addition to hand emasculation and pollination are available but the high cost of producing hybrid seed is a major hurdle to produce F₁ seed for commercial cultivation. The drawback of these systems—fertility restoration, elimination of 50% of population, phytotoxicity of multiple applications of gametocides and labor intensiveness respectively—can be overcome through identification and incorporation of foreign genes capable of inducing self male sterility in one generation. It was noted that such a male sterility gene has already been identified

in tobacco and rapeseed and something similar is possible in cotton. It was also noted that work has begun on Coker 312 using the Agrobacterium mediated transformation method.

The early stage Israeli experience on hybrid cotton also showed that the textile industry had some concerns about commercial cotton hybrids. The low uniformity index of commercial hybrids in the case of interspecific hybrids was not liked by the industry. In Israel, the problem has been overcome through the use of parental lines which do not give rise to irregular fibers.

Variety Trials

The second round of variety trials, started after the Thessaloniki meeting in June 1992, included factors affecting varietal performance in addition to yield performance. In four years, thirteen institutions from ten countries participated in the Group activities. It was decided to establish joint trials and meetings with the Cotton Technology Group. During 1995, fifteen varieties from eight countries were tested and data for seed cotton yield, ginning lint percent and fiber characteristics were collected. The performance of selected varieties for five countries for the 1994/95 trial has already been reported in the December 1995 issue of *THE ICAC RECORDER*.

The 1995 trials again remained non-uniform, with different varieties planted at different locations. Intervarietal differences did exist but no variety emerged as the highest yielding at all locations. As in 1994, the trial conducted in Syria gave the highest yield followed by Spain. In Syria, the short stature Bulgarian variety Beli Izvor gave the highest yield and ginning outturn (42.1%). In addition to quality characteristics, crop phenology data, days to squaring, days to blooming, days to boll opening, height to node ratio, etc., were also collected. More detailed data using node numbers as indicators of the physiological age of the plant and heat units using a threshold level of 60°F were also recorded in Spain. Performance of varieties under different sets of climatic conditions could aid breeders, although the lack of homogeneity in the data has limited this utilization. Collection of the data did provide a valuable knowledge base of the plant material used in two regions.

Growth Regulators

Since the Group was formed in 1988, three meetings have been held in addition to Consultations of the Network. A cooperative program to manage cotton overgrowth through plant growth regulators, as well as exchange of information, is the recognized mandate of the Group. A survey was undertaken in 1989 on the use of plant growth regulators, the status of research, and current research projects on growth regulators in member countries. This survey served as a basis for information and discussions to identify the cooperative programs and actions with the widest interest and usefulness to all participating countries. The 1994 meeting discussed the results of cooperative research projects conducted from 1990 to 1993, while in 1995 another evaluation of the second cooperative research project was done.

The evaluation of activities has shown that there is a great need for cooperation and there are many areas of common interest on the use of growth regulators. Preliminary experimental work with Pix and a defoliant was used in designing the cooperative research program. The cooperative research project from 1990 to 1993 was conducted in most member countries. The project comprised a study of methods and rates of application of two growth retardants, Pix and Cycocel, in interaction with three levels of nitrogen fertilization aiming at maximum yield and improved lint quality.

In 1994, a new cooperative project was developed which included three new plant growth regulators, i.e. PGR-IV, Cytokinin and PHCA. They were tested in field experiments in Bulgaria, Egypt, Greece, Spain, Syria and the USA. Two more growth regulators (Atonic and Cytoplex) were added in 1995 and 1996.

The results indicated that Pix was effective in controlling plant height and avoiding excessive vegetative growth. In many experiments, Pix applications also favored yield and some fiber characteristics. Cycocel was also effective under certain conditions in controlling plant height. Greece further investigated the relationship between Pix and the endogenous level of leaf tannins, which helped to evaluate the performance of two growth regulators, their optimum use and inaction with N fertilization.

The 1995 and 1996 results showed that PHCA, PGR-IV and Cytokinin could increase yield significantly in Greece and the USA, however, some increase in yield was noticed at nearly all locations. Almost all chemicals enhanced boll retention, nitrate uptake and, in a few cases, improved fiber maturity. In the USA, in other experiments, PGR-IV in water-stressed and shaded cotton increased boll retention and lint yield. In other experiments, Cytokinin was tested in Egypt and Turkey, Pix in Bulgaria and Prep in Israel.

A review of the literature and a comprehensive list of publications on plant growth regulators were prepared and are ready for circulation. An inventory of growth regulators used on cotton has been prepared and will soon be ready for circulation. A directory of researchers involved in growth regulator research compiled by Dr. Oktay Gencer of Turkey was distributed to all members in 1995. The Working Group published the proceedings of the meeting held in 1994 and distributed them in November 1994. The proceedings of the meeting held in 1995 in Cairo, Egypt, are ready for publication.

It was recognized that even with the development of short stature and very early maturing varieties, which are less prone to disturb the balance between reproductive and vegetative growth, plant growth regulators will remain a management tool. Plant growth regulators enhance root development and more roots mean more branches. Growth regulators also help in proper translocation of carbohydrates within the plant, and improve stress tolerance.

Cotton Nutrition

The Working Group on Cotton Nutrition was established in the 1992 Consultation by merging two groups, Nitrogen Nutrition and Micronutrients. The Group has fifty-seven members in twelve countries in Europe and the Middle East and seven countries from Africa, Asia and the USA. The Group has initiated and already published four issues of a newsletter. A meeting was organized in Cairo in December 1995 together with the Group on Growth Regulators. Twenty papers presented on cotton nutrition dealt mainly with diagnostic measures, potassium needs and application and use of foliar fertilizers. The Group decided that the major field of research should be the optimization of cotton nutrition and increasing fertilizer use efficiency. In this regard, testing the efficiency of micronutrient foliar fertilizers and testing genotypes for their efficiency in using different nutrients were found to be of interest to the Group. The work so far has shown that N is very important for Bulgaria, Egypt and Morocco, while K is very important for Egypt. Foliar application of micronutrients and interaction among major nutrients are important for Egypt and Sudan. While discussing the need for K application under high yield production practices, the delegate from Iran noted that application of K decreased the likelihood of verticillium wilt in Iran.

Cotton Technology

All member countries were queried in 1994 to discover areas of mutual interest. From the eleven countries which responded to the questionnaire, the three most important topics of joint research were found to be the effect of the growing environment on cotton quality; standardization of cotton quality parameters; and cotton stickiness.

A joint study with the Working Group on Variety Trials was initiated after the 1994 survey to study the extent of variability in fiber characters based on changes in input applications and cotton growing conditions in various countries. The results for 1994 were published in the December 1995 issue of *THE ICAC RECORDER*. It was agreed in Adana that seed cotton samples for two picking dates from three locations would be sent to Greece. The seed cotton was roller-ginned and lint samples were provided to the Cotton Technology Laboratory of the CIRAD-CA in Montpellier, France, the Cotton and Industrial Plants Institute at Sindos, Greece and the Cotton Research Institute, Egypt, for fiber analysis and spinning tests. Data were available from France and Greece for lint percentage (only from Greece), micronaire and fiber length (for Fibrograph and HVI) and HVI measurement of uniformity index, strength, elongation, maturity and fineness. The data showed the strong effect of the environment on fiber quality in all varieties; a final report will be made available to all members. Though the differences were difficult to explain, in Spain the lint percentage value decreased in the second pick while it increased in Bulgaria. The magnitude of decrease in Spain and increase in Bulgaria varied from variety

to variety. Micronaire value and fiber length for most varieties were lower in Spain than in Bulgaria and Greece.

Cotton Biotechnology

The Cotton Biotechnology Working Group was established in 1992 and currently has nineteen member institutions from thirteen countries, including Dr. James McD. Stewart of the University of Arkansas, USA. The general objectives of the Group are to utilize biotechnological approaches such as tissue culture, transformation, molecular markers, with the ultimate objective of developing new genotypes. In the last four years, the Working Group has organized two meetings, i.e. Leuven, Belgium in 1993, and Thessaloniki, Greece, in 1995, to discuss the status of genetic engineering research in the world and to negotiate collaboration among researchers. The proceedings of both meetings have been published. The Cotton Biotechnology Group has been very active in exchange of published material and direct contacts. Communications and information transfer has worked well because more than 80% of the group members have access to e-mail. Knowledge about each other's research facilities has enhanced the exchange of students and group member visits. The Chair of the Group in cooperation with Group members prepared and submitted several research proposals to various organizations for consideration of funding, with some success.

Most members of the Group use the somatic method for regeneration of plants. Somatic regeneration is thought to be genotype dependent. In Uzbekistan, mechanical removal of larger cell clusters by sieving enhanced the chances of success. Embryo development was also noted to be higher in a glucose medium rather than in sucrose. No new methods are available to enhance the frequency of chimaeras produced through particle bombardment.

Reorganization of the Network

A need was expressed by the Coordinator of the Network to make some adjustments in the organization. After discussions and suggestions, it was decided to incorporate the working groups on Weed Control into the Group on Integrated Pest Management.

Despite the lack of activities of the Working Group on Water Management, it was agreed that the topic is of considerable importance in the Mediterranean and Middle East Region. Mr. Jonathan Spenser of Israel agreed to function as the new chair of this working group and stimulate an active program and participation.

Three new working groups on Economics of Cotton, Plant Growth Modeling and Cotton Production in Marginal Conditions were constituted. It was decided that Dr. George Raymond and Mr. Michel Cretenet of CIRAD, and Dr. Liliana Dimitrova Bozhinova of Bulgaria will prepare a detailed report on objectives, justification, feasible program activities and a list of people who have declared their interest/willingness to participate in the

above mentioned groups. It was agreed that these groups will be considered ad hoc working groups. At the next Consultation of the Network, if justified, they will be confirmed as full working groups.

Joint Activities of the Cotton and Flax Networks

In June 1996, at a meeting of the FAO European Cooperative Research Network on Flax and Other Bast Fibers (ESCORENA) held in Italy, it was decided to discuss the possibilities and mode of joint activities with the Interregional Cooperative Research Network on Cotton for the Mediterranean and Middle East Regions. Dr. Richard Kozlowski, Coordinator of ESCORENA was invited by the FAO to present a report on possible joint activities of the two networks. Since the Flax Network was established in 1989, four meetings have been held. The last meeting held in France was attended by 210 participants from twenty-nine countries. Flax, which represents less than 1% of natural fiber use, has working groups on Biology and Biotechnology, Breeding and Genetics, Extraction and Processing, Quality, Marketing and Textile Flax Fibers. ESCORENA also publishes a newsletter on regular basis. The Coordinator of the Flax Network briefly presented the main activities of ESCORENA and suggested areas of common interest which included fiber quality control and evaluation, fiber biology, biotechnology, plant growth modeling, alternative non-fiber products, technology and environmental matters. As a means of collaboration, he mentioned information exchange between working groups, address exchange, a joint newsletter and joint meetings. He said health and environment concerns will drive natural fibers into the 21st Century and that the development achievements in each fiber group should be made openly accessible for the benefit of others.

Some members, the ICAC and the Cotton Program of the CIRAD-CA said they would find it difficult to continue cooperating under a non-cotton network. The representative of the ICAC did not support joint meetings of the two networks except for the technology group. He was of the view that the two groups have different mandates. The network on cotton is more involved in cotton production research while the flax network concentrates on processing and marketing of flax. The production practices of the two crops are also entirely different. However, some participants expressed the opinion that despite the many and fundamental differences between cotton and flax, there could be some areas of common interest. Taking all interests into consideration, it was agreed that collaboration should start on a working group level, i.e. inviting members of interested working groups to meetings. In addition, it was agreed to recommend to the FAO a special study or meeting between Coordinators and Chairmen of Working Groups to outline precisely areas of collaboration. Such collaboration should begin on an ad hoc basis where feasible. Future developments will depend on the extent and perceived benefits of this collaboration.

Future Activities of the Network

Cotton Breeding

The Group will update the list of available germplasm every year and provide it to members of the Group. A year from now, the Group will have a joint meeting with the Group on Variety Trials. A scientific bulletin in the form of a newsletter common to the other working groups will be tried. Another idea for future activities is the use of a new method of selection (without competition or honeycomb selections). Details for the method will be distributed to the Group members after the meeting. Efforts will be made to organize a seminar on a selected topic most related to the Group activities. Finally, a list of breeders in all participating countries will be prepared and distributed among Group members.

Variety Trials

The Group will continue its activities along current lines and try to make the trials more uniform so that conclusions can be drawn. The Group will cooperate with the Breeding and Cotton Technology groups.

Growth Regulators

The Group will update and finalize the review of literature on cotton plant growth regulators and publish it for distribution among members. The inventory of plant growth regulators used on cotton will also be revised. A directory of researchers working on cotton within the network and in all other countries will be published. The cooperative research projects on new growth regulators will be continued. The 1996 program in member countries that have not completed three-years data will be continued. In 1997 a new cooperative project with treatments including the best treatment from the current project, late season PGR-IV application, seed treatment with ASSET, an innovative treatment according to each country's preference and control will be initiated. The Group will hold a meeting in the summer of 1998, alone or jointly with the Working Group on Cotton Nutrition, to discuss the work done in 1995-1997 and prepare a work plan for following years.

Cotton Nutrition

The Group will continue its activities in optimizing cotton nutrition and increasing fertilizer use efficiency. Work will also be done to reduce N use through increasing efficiency and efficient determination of needs; to identify the need for K fertilization, especially foliar feeding; and to assess needs for micronutrients in different areas. Each member will address one or more of these areas. A joint meeting is proposed with the Group on Growth Regulators in 1998. The Group will cooperate with the Breeding and Variety Trials Group to study genotype efficiency in using nutrients. The Group will publish proceedings of joint meetings with other groups, a directory of members and an annual newsletter.

Water Management

The new Chairman of the Working Group on Water Management contacted individual countries during the meeting and collected information concerning the main topics of interest. The main areas of cooperation identified are

- Irrigation methods
- Irrigation management and optimization including water quantities, intervals and timing
- Complementary irrigation, drought management and water saving
- Plant irrigation physiology including plant water status and measurement, plant irrigation control methods and monitoring
- Water quality issues

The immediate objectives of the Group will be to establish communication between members, define a short list of common fields of interest and priorities, set up an activity schedule including experimentation plans and knowledge exchange. Two meetings were proposed for the period between the third and fourth consultations (1996 and 2000), possibly joint with other working groups.

Integrated Pest Management

No new activity was proposed and neither any one else offered to take charge of the Group. The Group will try harder to prepare a list of members, collect information on research priorities, organize a meeting in 1997, improve communications and search for funding for a joint program.

Cotton Technology

The Technology Group will continue working in cooperation with the working groups on Breeding, Variety Trials and Growth Regulators. Cotton quality parameters standardization will be initiated at three laboratories in Belgium, France and Greece. Work on stickiness will be increased and valorization of cotton seed and by-products and reactivation of the courses on fiber technology will be added to the program. The Group will have its first meeting between March and May 1997 in Belgium, while a second meeting will be arranged during the Bremen Conference in March 1998. The World Cotton Research Conference—2 to be held in Greece in September 1998 could offer a chance for an additional meeting.

Cotton Biotechnology

The Group will have its first meeting in May/June 1997, at the Institute of Genetics in Bulgaria. A meeting will also be organized in 1999. Exchange of students and researchers for the purpose of training, exchange of plant material and information and technology knowhow will be continued.

Cotton Production in Marginal Conditions

The Group's Chairman will call for participation by all member countries and institutions with interest in growing cotton in marginal lands. A meeting/seminar will be organized where the major limiting factors for every country and its impact on cotton production will be discussed. The problems of common interest for several countries will be evaluated and the available knowledge and experience in overcoming the obstacles will be assessed. One or more joint projects will be prepared and submitted for financing to institutions (EU, NATO, PHARE). The Group will act in close collaboration with other working groups of the Network and other networks.

Election of Network Coordinator and Working Group Chairs

Network Coordinator

Dr. Urania Kechagia, Greece

Working Group Chairs

Cotton Breeding: Dr. Fotios Xanthopoulos, Greece

Variety Trials: Dr. Oktay Gencer, Turkey

Growth Regulators: Dr. Kiratso Kosmidou-Dimitropoulou, Greece

Cotton Nutrition: Dr. Mohamed El Fouly, Egypt

Water Management: Mr. Jonathan Spenser, Israel

Integrated Pest Management: Dr. Lahoucine El Jadd, Morocco

Cotton Technology: Dr. Urania Kechagia, Greece

Cotton Biotechnology: Dr. Osama Ahmed Momtaz, Egypt

Cotton Economics: Dr. Georges Raymond, France

Plant Growth Modeling: Mr. Michel Cretenet, France

Cotton Production in Marginal Conditions:

Dr. Liliana Dimitrova-Bozhinova, Bulgaria

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Cotton Modeling and Management

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Introduction

The use of a model, especially the use of a predictive model, is the basis of any intelligent activity in agricultural management. Without a predictive ability, it is not possible to make intelligent decisions. In fact, the notion of model is at the center of the scientific method which Descartes and others tell us is an intelligent process. We can expand on the above by saying that for any system to be intelligent or to be used in an intelligent way, it must make decisions. A decision can be described as how we use available resources given a varying environment. Further, the decision must involve a complex scenario, otherwise there is no true decision-making process. For example, a simple calculation of degree days involves a trivial surface description and a two-dimensional process, hardly the basis for a complex scenario. So we must make decisions in a complex scenario and in order to do this, we must have a goal. A goal is an objective. Objectives require a framework, a scenario. The scenario we have chosen is the cotton agroecosystem, the objective is production optimization and sustainability. Through our collaborative research (USDA and CIRAD), we are developing tools which we hope indicate some intelligent orientation in the model-based manipulation of the agroenvironment.

The objective of modeling can be defined at many scales. Defining why we model or why we want to produce a model is critical to the kind of model and decision support system which we will create. It has been often repeated that we model in order to better understand a complex system, for planning, to enable us to make predictions, to conduct surrogate experimentation, etc. But these are platitudes when faced with the real problem of field-level delivery and implementation of the model. At the level of application, we must first identify what is the objective of the grower. The objectives of farmers are often presented such that they imply the following: *Despite the obvious differences, the objective of different farmers in different regions is similar. They want to minimize risk, maximize returns (profit), while optimizing the management of resources.* The strictly quantitative nature of this assessment, negates reality. In our work we have found that maximization of return, for example, is often not the objective of producers. In fact, many producers have a different utility function than is commonly proposed by economists. This function is dynamic and adaptive in nature. Instead of trying to maximize yield, optimize resource utilization, or environmental protection, a farmer may simply want to avoid excessive work (keeping records, sampling, employing accountants and consultants) while at the same time producing the minimum which will ensure his long-term survival. Both the level of work he is willing to input and the level of desired

productivity are functions of a complex physical, biological, and social environment.

A farmer such as is described above may not be very impressed with models such as GOSSYM which assure him 20 to 40% increase in net returns! Surprisingly, this kind of farmer may form an important segment of the producer population. So the question is, What is the role of a modeler in such a scenario, if there is such a role? Of course, we will argue that our challenge in this case is to make the use of the model so painless and so simple, that the producer won't mind its use and the environment, for example, will benefit. But the point is that the modeler must first answer the question of what is the objective of the farmer before writing the first line of code. This issue must be foremost in the decision of whether and which simulation model should be used. The following article will describe the cotton model GOSSYM, especially as regards its utilization and functionality.

The Need for a Crop Model

Too often the management of a crop is characterized by a single factor: The yield at the end of the season. This factor, while important, hides the fact that management for a farmer is a daily activity. Management begins long before the crop is planted, presenting problems such as variety selection, soil management and preparation, and the allocation of farm and farmer resources in a way that optimizes the overall objectives of an individual producer. Once the growing season begins, management continues to be a daily activity. For example, the producer must continually assess the status of the crop in terms of water and nutritional stress and manage for competition from pests and diseases. When the crop is established, the rational use of plant growth regulators and the use of defoliators may help a producer change the timing of the maturation of his crop.

Farm-level daily activities are uniquely different from the planning or theoretical activity conducted by consultants or management experts. A management expert (e.g., agronomist, agricultural engineer) develops specialized techniques based on the state of the art of agronomic and management theories. On the other hand, a producer implements daily practices in which he must strike a balance between the techniques offered by the management experts and the economic and social constraints within which he/she is situated. In addition to these constraints and sources of information, the farmer considers his own wealth of empirical knowledge which further modifies the theoretical offerings of the specialists. It is thus the compromise made by the producer between the different sources of information and within the constraints of production that result in the daily management of the crop. Because the very nature of this process is unique to each producer's conditions, it is not possible for a

management expert to completely abstract these factors into a single, unique recommendation. It can be concluded from these observations that theoretical knowledge can not translate into actual daily management practices and that theoretical knowledge can not translate into optimized yield. Optimization criteria are too closely linked to individual producers. Given the complexity of the farm production scenario, a computer simulation model presents a unique opportunity to study all the relevant factors that affect production and are relevant at field level using a single, integrated tool that is customizable to an individual producer's conditions.

Crop models used for management today are mathematical simulations based on the system analytical approach to modeling. Prior to the formal emergence of quantitative models, several qualitative descriptions of biological interactions and processes existed. Amongst the early applications of quantitative models to biology were the exponential growth proposed by Malthus, the idea of carrying capacity and competition embodied in Lamarckian and Darwinian processes, and the Mendelian model of heredity. Today, qualitative modeling is still an important alternative in modeling but will not be further discussed here. Our discussion emphasizes the use of quantitative, mathematical computer-based simulation models.

Quantitative modeling has had a long history in theoretical and applied biosystems analysis. Dating back to the 1700s, René Antoine de Reaumur (cited by Uvarov, 1931) conducted the first experiments dealing with the relationships between plant and insect development and temperature. Lotka and Volterra (1925, 1926) tried to express the complexity of the coupled dynamics of two predator/prey species and, in 1951, Leslie formalized the matrix manipulation necessary for the treatment of age-structured populations over time using Eigen analysis. Eigen analysis allows finding exact solutions for systems of first order linear differential equations. A matrix is set up where the matrix elements represent rates of flow between compartments. The solutions for the system are found by estimating the latent roots or eigen values of the rate matrix. In a Leslie matrix, the first matrix row contains the rates of flow (reproductive fraction), and the off-diagonal values represent survival probabilities. The dynamics of a population are expressed for any time "t" as, $n(t+1) = A * n(t)$, where "n(t)" is a vector describing the population numbers (or mass) at each stage or compartment. This equation allows iterative calculation of a population for any time "t". If iterations of this equation are followed for a large number of iterations, a stable age distribution is obtained. The eigen-vector is the stable age distribution of population vector "n" at the time when the stable distribution is reached. When systems deviate from linear or incorporate multiple variables with feedbacks and non-linear interactions, the Leslie analysis becomes inappropriate.

With the formalization of statistical methods, statistical models, especially surface relation (regression) models were commonly used as a predictive tool in the early years of crop modeling.

Until the advent of digital computers, most biological modelers relied on analytical models due to their elegance or on statistical models due to the relative ease with which they could be developed. Analytical models are mathematically elegant, tractable and exact expressions of a process. Nevertheless, these models provide little insight into some of the more detailed processes relevant to population dynamics and development (e.g., response of a group of interacting processes to changes in a time and plant status-dependent cultural practice). Analytical models are limited in scope. The main reason is the requirement for limits (e.g. for the driving variables) and for continuous solutions. Statistical models are limited by their applicability to a narrow range of conditions, by the lack of causality, and by the independence of observations (and other restrictions) required by these surface models. Complex systems necessitating variable, dynamic, not pre-determined input cannot be analyzed with analytical models. Cropping systems and models of cropping systems used for management are examples of such complex systems. Quantitative processes in complex crop models are driven by abiotic and biotic factors. Because of these constraints, simulation models are deemed more appropriate than analytical or statistical models for simulating cropping systems.

Crop modeling based on simulation was born during the late 1960s and early 1970s with the application of quantitative methods developed in the area of the physical sciences to biology. Pioneering work in modeling and simulation in biology was conducted at Imperial College in England (e.g. Southwood, 1968) at Wageningen, Netherlands (e.g. deWitt 1970, 1982), and in the United States (e.g., Forester, 1961; May, 1976, Odum, 1983).

Cotton Modeling and the Cotton Model GOSSYM

Because of its economic relevance and the relatively large database available, cotton was one of the first crops to be modeled with the objective of aiding profit-oriented commercial agribusiness. Several cotton models have been proposed for management. Up to fifteen different models of cotton development have been proposed and published (Gutierrez et al. 1975; Wallach 1980; Jackson and Arkin, 1982; Stone et al. 1987; Baker et al. 1983; Landivar et al. 1991; Sterling et al. 1992; Sequeira et al. 1993). Of these models, only the GOSSYM-COMAX (Baker, 1983; McKinion et al., 1989) system is currently being used in commercial agriculture.

GOSSYM is a dynamic, daily simulation of the development and growth of the cotton plant. The description of the theoretical background and most mathematical functions have been published by Baker et al. (1983) and Jallas (1991). The GOSSYM system is based on the mechanistic paradigm which tries to maximize the number of causal relations present in the model and to minimize empiricism. To achieve this, the model is divided into two main daily, independent subsystems linked by

a partitioning process. The first subsystem calculates the carbohydrate supply. The second subsystem calculates the carbohydrate demand. During each daily time step, the partitioning process—which drives the yield components and storage—balances the whole system. This explains the term “materials-balance” often used to describe this model. Thus the partitioning process balances the total supply and demand in the model.

Lemmon (1986) coupled the simulation model with a decision support system which was later updated by Bridges (personal communication) and which provides users with expert decision support. GOSSYM is the simulation component in the GOSSYM-COMAX system. GOSSYM simulates the daily behavior of the crop based on user input. If the user wants the system to provide advice as to irrigation, nitrogen, or plant growth regulator use, he can use the decision support system COMAX. COMAX uses an expert system rule base to determine the optimal actions to perform given a projected or set of projected weather scenarios. If COMAX has been invoked, COMAX monitors the GOSSYM simulation in order to detect stress symptoms. If COMAX detects stresses, it may recommend different practices to solve the problems. GOSSYM output includes graphs of the daily mass accumulation and number of organs produced for different plant parts. Additionally, soil Nitrogen, soil water, stress factors, leaf area index, weather summaries, and other variables are also output. COMAX output includes recommendations for irrigation, nitrogen use, and for the application of plant growth regulators.

Applications of the Simulation Model, GOSSYM

GOSSYM is used in both tactical and strategic farm management. Tactical management refers to the within-season decision making process; whereas strategic management refers to decisions made before the cropping season begins. In the tactical mode, GOSSYM is run one day at a time. The simulation uses actual weather which is collected from a within-field weather station. This data collection process is automated within GOSSYM. A submodule of the user interface actually connects to the field weather station via a telephone line and modem and collects all the necessary daily data. The use of actual weather assures that the simulation will be as accurate as possible. The daily simulation allows the user to study the model's interpretation of the nutritional and productivity status of the plant. This is important because in the field, the plant's status can be assessed only by visual observations or destructive sampling and analysis. These manual alternatives are time-consuming and expensive. The model provides a quick and straightforward assessment of the plant at many levels of detail, as desired by the user. In addition to knowing the physiological status of the plant, the user can also project into the future using hypothesized weather scenarios.

Under the strategic mode, the farmer can also run the system either by setting up the simulation component only (GOSSYM)

or by using the automated decision support system, COMAX. The difference with the tactical mode, is that in strategic mode there is no actual weather. All simulation runs are made using projected or historical weather scenarios.

Typical strategic use of GOSSYM is the determination of the potential production of each field based on row spacing, variety, nitrogen, irrigation, growth regulator applications and others. Once the potential production has been determined for a given set of conditions, the producer can test different strategies regarding nitrogen application, irrigation timing and amount, growth regulator timing and amount. Once the results of these simulations are obtained, the producer can then choose how he will maximize his productivity and/or reduce his risk.

Producers in the different American cotton growing regions use the GOSSYM-COMAX system with different objectives. These objectives range from the maximization of yield, the maximization of profit, minimization of risk, minimization of plant stress, minimization of the length of the growing period, optimization of the use of plant growth regulators and crop termination. Evidently, several of these objectives are an indirect way of maximizing yield or profit.

In order to explore different objectives, the user modifies the GOSSYM simulation runs to suit his objectives as discussed in the section Sample Objectives below. Typically, the user sets up a matrix of current and alternative scenarios. The results can be formally compared using unreplicated factorial analysis as detailed by Milliken and Johnson (1989) and Stevens et al (1996).

Several examples of running GOSSYM-COMAX with different objectives are discussed below.

Sample Objectives

- Objective:
Determination of the best combination of cultivars (variety) and crop allocation in field. The system supports some twenty different cotton cultivars including the generic designations long season, early, and mid-season or average cycle cottons. Thus, a farmer wishing to determine the best allocation of a given cultivar may select different alternatives using the soil and weather conditions peculiar to his particular farm or even individual field.
- Objective:
Optimization of crop termination. The GOSSYM system includes the use of different crop growth regulators and crop defoliant. These products modify the growth of the plant or they terminate the season by defoliating it. The use of a crop growth regulator (e.g., mepiquat chloride or PREP) changes the maturation patterns of the plant but the response of the plant depends on its nutritional and stress status. This is where the simulation is important since it helps determine the effect of using these products at different times with a given weather pattern. Finally, defoliation will force the

opening of all capsules by terminating the plant. The careful timing of defoliation optimizes yield and fiber quality, and different aspects of farm management (e.g., irrigation and harvest scheduling).

- **Objective:**
Optimization of planting date. Planting date is critical to the management of cotton. Planting too early in temperate zones may result in damage due to frost or hail and planting too late in these areas will result in a crop that may not have time to mature or will be difficult to harvest. In tropical regions the problems are usually associated not with cold weather but with the timing of rains. The model helps a producer by determining the ranges and timing combinations possible with the different varieties under specific conditions.

Requirements to Use the GOSSYM-COMAX System

The GOSSYM model is initialized with hydrological and paedological descriptions of the site to be simulated in addition to the description of the agronomic characteristics of the culture (planting date, variety, plant density, fertilization, irrigation, etc). In-field weather stations are used to provide daily data to run the model with actual weather through the current date. Beyond this current date the model is usually run with several potential weather scenarios. Because of its mechanistic nature, the model is expected to be robust across many ranges of climatic and paedologic/hydrologic conditions.

A typical session with the GOSSYM-COMAX system has two parts. The first is the initialization (i.e., characterization) of the field which the model will simulate. The second is the initialization of the COMAX decision support system. We will first discuss the initialization and output of the simulation model.

The GOSSYM system has a graphical user interface that runs under DOS or Windows^R. When the user runs the system, he obtains a display of twelve different icons. Each of these icons transfers the user to a data-collection menu. The twelve menus correspond to field profile, cultural practices, insecticide applications, growth regulators, fungicide applications, model invocation, weather editor, utilities, soil hydrology, and plant map reports.

By interacting with the menus that are selected through this interface, the user provides the following input to the system: latitude, row spacing, planting date, crop emergence date, simulation start and stop date, plant spacing, weather, soil characteristics, irrigation, nitrogen applications, use of plant growth regulators, and timing of defoliation.

Once the system has been initialized, a simulation can be run or a COMAX recommendation can be requested. Figures output by the system show the cumulative weight and numbers of several organs. In total some fifty variables describing aspects

of growth and physiological status are output by the simulation model, including daily mass accretion, number of different organs, stress indices for water and nitrogen status, and summaries of the timing of the key phenological stages are all provided in this output.

Optimization Rationale in the Expert Advisor—COMAX

The process of automated optimization in COMAX is based on the minimization of plant stresses using a combination of heuristics and iterative search with the model. The system tries to reduce the irrigation and nitrogen deficiencies by providing recommendations regarding the timing and magnitude of applications. COMAX accomplishes this by taking over the control of the model; it runs the model in one day increments and on each day it determines whether the plant is stressed. If it is stressed it will implement a remedial action the following day.

At the end of the simulated growing season COMAX determines if the crop maintained a sufficiently healthy status. If this is not the case COMAX will re-run the simulation, this time increasing the magnitude of the remedial action. This process iterates until a near-optimal solution is obtained. At this time, the final schedule of irrigation and nitrogen fertilization is output as the recommendation for the farmer.

Potential Gains from Using a Simulation Model

There have been two assessments of the economic value of GOSSYM to farmers in the USA. Both of these assessments have been conducted at Texas A&M University by a group independent of the developers of GOSSYM (Ladewig and Powell 1989; Ladewig and Thomas, 1992). The analysis included users in twelve different American states. Surveys and interviews included details of the nature of the utilization of the model and the estimation of the value of the model in comparative terms to untreated (not managed with a model) controls.

The majority of farmers surveyed used the GOSSYM system as a crop termination, nitrogen utilization, or irrigation decision support system. The second largest utilization of the model was for variety selection and risk analysis. On the average, users of GOSSYM earned an average of US\$80.00 more per hectare when compared to control users who did not use any simulation system in their farms.

The characterization of American GOSSYM users showed that they all had personal computers at the farm, had at least two years of university education, and tended to be moderately to highly technified as evidenced by whole-farm resource optimization. Despite the relatively high educational level of GOSSYM users, the main disadvantage cited by producers was the complexity of the data entry required. They did however, agree that the system was coherent and manageable after the initial training period.

Current Research

Current collaborative research activities include the development of automated model calibration methods; the validation of the model in tropical and Mediterranean conditions; the conduct of basic biological research in plant physiology in the areas of fiber and seed development, morphogenesis, and in the broad area of partitioning under stress; the use of machine-learning techniques in the decision-support modules; the use of three-dimensional graphical techniques to include architectural functionality; and the inclusion of the effects of insect pests into the plant model. Two of these activities are further discussed below because they have been already made available.

In the area of insect pest management we have taken a two-pronged approach. The first is the Insect and Plant Damage Management System (IMS) which simulates the plant's response to insect and plant damage. Specifically, the dynamic responses of the cotton crop to attacks by direct pests (e.g., boll weevil, bollworm, cotton fleahopper) and indirect pests (aphids, whiteflies, armyworms, various leaf feeders) are simulated. In addition, response to leaf damage, such as produced by hail, is also supported. The power behind IMS is that it enables the user of GOSSYM to correct the simulation of the plant to account for external damage. The model responds by simulating the effect of damage depending on the physiological status of the plant. The decisions of a farmer as to whether or not to apply a control decision are supported by allowing him to run simulations with and without damage.

The second approach is to use insect simulation models in order to add a predictive capability to the IMS system. We are in the process of validating this research.

In the area of automation of model adaptation and decision support we have conducted extensive machine learning research. One of the problems with the use of any complex simulation model is its calibration to accommodate new cultivars or new system configurations (e.g., different subsystems). In the past, an expert has always been required to fine-tune a model so that it continues to be applicable given a new situation. Our machine learning system, GOSSYM-GA uses new techniques called "genetic algorithms" to automate the process of calibration. Specifically, GOSSYM-GA is an automated adjustment system to derive the best model to fit a given set of conditions such as an individual farmer's conditions or the introduction of a new cotton variety. The system uses periodic observations such as plant height, number of squares/plant, number of green bolls/plant and others to feed to the genetic algorithm which then compares it to the predictions from the simulation. GOSSYM-GA iteratively runs the model making progressive improvements until the best configuration of the model is produced. Although the GOSSYM-GA system uses some of the latest computer science techniques to evolve solutions using metaphors from both biology and operations research, most of this level of complexity is transparent to the user. Genetic

algorithms and other machine learning techniques are powerful new tools that will insure that a system that deviates consistently at a given site can be easily reparameterized and continue to be functional. Additionally, we are developing systems to use the model to automatically derive optimized technical itineraries (fertilization and irrigation) which take into consideration the idiosyncrasies of each site.

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More Genetically Engineered Cottons

Genetic engineering of crop plants involves induction of a foreign gene or genes into the seed or plant to perform a specialized task for achieving specific objectives. The objective could be protection against insects, quality improvement, or any other aspect of crop production, preservation and marketing. It is easier to insert non-related species genes into some crop plants than into others. Unfortunately, unlike some other field crops,

cotton is not very receptive to foreign genes. Varietal responses also exist. Of the 2,500 field tests conducted in the USA to September 1996 only 8% of trials involved cotton. The field trials on all transgenic plants were for herbicide tolerance (57%), insect control (43%), product quality (7%) and agronomic performance (2%). Thus, in all crop species, including cotton, most of the work done so far has been to control insect pests.

Very few efforts have been devoted to quality improvement. Only a small number of trials involved more than one feature.

Since the mid 1980s, research efforts to develop transgenic Bt cotton varieties resistant to bollworms have been intense. For almost ten years, researchers have been testing the usefulness of bioproduction of a toxin within the cotton plant and its impact on other morphological and quality characteristics in cotton. In October 1995, the first insect resistant Bt cotton was formally cleared for commercial cultivation in the USA. Later, Australian authorities also permitted commercial scale cultivation of Bt cotton in 1996/97. The insect resistant Bt gene has been licensed by Monsanto as Bollgard™ in the USA and Ingard™ in Australia. The Bt gene produces the protein toxin CryIA(c), found in most biological insecticides, throughout the life of the plant, without regard to growing conditions. Many other countries will ultimately start growing Bt cotton but how it will reach developing countries is not clear at this stage. One of the possible options could be joint ventures with owners of resistant genes and technologies. Such an agreement has recently been signed by Delta and Pine Land Company of the USA with Chinese companies. It is expected that transgenic Bt cotton with the Bollgard™ gene will be grown in China on about 200,000 hectares in 1998. Herbicide tolerant cotton was also grown on a commercial scale in the USA in 1996/97.

Insect control costs form the main component of the total cost of cotton production. In the face of enormous insect pressure, unusual in 1996, Bollgard cotton proved the worth of Bt gene in cotton. Further success of Bt cotton in the USA, Australia and, in two years, in China (Mainland) could redirect the money currently spent on chemical pesticides to biotech research.

It is reported from China and India that, in addition to a gene from soil bacteria, a cowpea gene has been induced into cotton to protect it against tobacco budworm, *Heliothis virescens*. Two other areas where significant progress has been made are colored cotton and cotton with changed thermal properties.

Recently, a pigment alteration patent has been granted to the American company Calgene, Inc. by the US Patent Office. A gene construct for the expression of the pigmentation gene, melanin, in cotton fiber has been identified and induced into cotton. The company owns Stoneville Pedigree Seed Company and claims that their scientists have developed blue and red fibers and now are focussing on enhancing the shades. Pigment alteration of genetically-modified cotton plants has improved the prospects of producing naturally-colored blue jeans. The fiber quality of naturally-colored green and brown fibers is not equivalent to that of white cotton. Development of pigment alteration in genetically-modified cottons will not require additional work to improve fiber quality. Pigment alteration will be an addition to the existing qualities of white cottons with no other effects on the plant. The foreign genes induced into the cotton plant are present in all cells and have a specific task to perform at particular stages of plant development. This specific

task in the future could be pigment production for black, yellow and all other colors in cotton.

Work to identify genes which could be assigned the task of doubling the size of bolls without affecting boll number, or doubling the number of bolls without affecting boll size, has not been reported as yet. Perhaps there is a need for improved understanding of the genetic control of boll numbers and size. Similarly, fiber quality characters like length, strength and micronaire could be improved significantly but no such genes have been identified yet which could bring improvements which have not been achieved through conventional breeding. However, with the latest achievements in genetic manipulation of non-species genes for accomplishing particular and well defined objectives, such developments do not seem to be impossible.

A report was published in the Proceedings of the National Academy of Sciences of the USA where the above mentioned approach has been adopted. According to the paper, a group of researchers at Agracetus (Monsanto) have changed the thermal characteristics of the cotton fiber through insertion of bacterial genes. The cotton fiber, which is an unicellular outgrowth from the seed coat, is comprised of up to 90% cellulose. It has three important developmental stages: Elongation and formation of a primary cell wall, which is completed in about twenty days after anthesis; formation of a secondary wall and deposition of cellulose, which starts about sixteen days after anthesis and is usually completed at forty-five days after anthesis; and chemical changes. Chemical changes, usually related to mineral contents and protein levels, take place after the formation of a secondary wall has been completed. Cellulose deposition and chemical composition of the cotton fiber not only affect the commonly measured fiber parameters but also affect properties like shrinkage, chemical reactivity, heat retention, water absorption, etc., which are very important in the manufacturing of textile products. The researchers at the Agracetus have been able to produce a new biopolymer inside the cellulosic walls which is capable of producing thermoplastic properties of the compound poly-D-(—)-3-hydroxy butyrate (PHB). PHB, produced by many genera of bacteria, is a naturally biodegradable thermoplastic with physical and chemical properties similar to polypropylene.

Using the particle bombardment method for transformation of cotton, researchers induced two bacterial genes capable of producing enzymes responsible for the production of PHB in the cotton fiber. As expected, the percentage of successfully transformed plants was very low, but plants with epidermal and germ-line transformations were achieved. In total, 14,000 seeds were attempted and thirty seeds after germination showed epidermal (twenty-one seeds) and germ-line (nine seeds) inductions. Because cotton fibers are an epidermal growth, even epidermal transformations could be used for evaluating modifications in fiber properties. Laboratory analysis by more than one method confirmed the presence of PHB in transgenic fibers. Quantitative measurement of PHB contents in the developing fibers was also studied at an interval of ten days until fifty days

after anthesis. The data showed that the quantity of PHB abruptly increased for 5-6 days after ten days of anthesis. The fiber weight continued increasing after fifteen days but the amount of PHB did not increase, thus reducing the quantity of PHB in proportion to fiber weight. The actual amount of PHB did not increase after the primary wall was formed (fifteen days after anthesis), and no degradation of PHB was noted with the formation of secondary walls and maturation of fibers.

Thermal properties of transgenic fibers vs. normal fibers were tested by measuring the heat flow rate through the cotton samples. The total heat uptake was 11.6% higher in transgenic fibers than in normal fibers. The analysis of samples from other plants with a varying amount of PHB showed that the heat uptake was proportional to the quantity of PHB in transgenic fibers.

Results showed that fibers from transgenic plants had 6.7% lower thermal conductivity compared to normal fibers, indicating slower cooling down of the fibers with PHB. The heat retention capacity of both cottons was tested at 36°C and 60°C. The data showed 8.6% higher heat retention at 36°C in the case of cotton having PHB. The heat retention capacity of cotton with PHB increased to 44.5% higher at 60°C.

Cotton from transgenic plants and normal plants was spun into yarn and unbleached and undyed fabrics were subjected to the heat uptake test again. Fabric made from the cotton from transgenic plants once again confirmed a higher uptake of heat by the same margin as in the case of lint.

Like Bt cotton resistant to lepidopteran insects, transgenic cotton having the bacterial genes *phaB* and *phaC* (capable of producing PHB) showed normal growth and morphology. Fiber quality in terms of length, strength and micronaire also remained unaffected.

The PHB cotton was stored for several months at room temperature and no change was found in PHB contents. However, similar stability effects in finished textile products have not been studied.

The authors consider the insulation properties of the experimental cotton not sufficient to satisfy customer needs. Agracetus is working to enhance the effect by increasing the amount of PHB produced in the fibers. PHB contents could be increased either through induction of more genes or different genes with stronger effects. However, identification of measurable quantities of PHB in transgenic plants has demonstrated that it is possible to change the thermal properties of cotton.

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World Organic Cotton Production

Over fifteen thousand tons of organic cotton was produced in the world during 1995/96. Though most countries are producing organic cotton on experimental basis as a result of small scale projects to assess prospects for commercial production, organic cotton is produced commercially in only eighteen countries. The USA is the largest organic cotton producer in the world. Australia and the USA are the only countries where organic cotton is produced by farmers on their own initiative. In all other countries, organic production started as a result of motivational, financial or technical support, usually from outside. Agencies like the Pesticide Trust and Bo Weevil were involved in many countries at the same time. Some of these organizations provided technical know-how at no cost to the farmers and arranged for the profitable sale of organic produce, while others charged a fee to growers or arranged production for contract. Although such projects have been underway since 1990/91, the area under organic production has not increased significantly. Even in the USA, area is not increasing at the rate it did the first few years

in the early 1990s. The main reason for stagnation in area is related to complex marketing problems. The demand for organic cotton is not certain and potential buyers and sellers are not known to each other. On the production side, low yields and high production costs make it uneconomical to expand organic cotton production. Low yields and high per-unit costs must be compensated through attractive premiums, which are not always available.

In the USA, where about two-thirds of the world's organic cotton is produced and used, only a small quantity is exported. Almost all the organic cotton produced outside the USA ultimately ends up reaching the European countries. Roughly five thousand tons of lint is spun and woven in Europe. A recent study carried out by Mr. Peter Ton of the Netherlands, for the Dutch development organization Foundation Ecooperation, found that Germany is the largest importer of organic cotton in Europe. The study was conducted in connection with support for an organic cotton

World Organic Cotton Production (Tons)

Country/Region	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96
Argentina	NA	NA	81	2	75	75
Australia	NA	NA	479	500	750	400
Brazil				2	8	1
Egypt	1	11	38	140	598	600
SEKEM	1	11	38	140	598	NA
UGEoba						NA
Greece				3	3	500
India			206	268	398	929
Gujarat			200	200	200	200
Madhya Pradesh			6	68	190	463
Maharashtra						250
Srida					8	16
Israel			NA	NA	NA	NA
Mozambique						90
Nicaragua					16	20
Paraguay				100	75	50
Peru			400	700	924	*900
Pekucho			200	375	484	NA
Verner Frang			200	325	440	900
Senegal						2
Tanzania				15	33	100
Turkey	5	60	120	198	610	720
GFF/Bo Weevil	5	60	100	110	440	320
Rapunzel			20	88	170	400
Morgenland	NA	NA	NA	NA	NA	NA
Uganda					150	250
USA	330	820	6,530	**5,387	**7,075	**5,250
Arizona	NA	NA	1,250	1,339	NA	NA
California	200	300	800	3,364	2,200	NA
Tennessee/Missouri	NA	NA	60	131	NA	NA
Texas	130	520	4,420	653	4,875	5,250
Zambia						35
Zimbabwe						20
Known Total	335	81	7,854	7,415	10,715	9,342

* The largest estimate of production in Peru for 1995/96 is 1,400 tons.

** The largest estimate of production in the USA from 1993-95 is 10,000 tons/year.

Source: *The European Market for Organic Cotton and Eco-textiles: A Market Survey*, a report prepared by Mr. Peter Ton for the Foundation Ecooperation, Herengracht 435-437, P. O. Box 2847, 1000 CV Amsterdam, Netherlands; and *Growing Organic Cotton*, ICAC, October 1996.

production project in Benin. With the current production trend, it is assumed that in the next few years the area under organic production will not increase significantly in any country, thus restricting organic production to less than 1% of world production. It is estimated that since 1990/91, about fifty thousand tons of organic cotton have been produced in various countries. Production for eighteen countries is given in the table.

Organic cotton production started in Turkey and the USA almost at the same time. Some data are available for 1990/91 but it is

possible that some area was under organic production in the late 1980s. Organic cotton production was begun in African countries in 1994. Egypt hosted the First International Conference on Organic Cotton Production and is the first country to start producing extra-fine cotton under organic conditions. Most of the data in the table are estimates based on the area planted and rough estimated yields. Except for the USA and Peru, all data are for normal white cotton varieties. Some organic cotton produced in the USA and Peru was also colored cotton. NA denotes production of unknown quantities.

Boll Weevil Mailing List

The cotton boll weevil, *Anthonomus grandis*, is a major pest of the Americas. It was first discovered in the USA in 1892. Within thirty years it had infested the entire southeastern part of the country. It spread to Venezuela in 1949 and to Colombia in 1950. In 1983, the boll weevil was detected in Brazil. It is estimated that some 90% of the cotton growing area of Brazil is now infested by the boll weevil. The pest has also spread throughout the cotton growing region of Paraguay and it is estimated that 35,000 ha of cotton are now affected. In 1993, the boll weevil was detected in Argentina in the areas bordering Paraguay. By January 1996, it had spread into the province of Formosa, close to Chaco, which is the main cotton cropping area in the country. The next destination may be Bolivia. Successful control programs have led to the eradication of the pest in most of the southeastern USA. Argentina, Brazil and Paraguay are working cooperatively to bring the pest under similar control.

In July 1996, the ICAC introduced a Boll Weevil Mailing List on the Internet to bring interested researchers together to exchange views and opinions on the behavior of the boll weevil and its control strategies. Mailing lists are one of the simplest ways to collaborate and discuss ideas. These on-line communications allow participants to send a single mail message to all members of a list anywhere in the world. A message sent by one person to the ICAC office is automatically copied to all subscribers on the mailing list. Answers are, in turn, sent to the ICAC where they are again reflected to the list memberships. In this way many can benefit from the exchange of questions, answers and comments.

Who Can Participate in the List?

The list is open to anyone anywhere in the world with an interest in boll weevil control. The only requirement is an active Internet mail address. Technical questions concerning the boll weevil issue should be addressed to M. Rafiq Chaudhry (rafiq@icac.org), Head, Technical Information Section at the ICAC Secretariat. Administrative questions concerning this list should be addressed to John Mulligan (johnm@icac.org), Manager, Information Systems of the ICAC.

What is the Cost of Participation?

The list is sponsored by the ICAC and offered to all participants at no cost. Messages can be sent and received in any language (generally English, Portuguese and Spanish). However, the ICAC does not have the resources to act as a translation service.

How to Subscribe?

You can join the list in one of two ways; you can use the form on the ICACs web page at URL: <http://www.icac.org/liststar/listserver.cgi>, or you can send an e-mail message to boll-weevil@liststar.icac.org with the word "subscribe" in the subject field. As a member of the list you will receive postings from other members. You will also be able to post your own comments to the list.

To remove your name from the mailing list send a message to the same address (boll-weevil@liststar.icac.org) with "unsubscribe" in the subject field. Once unsubscribed you will no longer receive messages from the list or be able to send messages to the list.

A DIALOG Search of the Agricola Database on Growth Modeling

The key words used in the DIALOG search of the Agricola Database are **Cotton** and **Modeling**. The search listed forty-five references but not all were related to growth in cotton. Twenty-five references directly related to growth modeling from 1971 to date are listed here.

3506979 20511788 Holding Library: AGL
Modeling ethephon-temperature interactions in cotton
Reddy, V.R.
System Research Laboratory, USDA, ARS, Beltsville, MD.
Amsterdam: Elsevier, 1985. Computers and electronics in agriculture. Aug 1995. v.13 (1) p. 27-35.
ISSN: 0168-1699 CODEN: CEAGE6
DNAL CALL NO: S494.5.D3C652
Language: English
Includes references
Place of Publication: Netherlands
Subfile: IND; OTHER FOREIGN; AR-BARC;
Document Type: Article

3444328 20457867 Holding Library: AGL
Growth dynamics of the cotton plant during water-deficit stress
Ball, R.A., Oosterhuis, D.M. and Mauromoustakos, A.
University of Arkansas, Fayetteville, AR.
Madison, Wis.: American Society of Agronomy, 1949, Agronomy Journal. Sept/Oct 1994. v. 86 (5) p. 788-795.
ISSN: 0002-1962 CODEN: AGJOAT
DNAL CALL NO: 4 AM34P
Language: English
Paper presented at the "Symposium on Rhizosphere Research in honor of Howard M. Taylor," November 2, 1992, Minneapolis, Minnesota.
Includes references
Place of Publication: Wisconsin
Subfile: IND; OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76);
Document Type: Article

3422002 20441800 Holding Library: AGL
Relationships of cotton dry matter production and plant structural characteristics for wind erosion modeling
Bilbro, J.D.
Cropping Systems Research Laboratory, ARS, USDA, Big Spring, TX.
Ankeny, Iowa: Soil and Water Conservation Society. Journal of Soil and Water Conservation. Sept/Oct 1991. v. 46 (5) p. 381-384.
ISSN: 0022-4561 CODEN: JSWCA3
DNAL CALL NO: 56.8 J822
Language: English
Includes references
Place of Publication: Iowa
Subfile: IND; OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76); AR-SPA;
Document Type: Article

3404107 20427174 Holding Library: AGL
Modeling light propagation in cotton with radiation heat transfer methods
Thomasson, J.A., Menguc, M.P., and Shearer, S.A.
St. Joseph, Mich.: American Society of Agricultural Engineers, Paper/Winter 1993. (931610) 17 p.
ISSN: 0149-9890 CODEN: AAEP CZ
DNAL CALL NO: 290.9 Am32P
Language: English
Paper presented at the "1993 International Winter Meeting sponsored by The American Society of Agricultural Engineers," December 12-17, 1993, Chicago, Illinois.
Includes references
Place of Publication: Michigan
Subfile: IND; OTHER US (NOT EXP STN, EXT, USDA; SINCE 12/76); AR-MSA;
Document Type: Article

3349348 20376768 Holding Library: AGL
Modeling cotton growth and phenology in response to temperature
Reddy, V.R.
Amsterdam: Elsevier, 1985 - Computers and Electronics in Agriculture. Jan 1994. v.10 (1) p. 63-73.
ISSN: 0168-1699 CODEN: CEAGE6
DNAL CALL NO: S494.5.D3C652
Language: English
Includes references
Place of Publication: Netherlands
Subfile: IND; OTHER FOREIGN;
Document Type: Article

3338003 20367033 Holding Library: AGL
Cotton yield losses and ambient ozone concentrations in California's San Joaquin Valley
Olszyk, D., Bytnerowicz, A., Kats, G., Reagan, C., Hake, S., Kerby, T., Millhouse, D., Roberts, B., Anderson, C. and Lee, H.
Madison: American Society Of Agronomy, Journal of Environmental Quality. July/Sept 1993. v. 22 (3) p. 602-611.
ISSN: 0047-2425 CODEN: JEVQAA
DNAL CALL NO: QH540.J6
Language: English
Paper presented at the USDA-ARS Beltsville Agricultural Research Center Symposium XVII, "Agricultural Water Quality Priorities, A Team Approach to Conserving Natural Resources," May 4-8, 1992, Beltsville, MD.
Includes references

- Place of Publication: Wisconsin
 Subfile: IND; OTHER US (NOT EXP STN, EXT, USDA;
 SINCE 12/76);
 Document Type: Article
- 3294921 93038364 Holding Library: AGL
 Modeling mepiquat chloride-temperature interactions in cotton:
 the model
 Reddy, V.R.
 NRI Systems Research Laboratory, USDA, ARS,
 Beltsville, MD.
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 ISSN: 0168-1699
 DNAL CALL NO: S494.5.D3C652
 Language: English
 Includes references.
 Subfile: OTHER FOREIGN;
 Document Type: Article
- 2809262 88024733 Holding Library: AGL
 Cotton growth functions: their determination and
 application to modeling
 Nagiev, A.T.
 Leningrad: Gidrometeoizdat.
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 DNAL CALL NO: QH541.15.M3P68
 Language: Russian Summary Language: English
 Includes references.
 Subfile: OTHER FOREIGN;
 Document Type: Article
- 2621194 86065538 Holding Library: AZUA; AGL
 Modeling cotton fruiting form abscission
 Lieth, J.H., Arkin, G.F., Hearn, A.B. and Jackson, B.S.
 Madison, Wis.: American Society of Agronomy.
 Agronomy Journal. July/Aug 1986. v. 78 (4) p. 730-735.
 ISSN: 0002-1962 CODEN: AGJOAT
 DNAL CALL NO: 4 AM34P
 Language: English
 Includes references.
 Subfile: OTHER US (NOT EXP STN, EXT, USDA;
 SINCE 12/76);
 Document Type: Article
- 2489370 85061218 Holding Library: AGL
 Modeling the dynamics of the architectonics of the above-
 ground part and root system of cotton during the growing period
 Nagiev, A.T.
 Baku: "Elm".
 Izvestiia Akademii Nauk Azerbaidzhanskoi SSR.
 Serii biologicheskikh nauk. 1984. (4) p. 104-108. ill.
 ISSN: 0132-6112 CODEN: IANAB
- DNAL CALL NO: 442.9 AK132
 Language: Russian
 Includes 6 references.
 Subfile: OTHER FOREIGN;
 Document Type: Article
- 2261211 84008311 Holding Library: AGL
 Models for cotton insect pest management
 (Computer modeling)
 Hartstack, A.W. and Witz, J.A.
 Washington: The Department of Agriculture Handbook
 United States Department of Agriculture. Nov. 1983.
 (589), Nov. 1983. p. 359-381. ill.
 ISSN: 0065-4612
 NAL: 1 AG84AH
 Language: English
 Includes references.
 Subfile: USDA (US DEPT. AGR);
 Document Type: Article
- 2158827 83063726 Holding Library: AGL
 Cyclicity and problems of yield modeling
 (Farm production planning, cotton cultivation).
 Abdullaev, M.
 Moskva: "Kolos".
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 ISSN: 0023-1231
 NAL: 72.8 K522
 Language: Russian
 Subfile: OTHER FOREIGN;
 Document Type: Article
- 1982398 82031769 Holding Library: AGL
 Simplified method of modeling cotton insect damage
 Hartstack, A.W. and Witz, J.A.
 St. Joseph, Mich., The Society.
 Paper - American Society of Agricultural Engineers. 1981.
 (81-4019), 1981. 7 p. ill.
 ISSN: 0031-1073
 NAL: 290.9 AM32P
 Language: English
 Includes 4 ref.
 Subfile: OTHER US (NOT EXP STN, EXT, USDA;
 SINCE 12/76);
 Document Type: Article
- 1847443 81042144 Holding Library: AGL
 Modeling cotton lint development
 Wanjura, D.F. and Newton, O.H.
 St. Joseph, Mich., The Society.
 Transactions of the ASAE - American Society of Agricultural
 Engineers. v. 24 (2), Mar/Apr 1981. p. 496-499. ill.
 ISSN: 0001-2351
 NAL: 290.9 AM32T
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 Subfile: OTHER US (NOT EXP STN, EXT, USDA;

SINCE 12/76);

Document Type: Article

935497 779042135

Variety & row spacing comparisons, modeling & experimental data [Cotton]

Davis, J.B. and Garner, T.H.

Proc. Beltwide Cotton Prod. Res. Conf. 1976 p. 113-114.

LC: SB249.N6

Language: English

Subfile: OTHER US;

Document Type: ARTICLE

907832 779018913

Oscillatory transpiration in a cotton plant: an IBM/CSMP [International Business Machines/Continuous System Modeling Program] computer simulation

Shirazi, G.A., Stone, J.F. and Bacon, C.M.

Oklahoma, Agricultural Experiment Station

Tech Bull Okla Agric Exp Stn Oct 1976 T-143, 27 p.

LC: 100 OK4 (4)

Language: English

Subfile: EXP STN;

Document Type: Article

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Status of cotton-production-system modeling in regional research project S-69

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A New Publication by the Technical Information Section

Growing Organic Cotton (US\$100)

The Technical Information Section of the ICAC began reporting on organic production in early 1993 when an article on the subject was published in *THE ICAC RECORDER*. Since 1993, a number of ICAC articles have been written and papers have been presented in international meetings. Because of the interest shown by the cotton industry in organic production, all ICAC work on organic cotton has been compiled in this report for convenient reference.

An objective of the Technical Information Section is to review technical reports and journals and provide updates on production research through *THE ICAC RECORDER*. The reports on organic production were published with this objective in mind. During the course of almost three years, we have found that there are many important issues in organic production which need the urgent attention of the cotton researchers. These issues include societal concerns regarding environmental degradation; allergies to insecticides; product novelty; the increasing cost of insecticides; awareness of disadvantages of extensive use of insecticides such as damage to natural flora and fauna, insecticide resistance, etc. Organic production is not just the elimination of undesirable chemicals from the production system but rather a complete package of production technology. Organic production also demands a higher level of skill compared with conventional production but as yet no systematic research has appeared to provide guidelines for shifting from conventional to organic production.

Culture du Coton Organique (US\$100)

La Section d'information technique du CCIC a commencé à faire des comptes rendus sur la production organique au début de 1993 lors de la parution d'un article sur le sujet dans *THE ICAC RECORDER*. Dès lors, un certain nombre d'articles ont été rédigés et des documents ont été présentés lors de réunions internationales. Au regard de l'intérêt dont témoigne l'industrie du coton à la production organique, tous les travaux du CCIC sur le coton organique ont été compilés dans ce rapport aux fins de référence rapide.

Un des objectifs de la Section d'information technique est de revoir les rapports et les revues techniques et de présenter, dans *THE ICAC RECORDER*, des mises à jour sur la recherche en matière de production. C'est dans ce but que les comptes rendus sur la production organique ont été publiés. Pendant cette période de presque trois ans, nous avons constaté qu'il y avait de nombreuses questions importantes concernant la production organique qui demandent l'attention urgente des chercheurs du coton. S'agissant des préoccupations de la société devant la dégradation de l'environnement, des allergies aux insecticides, du caractère nouveau du produit, du coût accru des insecticides, de la connaissance des inconvénients liés à l'emploi répandu des insecticides tels que les effets négatifs sur la faune et la flore et la résistance aux insecticides. La production organique ne se résume pas simplement à l'élimination de produits chimiques peu souhaitables du système de production mais plutôt à l'ensemble complet de la technologie de production. La production organique demande également des compétences plus poussées que la production conventionnelle et pourtant, aucune recherche systématique n'a encore apporté des directives sur la manière de passer de la production conventionnelle à la production organique.

Cultivo del Algodón Orgánico (US\$100)

La Sección de Información Técnica del CCIA comenzó a informar sobre la producción orgánica a inicios de 1993, al publicarse un artículo sobre el tema en *THE ICAC RECORDER*. A partir de entonces, se han escrito algunos artículos y presentado ponencias en reuniones internacionales. Visto el gran interés demostrado por la industria algodonera en la producción orgánica, en el presente informe se recopila todo el trabajo hecho por el CCIA sobre el tema para facilitar su uso como material de referencia.

Uno de los objetivos de la Sección de Información Técnica consiste en examinar revistas e informes técnicos, y proporcionar actualizaciones relativas a la investigación sobre la producción a través del *ICAC RECORDER*. Los informes sobre la producción orgánica fueron publicados teniendo presente dicho objetivo. Durante el transcurso de casi tres años encontramos que son muchos los temas de la producción orgánica que necesitan la atención urgente de los investigadores que trabajan en el algodón. Entre dichos temas se cuentan los siguientes: inquietudes de la sociedad sobre la degradación del medio ambiente; alergia a los insecticidas; novedad de los productos; costo creciente de los insecticidas; toma de conciencia sobre las desventajas del uso extenso de los insecticidas, como el daño a la flora y la fauna naturales y resistencia a los insecticidas. La producción orgánica va más allá de la simple eliminación de los productos químicos indeseables del sistema de producción, constituyendo más bien un paquete completo de tecnología para la producción. La producción orgánica exige además un nivel más elevado de habilidad respecto a la producción convencional, pero hasta ahora no ha aparecido ninguna investigación sistemática que brinde pautas y directrices para cambiar de la producción convencional a la orgánica.