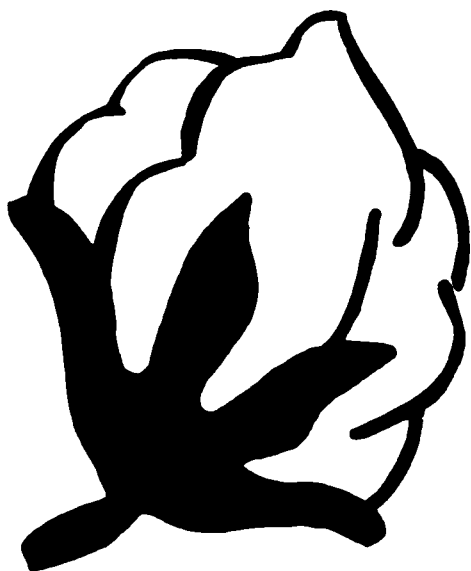




THE ICAC RECORDER

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

In Bangladesh, cotton is grown on an average area of 50,000 hectares, and local production is only enough to meet about 15% of the total requirements in the country. Bangladesh has plans to expand production to 100,000 hectares by 2002/03, while cotton can successfully be grown on 250,000 hectares. Well-scattered rains received during the growing season are enough to meet the water requirements of the cotton plant. Though the breeding program is carried out at three locations, all varieties have been either directly adopted or selected from varieties of Deltapine origin. In Bangladesh, about 15,000 hectares are grown under diploid varieties of *G. arboreum*. Such cotton is popularly called "Comilla" cotton and is grown under "jhum" conditions. *Helicoverpa armigera* is the most serious pest, but an average of 2-3 sprays is also required against sucking insects, making for a total of 5-6 sprays. The Cotton Development Board is responsible for research and development on cotton in the country. More details on cotton production conditions and the system are given in the first article.

The second article gives summaries of papers presented at a regional meeting held in Multan, Pakistan the last week of June 1999. China (Mainland), India and Pakistan shared over 47% of world cotton production in 1998/99. The most destructive bollworm in these countries is the cotton bollworm *H. armigera*. Because of misuse and extensive use of insecticides, the bollworm has developed resistance. China (Mainland) and Pakistan have suffered more than other countries and cotton production has been significantly affected in the region. ICAC sponsored the "Regional Consultation on Insecticide Resistance Management in Cotton," which was held at the Central Cotton

Research Institute, Multan, Pakistan, from June 28 to July 1, 1999. Delegates from sixteen countries attended the Consultation and for four days discussed the status and mechanism of resistance to various insecticides in their countries, and shared their experiences in tackling the resistance problem.

Short notes on a new disease in Australia and detection of the boll weevil in Bolivia are also included in this issue of the publication.

The Technical Information Section of the ICAC has updated its survey on cotton production practices. The database includes information from 40 countries on various aspects of growing cotton, including varieties planted and their characteristics, rotations, soil types, fertilizer application, insects and control measures, diseases and control methods and harvesting and ginning. Detailed information is available on every aspect of production practices. The report is available from the ICAC Secretariat at US\$150.00 per copy. Requests can be addressed to fax 202-463-6950, attention Ms. Patricia Buignet or emailed to <publications@icac.org>.

Food Products Press® has published a new book, *Cotton Fibers: Development Biology, Quality Improvement and Textile Processing*. Fourteen researchers have contributed twelve chapters spread over 387 pages. The chapters are related to fiber initiation and histodifferentiation, fiber growth regulation, fiber growth in vitro, cellular biosynthesis, non-cellulosic carbohydrates, structural development in relation to fiber quality, germplasm resources, genetic variation for quality, molecular genetics of developing fiber, genetic engineering strategies for

cotton fiber modification, post-harvest management of fiber quality and fiber to fabric. Dr. Amarjit S. Basra of the Punjab Agriculture University, Ludhiana, India, has edited the book, which can be ordered from:

Food Products Press®, an imprint of The Haworth Press, Inc.
10 Alice Street
Binghamton, NY 13904-1580
USA

Meetings

The 7th Meeting of the Latin American Association for Cotton Research and Development (ALIDA) will be held in Santa Cruz, Bolivia, from November 23-27, 1999, hosted by the National Association of Cotton Producers (ADEPA) of Bolivia. The meeting will include expositions from countries in the region, country reports and discussions on new technologies; however, the main emphasis of the meeting will be on direct cultivation of cotton production. More information on the meeting can be obtained from the Technical Information Section of the ICAC or from the coordinator of the 7th ALIDA Meeting at the following address:

Ing. Daniel Durán-Parada
Gerente Técnico
Asociación Nacional de Productores de Algodón - ADEPA
Av. Cumavi No. 10
Santa Cruz, Bolivia
Fax: 591-3-466267
Email: adepa@cotas.com.bo

ICAC is also supporting a regional network in Africa—the Southern and Eastern African Cotton Forum—which is going to have its next technical meeting in Malawi on November 3, 1999. The venue of the meeting will be the Agricultural Research and Extension Trust (ARET). The meeting is being sponsored by the ICAC. More information on the meeting can be obtained from Dr. James Munthali, Director of ARET, at email: makokaresstn@malawi.net or from Dr. G. D. Joubert of the Tobacco and Cotton Research Institute, South Africa, at the following address:

Dr. G. D. Joubert
Director
Tobacco and Cotton Research Institute
Private Bag X 82075
Rustenburg 0300, South Africa
Fax: 27-14-5363113
Email: director@nitk1.agric.za

Participants of the Regional Consultation on Insecticide Resistance Management in Cotton, sponsored by ICAC and held at the Central Cotton Research Institute, Multan, Pakistan, from

June 28 to July 1, 1999, formed an Asian Cotton Research and Development Network. The objectives of the network are to promote exchange of information through newsletters, occasional publications and cooperative research programs, and to organize visits to each other's laboratories. The next meeting of the network will be held in India in about two years. The following persons were selected as chairman and co-chairman of the network:

Dr. Zahoor Ahmad
Chairman, Asian Cotton Research and Development Network
Central Cotton Research Institute
P. O. Box 572
Multan, Pakistan
Fax: 92-61-75153
Email: zahoor@ccri.org.pk

Dr. Lakhwinder S. Randhawa,
Co-chairman, Asian Cotton Research and Development Network
Department of Plant Breeding
Punjab Agriculture University
Ludhiana 141004, India
Fax: 91-161-400945
Email: lsr@satyam.net.in

To commemorate the Platinum Jubilee of the Central Institute for Research on Cotton Technology and the Silver Jubilee of the Indian Society for Cotton Improvement, the Indian Society for Cotton Improvement is organizing an international seminar on cotton and its utilization in the 21st century. The seminar will be held at the Central Institute for Research on Cotton Technology in Mumbai from December 10-12, 1999. The seminar intends to bring together experts in the field of cotton production, processing, marketing and by-product utilization on the one hand, and all those related to policy planning and implementation on the other, at one platform for an effective dialogue. The deliberations are expected to culminate in the preparation of a performance oriented action plan that will focus on economically viable technologies for effective use of cotton. Post seminar trips to tourist sites and textile mills in and around Mumbai will be arranged for the delegates. Those interested in attending the conference and presenting papers can contact Dr. S. Sreenivasan at the following address:

Secretary, Organizing Committee
Central Institute for Research on Cotton Technology
Adenwala Road, Mtunga
Mumbai – 400019, India
Fax: 91-22-4130835
Emails: circot@bom3.vsnl.net.in and
circot@x400.nicgw.nic.in

Cotton Production in Bangladesh

Since the late 1980s, Bangladesh has emerged as a cotton consuming country more than as a cotton producer. Cotton consumption has more than tripled in the last twelve years and is expected to reach 170,000 tons in 1999/00. About 15% of mill consumption is produced locally in five regions which have growing conditions similar to each other. *Gossypium arboreum*, commonly known as "Comilla cotton," is planted in Bangladesh under specific growing conditions not suitable for upland cotton.

Bangladesh's Soil Survey indicates that about 250,000 hectares are suitable for cotton production. Current plans are to expand upland production to 100,000 hectares and Comilla production to 30,000 hectares at the end of the fifth Five-Year Plan in 2002/03.

Cotton Growing and Fertilization

Mechanical cultivation is limited, and most field operations are done with bullocks. No land preparation or pre-planting irrigation is done in Bangladesh. Residual moisture is enough to prepare the land for planting. Land is cultivated 3-4 times before furrows are made for planting seed. Furrows are spaced at a distance of one meter and it is recommended to maintain a plant-to-plant distance of 60-70 centimeters for a population of 45-50,000 plants per hectare. Sowing is done by dibbling 3-4 seeds per hill. First, thinning is done ten days after planting when two plants per hill are maintained. Ten days later one plant is removed to get a final stand of one plant per hill. In Bangladesh, three important weeds, *Cyperus rotundus*, *Cynodon dactylon* and *Panicum* spp., show up every year in almost all fields. Weeding, which is mostly a manual operation, normally starts after 20-25 days of planting. Some fields may be cleaned mechanically but herbicides are not used.

Nitrogen is applied to almost 100% of upland cultivation; some Comilla cotton may not be fertilized. One-fourth of the recommended nitrogen dose is applied at the time of planting, one-fourth is applied when the plant is 50-60 centimeters tall, and two other similar splits are applied 45-50 days and 65-70 days after planting. Fertilizer application is completed just before the peak flowering stage.

Fertilizer Recommendations for *G. hirsutum*

Nitrogen	250-300 kg/ha (Urea)
Phosphorous	175-200 kg/ha (Triple super phosphate)
Potassium	150-175 kg/ha (Gypsum)
Sulfur	15 kg/ha (Murate of potash)
Boron	10-11 kg/ha (Borax)

Fertilizer Recommendations for Comilla Cotton (*G. arboreum*)

Nitrogen	45 kg/ha
Phosphorous	20 kg/ha
Potassium	25 kg/ha

Fertilizer recommendations are based on work by the Bangladesh Agricultural Research Council, which currently does little research on cotton. Almost all nitrogen is applied in the form of urea, phosphorous as a triple super phosphate, potassium in the form of murate of potash and boron as borax. Among other micronutrients, if zinc has to be applied, it is applied as zinc sulfate at the rate of 3 kg/ha. The other source of sulfur is a phosphatic fertilizer applied in the form of triple super phosphate, preferred because of comparatively less solubility in water and also least effect on soil pH.

Average Nutrient Status in Jessore

Nutrient	Status
Nitrogen	5-20 ppm
Phosphorous	25-35 ppm
Potassium	0.1-0.25 ppm
Zinc	1.5-3.0 ppm
Sulfur	10-20 ppm
Boron	0.15-2.0 ppm

In Bangladesh, cotton-growing areas have sandy to silt loam soils, one of the reasons up to 80% of soils are deficient in boron and why it is officially recommended to apply it. Some of the recent trials conducted at the Central Cotton Research, Training and Seed Multiplication Farm, Shreepur, Gazipur, have proved that adding 2-3 kg/ha of borax significantly improved yields. However, higher quantities of boron had negative effects and reduced yields when applied as a single fertilizer or in combination with other fertilizers. A detailed article on cotton's need for boron was published in the June 1999 issue of *THE ICAC RECORDER*.

Rainfall is normally well scattered and there is no need for irrigation. In October, there is a late rain in the cotton areas, but there may be a need for irrigation if it is not received. Otherwise, all cotton in Bangladesh is grown under rainfed conditions, and yields do not suffer because of lack of water.

Cotton Producing Regions in Bangladesh – 1998/99

Region	Area Ha	Production Tons	Yield Kg/ha	Main Varieties	Planting Time
Jessore	15,887	6,903	435	CB-1, CB-5	1/7-15/8
Kushtia	14,984	6,143	410	CB-1, CB-5	1/7-15/8
Rajshahi	3,382	1,312	388	CB-3	15/7-30/8
Rangpur	2,525	1,100	436	CB-3	15/7-30/8
Dhaka	3,967	1,453	366	CB-3	15/7-30/8
Chittagong	13,919	950	70	Comilla Cotton	April/May

Comilla Cotton

About 12% of land in Bangladesh consist of hilly tracts. Comilla cotton, which is all *G. arboreum*, is planted on hills under “jhum” conditions with no irrigation facilities. Jhum cultivation is a term used to designate land for shifting cultivation. Because of enough rainfall, hilly tracts are usually heavily vegetated with a variety of plants. Jhum is a form of dryland farming in which an area is cleared from natural vegetation, cropped for one or two years, and then allowed to revert to natural vegetation. After several years, the same area may be cleared and cultivated again, but not necessarily within the same boundaries nor by the same cultivators.

The area selected for jhum cultivation is cleared of vegetation early during the dry season. Vegetation, which may include small trees, shrubs and grass, is burnt in March/April as soon as it dries out. Cotton is planted when the field is ready soon after burning the material. Usually, cottonseed is mixed with seeds of other crops and planted as a mixture. The crops commonly grown along with cotton are Aus rice, marpha, maize, chili, pumpkin and sesame. The combination may vary from farmer to farmer; however, rice is the most important component of jhum, while cotton may be as low as 20% of all crops. In Bangladesh, three rice crops are grown year round: Aus rice, which is the lowest yielding crop and belongs to indigenous varieties; Aman rice, which competes mainly with cotton, though it is planted a month before; and Boro rice, which is planted just after harvesting cotton in December/January.

It is difficult to assess the yield potential of individual crops grown with cotton as they are grown in mixture and under less-cared conditions. But one of the reasons for low cotton yield is poor germination due to low quality of planting seed and seed-born diseases, particularly fusarium wilt and damping off caused by *Rhizoctonia* spp. Currently, four types of Comilla cotton, easily distinguishable from each other, are known in Bangladesh, i.e. Khaki cotton, Okra leaf, Broad leaf and Mesorum. Among these, Okra leaf has a comparatively gray color and is more susceptible to pests, including seedling diseases. Jhum cultivation is practiced in three districts: Khagrachari, Bandarban and Rangamati, with a total area suitable for jhum cultivation of about 20,000 hectares. All field operations are done manually. Fertilizer is applied but not to meet the optimum needs of the crops, and insecticides are rarely used. Some research is done to improve Comilla cultivation but with little impact on yields.

Variety Development Program

As in other cotton producing countries, the main emphasis in Bangladesh has been on development of new varieties. All research farms have breeding teams, in addition to other disciplines. The farms are not only experiment stations but also serve as seed multiplication farms. Breeders' seed (pre basic) and foundation seed (basic) are also produced at the farms under the direct supervision of breeders. Certified seed is produced at farmers' fields with registered growers. Production of the upland cotton started in Bangladesh with the introduction of Deltapine varieties that still continue to dominate in the country. Cotton is labeled as a “non-notified crop” and hence there is no variety approval process in Bangladesh. Any variety that is considered to be high yielding by the Cotton Development Board can be multiplied and planted on a commercial scale. The National Seed Board deals with all crops except cotton. About 400 tons of certified seed of straight varieties are produced under the direct supervision of the Cotton Development Board and offered to farmers at a price of US\$0.21/kg as against a market price of US\$0.15/kg for commercial non-planting seed.

The breeding program is still too young and has not been able to replace Deltapine varieties with locally developed varieties. Lack of varieties suitable for local conditions is considered to be one of the most important reasons for lower yields in Bangladesh. Three upland varieties are grown on a commercial scale in Bangladesh.

While CB-1 and CB-3 have been directly selected from Deltapine 90 and Deltapine 50, respectively, CB-5 is claimed to be a selection from an outcrossing between Deltapine 16 and a local variety. A number of strains have reached yield trials, including SI/91/646, BC-397 and DPL 20, but only BC-397 has a non-Deltapine background. Experiments have been completed on SI/91/646 (selection from DPL 16) which is ready for commercial scale cultivation. Breeding objectives are the same as in other countries: high yields, early maturity, higher tolerance to insect pests, and better fiber quality. There are no significant climatic differences among regions but breeding work is diluted at four locations. A stronger variety development program could be managed efficiently if one centralized program would be implemented. No doubt, Comilla cotton requires a separate program.

Some private companies are trying to introduce hybrid cotton in Bangladesh, but the Cotton Development Board does not

Cotton Varieties Grown in Bangladesh

Variety	Approximate Area (%)	Origin	Duration (Days)	Ginning Outturn (%)	Fiber Length (mm)	Micronaire	Fiber Strength (tpps)
CB-1	40	Deltapine 90	170-180	37-38	28-30	4.0-4.9	84-88
CB-3	10	Deltapine 50	150-160	34-36	28-30	4.0-4.9	84-86
CB-5	50	Deltapine 16	170-180	38-40	28-30	3.5-4.6	84-88

have sufficient evidence to support the propagation of hybrid cotton. Hybrid seed has been imported from India for the last two years. 500 kg of F_1 seed were imported in 1998/99, and an estimated 1,200 kg was imported for 1999/00. A private company claims that hybrids outyield other varieties by significant margins of up to one bale of lint per hectare. The Cotton Development Board is not supportive of such claims. Hybrid seed is sold at US\$25.00/kg (twenty-five dollars per kilogram). Closer monitoring and preferential treatment for the highly expensive seed probably contributes to the higher productivity of hybrids.

Pest Control

Insect control is important in the Bangladeshi cotton production system, but most entomological work is focused on screening of new insecticides. Cotton is attacked by sucking insects as well as bollworms, and 100 percent of upland area is sprayed with insecticides. Major insects and their thresholds are

Insect	Economic Threshold
<i>Amrasca biguttula</i>	2 nymphs/plant
<i>Aphis gossypii</i>	10-15 aphids/plant or 1.5 grade/plant
<i>Bemisia tabaci</i>	Not yet established
<i>Helicoverpa armigera</i>	0.25 larvae/plant
<i>Earias vittella</i>	0.25 larvae/plant
<i>Pectinophora gossypiella</i>	Spray against the cotton bollworm takes care of the pink bollworm

Aphid attack is divided into four different grades:

No. of aphids/plant	Grade
0-10	Grade 1
11-20	Grade 2
21-30	Grade 3
Over 30	Grade 4

Jassid followed by aphids are the first to show on the cotton plant. Several species of jassid have been recorded on cotton in Bangladesh, but *Amrasca biguttula* is the most prevalent. After four weeks of planting, the jassid or aphid populations may cross the economic threshold level and require insecticide applications. Resistant varieties having profusely hairy leaves can effectively control jassid, but the hair density of Deltapine types is not enough to protect them against jassid attacks. Initially, jassid was controlled by spraying monocrotophos insecticides that were very effective against sucking insects but could not control bollworms. Thus, farmers shifted to pyrethroids, which have their own implications.

Whitefly may also show up at a later stage, but no sprays are yet needed to control it. Whitefly has appeared on cotton for the last three years, and based on its multiplication rate since then, it is feared that in about three years it will become a major

pest in Bangladesh. It is alleged that excessive use of pyrethroids on cotton, vegetables and mango is responsible for the flare up, but no concrete steps have been taken to contain the spread of whitefly. However, currently an average of 2-3 sprays/season is enough to control sucking insects.

The red cotton bug *Dysdercus cingulatus* also appears on cotton, although not throughout all the cotton production regions and not every year. The red cotton bug is the last pest to show, and if the population builds enough it may affect lint quality.

The spotted bollworm was the most destructive pest during the 1980s, but now the cotton bollworm *Helicoverpa armigera* has emerged as a more damaging pest on cotton in Bangladesh. It stays on cotton for a longer period of time starting from early boll formation to the boll maturation stage. The spotted bollworm *Earias vittella* requires spraying, but losses are much lower than those of the cotton bollworm. Pink bollworm *Pectinophora gossypiella*, mainly a pest of the northern region, rarely crosses the economic threshold level. In 1998/99, the Egyptian bollworm, *Spodoptera littoralis*, also appeared but not everywhere. However, on average, three sprays are enough to keep bollworm pressure below economic injury levels. Because of the availability of cheap labor, non-chemical methods of insect control are commonly practiced. Light traps are used to catch bollworm moths, bollworm larvae are handpicked, infested buds carrying worms are removed and insecticides are used as a last resort.

Comilla cotton requires almost no spraying against jassid and aphids. The pink bollworm may cross economic threshold levels but usually it is not sprayed because of mixed cropping and low expectations for high yields.

Among diseases, bacterial blight and boll rot are important and in cases of severe attacks yield losses may go up to 70%. It is recommended to use acid delinted and treated seed. Though the severity of diseases may not be the same every year, a number of fungicides are being tried to avoid losses.

Role of the Cotton Development Board

The Cotton Development Board (CDB) has the sole responsibility of cotton production, research, and extension activities throughout the country. The Board was established in 1972 and has the primary objective of promoting cotton cultivation in Bangladesh through extension and development programs. Practically, the Board became active in 1977 with the introduction of the cotton variety Deltapine 16 from the USA. The area under upland cotton increased slowly and, accordingly, the functions of the CDB were revised in 1991. Now the Board is charged with the responsibility of conducting research on all aspects of cotton, develop a package of production technology, produce good quality seed, carry out extension activities, train cotton growers in production technology and help in cotton marketing.

The Cotton Development Board, headquartered in Dhaka, has a well-organized infrastructure to fulfil its mandate. Most of the facilities were established with help provided by the European Economic Community in the form of grants and experts. The European Economic Community helped Bangladesh from 1982 to 1994, during which three research farms were established/developed. They are

1. Central Cotton Research, Training and Seed Multiplication Farm, Shreepur, Gazipur – 65 hectares
2. Regional Cotton Research, Training and Seed Multiplication Farm, Jagadishpur, Chowgacha, Jessore – 60 hectares
3. Regional Cotton Research, Training and Seed Multiplication Farm, Sadarpur, Dinajpur – 52 hectares

Each farm is equipped with an office building, a training room for farmers, a farmers' hotel, repair workshops, a ginning facility, residences for the staff, and farm machinery and implements. Growers who contract with the Board to multiply seeds are invited to the farms every year, where they stay for 3-4 days and are trained in cotton production technology. Farmers are not only provided free accommodation and food but are also paid for the cost of their travel to and from the farm. At least two training courses are conducted every year: one in June/July before the planting starts and the other before harvesting the crop in October or early November. Additional research facilities include a fiber testing lab at the Board's offices in Dhaka and a ten-hectare Cotton Breeding Farm at Mahigonj, Rangpur, for the sake of germplasm preservation and testing. Ginning and marketing were fully controlled by the Board until 1988, but now a number of private gins have been installed and private enterprises have become active in the marketing of cotton.

For the sake of extension activities, Board offices are headed by deputy directors in five upland cotton regions and in one Comilla cotton region. Each region is divided into 2-3 zones and there are 14 zones in total. At each zone, a chief cotton

development officer is in charge, helped by a number of cotton development officers who have at least a graduate degree in agriculture.

Harvesting and Marketing of Cotton

In its majority, farmers are small growers cultivating not more than two hectares. Comilla cotton cannot be machine-picked and all upland cotton is still handpicked. Herbicides are not used, and growth regulators are not used for early termination of the crop. While a period of 170-180 days seems like a lengthy growing season, no significant work has been done to assess the usefulness of applying growth regulators. Because of its poor holding ability, Comilla cotton needs to be picked frequently and the total number of picks may reach ten. In the case of upland cotton, boll formation spread over a long period of time causes bolls to mature accordingly.

The Cotton Development Board procures seedcotton from contracted growers at US\$0.54-0.62/kg for seed purposes. All other farmers are free to sell seedcotton in the open market. The Board owns seven ginning factories (out of 54), where seedcotton is ginned under the direct supervision of seed production specialists. The seed produced by the Cotton Development Board is packed in 2-kg bags and stored at gins. The seed is sold to farmers through the Board's network of extension agents. Certified seed is produced only in eight regions that have ginning facilities. The 2-kg polythene bags show all the important information like variety, purity, germination percentage, moisture content at the time of packing, origin of seed, etc. The bags also show instructions from the Cotton Development Board for input use and interculturing operations for harvesting high yields. Other sources of seed supply are self seed from the previous year, private gins and supply by the Bangladesh Rural Development Committee, which has its own gins. There is no guaranteed minimum support price for seed cotton or lint. Market forces determine lint prices but textile mills are asked to buy at least 10% of their requirement from the local market.

Regional Consultation on Insecticide Resistance Management in Cotton

The Technical Information Section of the International Cotton Advisory Committee in collaboration with the Central Cotton Research Institute, Multan, of the Government of Pakistan, organized the "Regional Consultation on Insecticide Resistance Management in Cotton – Asia," from June 28 to July 1, 1999. The Central Cotton Research Institute (CCRI), Multan, is a mono-crop multidisciplinary institute of the Pakistan Central Cotton Committee, an autonomous organization under the federal Ministry of Food, Agriculture and Livestock. ICAC sponsored the Consultation with a large part of the costs paid by the Institute. Dr. Zahoor Ahmad, Director of the CCRI, served as

the Coordinator of the Consultation. The Technical Information Section of the ICAC helped to obtain nominations from various countries and prepare a program. The Consultation was attended by delegates from twelve countries in the region, in addition to participants from Australia, the Centre de coopération internationale en recherche agronomique pour le développement, France, the United Kingdom and the USA. A list of participants is enclosed.

During 1998/99, China (Mainland), India and Pakistan shared 47% of the world cotton production, and the three countries are faced with a problem of resistance to a variety of insecti-

cide groups. With other smaller cotton producing countries like Thailand and Vietnam also affected by the same problem, resistance to insecticides has emerged as a regional problem in Asia. The twelve countries represented in the Consultation from the region shared about 69% of total production in 1998/99. This is the main reason ICAC decided to hold the meeting on the issue of resistance management in cotton. The main objectives of the Consultation were to:

- Review the current status of insecticide resistance in various countries and in the region.
- Obtain information on research programs and insecticide resistance monitoring strategies.
- Share information on insecticide resistance management programs being developed in different countries, and exchange experiences in the implementation of resistance management practices.
- Consider possible collaboration among different countries to tackle the resistance problem.

The Federal Minister for Food, Agriculture and Livestock, Government of Pakistan, inaugurated the Consultation. Many government officials from the Federal Government and from the cotton producing provinces of Punjab and Sindh attended the Consultation. In his inaugural address, the Minister said that pesticide use on cotton has increased many fold in most countries and it is time to develop pest control strategies that are not harmful to the environment, wildlife and humans. After a record crop of 2.18 million tons in 1991/92, cotton yields in Pakistan have suffered because of resistance to insecticides. He urged researchers to find alternate methods of pest control. The Minister cautioned that the continuous increase in pesticide use could not sustain cotton production on economical terms. Integrated pest management is an option but more countries should join hands for collaborative efforts to tackle the vagaries of pests. The Minister said that the ICAC platform should be used to develop regional programs and to take advantage of the work done in other countries.

Dr. M. Rafiq Chaudhry, Head of the Technical Information Section, welcomed participants on behalf of the ICAC and gave

an overview of the cotton situation in the world in addition to explaining the need and objectives of the Consultation. He said that cotton is passing through a critical stage of concern to many segments of the cotton industry. Cotton yields are not increasing in most cotton producing countries of the world and, because of the extensive use of insecticides, the cost of producing cotton has increased to uneconomical levels. There is no agency at the international level to promote cotton use, and consequently cotton is losing its share against synthetic fibers. A new technology has to be developed, and less expensive and non-toxic methods of insect control have to be found for sustained increases in yields.

Summaries of the papers presented at the Consultation are given here.

Keynote Paper

Dr. Zahoor Ahmad in his keynote paper on the pest problems of cotton: a regional perspective, stated that Asia accounts for over 60% of world production. But heavy pest pressure has resulted in increased use of insecticides and many secondary problems. Natural biological controls have been imbalanced and secondary pests have flared, in addition to the development of resistance to insecticides. Failure to control insects due to resistance not only enhanced the use of insecticides, but also affected yields which are currently stagnant or rather declining in some countries in the region. According to him, the most important insects in some countries in the region are shown in the table below:

Major pests normally require insecticide applications almost every year while important pests may require spraying in certain years. Pests of no economic importance do not require insecticide control. While some pests exist in some countries as important and in other countries as pests of low importance, the cotton bollworm *Helicoverpa armigera* is the most dangerous pest of the region. Dr. Ahmad quoted the example of China (Mainland), Pakistan and Thailand, where the cotton bollworm has developed resistance to most pyrethroids and farmers have suffered heavy losses. The pink bollworm is another pest that requires chemical control in all countries mentioned above. The CIS countries of central Asia are still safe from this pest.

Important Insect Pests of Cotton in Asia											
	Bangladesh	China (M)	India	Indonesia	Myanmar	Pakistan	Philippines	Sri Lanka	Thailand	Turkey	Vietnam
Bollworms											
<i>Helicoverpa armigera</i>	●	●	●	●	●	●	●	●	●	●	●
<i>Pectinophora gossypiella</i>	●	●	●	●	●	●	●	●	●	●	●
<i>Earia vittella</i>	●	●	●	●	●	●	○	●	●	○	○
<i>Earia insulana</i>	○	○	●	●	○	●	○	○	○	●	○
<i>Spodoptera spp.</i>	○	○	●	○	○	●	○	○	●	●	●
Sucking											
<i>Amrasca devastans</i>	●	●	●	●	●	●	●	○	●	●	○
<i>Aphis gossypii</i>	●	●	●	●	●	●	○	○	●	●	○
<i>Bemisia tabaci</i>	○	○	●	○	○	●	○	○	○	●	○
<i>Thrips tabaci</i>	●	●	●	○	●	●	○	○	○	●	○
<i>Tetranychus spp.</i>	○	●	●	●	●	○	○	○	○	●	○
Legend	●	Major pest	●	Important pest	○	Pest of no economic importance					

Talking about the situation in his own country, Dr. Ahmad stated that since 1992/93 cotton production has declined significantly because of the widespread attack of the leaf curl disease and the inability to control the cotton bollworm and whitefly, vector of the leaf curl virus. He said that in Pakistan the cotton bollworm was first recorded on cotton in 1967 and now is the number one cotton pest in the country. It has developed high resistance to pyrethroids and endosulfan. Whitefly gained importance with the appearance of the leaf curl disease and has developed resistance to organophosphates like metamidophos and monocrotophos, and to pyrethroids like cypermethrin, deltamethrin and bifenthrin.

Australia

The paper from Australia by Dr. Robin Gunning of the New South Wales Department of Agriculture reported on a biochemical method to monitor resistance in the cotton bollworm. In Australia, pyrethroid resistance in *H. armigera* is caused by massive overproduction of esterase enzymes that detoxify pyrethroids by sequestration and hydrolysis. Two different types of insensitive acetylcholinesterases are responsible for resistance to carbamates and organophosphates. But, traditionally, resistance in the cotton bollworm has been measured by discriminating-dose-bioassay technique. The process is slow, labor intensive and sometimes unreliable. It also does not differentiate among the susceptible, heterozygous and highly resistant worms. For resistance to carbamates and pyrethroids, biochemical assays for total esterase activity were conducted to assess the level of resistance. The results were insignificantly different from the discriminating-dose-bioassay technique. The biochemical assays produce a colored reaction and a field based resistance kit has been developed. The kit involves egg or larvae homogenization followed by addition of substrate and dye. The results can be read in 10-20 minutes with a visual eye showing resistance and the proportion of individuals, homozygous and heterozygous, for that chemical. Both, carbamate and pyrethroid kits, have been tested for many years.

China (Mainland)

In China (Mainland), about 80,000 tons of insecticides are used on cotton each year, about one-third of total insecticide use in the country. Dr. Jianguo Tan of the University of Nanjing Agricultural University, Nanjing, presented the status of resistance in various insects and also gave details on how it has slowly developed in various regions. In China, almost all major pests, i.e. spider mites, mainly *Tetranychus urticae* and *T. cinnabarinus*, pink bollworm, aphids and the cotton bollworm, have developed resistance to a variety of insecticides. Organophosphate and organochlorine insecticides were used to control mites on cotton since the 1950s. One species, *T. cinnabarinus*, was found to have developed resistance in Hebei province in 1964. By the end of the 1980s, spider mites had developed resistance to organophosphorus compounds, particularly methyl parathion and monocrotophos in Henan province.

The pink bollworm is a pest in the Yangtze River Valley, and for a long period of time has been controlled only with insecticides. Recent studies proved that the bollworm has developed resistance to deltamethrin, fenvalerate and methyl parathion. Pink bollworm samples were collected from various areas and the level of resistance was noted to vary from 95 to 699 folds. Resistance to methyl parathion was low (4-10 fold).

Aphids are a major pest on cotton and persist in the field for about 6-7 weeks until mid June. For almost 20 years, from 1950 to 1970, aphids were controlled with BHC and organophosphate compounds. From the mid-1970s, carbamates were used and organophosphate compounds were replaced with newer organophosphate insecticides. With the introduction of pyrethroids in the early 1980s, the emphasis changed to a more efficient and effective control, and most carbamates and organophosphates were replaced with pyrethroids. Resistance monitoring programs have shown that aphids have developed resistance to most organophosphates, carbamates and pyrethroids. Successive testing in the same area has shown a continuous increase in the LD₅₀s based on the frequency of different products used.

The cotton bollworm was not a major pest but now it has attained the status of the most destructive pest in the cotton production system in China (Mainland). The first outbreak occurred in 1971/72, but by 1990 it had become a severe problem and has caused a major setback to cotton production in China since 1992. The history of the development of resistance in the cotton bollworm is almost on the lines of aphids. Efforts to control aphids have contributed to the development of resistance in the cotton bollworm. Now, the cotton bollworm is not only resistant to all the commonly used carbamates, organophosphates and pyrethroids but has also developed resistance to Bt insecticides.

The Government of China (Mainland) has implemented insecticide resistance management programs since 1995, but small landholdings, the intercropping of cotton with wheat, corn, etc., and poor insecticide distribution, regulations and management systems are limiting the success of these programs.

Dr. Jingyuan Xia of the Chinese Cotton Research Institute, Anyang, Henan, presented a paper on the effects of Bt cotton on the behavior and mortality of bollworms and also on non target insects under laboratory, cage (in the field) and field conditions. Work continued from 1994 to 1998. Dr. Xia concluded that bollworm resistance to Bt cotton varied with the crop season, plant structure and larval stage. But, in general, the rate of development, survival, oviposition and egg hatching of bollworms fed on Bt cotton decreased compared to non-Bt cotton. There was no difference in the number of eggs laid on transgenic and non-transgenic varieties under cage and field conditions, but the number of larvae on transgenic cotton were significantly lower than on non-transgenic plants. The time the bollworm's first to third instar larvae spent on feeding on transgenic plants, compared with the non-genetically modified plants, was sig-

nificantly decreased; however, the time spent on resting and spinning-down substantially increased.

Transgenic plants imposed severe detrimental effects on the survival and growth of *Agrotis ipsilon* and *Ostrinia furnacalis* as well as on the seasonal dynamics of *Anomis flava* field populations. There was a tendency to have a higher population of sucking insects; aphids, mites and thrips on transgenic cotton. Bt effects on beneficials were also studied and it was found that the preying rate of larvae fed on Bt cotton was 1.5 to 3.0 times lower compared with the non-transgenic control. Parasitization, survival rates and body weight of some of the predators monitored were significantly reduced in the case of larvae fed on Bt cotton. There was a slight increase in predator populations in the Bt cotton fields.

India

In India, five resistance monitoring laboratories have been set up throughout the cotton and legume producing areas. Laboratories were set up to assist the agriculture extension staff on the most effective and efficient agrochemicals, particularly insecticides, and manage the cotton bollworm, which has already developed resistance. Dr. Derek Russell from NRI, UK, presented a report on the resistance scenario in India. Bioassay methods using specific discriminating doses of cypermethrin, endosulfan, fenvalerate, methomyl and quinalphos were used to measure resistance frequency in whitefly and cotton bollworm.

According to Mr. D.R. Jadhav from ICRISAT, resistance status to the major insecticides used as discriminating doses for cypermethrin (0.1 and 1.0 mg/ml) in the cotton bollworm was high throughout the season. Resistance to fenvalerate was also very high throughout the season, and low to endosulfan early in the season, with a significant increase in mid-season. Resistance to quinalphos was low at the beginning of the season and rose sharply during December-March.

For whitefly resistance measurement, whitefly adults were bioassayed by the leaf dip method with the exception of the petiole dip method for imidacloprid. The susceptible strain was received from the Rothamsted Experimental Station in the UK, originally from Sudan. The results showed that the whitefly has already developed high resistance to cypermethrin and acephate, but only a moderate resistance to monocrotophos. Endosulphan and triazophos can still be successfully used to control whitefly in India.

The third paper, by Dr. K.R. Kranthi, dealt with the mechanism of resistance to various chemicals and insecticide resistance management strategies for sustainable pest management in India. Metabolic detoxification through enhanced esterase activity is the most important mechanism by which the cotton bollworm has developed resistance to pyrethroids and organophosphate compounds. Esterases are also involved in resistance to endosulfan. In areas where pyrethroid use has been high in recent years, nerve insensitivity was also found to be responsible for the development of resistance. The paper emphasized the

need to investigate how slow or fast resistance is developed to specific chemical groups and, once resistance is developed, how far it remains stable within the population even if the insect is not exposed to that insecticide any more. There is also a need to establish that if the bollworm has developed resistance to a particular insecticide, what are the chances that it has also developed resistance to other chemicals and how much. The role of mixing certain chemicals used on slightly resistant and all susceptible populations, in further enhancing the resistance problem, also needs to be investigated.

The insecticide resistant management program in India is comprised of rational and sensible use of insecticides, growing resistant genotypes, and chemical seed treatment for delaying the initiation of the first insecticide application, avoiding the use of broad spectrum organophosphates such as monocrotophos, acephate, etc., especially as early season sprays, and use of endosulfan at early stages of crop development. In addition to the cultural control methods, the use of safer and bio-insecticides like neem, *Azadirachta indica* and Bt or NPV, is also strongly recommended.

Dr. Joginder Singh reported on the results of the IPM technology implemented in eleven villages in the Northern Region of India. His results also showed higher yield in IPM fields over non-IPM or conventional insecticide applied fields. IPM farmers spent less money on insecticides thus reducing the cost of production and improving the economics of project IPM farmers.

Dr. Lakhwinder Singh Randhawa from the Punjab Agriculture University, Ludhiana, reviewed the role of biotechnology in alleviating the development of resistance to insecticides. Biotechnology can contribute to delay the development of resistance through accurate identification of insects when it is not possible to do so visually, identify suitable resistant genes and incorporate resistant genes into the host plants. A number of biotechnological tools like restricted fragment length polymorphisms, randomly amplified polymorphic DNA, short sequence repeats, microsatellites, and amplified fragment length polymorphism can be used in marker assisted identification of morphologically confusing insects. The paper also critically reviewed the role of CryI(A) within Cry genes and endotoxins in addition to the current status of Bt cotton. Insects can develop resistance to endotoxins faster than to insecticides and are also prone to develop cross-resistance to different endotoxins. However, it is difficult to predict the mechanisms by which different insects will develop resistance to various toxins.

Biotechnology can contribute in many ways to delay the emergence of insect populations that are resistant to Bt toxin. These ways possibly include enhanced expression of toxin genes, use of refuge crops, use of tissue specific or inducible promoters, gene pyramiding, exploration and utilization of insecticidal proteins, use of trypsin inhibitor genes, lectin genes, vegetative insecticidal proteins, cholesterol oxidases and integration of baculoviruses. The tissue specific or inducible promoters will permit the plant to produce endotoxin in specific plant parts

while other parts will be left free of the toxin. Similarly, various other approaches can help and may be integrated into the multi dimensional approach. In the future, development of transgenic cotton having the ability to express predetermined stress, development of mutated insects carrying transferable viruses pathogenic to the insect himself and also to others, enhance predators and parasites' abilities to withstand insecticide applications, development of DNA based field diagnostic kit, and development of bio indicators that can provide simple color changes that are proportional to particular biotic stress could further enhance the role of biotechnology to delay the development of resistance to insecticides.

Indonesia

The cotton bollworm is also the most important pest in Indonesia, closely followed by the pink bollworm *Pectinophora gossypiella* and spotted bollworm *Earias vittella*. Little work has been done to ascertain the level of resistance and monitor it on a continuous level. However, pesticide spray table bioassay work done many years ago showed that the LD₅₀ for the field population of the cotton bollworm had reached 80, 81, 111 times to endosulfan, profenofos and permethrin, respectively, in different parts of South Sulawesi—the second largest producing region in Indonesia.

A number of measures have been adopted to tackle the resistance problem. Based on the cotton bollworm reaction to endosulfan in other crops, in 1996 the Pesticide Commission in Indonesia discontinued production and distribution of endosulfan in the country. Integrated pest management was launched five years ago whereby insecticide use was streamlined, spraying based on threshold was adopted, varieties resistant to insects, particularly jassid, were promoted, and trap cropping was popularized. Starting from 35-50 days after planting, the release of *Trichogramma* spp. based on a threshold of 29 cotton bollworm eggs/25 plants was recommended. Release of 200,000 parasitoids/ha resulted in 46% parasitization. Chemical control was also supplemented through other biocontrol agents and botanical insecticides wherever possible.

Iran

Mr. Taghi Darvish Mojeni reported on the susceptibility of aphids and whitefly to a number of insecticides under field and lab conditions in Iran. In the last few years, whitefly has emerged as one of the most important pests in Iran. The aphid population peaks during August and September while whitefly overlaps with aphids in September but continues until the end of October. The damage has been in the form of lower yields and honeydew deposition on green leaves. Organophosphates, carbamates and pyrethroids have been used to control these sucking pests for the last 15-20 years. But, lately, farmers and researchers noted that certain insecticides did not provide sufficient control of these insects. Studies were undertaken and it was concluded that resistance to insecticides, low quality formulations, mismanagement of spraying and poor quality of the

spraying equipment were responsible for failures to control aphids and whiteflies in the field.

Experiments were conducted on a number of commonly used insecticides against aphids and whitefly under field and lab conditions. In the field, samples were collected a day before spraying and 1, 3, 6 and 9 days after spraying insecticides to analyze the effect on the population. In the lab, two aphid populations, one from the high insecticide use area and the other from the area where insecticide use is not common, were sprayed with different doses of insecticides. Results confirmed that aphids and whitefly have developed a fairly high tolerance to some insecticides, while some other insecticides can still be used to control sucking insects. Based on these studies, the use of some chemicals has not been recommended on cotton to control aphids and whiteflies.

Pakistan

Dr. Mushtaq Ahmad of the Central Cotton Research Institute, Multan, Pakistan explained the development of resistance in the cotton bollworm and whitefly under Pakistan conditions. A number of factors including monoculture, misuse of insecticides and destruction of beneficial insects in addition to resistance to insecticides have changed the status of the cotton bollworm and whitefly in Pakistan. The resistance data for 1993 and 1998 showed that the bollworm has increased resistance from 7-34 fold in 1993 to over 50 fold to endosulfan and pyrethroids. Because of the change in insecticide use, resistance to monocrotophos and methomyl that was high in 1993 dropped significantly. Whitefly had high resistance to dimethoate, metamidophos, cypermethrin and deltamethrin in 1993 and that has significantly dropped due to intervention from the government. In the cotton bollworm, oxidative as well as hydrolytic enzymes, and maybe nerve sensitivity, are involved in the development of resistance. Esteratic detoxification of some organophosphates and pyrethroids is the main reason for development of resistance but alterations at the target site are also thought to be contributing to the development of resistance in whitefly. No method is available to tackle the resistance problem. However, recommendations include that use of mixtures and broad spectrum insecticides be avoided, no misuse of insecticides, avoid too much use of the same insecticides, use novel chemistries for the bollworms and insect growth regulators for whitefly and delay start of insecticide spraying in the beginning of the season as much as possible.

Dr. Agha Ikram Mohyuddin, a private consultant, shared his experience on the role of *Trichogramma chilonis* to provide a natural control of bollworms. *T. chilonis* was artificially reared using *S. cerealella* on wheat grains. Trials were conducted for five years, from 1994 to 1998, on large as well as small growers' farms. Cards parasitized by *Trichogramma* called 'trichocards' were prepared and stored at 10°C before use in the field. 20-25 trichocards per hectare, each having about 3,000 to 4,000 parasitized eggs, were stapled to cotton leaves in the field at weekly intervals. In some cases even yields were higher

in the IPM plots over conventional spraying fields, but in all fields it was more economical to use IPM than sole reliance on insecticides.

Dr. Shahid Karim explained the role of Bt in delaying the development of resistance to insecticides, the mechanism of Bt toxin and the development of resistance to Bt toxin by the pest. The mode of action of δ -endotoxins depends on a series of processes that include ingestion, solubilization, prototypic activation, peritrophic membrane, receptor binding, membrane insertion, ion channel formation and cell lysis. Though the process is complicated, development of resistance to Bt toxins raises concerns about the future of transgenic Bt cotton and Bt biopesticides. In order to deal with such a problem in insecticides, the latest approaches have relied mainly on the ecological and genetic knowledge about insects. Similar investigations showed that the possible factors that can affect the ability of toxins to kill bollworms are lower solubilization of Bt crystals, reduced cleavage of full length Bt protein into an active fragment, increased proteolytic digestion of the active fragment, less binding of the active fragment to the midgut epithelium and reduced functional preformation. However, initial frequency of resistant alleles in the population could also affect the process of resistance development. As far as the insect is concerned, generations and percentage of the population exposed to the toxins, insect behavior and movement can also affect the insect's ability to become used to the toxin. The possible solutions are gene pyramiding, use of promoters, protein engineering, mixing or rotation of toxins and creation of hybrid population by planting refuge crops. Some *Bacillus thuringiensis* toxins like Cry1Aa, Cry1Ab and Cry1Ac are not good choices to control the cotton bollworm because of their cross reactivity in receptor binding.

Philippines

In the Philippines, identification of the resistance problem is related to lower yields. Farmers and researchers alike complained about the ineffectiveness of insecticides in the late 1980s. The issue was analyzed in detail and related to farmers' production practices. Insecticides were the most commonly used method of insect control and the cost of pesticide use increased to 48% of the total agricultural inputs. Ms. Aida D. Solsoloy of the Cotton Development Administration, Philippines, stated that, in general, farmers, applied pyrethroids in higher doses than recommended, while organophosphates and carbamates were under-dosed. Farmers also used insecticide mixtures indiscriminately and they ratooned cotton in some areas, which contributed to the easy survival of pests during the off-season. In order to establish the level of resistance, the field population of the cotton bollworm was exposed to various doses of endosulfan and deltamethrin. It was observed that the bollworm developed a higher tolerance to endosulfan compared with deltamethrin. As the number of generations progressed from first to the later generation, the resistance factor increased significantly.

The Cotton Research and Development Institute developed a package of technology based on a multidimensional approach to alleviate the resistance development problem. The major emphasis has been to avoid the misuse of insecticides. Critical threshold levels for various pests were established and strictly implemented. Farmers were advised to stop using products that required manyfold increases in the quantity to be used to control bollworms. It was strongly recommended to use products that persist in the field for a short period of time. Organochlorines were removed from the recommendation list and organophosphates and carbamates were advised to be used for early and late season control, respectively. Pyrethroids were permitted only during the peak bollworm stage. In general, the use of mixtures was discouraged but permitted under specific recommendations. Farmers were encouraged to use *Trichogramma chilonis* at the rate of 67,000 parasitoids per ha. At least one company is already commercially producing the bio agent and selling it to farmers. Farmers were encouraged to use trap crops, and they were educated to stop ratooning.

Thailand

In Thailand, the cotton bollworm started developing resistance to insecticides as early as 1969, and by 1984, it had developed resistance to pyrethroids, in addition to recurrence of whitefly at the end of the season close to picking. Extensive work has been done in Thailand to assess the level and mechanism of resistance developed by the cotton bollworm to synthetic pyrethroids (fenvalerate, deltamethrin and cypermethrin), organophosphate (sulprofos) and organochlorine (endosulfan). The report presented by Ms. Kesara Jee-Rejunya of the Department of Agriculture, Thailand showed that the bollworm was more resistant to synthetic pyrethroids compared to organophosphate and organochlorine insecticides. Resistance to organophosphate and organochlorine products was more consistent among different generations compared with pyrethroids. Cross-resistance was discovered only in later generations.

The main strategy to tackle the resistance problem has been to preserve the efficacy of insecticides used on cotton for a longer period of time. In this regard, understanding the development stages of the bollworm, insecticide efficacy and formulations, application technique and application intervals were considered to be of high importance. The general recommendation was not to apply one group of insecticides for more than four weeks. Endosulfan or amitraz+endosulfan were recommended to be sprayed from day 30 to 60-day-old crop. It was recommended that pyrethroids be used only between 61-90 days after emergence. Organophosphate or organochlorine insecticides could be applied on 91-120-day-old crop. However, no single insecticide should be repeated 3-4 times per season.

Turkey

The paper from Turkey by Dr. Erdal Sekeroglu mainly dealt with the pest problem in general in the Çukurova Region of Turkey. Following the epidemic in 1974, the whitefly contin-

ued to be the most important cotton pest in Turkey. A number of agronomic measures, in addition to resistant varieties, have been adopted to escape heavy losses. Though in the recent past the pink bollworm has gained significance, the control of the cotton bollworm remains important. The economic threshold for the cotton bollworm is two young larvae per three meters of cotton row. During the season, five generations appear but only three seem to be causing economic losses. It is recommended that the natural biological control be established and that insecticides not be used against the first generation. Lately, farmers have started reporting their inability to control the bollworm with insecticides.

United Kingdom

A paper by Dr. Robert Perrin of Zeneca Agrochemicals emphasized the need for preventive measures before resistance develops. Agrochemical companies have become more active in their collaborative role to avoid the development of resistance. The Insecticide Resistance Action Committee, which acts as a voice for the insecticide industry with governments, has undertaken extensive programs in hot spot areas in the form of workshops, fund research and development of guidelines and training material in many countries. A community wide approach is needed rather than individual farmers' efforts. Though no single chemical such as pyrethroids is expected to dominate the market in the future, as it did during the 1980s, the effective means of managing resistance lie in the strict control of insecticides. Susceptibility management is more important than resistance management, and transgenic cotton can play an important role in this regard.

USA

Dr. Thomas J. Henneberry and Dr. Steven J. Castle of the USDA-ARS Western Cotton Research Laboratory, Phoenix, Arizona presented two papers on the occurrence and control of whitefly.

The whitefly has been a pest in the USA for over 100 years but it gained economic importance only after it was identified as a vector of the virus responsible for causing the leaf crumple disease in cotton. Cotton plowdown regulations were strictly applied and the pest population slowed to uneconomical levels for almost two decades. The whitefly population started increasing from 1975 to 1980 and acquired outbreak status by 1981 in the Imperial Valley in the West. Large increases in cotton area, a high rate of insecticide use to control whitefly, and year-round insecticide exposure to the pest on the host crops in the field and resistance to insecticides are considered responsible for large increases in the whitefly population. Thereafter, serious work was undertaken to assess resistance to insecticides and a yellow sticky card resistance monitoring bioassay system was developed. But, with the introduction of a biotype 'B,' the problem became complicated. Strain B happened to have a vast host range and also showed higher resistance to insecticides.

In the US, the whitefly resulted in heavy losses to cotton and

vegetables in 1991. A number of measures have been adopted since then to contain the pest, and they have proved to be successful. Some of them are

- Resistance monitoring programs were intensified and chemical insecticides were accepted as efficient means to control the whitefly. Application of insecticides based on action thresholds was advocated and followed. In order to improve the effectiveness of insecticides, the use of insecticide mixtures and the rotation of chemicals, both within and between seasons, was promoted.
- Farmers were advised to use insect growth regulators, particularly from 1996 onward, and also to delay the application of pyrethroids as long as possible. Other new insecticide chemistries were also adopted to control the whitefly.
- Awareness for the integrated and community wide approach was propagated. Host plants were destroyed on a large scale.
- Realizing that water stress conditions provide favorable conditions for multiplication of the whitefly, recommendations were made to avoid water stress in cotton.
- Numerous local and imported predators and parasites were tried as biological control agents to integrate with other control methods. Natural enemy efficacy, ecosystem compatibility, adaptability of the agent to local conditions are being studied. Strains of *Paecilomyces fumosoroseus* and *Beauveria bassiana* have been found to be effective.
- Changes in cropping systems were introduced to produce susceptible populations for interbreeding with the populations more exposed to insecticide applications.

The second paper by Dr. Steve Castle dealt with the general belief that whitefly developed resistance to insecticides and thus emerged as a major pest in most countries. Insecticides played a major role in elevating the status of whitefly as a major pest on cotton, but not because the pest had developed resistance to insecticides, rather because the natural biological control system was imbalanced which required higher use of insecticides. The paper advocated that the large increases in area planted to cotton improved the resources available to the pest for faster multiplication. In Pakistan, when upland cultivation replaced cultivation of desi cotton *G. arboreum* in the 1920s, broad leaf upland types improved the quality of resources available to whitefly. In Sudan, expansion in irrigation facilities, larger cotton area, higher doses of synthetic fertilizers, an increase in the alternate host crops and early planting of cotton helped the whitefly to establish and multiply at a much faster rate. Resistance to insecticides, like any other factor, may have contributed to the build up of the whitefly population in many countries, but the general perception about the only or major role of insecticide resistance is not true.

Uzbekistan

Uzbekistan has developed a new peptide from melon (*Cocumis melo*) seeds for controlling *H. armigera* in cotton and other

insects in agricultural crops. Dr. Amdusattar Abdugarimov of the Institute of Genetics and Plant Experimental Biology in Tashkent explained how peptides were removed from seeds and what was their efficacy against a number of agricultural pests. Proteins were precipitated in the seed mass with the help of trichloroacetic acid and removed by centrifuging the material. Peptides were precipitated with acetone and fractionated with gel filtration on TSK HW-40F. The fraction was further purified by HPLC on Beckman Gold Chromatograph. Molecular mass and amino acid composition of the extract were determined. The toxic effect of peptide extract was determined feeding the larvae on an artificial diet impregnated with peptides. The lethal dose was determined by killing 50% of the early fourth instar larvae of the target pest. The results showed that 10 microgram of the peptide extract per larvae of the test insects were enough for effective control. In the artificial diet, LD_{50} was established at 0.01 to 0.02% of the diet. The peptide is not toxic to higher animals.

Vietnam

Dr. Nguyen Thi Hai of the Nha Ho Cotton Research Centre presented a report on insecticide resistance management as a part of the IPM program in cotton in Vietnam. Major pests that require sprays every year are aphid, jassid and the cotton bollworm. Secondary pests that may also occasionally become a problem are thrips, mites and different types of bollworms including pink bollworm. Up until the mid 1980s, insects have been controlled mainly by spraying insecticides such as organophosphates, carbamates and pyrethroids. The average number of sprays that had increased to ten started showing failure to control sucking pests as well as bollworms.

Insecticide resistance studies on the cotton bollworm were undertaken in 1984 through 1986, and the bollworm indicated no signs of resistance. However, the work done from 1986 to 1990 showed clear indications of lower efficacy of insecticides like cypermethrin and lambda cyhalothrin. It was also noted that lower and lower numbers of bollworm larvae were killed from 1986 onward.

Different aspects of the resistance management strategy, as part of the IPM, included growing varieties particularly resistant to jassid, cultural control by intercropping cotton with corn, extensive studies on the population dynamics for the sake of preserving beneficials, minimum use of insecticides and adoption of biological control. In Vietnam, it is recommended to apply nuclear polyhedrosis viruses (NPV) and Bt if the bollworm reaches economic threshold levels. Mixing of NPV with Bt is also recommended. NPVs have been produced on a commercial scale in Vietnam since 1985.

CIRAD-CA, France

Dr. Maurice Vaissayre of the Annual Crops Division of the Centre de coopération internationale en recherche agronomique pour le développement (CIRAC-CA), France presented a regional perspective of cotton bollworm resistance to pyrethroids

in West African countries. In 1984, after some initial indications from Chad, CIRAD proposed to the countries in the region to set up a network for monitoring the development of resistance. Many farmers from Benin, Burkina Faso, Côte d'Ivoire and Mali complained about the ineffectiveness of insecticides to control bollworms. Though, as usual, farmers alleged the purity of insecticides, studies undertaken by CIRAD in Benin and Côte d'Ivoire showed that bollworms have developed resistance to pyrethroids. Lab work undertaken against a susceptible population, maintained at CIRAD in Montpellier, France, further proved that the cotton bollworm has developed resistance to commonly used pyrethroids and the metabolic detoxification involving oxidases is the reason for development of resistance. Probably some esterases are also involved in the process of resistance development.

CIRAD in collaboration with national staffs in each country, and the respective cotton companies and pesticide companies represented through the Insecticides Resistance Action Committee, prepared a plan to combat the problem. The plan was implemented in the 1998/99 season. The survey concluded that resistance has developed in each country but the level of resistance varies among the populations within each country. The results also showed that the first generation is least resistant and as the generation number progressed the level of resistance increased. Based on the results achieved so far, a "prevention of resistance" regional program to start in 1999 has been proposed to the cotton companies in various countries. Important recommendations are to ban pyrethroid use at an early stage (from June to August), start first spraying only after vigilant field observations and, thereafter, follow schedule spraying where pyrethroids are mixed with organophosphates from September to November. However, the success of the program lies in the level of hybridization between the susceptible and resistant populations and the implementation of the recommendations on other crops.

Cotton Leaf Curl Disease

Though the meeting concentrated on resistance management issues, one session was devoted to the leaf curl virus disease that is affecting cotton production in India and Pakistan. In 1991/92, the average lint yield in Pakistan was 769 kg/ha, but the next year it dropped by 226 kg/ha. The disease is caused by a geminivirus transmitted by whitefly. Inoculum of the disease spread very quickly throughout the Punjab province. In the next few years, the disease showed up in the Northern Region of India particularly in the Punjab and Haryana states. Six papers by Indian and Pakistani researchers were presented on various issues related to the management of leaf curl disease. At the end of the Consultation, a meeting of the Indian and Pakistani researchers was organized by the ICAC to exchange views and share experiences in tackling the disease. Both countries have noted that cultivation of a susceptible variety has played a big role in the multiplication and spread of the inoculum. No short-term solution is available and researchers promised to remain in touch for successful control of the disease.

Recommendations

The Consultation at the end of the meeting decided the following recommendations:

Transgenics:

- There is a need to explore resistance prevention strategies for small-scale farming systems.
- Ecological implications of transgenics must be studied for other aspects of pest control.
- Efforts should be made to explore more appropriate constructs in activity range, tissue expression and species activity levels for Asian cotton pest situations.
- There is a need to explore preferential financial support for the development of transgenic national cotton laboratories.

Conventional Insecticides

- There is a need to clarify the relationship between laboratory-measured resistance and field effectiveness of chemicals (including persistence and life stage effects).
- Explore and decide appropriate models of resistance management at the field level in small-scale farming systems.
- Ascertain principles of development of effective synergists/mixtures for particular resistance mechanisms.
- There is a need to strengthen the technical and regulatory (registration, labeling and quality control) work to ensure pesticide quality for farmers, including the development of cheap, easy to use, pesticide quality test kits.
- There is a need to document the details and impacts of poor quality insecticide application practices and to develop clear recommendations on minimum effective pesticide application practices for application technologies available (if some of these technologies are wholly inadequate, we should say so).

Helicoverpa armigera

- Explore the implications of dispersal/migration for resistance management strategies.
- Examine the importance of diapause in conservation of resistance/susceptibility.
- Explore the genetic basis of resistance in particular geographic areas and to particular chemistries
- In the new chemical groups there is a need to watch cross-resistance, positioning and abuse of chemicals.
- The Consultation noted the upcoming project in the region by China (Mainland), India, Pakistan and the UK on insecticide resistance management of *H. armigera* in small

scale farming systems. The project is sponsored by the ICAC and funded by the Common Fund for Commodities.

Bemisia tabaci

- The Consultation emphasized the need to look at chemical effectiveness vs. resurgence implications.
- Explore the causes of resurgence.
- Ensure national monitoring of resistance development and the development of appropriate resistance management strategies.
- Develop (exploit) better spraying technologies.

Beneficial Insects

- Examine more closely the profile of the effect of the old and new chemistries and of Bt use on the parasite and predator complex.
- Further explore the potential for deployment of insecticide resistant beneficials, as done with mites in orchards and endosulfan resistant *Trichogramma*.

General

- Notwithstanding the above, focus on the development of programs encompassing the whole pest management/cropping system rather than individual species.
- The development of pest resistant germplasm remains a top priority.
- The range of CLCuV resistant material is expanding but so is CLCuV. Other countries should be prepared.
- An existing forum for the dissemination of material is the *Resistant Pest Management Newsletter* published from Michigan State University with the support of the Insecticide Resistance Action Committee (IRAC).

Asian Cotton Research and Development Network

The representative of the ICAC informed participants that, as part of its mandate, the Technical Information Section of the ICAC encourages continuous contact and communication among cotton researchers within regions and across regions. While this Consultation was a one-time opportunity to bring cotton researchers together and discuss an issue that is of concern to most countries in the region, the ICAC representative proposed to set up a network for continuous exchange of information in the region. Accordingly, the Asian Cotton Research and Development Network was established with the objective of promoting an exchange of information through newsletters, occasional publications, cooperative research programs and exchange visits to laboratories in the countries of the region. Participants committed to organize focused meetings of the network. Dr. Zahoor Ahmed of Pakistan was selected as the

first Chairman (see address among list of participants) of the network. Dr. Lakhwinder Singh Randhawa of India (see address below) was elected as Co-Chairman of the network. It was also decided that the next meeting of the network would be held in India in about two years. The third meeting will be held in China and then in Uzbekistan.

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Short Notes

• **Bonsai Bunchy Top—A new Disease in Australia**

During 1998/99, Australian cotton growers noted an unidentified disease that was affecting yields. The disorder was named Bonsai Bunchy Top (BBT). Leaves on affected plants remained small and became thickly clustered. The main stem node was affected first, followed by slow growth of branches. Some leaves showed mottled chlorosis or light green color around the edges with normal green color inside. Red color around the edges was also noted, but it was not common. Shorter internodal length resulted in a bunchy top. Consequently, bolls also remained small, thus affecting yields; small bolls were consistent among the disease symptoms. Though the disease was new on cotton, similar symptoms had been noted on weed plants in Australia.

Disease symptoms may appear at any stage of the plant and can vary significantly among plants. But, if the disease appears early in the season, the plant may show severe stunting with heavy losses in yield. In the first year of the disease, disease symptoms have been witnessed more commonly at later stages, with the lower part of the plant growing normal and bearing normal bolls. Total loss in yields was directly related to the stage of the crop when the disease attacked. Lint quality was also affected due to higher barky trash coming from the top dry stem.

The causal organism and how this disease could be avoided are still to be determined. However, according to Neil Forrester and Jonathan Spenser of Delta & Pineland International, Narrabri, Australia, disease symptoms are often related to early season aphid attack. The strong association of BBT to aphid attack indicates that either the disease appears as a result of residual aphid toxin, residual physical damage to vascular tissues, or it could be a viral disease where aphids serve as a vector for transmitting the causal organism. But, the latest studies have failed to confirm evidence of virus infection. Work is ongoing to gather more information on the disease.

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• **Boll Weevil Arrives in Bolivia**

The cotton boll weevil *Anthonomus grandis* is one of the most destructive cotton pests in the Americas. Over its lifetime, a boll weevil, can damage more fruiting parts on each plant than all bollworms. But, because all damaged flower buds are shed, the actual damage is usually underestimated. Over the 107 years, since the boll weevil moved from Mexico to the USA in 1892, a lot of work has been done to contain the pest. The boll weevil was first found in South America in Venezuela in 1949, and then in Colombia in

1950. The most recent victims of the boll weevil are Brazil, Paraguay and Argentina. In Brazil, the boll weevil was first found infecting cotton in 1983. In the next 2-3 years, the boll weevil moved to the border close to Paraguay. In April of 1991, it was discovered that the boll weevil had affected a significant area in Paraguay. Now, the boll weevil is found throughout the cotton growing regions of Paraguay. The boll weevil continued moving, and it was detected in traps in Argentina in 1993, close to the border with Paraguay.

Experts have warned Bolivia that the next move of the boll weevil could be towards Bolivia. The Bolivian Committee for the Prevention and Elimination of Boll Weevil, the National Association of Cotton Producers (ADEPA), the Chamber of Exporters of Santa Cruz (CADEX), and the National Association of Cotton Ginners have reported that on June 23, 1999, the Bolivian Ministry of Agriculture detected the boll weevil in an area close to the border with Brazil through a monitoring program that has been carried out for many years. The moth catches in the traps indicated the presence of boll weevils in Bolivia near the provinces bordering Brazil (Velasco-Sandoval), especially the places called San Vicente and San Matias, located 600 and 1,000 km, respectively, from the cotton production area. Similarly, the program has also detected boll weevils 100 kilometers from the border, a movement towards the cotton area.

The authorities of Santa Cruz, the largest cotton production area in Bolivia, and the Committee for the Prevention and Elimination of Boll Weevil are working together in different phases to anticipate infestation in the field. Bolivia shares the largest border with Brazil, which is infested with the boll weevil; the Argentinean border with Bolivia is also infested, as well as the whole cotton producing area in Paraguay. The boll weevil intrusion has occurred from the long anticipated route from Brazil. The pest carries a great threat to cotton production in Bolivia. If appropriate measures are not taken, the boll weevil could spread to the cotton areas quickly. Some programs similar to the ones being practiced in Argentina, which have helped to contain the pest to certain areas, are required on an emergency basis. Apparently, one of the limitations is the inexperience of Bolivian researchers to tackle this pest.

Cotton exports from Bolivia amount to US\$50-60 million annually, and cotton production and processing employ a work force of over 100,000 people for a period of 6-8 months. The Government of Bolivia and growers through the National Association of Cotton Producers are coordinating a program to prevent this pest. Other programs initiated include a legal elimination and prevention program, a study into the causes of intrusion, and a technical training program. A lack of expertise and the means to launch extensive programs may hamper the success of any efforts. If the

boll weevil extends to production areas, cotton yields will be affected, the cost of insect control will go up, and the quality of cotton will be affected.

The International Cotton Advisory Committee is sponsoring a project in the region: the "Integrated pest management of the boll weevil in Argentina, Brazil and Paraguay," funded by the Common Fund for Commodities. The aims of the project are to advance the use of biological control, exploit the diapause behavior of the weevil, find new ways to deprive the boll weevil of breeding and feeding hosts and provide area-wide strategies for multi-dimensional control. Bolivia could benefit from this project.

• Organic Cotton

Organic cotton production area in the U.S. in the last two years is shown below:

Organic Cotton Area in the USA (Ha)

States	1998/99	1999/00
Arizona	346	376
Arkansas	-	405
California	516	438
Missouri	183	263
New Mexico	209	1,437
Tennessee	-	243
Texas	2,558	3,505
Total	3,812	6,667
