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Introduction

The first article of this issue of *THE ICAC RECORDER* is about the production aspect of organic cotton. According to the information available at the time of publication, three private companies and one government agency are involved in the certification of organic cotton. In the USA, two farmer-owned associations, California Certified Organic Farmers and Organic Crop Improvement Association International, and a government agency, the Texas Department of Agriculture, have established certification procedures for the production of organic cotton. In addition, a Dutch company, Bo Weevil, is involved in the production of organic cotton, as well as knitting T-shirts from organically grown cotton. After having a successful experience in Turkey, this company plans to expand production to Paraguay and India. The USDA is expected to develop a national standard for organically grown cotton later this year.

Bemisia tabaci is a worldwide pest of cotton notorious for the transfer of diseases, the cause of stickiness in cotton, in addition to economic losses in yield. It has different biotypes, but the biotypes "A" and "B" are the most

well known. It was known that the biotype "A" had been causing damage in the US. After 1985/86, significant change occurred in the population type of *B. tabaci*. It has been observed that a new biotype "B" has replaced the biotype "A" in the last 6-7 years. How the "B" type population came to the US and why it replaced the "A" population so quickly are not very clear. The latest work shows that these two biotypes, though morphologically similar, are two distinct species. The most pronounced difference noted is reproductive isolation. The second article of this issue provides a review of the work done on the biotypes of *B. tabaci*. The common features which support classification of the "B" population as a biotype of *B. tabaci* and reproductive isolation between these two populations are discussed in this article.

The third article, "Status and Management of Insecticide Resistance of Cotton Insect Pests in China," has been contributed by Mr. Jingyuan Xia, Associate Professor at the Cotton Research Institute, Chinese Academy of Agricultural Sciences, Anyang, Henan, China. Mr Xia reports that eight species, having developed resistance to one or more conventional insecticides, have caused a big problem in controlling cotton insects. In his paper, he discusses the incidence, status, measuring and monitoring insecti-

cide resistance of cotton aphid, cotton boll worm, red spider mite, pink boll worm, cut worm, spotted boll worm, plant bugs and plant hoppers. Ecological, biological and chemical strategies of resistance management in practice in China (Mainland) are covered.

The regional cooperative network on cotton research in Latin America, instituted in 1986, is strengthening. The Fourth Meeting of the Latin American Association for Cotton Research and Development is planned for Girardot, Colombia from May 24-28, 1993. The meeting is sponsored by the Federación Nacional de Algodoneros of Colombia (Federalgodón). Dr Guillermo Alvarez Alcaraz of Federalgodón is responsible for the local arrangements. The International Cotton Advisory Committee has extended invitations to all cotton producing countries of the region to send delegates and actively participate in the meeting. for more information on the meeting, please contact the Technical Information Section of the ICAC or the coordinator of the meeting at the following address:

Dr. Guillermo Alvarez Alcaraz
Director División Técnica
Federación Nacional de Algodoneros

Carrera 8a No. 15-73, A.A. 8632

Bogotá, Colombia

Phone: 57-1-3344221 Fax: 57-1-2833162 Telex: 044-864

A revised brochure with more details on the World Cotton Research Conference-1 to be held in Australia from February 13-17, 1994, has already been mailed to you. Registration forms, along with the registration fee, are now being received by Ms. Sally Brown, Conference Registrar in Australia. The last date for the submission of summaries of papers to be presented at the conference is September 30, 1993. In case you have not received the revised brochure or you are interested in more information, please contact the Technical Information Section of the ICAC.

Please note that as of March 1, 1993, the office of the ICAC Secretariat has moved to the following address:

1629 K Street, NW, Suite 702

Washington, DC 20006 USA

Telephone, telex and fax numbers remain the same.

Organic Cotton Production

In conventional production, all producers in the developed countries and in the majority of the developing countries heavily rely on chemical control of weeds, insects, diseases, in addition to the abundant use of fertilizers and defoliants. The use of chemicals has increased so much that they have not only posed a threat of environmental pollution, but also rendered cotton production a very expensive business. The cost of production is rising to the extent that cotton is losing its profitability. The residual effects of extensive use of chemicals are also being realized. The increased cost of production and environmental concerns have compelled researchers to look for agroecological approaches. The combination of cultural practices with environmentally safe control methods make it possible to grow cotton without the use of chemicals.

Cotton grown without such environmentally dangerous chemicals is called clean, natural, green or organic cotton. Sometimes the classification does not specify the length of time which the cotton was free of chemical use. In other words, green clean or natural cotton may be a cotton grown without

conventional practices, but is not certified by a recognized authority as an organic cotton. Such cotton may or may not bring a premium price to the producer.

Farmers intending to produce organic cotton and desirous to have their cotton certified as organic cotton must enroll with one of the certifying organizations accepted by their state or country. The producers entering into an agreement with the certifying organization to produce organic cotton must terminate the use of synthetic fertilizers and pesticides and all other materials prohibited by the registering organization. A period of three years from the last application of prohibited inputs will make them eligible to obtain organic certification status. A producer which meets all applicable standards under the agreement of organic production for the first and second annual cropping seasons will be certified as "Transitional - Organic Certification Pending." The produce of the third year where prohibited chemicals were not used will be certified as organic cotton.

In the USA, the following three organizations certify organic cotton:

- **California Certified Organic Farmers** was established in 1973. It has a membership of 635 growers, but only two of them are certified organic cotton producers, Cal-Organic and Miss Sally Fox of Natural Cotton Colors. More farmers are expected to join in the coming season.
- **Organic Crop Improvement Association**, based in Ohio, is an internationally recognized farmer-owned and operated certification program. The membership of over 2500 growers comes from Argentina, Bolivia, Canada, Germany, Holland, Japan, Mexico, Peru and the United States. It covers all crops, including cotton.
- **The Texas Department of Agriculture** started its Organic Certification Program for cotton in 1989 in response to a request about the production of organic cotton for baby diapers by a US company. An active program started in 1990, and a pilot project was launched in 1991 producing 600 bales from over 200 ha. The area for 1992 included 600 ha of transitional and 200 ha of organic cotton. The projected area for 1993/94 is 3200 ha of transitional cotton and 1600 ha of organic cotton. The Texas Department of Agriculture's certification program has been recognized as one of the

most important programs developed to enhance environmentally safe production practices.

Outside the US, a private company, **Bo Weevil** of Holland, is actively involved in the production of organic cotton and sustainable textile production. It works together with the Good Food Foundation, a cooperative of five European companies active in the development of organic food production. Bo Weevil initiated its first project on cotton in 1989 on an experimental basis in Turkey. In the meantime it expanded to 150 ha. In 1992/93, they set up a project in Paraguay. This year they are going to realize another project in the state of Gujarat in India. It is expected that a total area of 1500 ha will be involved in these projects.

Who Can Grow Organic Cotton?

The growing of organic cotton is risky. A farmer who grows cotton traditionally probably cannot switch easily to growing organic cotton in just one year. It will take at least three years before he is able to receive the price premium for organic cultivation. It is understood that farmers will learn quickly how to maintain a desirable level of soil fertility and to deal with vari-

ous pests. The initial financial loss cannot be waived, but can be minimized. The farmers have to study the ecosystem of the area where they are going to farm. They have to learn a whole new system of farming where soil management takes a high priority. It is also possible that some areas may not be economically suitable for organic production.

Yield Loss

The absence of synthetic fertilizers, herbicides, insecticides and maybe growth regulators under specific conditions will certainly result in loss of yield. How much of a loss will greatly vary depending on the level of soil fertility, weed population and prevalence of insects and diseases. If the soil is rich in organic matter, it does not need nutrients other than nitrogen for conventional cultivation and if the precious crop was a leguminous crop, the yield loss may be at a minimum. There is no doubt that the reduction in yield will be the highest for the first year and will decrease in the following years. The reduction in yield on account of diseases and pest infestation will wholly depend on the severity of the pest occurrence. It will also be affected depending on the availability of non-conventional methods of control permitted by the certifying organizations. The yields may dip to one fourth of

those using conventional practices, but will rise steadily. It is difficult to say if they can attain the normal yield level of conventional practices.

Varieties

Organized organic cotton production is only 3-4 years old and reliable data are not available to make a final decision on many issues. Presently it is advocated that the selection of cotton varieties for organic production is not different from conventional production and producers can select varieties which perform the best in their region. Response to soil type and irrigation conditions will not change, but undoubtedly their reaction to the absence of chemicals will make a big difference. The principal priorities like high yield, earliness and lint quality will not change, but organic production practices are going to affect them significantly.

Breeders have been inadvertently developing varieties which have a high response to synthetic fertilizers. Such varieties are going to behave differently under unfertilized conditions. Fertility stress in the form of low nitrogen supply will affect the vigor of the plant and thus, the fiber characters as well. Deficiency of other nutrients is also going to have an impact on yield

and quality of the lint. It seems that the breeding objectives will have to be reconsidered according to specific situations. Varieties which are hardy and capable of giving higher yields in less fertile soils will have to be bred. Natural plant tolerance in the form of genetic or morphological characters could prove to be a very desirable feature of varieties for organic farming. Yield evaluation trials of the breeding material and assessments of fiber characteristics have to be conducted under organic conditions, i.e., without inorganic fertilizers, herbicides, insecticides or growth regulators.

Site Selection

Site selection is the most critical factor in organic cotton production. Selecting land with depleted fertility and a perennial weed problem will limit the production capabilities. Such land should not be considered for organic farming. Since organic farming is not farming by neglect, the fertility level of less fertile soils should be improved through organic means before opting for an organic cultivation program. A period of three years from the last application of inputs of synthetic fertilizers and pesticides or other materials prohibited by the registering authority is required to obtain organic certification status. In the meantime, soil reaction can be ascertained and im-

proved. Potential drift from run off or spraying from the adjacent fields has also to be avoided.

Weed Control

Herbicide use for the control of weeds is prohibited in organic cotton production. In the advanced countries, the producers shifted from hand weeding to mechanical weeding in the 1940s and then to herbicide application in the 1960s. Now weeds are killed by chemical application either at pre-emergence stage when they are still in the soil or just after germination before they cause any damage or become capable of producing seed for multiplication. In countries like the US where herbicide application is as old as 35 to 40 years, significant ecological shift has been recorded. In the absence of competing weeds, weeds like prickly sida, nutshade, silverleaf nightshade and perennial vines, which were previously non-existent, emerged as major weeds. Such ecological shifts demanded the attention of researchers to study and describe new weeds. They also had to predict the new weeds which would grow as a result of the continuous use of herbicides.

It may not be wrong to anticipate a different ecological shift when the use of chemicals is stopped. The original weed pattern may return or some minor weeds might become major weeds. In any case, they have to be controlled by hand or by mechanical means. In this regard, precise cultivation closer to the plant will be very desirable. Even then, hand crews will probably be required to make more than one sweep. The cost of this operation will increase instead of decrease as in the case of fertilizer and insecticide use. A good program of pre-irrigation and timely cultivation can keep hand labor costs at a minimum. Suitable crop rotations can play a very important role in minimizing the weed problem. Otherwise, the certification rules do not permit the use of spot spraying, contact herbicides or any other method of herbicide use. Once the weed control system is established, cotton can probably hold its own against weeds.

Soil Fertility

In order to realize an economical harvest, fertility of the soil has to be maintained. It can be maintained primarily through applications of compost and decomposed livestock manure from sources like cattle-feeding operations, animal husbandry or production facilities including horses, poultry and

dairy manures. Suitable crop rotations will have to be found which cause the least depleting effect on the soil. The cropping intensity might be also affected. Legume cover crops (grown without inorganic fertilizers) may be necessary to increase organic matter and soil nitrification. In this regard, inoculation may be necessary to achieve maximum nitrogen fixation. fertilizers such as granular fish emulsion, humate or other blended organic fertilizers have to be added to the seed row and used for starter fertilization. Supplemental nutritional needs are supplied through foliar applications of seaweed, fish emulsion, humate, cytokinin or other approved organic fertilizers. Micronutrients have to be supplied through organic formulations so that the fiber quality is not affected. Biological enhancers are also permitted to be used for improving nutrient availability and their uptake. Green manuring can improve the fertility status of the soil in addition to its texture. Application of organic fertilizers will have the following advantages:

- Artificial fertilizers give rise to vigorous growth thus attracting insect pests. It is anticipated that the use of organic fertilizers on suitable hard varieties will result in lower pest infestation.

- Abrupt availability of nitrogen from synthetic fertilizers causes rapid cell elongation, but weakens the cell structure causing more stress and less tolerance to penetration by pests. Thus, cotton grown using organic fertilizers will be less vulnerable to sucking insects.

Pest Management

Pest types and pressure vary in various countries and regions, but it is estimated that on a world scale, about 20% of all agricultural chemicals are used on cotton alone. Pesticides are a major part of these chemicals.

Yields are going to be much lower in the absence of insecticides. Alternate methods of insect and disease control must be adopted to realize an economical yield level. Some methods permitted under the certification systems are the following.

- Sprays with local botanicals
- Use of sex pheromones/confusion techniques
- Use of *Bacillus thuringiensis* and baculoviruses
- Enhanced use of biological control through the release of predators and parasites

- Use of novel insecticides like soaps and oils which are permitted under certification rules

The transitional period may be difficult due to higher pest pressure, lack of experience with new methods of cultivation and disappointingly low yields. Volunteer predators will multiply in a couple of years and help to reduce the insect pest pressure. While the role of built-in genetic mechanisms of the plant cannot be ignored, new practices which can be regulated under specific conditions have to be further explored. Higher plant resistance at the cost of lower yields may also be acceptable. For the control of diseases, the Multi Adversity Resistance program may help.

Harvesting Aides

Defoliation of cotton is not important in countries where cotton is hand-picked, but it is one of the most important aspects of harvesting where cotton is machine-picked. In certain areas, defoliation consumes a significant portion of pesticide use. Defoliants serve three purposes: (1) they make mechanical picking easier by eliminating the green leaves which might jam the picker; (2) hibernation of late season insects in green leaves can be reduced if green leaves are eliminated from the open cotton; (3) they reduce

the moisture content of the seed cotton by easing evapo-transpiration in the canopy.

Alternate methods of defoliation have to be found. In California, several naturally occurring materials have been tried for defoliation, with little success. Other possibilities explored also included a machine that defoliated cotton with heat from propane gas. Defoliation was comparable, but, due to higher cost, the machine was abandoned.

The best way to prepare the crop for harvesting would be to manage nutrients and irrigation so that the plant cuts out in time for leaves to dry up and fall off before picking.

Excellent cotton defoliation can be obtained from a frost occurring at a time when the crop has terminated, but still has green leaves. Producers in areas with seasonal frosts thus have a natural advantage. Also, some varieties shed leaves at a faster rate than others. This characteristic could be further investigated and utilized.

In the absence of any other suitable defoliation method, attempts are being made to try approved materials such as magnesium chloride, sea salt,

weed oils or other natural chemicals. Spindle picking of green cotton (undefoliated) is also being tried in the US.

Certification

All cotton certified as organic or transitional must be inspected during growing by designated personnel from the certifying organizations. A list of the authorized methods and materials is published by each certifying organization and made available to the producers registered with them. Buffer zones are designed and inspected for cleanliness, especially if the harvest is being conducted by a contract harvester or someone other than the producer.

Each gin which handles organic or transitional cotton must be certified as an organic processor prior to ginning any certified cotton. A complete record of the cotton is maintained for tracing each bale of organic or transitional cotton at the gin. If any byproduct of ginning, such as motes, seed or gin trash and burs, is to be sold as certified organic or transitional, it must also meet the same inspection and physical segregation standards as the cotton lint.

Standards for post-harvest handling from the gin to the consumer are not available yet, but are being developed by the Texas Department of Agriculture. Regulations for production methods have been established by each certifying organization. Production, processing and all following operations are monitored in the light of established principles.

Certification of production and processing of organic cotton is handled mainly by private organizations, with the exception of the Texas Department of Agriculture which is a state program. Arizona is just entering the certification program. It is reported that the USDA is expected to develop a national standard for organically grown cotton later this year.

Textile Manufacturing

The Texas Department of Agriculture is also developing certification standards for the production of organically produced fibers into textile materials. Because finishing and dyeing are mostly chemical processes, they will require the most attention if apparel manufacturers want to label finished products as organic. Currently, organic cotton is knitted into T-shirts, sweaters, interlocks, shorts, denims, infant wear, pajama fabrics, cotton sheets, tow-

els and kitchen linens. The international interest in organic cotton is growing, encouraging producers in the form of higher prices to produce more and more cotton grown without the use of chemicals.

It is difficult to assess the long term trend. It seems organic cotton in the long run will capture a small but viable segment of the market. The size of the organic cotton market will depend on the price of the organic cotton in comparison with its cost and yields level. The premium price of US\$1.75 to \$1.95 fetched by California producers and US\$1.0 to \$1.35 by the Texas producers is certainly due to scarce supply and relatively higher demand. Probably such a margin will not be sustained.

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Current Views About Biotypes of *Bemisia tabaci*

The sweetpotato whitefly, *Bemisia tabaci* (Gennadius) is a worldwide pest of cotton throughout the tropical and subtropical cotton producing countries. It has a wide range of recognized hosts comprising more than 500 plant species. Whitefly causes three types of losses to the cotton crop: direct yield loss, economic losses caused by sweetpotato whitefly-vectoring diseases and quality deterioration. The direct loss in yield occurs on account of reduced photosynthetic activities in whitefly-affected leaves. Cotton leaf curl, cotton leaf crumple and African cotton mosaic are important viral diseases transmitted by whiteflies. These diseases are also reported to be transmitted by other vectors like aphids and leafhoppers, but whitefly is the dominant source of transmission of these diseases (Hillocks, 1992). The losses in Sudan caused by leaf curl virus, transmitted by whitefly, are notable. The widespread occurrence of cotton leaf curl in Pakistan and its effects on cotton yields during 1992/93 are repeating the history of Sudan. The very existence of whitefly as a pest in any country poses a potential threat to transmit viruses and to cause any of the above diseases if the in-

oculum already exists. Losses in quality due to honeydew and sooty mold caused by the whitefly adults are most widely known. The survey undertaken by the International Textile Manufacturers Federation biennially shows that the occurrence of sticky cotton is on the increase. According to the 1991 survey, roughly 27% of the cotton produced in the world carries some level of stickiness, mainly caused by whitefly.

At least 18 species of *B. tabaci* are known worldwide. Early reports from tropical regions have described host related references among local populations which were termed "races" or "biotypes" of *B. tabaci*. The observations showed that continuous exposure of *B. tabaci* with strong host preference to a new plant species resulted in the ability to colonize additional hosts. The term "race" or "biotype" was used to refer to the population with recognized specific host preferences. For example, *B. tabaci* did not colonize cassava, *Manihot esculenta*, in the US, whereas cassava served as a host plant for populations found in Africa. The data were considered inferential due to the lack of supporting information based on morphological or genetic differences. The increase of whitefly as a major pest in the last 10-12 years and its devastating effects in many cotton producing countries

have prompted a thorough investigation into its biology, behavior and host related preferences.

The term "biotype" is used to denote morphological, ecological or behavioral differences within species of insect populations. In the context of agricultural crops, biotypes refer to insects with similar genotypes for biological attributes, which are encountered primarily in association with resistant crop cultivars. Biotypes represent populations in the process of speciation, which develop through natural selection in connection with genetic diversities in insect and host plant population. Cultivation of genetically diverse varieties may reduce the rate at which the biotypes are developed.

In the US during 1991/92, Arizona, California, Florida and Texas suffered heavy direct losses in cotton and vegetable production. The continued danger of yield losses and fear of transporting viruses have become pertinent concerns for all in the US for the first time. In 1992, experts from federal, state and private sectors formulated a joint "National Research and Action Plan for Development of Management and Control Methodology for Sweetpotato Whitefly" to carry out detailed studies on whitefly. An important part of this plan is to understand the population dynamics of a new biotype ("B")

relative to the old biotype ("A"). the systematic studies of taxonomy of whitefly have been a problem due to the extreme plasticity of the morphological characters to change in order to adjust to the changing morphological features of host plants.

Non-specific Esterase

When it is not possible to distinguish two biotypes or species having similar morphological characters on the basis of host preference, non-specific esterases are used as markers to differentiate insect species and biotypes. Brown (1992) analyzed the adult *B. tabaci* for non-specific esterase by a Modified Laemmli Buffer System. She identified the "A" and "B" biotypes in the US, Mexico and Caribbean Basin, while samples from Central American sites in Costa Rica and Nicaragua had a distinctly different pattern. The Costa Rica and Nicaragua phenotypes on the basis of their non-specific esterase patterns were termed as "C" and "D" biotypes respectively.

The survey undertaken from 1988 through 1991 in the states of Arizona, California, Florida, Tennessee and Texas indicated predominantly B esterase population of *B. tabaci* regardless of the host species samples.

The data from 1991 showed that the indigenous population or "A" biotype was generally associated with rural areas while the 1988 population was a mix of both. Data before 1988 are not available, but in a few years, nearly all *B. tabaci* tested in the US have changed to B type non-specific esterase pattern. The data revealed that there has been a continuous shift from the "A" to "B" biotype. the "B" biotype was found nearly exclusively in Dominican Republic, Grenada, Guadelupe, Puerto Rico and some other regions proximal to the US where the same biotype has been recorded. In contrast, the *B. tabaci* samples from northwest Mexico, Costa Rica and Nicaragua were characterized by A, C and D esterase pattern types respectively.

Higher occurrence and/or replacement of the "A" with "B" biotype showed that either genetic drift has occurred in the indigenous local population or an exotic "B" biotype had been introduced to the US around 1985/86. In any event, origin of "B" biotype in the US has not yet been ascertained.

Host Habituation

Most of the species of *B. tabaci* have a wide host range with no specificity to any plant species, but there are species known which have a narrow

host range and, in certain cases, they are specialized to one or a few host plants. Host preference is also determined by the ability of the female to lay eggs on any specific crop plant, particularly in the case of "B" biotype. Indeed the females of the "A" biotype do not appear to discriminate between host quality of the plant species upon which they deposit eggs. The "A" type population is shown to lay eggs on several hosts, including lettuce, which are not conducive to the life cycle. According to Brown (1992), perhaps the potentially great number of eggs produced by *B. tabaci* females (100-300/lifetime) precludes the need for discrimination of hosts.

In host habituation experiments, Brown (1992) noted preference differences in both biotypes. The order of preference from highest to the lowest based on the survival rate and reproduction is as follows:

"A" biotype: Squash>muskmelon=cotton=pumpkin>watermelon>lettuce=
tomato>broccoli>lettuce>poinsettia

"B" biotype: Cucumber>muskmelon>broccoli>cotton>okra=poinsettia>
watermelon>cauliflower>tomato=lettuce=cassava

Virus Transmission

Both biotypes, i.e. "A" and "B," are successful virus vectors of geminiviruses of tomato. However, they differ in their efficiency to transmit viruses. Successful transmission and efficiency is positively correlated with the population of the adults transmitting the virus. The "B" type population has been found to be more efficient with rates of transmission for 10 adults of 56% and 83% for the "A" and "B" populations respectively. Why the biotypes differ in their ability to transmit viruses is not clearly understood. The "A" type population does not appear to prefer tomato for feeding while the "B" type can and does use tomato for feeding and laying of eggs when other preferred sources of host species are not available. This partially explains the higher efficiency of the "B" type population; otherwise, any strong evidence of higher efficiency is not available. In fact, the factors which govern the ability of the *B. tabaci* to serve as a vector of viruses need to be investigated.

Characteristics of "A" and "B" Biotypes

There are three important means of differentiating "races" or "biotypes" which are commonly used by researchers for identification purposes. These are: (1) ability of the population to colonize different host plants; (2) laboratory analysis of non-specific esterase and (3) genome analysis. These, along with differences in behavior, are given below.

Some Characteristics of the Two Biotypes of *Bemisia tabaci*

Character	"A" Biotype	"B" Biotype
Partial host range	Beans, cotton, cucurbits, melons, squash, watermelon	Broccoli, cauliflower, grape, citrus, cotton, cucurbits, melons, papaya, pepper, poinsettia, rappini, lantana, rose squash, tomato, ornamentals, watermelon
Fecundity	100+ eggs/female	200+ eggs/female
Virus vector	+	+
Non-specific esterase marker	A-type	B-type
ds/ss RNA	-	+
Direct feeding damage	+/-	+
Honeydew associated problems	+/-	+++
Phytotoxic disorders	-	+

Effect of Temperatures on Population Development

Wagner (1993) studied the effects of temperature on development times of the "B" biotype which can be used to determine life-stage development of populations as a function of variable temperatures. The whitefly population moved to the cotton grown in the adjacent greenhouse after the termination of the field crop. The cotton seedlings of true leaf stage were placed under the young plants in the greenhouse. As the greenhouse plants were disturbed, the whitefly adults moved to the cotyledonary and the first true leaves of the small seedlings. The tender leaves were exposed to the whiteflies for oviposition for 2-3 hours between 12:00 and 16:00 hours. As the plants aged, the cotyledonary and first true leaves were removed for laboratory studies. While the eggs were counted on the underside of the leaves, the plants were placed in growth cabinets at different constant temperatures ranging from 10°C to 40°C. The experiment was conducted during the months of February and March and June and July and was also repeated on a Pima variety.

Egg laying. The median duration of the egg stage varied from 22.7 days at 15.4°C to 4.6 days at 32.3°C. There was a slight shift in the development rates of eggs over all temperatures, induced by season. While there were no varietal differences, the development rate of eggs reduced in the months of June and July over February and March. The effect is more pronounced at high temperatures, thus indicating reduced adaptation of eggs to high temperatures at the hottest time of the year. Comparisons among biotypes indicated that they vary considerably in the incubation period, especially in the mid-temperature range where the biotype "B" hatches up to 40% earlier than its counterparts. Egg development was similar at low temperatures and around the optimum. The varietal differences were not pronounced.

Nymph development. The development times of nymphs greatly varied with the temperature variations. The plants in the cabinets at higher temperatures took much less time for the development of nymphs. Median development times of nymphs ranged from 36.3 days at 17.7°C to 10.7 days at 27.6°C. Variety, whether upland or Pima, did not affect the development of nymphs. Wagner (1993) noted that the nymphs from Mississippi require less time to develop than those from Sudan at all temperatures, with

greater differences occurring between 20-25°C. Between 20-27.5°C the biotype "B" requires as much as 28% less time to develop than the Arizona "A" biotype. In general, the *B. tabaci* nymphs were able to complete development at temperatures well above the optimum though at a reduced rate.

Combined immature stages development. At 17.6°C, *B. Tabaci* takes over 7 weeks to complete its development stages and emerge, but only 16.2 days at 27.6°C. Cotton variety and season, i.e. February and March and June and July, have apparently no effect on the period taken to complete emergence. Since the nymphs take 70% of the total development time, combined immature stages of the development period showed almost the same trend as in the case of nymphs. On the average it took 16.5 days to complete development at an optimum temperature of 28.1°C. Below the temperature of 20°C, the development times of the biotype "B" are similar to "A." The "B" population requires less time relative to the "A" population to complete development stages and emerge at temperatures between 20-29°C (e.g. 18% less at 25°C), while it takes longer above 29°C.

Biotype or a New Species

Researchers agree that there is almost a complete shift in the population from the "A" to the "B" biotype in the US, but the issue whether the new population is really a biotype or a new species is still controversial. The host preference of the "A" and the "B" biotypes is accepted by many researchers. How host preference has favored the shift of population was studied by Li et al (1992) with an equal number of males and females of both biotypes enclosed in large muslin-covered cages. Esterase isozyme analysis made on the caged mixed population showed that the parent survivors and subsequent generation adults on most hosts were a mixture of the "A" and "B" biotypes. However, as there was a significant number of hybrids or segregates, it is possible that a breakdown of apparent reproductive barriers occurred during prolonged mixing of the two populations. It was also observed that the whitefly population maintained on sweetpotato and bean quickly shifted to the "A" biotype, whereas the population maintained on broccoli and melon shifted to the "B" biotype. Such a host preference is also confirmed by Brown (1992), leading to the conclusion that un-

der the laboratory and field conditions these two populations do not remain distinct and thus cannot be regarded as different species.

Byrne (1992) examined the carbohydrate and amino acid differences in the phloem sap of cotton and poinsettia and honeydew produced by both the biotypes. He did not note any differences in the way the two strains processed these compounds. However, he was able to find a carbohydrate, trehalulose, which was not associated with the indigenous population of the "A" biotype. The genetic DNA structure differences were very prominent. Although more work is going on at Clemson University and the University of Arizona to identify differences in the honeydew production of both populations, in addition to the esterase patterns, egg production, pathogen transmission characteristics and host range, the present knowledge is considered sufficient to suggest that the two populations cannot be considered under the same specific designation.

however, work done by Perring et al (1993) has observed that the "A" and "B" biotypes do not mix with each other. According to one of the definitions of species, "natural populations that are reproductively isolated from one another and that follow distinct independent evolutionary paths," they re-

garded them as two distinct species. The experiment was conducted on crossing and mating behavior to study the reproductive isolation aspect. They also studied genetic distance analysis based on isozyme and polymerase chain reaction-based differentiation to elucidate the evolutionary path followed by both populations. The unmated adults of colony A₁ and colony A₂ of biotype "A" and biotype "B" were removed from the leaves and, after determining their sex, placed as single pairs of all possible combinations in leaf cages. Male and female populations were noted in the crosses within A₁, A₂, so called "B" biotype and between A₁ and A₂, but they did not note any female population in the crosses involving the colonies of "A" biotype and "B" biotype (A x B biotype). The male population in these crosses, they claim, might come out parthenogenetically from unfertilized eggs, thus claiming that no cross mating has occurred between the two populations. Mating behavior studies using video recording did not show any copulation between the two biotypes. They noted the differences in two enzymes, phosphoglucomutase and phosphoglucose, isomers which were very useful to differentiate the two biotypes. They believe that the two populations of whiteflies, which due to morphological similarities have preciously been classified as biotypes of a single species, are in fact

distinct species. They proposed that the whitefly previously called biotype "B" now be named "Silverleaf whitefly" because it has shown to be correlated with a disorder in squash known as silverleaf disease.

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Status and Management of Insecticide Resistance of Cotton Insect Pests in China (Mainland)

**Jingyuan Xia, Associate Professor, Plant Protection Dept.,
Cotton Research Institute, Chinese Academy of Agric. Sci.,
Anyang, Henan 455112, P.R. China**

Abstract

China is the largest cotton-producing nation in the world with a total annual production of 4.4 million metric tons and unit lint yield of 800 kg/hectare. Insect pests constitute a major limiting factor to cotton production with the estimated annual loss over 15%. Insecticide resistance has become the most difficult problem in controlling cotton insect pests with eight species reported to have developed resistance to one or more conventional insecticides. In this paper, incidence, status, measuring and monitoring of insecticide resistance of cotton insect pests are reviewed. Based on analyses of causes and mechanisms of resistance, three strategies (ecological, biological,

cal and chemical) of resistance management are discussed with their effects demonstrated. Further development of insecticide resistance management systems is suggested.

Key Words: Cotton, insect pests, insecticide resistance management

Introduction

Cotton, the most important cash crop in China, has been playing a significant role in its economy. About 5.5 million hectares of cotton are grown annually with a total production of 4.4 million metric tons. Insect pests constitute a major limiting factor to cotton production with an estimated annual loss of over 15% of the potential yield. Insect pests control has been an essential part of cotton production systems [2,25].

Insecticide resistance has become the most troublesome problem in controlling cotton insect pests in China, posing a great threat to stable development of its cotton production. Eight species of cotton insect pests were reported to have developed resistance to one or more conventional insecticides: cotton aphid (*Aphis gossypii*), cotton bollworm (*Heliothis armigera*),

red spider mites (*Tetranychus* spp.), pink bollworm (*Pectinophora gossypiella*), cutworms (*Agrotis* spp.), spotted bollworms (*Earias* spp.). Of these species, insecticide resistance of the first two are the most serious, particularly to pyrethroids [27].

Incidence and Status of Resistance

Cotton aphid, distributed throughout China, is a very destructive cotton insect pest at the seedling stage, particularly in the North [2, 25]. In the 1950s, parathion and demeton were applied for its control. Resistance to both of them, monitored in Faomi county of Shandong province, increased to 23-148 fold in 1963 [4] and 800-1400 fold in 1977 [16]. Starting from the 1960s, dichlorvos, phosphamidon and parathion-methyl were used for its control. High resistance to all of them was detected in the mid-late 70s [16, 21].

In the early 1980s, pyrethroids were employed to control the aphid in the North. In only 2-3 years, resistance rapidly developed and expanded throughout the region. In the mid-80s, pyrethroids failed to control the insect because of high resistance and them had to be temporarily banned in

production [12]. Detection in 1982-1985 showed that resistance to deltamethrin, fenvalerate and cyhalothrin rose to 160.7-268.4 fold in the North, and that resistance to deltamethrin increased to 11.2 fold in the South [19]. Monitoring in the North during 1986-1990 revealed that the aphid developed extremely high resistance (over 160 fold) to deltamethrin, fenvalerate, cyhalothrin, cyfluthrin, dimethoate, omethoate and parathion-methyl; high resistance (40-160 fold) to malathion resistance (10-40 fold) to carbaryl and carbofuran; and lower resistance (5-10) to fenthion [9, 12, 19, 27].

Cotton bollworm, distributed widely in the country, is a principal insect pest at the squaring-boll stage of cotton, especially in the North [2,25]. Before 1982, the insect was controlled by using DDT and carbaryl. Resistance to DDT increased to 116-136 fold in Henan and Hebei provinces in 1975 [23], and rose to 12 fold in Jiangsu province in 1982 [31].

Since 1983, pyrethroids were extensively applied for bollworm control in the North. Resistance to deltamethrin and fenvalerate in the region reached 16..3-36.4 fold in 1985 [8]. During 1986-1990, the bollworm developed high resistance to fenvalerate; moderate resistance to monocroto-

phos [7, 11, 13, 15, 18, 22]. In 1990, the 1st field failure associated with pyrethroid-resistance occurred in the 3rd and 4th generations in Shandong, Hebei and Henan provinces [27]. Serious outbreak attributed greatly to pyrethroid-resistance prevailed throughout the North in 1992 with estimated production loss by 20-40% [28].

Red spider mites, found infesting cotton plants throughout the nation, are the most important pests at the seedling stage, particularly in the South [2, 25]. In the 1950s, the mites were controlled by using demeton, parathion, methidathion and phosemet. In the early 1960s, resistance to those four insecticides in Hubei and Zhejiang provinces increased to 62, 16-26 and 7 fold respectively [23,30]. In 1983, resistance to demeton rose to 467 fold; and that to phosphamidon and malathion went up to 42 and 16, respectively [17, 23]. During 1986-1990, the mites developed low resistance to dicofol both in the North and South [27].

Pink bollworm, a nationwide cotton insect pest except in Xinjiang Autonomous region, is most injurious at the squaring-boll stage, especially in the South [2, 25]. During the 1960s-70s, the insect was controlled by applying DDT. High resistance to the insecticide was detected in Zhejiang province,

resistance to fenvalerate increased to 20 fold in 1985 and 37 fold in 1986. During 1986-1990, the bollworm developed lower-moderate resistance to fenvalerate and cypermethrin in Zhejiang. Jiangsu and Anhui provinces [24, 26, 29].

Cutworms are important underground pests early in the cotton season all over China [2, 25]. During the 1960s-70s, they were controlled by applying BHC, DDT and trichlorphon. Compared with that in 1965, resistance to DDT and trichlorphon in 1986 increased to 6.5 and 6.3 fold, respectively [6]. In the early 1980s, pyrethroids were employed for their control in the North. Resistance to fenvalerate in Henan province rose to 5.9 fold in 1990 [27].

Measuring and Monitoring of Resistance

Measuring resistance. Resistance measuring plays a vital role in detecting insecticide resistance and in evaluating changes in resistance frequencies of field populations. Several methods for measuring insecticide resistance have been adopted and established for cotton aphid, cotton bollworm, red spider mites, pink bollworm, cutworms and plant bugs, such as topical ap-

plication applied for bollworms and cutworms [1, 14, 31], droplet application via micro-capillary tube used for cotton aphid [8,19], and leaf residue employed for red spider mites [17].

Monitoring resistance. Resistance monitoring is an important component of cotton pest management programs. A nationwide network for monitoring insecticide resistance of cotton insect pests has been organized under supervision of the Ministry of Agriculture, consisting of over 20 detecting locations. With application of standardized methods, toxicological baselines of 19 insecticides have been established for cotton aphid, 13 for cotton bollworm, 11 for cutworms and 8 for red spider mites [27].

Causes and Mechanisms of Resistance

Causes of resistance. Development of insecticide resistance is a complex process involving interactions of genetic, biological and management factors.

Genetic factors. Resistance of cotton aphid to organophosphates (OPs) was closely related to the ACHE-R (altered acetylcholinesterase) gene

[16]. Cotton bollworm resistance to pyrethroids was significantly correlated with the *kdr* (knockdown resistance) gene [13].

Biological factors. Studies showed that development of resistance is faster in the insect with more generations annually owing to high frequencies of insecticide selection. Thus, cotton aphid with over 30 generations annually in the North obtained a high level of resistance in the 12th generation when treated with pyrethroids 4 consecutive times [12, 24].

Management factors. High resistance was acquired by cotton aphid through continuous application of pyrethroids within a single crop season because of high selection pressure. Field failure occurred when pyrethroids were applied to control DDT-resistant cotton bollworm because of cross-resistance [12, 23].

Mechanisms of resistance. Much research has been conducted on mechanisms of cotton insect pests resistant to organochlorines, OPs, carbamates and pyrethroids, with three principal mechanisms revealed.

Reduced cuticular penetration. Penetration to demeton was significantly delayed in the insecticide-resistant cotton aphid [16]. Uptake of DDT in the

resistant pink bollworm was only one-third as much as in the susceptible, but that of DDE in the resistant was three fold as much as in the susceptible [21]. Resistance of cutworms to Sunioa-I was closely associated with decreased uptake which was in turn ascribed to changes in ultra-structure of the cuticle [3].

Increased metabolic activity. Resistance of cotton aphid to OPs was mostly due to increased metabolic activity of different detoxifying enzymes, such as mixed-function oxidase (MFO, carboxylesterase, and anaphthyl acetate, and that to pyrethroids was greatly attributed to detoxification by MFO, carboxylesterase and glutathione-s-transferases [16, 20, 27]. Cotton bollworm resistance to pyrethroids was closely associated with increased activity of MFO [13].

Nerve insensitivity. Compared with the susceptible, resistant cotton aphid showed considerably more nerve insensitivity to OPs and pyrethroids [12, 16].

Strategies of Resistance Management

Integrated pest management (IPM) has been proven to be the most effective approach for insecticide resistance management (IRM) of cotton insect pests as it offers cotton growers more opportunities to reduce insecticide applications. Reduced insecticide use not only minimizes resistance selection pressure on insect pests and prolongs effective life of insecticides; but also preserves natural enemies and other nontarget species, and reduces environmental contamination and exposure of cotton growers to potentially toxic materials [27].

Ecological strategy. Ecological strategy refers mainly to modification of insect habitats/niches through cultural practices as to make them favorable for host plants and natural enemies, but not for insect pests. Altering cropping systems, planting early maturing cultivars and managing crop residues are commonly-practiced methods. Thus, cotton aphid abundance early in the season in the North is significantly reduced through cotton/wheat skipped or intercropped, and that of red spider mites in the South is effectively decreased via cotton/rice rotation. Growing early maturing Zhongmian 16 in the North and E-main 545 in the South satisfactorily

avoided problems resulting from cotton aphid and pink bollworm, respectively. Survival of over-wintering pupae of bollworms is minimized through ploughing and irrigating cotton fields during winter [2, 25, 26].

Biological Strategy. The essential role of biological strategy is to increase biological-regulating mechanisms through utilizing host plant resistance, natural enemies and biological agents as to decrease insecticide applications.

Exploitation of host plant resistance. Recently-released cultivars/lines resistant to cotton aphid and/or cotton bollworm are Zhongmian 237-2 with hairy leaves, glandless and non-hairy Jimian u82-3 and Jimian 83-1 [10] with antibiosis; and that resistant to red spider mites in Chuanmian 98 with high tannin content [5]. Injury from bollworms is largely reduced via regulating plant growth by artificial or chemical removal of early squares, or systematic application of Pix [2,25].

Preservation of natural enemies. Methods for augmenting natural enemies to control early season cotton aphid involve plating a small portion of rape in wheat and cotton fields; and those for cotton bollworm control at early-

mid season include growing certain amounts of corn, sorghum or mango bean in cotton fields. Measures for protecting natural enemies to control cotton insect pests in early-mid season are the application of selective insecticide (i.e. omethoate and monocrotophos) for cotton aphid control; and droplet-spraying of cotton terminals with monocrotophos or pyrethroids for cotton bollworm control at the 2nd generation [22,26].

Application of biological agents. Microbial insecticide *Bacillus thuringiensis* (Bt) and *Heliothis* nuclear polyhedrosis virus (NPV) have been extensively used for cotton bollworm control. Use of insect growth regulator chlorfluazuron and flufenouuron has shown satisfactory control of cotton bollworm and minimal impact on natural enemies. Cotton bollworm sex pheromones have been recently introduced in management [26, 27].

Chemical Strategy. Chemical strategy plays a central role in resistance management through judicious uses of insecticides as to minimize the selection pressure.

Mixed use of insecticides. Simultaneous use of two or more insecticides possessing different mechanisms of action or target sites, but no positive

cross-resistance, is a very important tactic to manage resistance. Effective mixtures for control of resistant cottonaphid are phosphamidon with fenvalerate or deltamethrin, and omethoate with deltamethrin [10,27]. Those for resistant cotton bollworm are deltamethrin with chlordimeform, amitraz, parathion, omethoate, methamidophos, monocrotophos or malathion; fenvalerate with fenitrothion or omethoate; cypermethrin with methamidophos; monocrotophos with omethoate; and parathion with phoxim [18, 23, 27]. Those for resistant cutworms are trichlorphon with phoxim [1, 27].

Application of synergists. Control efficacy to resistant cotton aphid and bollworm is largely increased by use of synergists, such as SV_1 added to cypermethrin, deltamethrin, fenvalerate, monocrotophos, omethoate or phosphamidon; octacide added to alphacypermethrin, cypermethrin or deltamethrin; and piperonyl butoxide added to conventional pyrethroids [23, 27].

Rotation of insecticide application. Area-wide-rotated applications of insecticides for cotton bollworm control in the North have been practiced more and more. Thus, control of the 1st generation (mainly on winter wheat) depends on principally on Bt, NPV or either of them mixed with pirimicarb.

The 2nd one (on cotton) is suppressed by using selective insecticides (i.e. Bt, NPV and Chlorfluazuron); pyrethroids (i.e. alphacypermethrin, cypermethrin, cyphalothrin and deltamethrin); and pyrethroids mixed with Bt or synergists. Control of the 3rd one (on cotton) relies mainly on OPs (i.e. monocrotophos, methamidophos or either of them mixed with SV₁); carbamates (i.e. methomyl and thiodicarb); and OPs mixed with pyrethroids (i.e. malathion with fenvalerate) or with carbamates (i.e. methomyl with monocrotophos). The 4th one is controlled by applying OPs (i.e. phoxim, phoxim mixed with parathion, or powder-formulated parathion and trichlorophon) [28].

Restricted use of insecticides. Pyrethroids have been banned for cotton aphid control. They are forbidden to be used for cotton bollworm control in the highly resistant area, allowed to be applied only 1-3 times at the 2nd generation in the moderate resistant area, and recommended to be rotated with Bt, NPV, OPs and carbamates in the lower resistant area [23, 27, 28].

Replacement with new insecticides. New insecticides like methomyl, Marshal and combination of carbofuran with monocrotophos are introduced to control pyrethroid-resistant cotton aphid. Endosulfan, Thiodicarb,

Methomyl and Polytrin are suggested for control of pyrethroid-resistant bollworms, and Rufast for resistant red spider mites [27, 28].

Treatment based on economic thresholds. This tactic is a very useful means of not only reducing the selection pressure for resistance, but also exploiting natural control of host plants and beneficial species. Economic thresholds for most major cotton insect pests have been determined and extensively practiced. thus, thresholds levels for cotton aphid at the seedling stage are 2500-3000 insects/100 plants, 20-30% of plants with curling leaves or ratio of the beneficial to pest 1:150-200. Those for red spider mites are 10-20% of plants with red leaves. Those for cotton bollworm are 200-300 eggs or 20-25 young larvae/100 plants at the 2nd generation, 100-150 eggs or 10-15 young larvae/100 plants at the 3rd, and 200-300 eggs or 30-35 young larvae/100 plants at the 4th. Those for pink bollworm are 300 eggs or 20 larvae/100 bolls at the 2nd generation and 200 eggs or 15 larvae/100 bolls at the 3rd. Those for plant bugs are 5 insects/100 plants at the seedling and 10-13 insects/100 plants at the squaring [2, 23, 25].

Perspective of Resistance Management

Effect of resistance management. Implementation of IRM strategies has brought about significant effects not only in resistance management, but also in economical, sociological and ecological profits. As demonstrated at the Anqiu county of Shandong province with 10,000 hectares of cotton annually, population numbers of cotton aphid and bollworm were brought down below their economic injury levels. Development of resistance to conventional pyrethroids was slowed down with resistance levels remaining below 10 fold. Use of insecticides was decreased by 30-50%. Production loss by insect pests was reduced below 10%. Abundance of natural enemies was increased by 3-5 fold [2, 22, 25].

Development of resistance management. Insecticide resistance management has become a central part of cotton IPM systems. For further development, efforts should be expanded to develop IPM systems and steps taken to encourage their use as an essential feature of IRM programs. To do so, the following aspects are of importance: (a) establishing regional cotton IRM systems based on detected insecticide resistance; (b) developing germplasm/cultivars with multiple stress resistance; (c) quantifying mor-

tality effects of endemic biological agents; (d) exploiting sex pheromones, insect growth regulators, and new insecticides and synergists; (e) determining dynamic thresholds for complex pests and instant migration of cotton bollworm; (f) strengthening research in mechanisms and effective detection techniques of resistance; and (g) extending IRM strategies of large scales [25, 27].

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Short Notes

- It takes on the average 45-50 days for a boll to mature and open. Bolls are formed at different times so they mature and open at different times. Early-formed bolls open earlier and remain in the field unpicked for a longer time. During this time, they are exposed to all sorts of contamination. Studies presented at the 1993 Beltwide Cotton Conferences showed that dust and associated bacterial populations increased in the cotton which was picked late. The open bolls were picked at a weekly interval, ginned by hand and processed through a Microdust and Trash Monitor. The amount of dust and bacteria showed a cumulative increase with the growing season and rainfall. This dust is responsible for causing bronchitis, byssinosis and shortness of breath in textile mills. A study on exposure-related declines in lung function of cotton textile workers was also presented at the conferences. 1917 subjects, who throughout their textile work history were exclusively in cotton yarn manufacturing and weaving or in synthetic textile mills, were analyzed to evaluate the effectiveness of the current workplace standards in preventing chronic health problems from cotton dust exposure. After five years, cotton yarn workers exhibited

a steeper annual decline in lung function than did workers in weaving. However, workers in synthetic mills showed larger declines in lung function compared with cotton textile workers, which was not explained by smoking or duration of employment. Full papers will be available in the *Proceedings of the 1993 Beltwide Cotton Conferences*.

- The results of module averaging to improve the repeatability of strength data were published in *THE ICAC RECORDER*, Volume X No. 2 1992. Strength was the only character under study in the previous report. Mr. Jesse F. Moore, who is in charge of the Cotton Division of the USDA Agriculture Marketing Service, in his presentation on "Changes in Cotton Classing" at the Beltwide Cotton Conferences held in New Orleans from January 11-14, 1993, disclosed that length, length uniformity and micronaire have also been included in the studies on module averaging. He presented data from the 1992/93 crop which showed that the repeatability of strength improved from 72% to 80% in the case of module averaging. Staple length data showed a repeatability of 87% over 78% in the case of bale data. Repeatability of length uniformity and micronaire in the case of module averaging also improved, but by a comparatively smaller margin of 5-6% over individual bale testing. He said it is quite possible that one

day the industry might change to module averaging to avail itself the dual advantage of better reliability of data and reduced cost of classification.

- A cotton grower in Arizona, with the help of a biochemist, sprayed cotton plants with solutions containing methyl alcohol. The preliminary observations are that it increased yield, enhanced maturity and reduced water use in comparison to untreated plants. Since methanol is toxic and may cause the burning of leaves after a certain limit, doses were adjusted below the burning level. The observations showed that a dose slightly below the burning level was most effective. bright sunlight and additives to the mix such as urea, mineral nutrients and glycine were vital in preventing leaf burning. After spraying, the most rapid response was that the crop looked green and healthier compared with the untreated crop. Delayed wilting symptoms in the treated crop allowed increases in irrigation intervals, resulting in reduced use of water. It is believed that sunlight detoxifies solutions containing methanol and in this process, the photorespiration rate of the crop is suppressed. If the reduced photorespiration effect of the methanol is confirmed, this may be a breakthrough for the improvement of yields in many crops, particularly for those like cotton which cannot use

all of the carbohydrates produced by the plant in photosyntheses (Source: *Cotton Grower*, Volume 29, No. 1, 1993).

New Book, Cotton Diseases, Edited by Dr. R. J. Hillocks

C•A•B International has published a new book, *Cotton Diseases*, which gives a comprehensive review of the work done so far on diseases of cotton. This resource book has brought together a large volume of references on cotton diseases caused by fungi, bacteria, viruses and nematodes. The book is a bundle of knowledge on history and distribution of the cotton diseases, origin, their causal organisms, physiology of the symptom expressions, factors affecting the infection, extent of the losses and curative measures and all feasible control methods. It is anticipated that the book will be equally useful for researchers, teachers and students anxious to learn more about cotton diseases.

Publisher

The book has been published by C•A•B International, an intergovernmental not-for-profit organization. The International Cotton Advisory

Committee and the Overseas Development Administration of the UK have contributed toward the cost of colored plates on disease symptoms

Authors

The book has been edited by Dr. R. J. Hillocks of the UK. Dr. Hillocks worked as a pathologist for ten years in African countries. Currently he is working as a Senior Research Fellow at the University of Reading, Reading, UK. As he worked on verticillium wilt and bacterial blight in Zimbabwe and fusarium wilt in Tanzania, he has a deep knowledge of the soil borne diseases. Dr. Hillocks has contributed six chapters out of eleven. The other chapters have been written by eminent scientists from the UK and the USA. They are the following:

- Alois A. Bell. Research Plant Pathologist, Cotton Pathology Unit, USDA-ARS, Southern Plains Area, Southern Crops Research Laboratory, Route 5, Box 805, College Station, TX 77840, USA
- John Bridge. International Institute of Parasitology, 395a Hatfield Road, St. Albans, Herts AL4 0XU, UK

- Judith K. Brown. Department of Plant Pathology, College of Agriculture, The University of Arizona, Forbes Building 36, Tucson, AZ 85721, USA
- S. C. Hodges. Extension Agronomist, Cooperative Extension Service, University of Georgia, College of Agriculture, P. O. Box 1209, Tifton, Georgia 31793, USA
- M. J. Jeger. Head, Food Crop Commodity Department, Natural Resources Institute, Chatham Maritime, Chatham, Kent ME4 4TB, UK
- C. M. Kenerley. Department of Plant Pathology & Microbiology, Texas A&M University, College Station, TX 77843-2132, USA

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