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# Introduction

All the quality characteristics of cotton fiber are not yet completely understood. However, what is known is not properly utilized by the industry because of the complex interaction of various parameters. Variations exist within bales and between bales and mixing cotton in mills is unavoidable. It is a challenge for spinners to utilize the full technological value of cotton. In order to avoid human error in mixing various qualities of cotton and to meet target specifications of the end products at low cost, Cotton Incorporated in the USA developed computer software called the Engineered Fiber Selection® (EFS®) System in the early 1980s. Since 1982, EFS® has been utilized at mills to purchase more suitable cotton for a mill/end product, to store it in the warehouse by quality for easy selection and to mix it based on cotton performance. During 1995, in the USA, Europe and the Far East, over two million metric tons of lint will be handled by EFS® at the mills. EFS® has various components for electronic communication of data among all segments of the industry. Details are given in the first article.

According to the survey undertaken by the ICAC during 1994, breeders are the largest group of researchers among all disciplines working on production research. They have made significant contributions to improve quality characteristics and to change the plant type to yield more lint. It is claimed that yield improvement has come as a result of the accumulation of desirable genes for yield, said to be a multigenic character greatly influenced by the environment. In the second article, a new concept of yield improvement is presented. The article shows that the botanical nature of the cotton plant is such that, unless internal or external conditions inhibit the plant from growing, it continues to grow and form bolls. Thus, the cotton plant has great genetic potential, but the realization of this yield potential depends on growing conditions. According to the concept proposed in the article, yield has improved by improving the plant type and by selecting the most suitable genotype for a given set of growing conditions, not through changes in genetic potential. Proposals are made to compare obsolete varieties with present commercial varieties under the old set of growing conditions and current production practices to test the hypothesis.

Articles have been published on whitefly damage and control measures in various issues of *THE ICAC RECORDER* in addition to a review article,

*Stickiness in Cotton*, and a report, *New Methods to Test Stickiness in Cotton*. Whitefly has become notorious as a sucking pest of cotton, a source of stickiness in cotton and a virus vector. There are currently no non-chemical means to control this insect except using glabrous leaf varieties. The Common Fund for Commodities is currently financing two projects to develop new methods of pest management for the whitefly and genetic resistance to whitefly-transmitted viruses. Information on whitefly damage, species, life cycle and transmission of diseases is assembled in the third article.

The 23rd International Cotton Conference Bremen will be held from March 6-9, 1996, in Bremen, Germany. The conference, held biennially, is organized jointly by the Faserinstitut Bremen and Bremer Baumwollbörse. Normally, about 500 participants attend. There will be about 30 papers presented at the 23rd Conference related to fiber processing, testing procedures, reference methods, new testing equipment, stickiness, genetic engineering, colored organic cotton and production costs. On March 5-6, 1996, the ITMF International Committee on Cotton Testing Methods will meet and its five working groups on HVI testing, Maturity, Honeydew, Fiber Length and Dust and Trash will discuss harmonization of testing methods

and recommend reference methods to be used to calibrate machines. The ITMF meeting is open to working group members only; however, conclusions of the working groups will be presented to the Bremen Conference on March 7/8, 1996. More information on the conference is available from Faserinstitut Bremen, Postfach 106727, D - 28067 Bremen, Germany, phone: 49-421-3608910, fax: 49-421-3608913.

Preparations for the Fifth Meeting of the Latin American Association for Cotton Research and Development (ALIDA), being held in Nicaragua from November 13-18, 1995, are well underway. The theme of the meeting will be "Management of Varieties with Emphasis on Fiber Quality." The detailed program is being finalized by The Fundación Nicaraguense para el Desarrollo Agrícola - FUNDA (Nicaraguan Foundation for Agricultural Research). Papers are still being accepted for presentation. For more information on the meeting, contact the Technical Information Section of the ICAC or the coordinator of the Fifth ALIDA meeting at the following address:

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The 1996 Beltwide Cotton Conferences of the National Cotton Council of America will be held in Nashville, Tennessee, January 8-12, 1996. The Beltwide Cotton Conferences are still considered a local event, but foreign participation has grown significantly in recent years. Over 4,000 people from all sectors of the US cotton industry attend these conferences. The Beltwide Cotton Conferences are, in fact, a group of many conferences held simultaneously at the same location. The latest research achievements are discussed in specialized conferences. The first two days are usually devoted to research of practical significance and include an exhibition from agro-chemical and farm machinery companies. More information is available from the National Cotton Council of America, Box 12285, Memphis, TN 38182-0285, USA, phone: 901-274-9030, fax: 901-725-0510.

# Engineered Fiber Selection® System

All fibers on the same seed and all bolls on the same plant do not have the same quality measurements. Consequently, variations exist within a bale and between bales picked from the same field. The same varieties picked from different fields and farms show more drastic differences in fiber properties. It is a challenge for spinners to convert such a high variability in input fibers into a uniform end product. Variability can be reduced through various field operations, but it is also possible to avoid variation defects through optimum blending at the mill. However, the old method of mixing by grades or area of production is not able to utilize optimally the real value of fiber qualities and to keep raw material costs down.

With the automation of the spinning industry, the cost of labor in the overall cost of producing yarn has decreased significantly, enhancing the importance of raw materials cost. Now, cotton yarn comprises 52% of the total cost of producing one kilogram of ring-spun yarn. The share of cotton yarn in open-end spinning in the overall cost of producing one kilogram of yarn is even higher. On the other hand, due to the extensive use of inputs, the

cost of producing cotton is increasing. Hence, exploring other options to decrease the cost of raw material to a spinner, to utilize the maximum technological value of cotton and to produce more uniform yarn/fabric is pertinent.

In comparison with competing mills, the cost of raw material can be decreased by selecting and purchasing raw material on a more scientific basis. High Volume Instrument (HVI) testing has become more popular and, with HVI data available for each bale of cotton, selecting the most suitable cotton for a desired quality of yarn is possible. If the HVI data are properly utilized, the cost of cotton, given the target quality of the end product, can be minimized by selecting the best suited type of cotton to meet the required specifications. Cotton Incorporated in the USA has developed software to manage cotton acquisitions, warehousing and mix selection. The software known as the Engineered Fiber Selection® Cotton Fiber Management System (EFS®) provides a mill with a system to handle cotton inventories based on HVI data and to select the most suitable cotton for a mill/end product as well as to decide the most suitable mixes for uniform and smooth running of machines.

A mill may purchase cotton and, by utilizing computer aided selection, analyze and select only those bales which can most profitably be consumed to produce a particular quality of yarn. This software is compatible with Motion Control Inc. and Zellweger Uster (Spinlab) HVI machines. The first EFS® program was put into operation in 1980 utilizing software written for mainframes and/or minicomputers. In 1982, a program for the IBM series of Personal Computers also became available, which led to commercial adoption of EFS® in the mills.

There are three components of the mill-oriented system: Warehouse management and mix; data communications; and data presentation. The system is capable of supporting multiple HVI lines and/or multiple EFS® stations. Now, sellers and buyers can exchange data using a third party electronic mail box. Since the adoption of the EFS system in the mills, improvements have been made in acquisition and analysis of HVI calibration data and warehousing techniques to reduce handling charges.

The calibration of HVI machines forms the basis for accurate testing of any cotton. In 1989, a Task Group was established to investigate methodology to improve HVI calibration and to forecast cotton performance. Mills also

demanded short fiber content and fiber maturity measurements by HVI, without which it is difficult to correlate fiber characteristics with yarn properties. Now, short fiber content and maturity are among the 14 properties measured by a fully-equipped HVI system.

Perfect quantification of fiber qualities is still not possible because of the variation in growing conditions and their effects on bolls at different positions. According to Bradow (1995), fiber quality at individual boll, locule and seed levels revealed wide variations in fiber maturity (circularity, fineness and micronAFIS) that are not noticed in a sample drawn at the bale level. She observed, like many others, that some motes are capable of producing equally long fibers as mature seeds, but these fibers are always immature and do not spin normally, in addition to showing up as specks after dyeing. Previous articles published in *THE ICAC RECORDER* show that repeatability of HVI data increases as the quantity of material from which a sample is drawn increases, seemingly one of the reasons that reproducibility of data is more reliable for a module rather a bale. In this article, we will restrict discussion to the EFS® System rather than the validity of testing methods and the type of work going on to improve reliability of the various equipment.

# Components of EFS® System

EFS® has established an effective feedback link between producers and processors of cotton. With the help of EFS®, it is possible to respond efficiently to the queries of the spinner, thus continuously and rapidly improving the quality of the product produced. EFS® System computer programs have been developed for each segment of the industry, leading to an eventual electronic data interchange network from a farm to a mill. The EFS® System flow chart includes MILLNet for mill use, QRNet for merchants, CALNet for calibration of HVI and the recently introduced GINNet for ginners and producers. CD~EDI was introduced only at the Eighth Annual Cotton Incorporated Engineered Fiber Selection® System Conference in Memphis, Tennessee, held from June 12-14, 1995. CD~EDI is an electronic mail box service designed to improve the efficiency of HVI data transfer from a producer/merchant to a mill. Presently, all software computer programs of the EFS® System have been written and leased by Cotton Incorporated, but some mills have already attempted to make changes in the programs or to write their own programs.

## GINNet

GINNet is a computer program which analyzes HVI data to determine fiber qualities and the monetary value of cotton. It is utilized by ginners and farmers to maintain a record of the cotton produced at one or more farms. As soon as cotton is received in the gin, information regarding the producer and cotton is entered into the database. After the cotton has been ginned, a sample is collected and sent to the USDA classing office for HVI testing. GINNet downloads the data for each bale of cotton from the USDA main database or from the USDA-Agriculture Marketing Service's local classing office. HVI data can also be acquired as an ASCII file, imported or entered into the computer manually. The downloaded HVI data are merged with the GINNet database for the farmer and transmitted to the spinner. Currently, the GINNet database contains information on producer, farm, field number, variety, area, soil type, planting date, harvesting date, picking method, module or trailer information, lint weight, gin identification, ginning conditions (temperature and humidity), bale number and bale weight in addition to fiber characters measured by HVI.

GINNet enables producers to correlate fiber characters with varieties and field operations followed during growing until harvesting. The GINNet database helps to identify bad picker adjustments, improper defoliation, grassy crop and undesirably maintained module operations and to bring improvement in fiber quality. Comparing HVI data among producers, farms, fields and varieties is also possible, thus providing another option for bringing improvement in agronomic operations for quality enhancement. The computer program can print the data and keep a record for consultation and improvement in operations in the next year and also keep permanent records on the history of the field.

## CALNet

CALNet stands for Calibration Network. The system's main objective is to understand the calibration history of HVI lines. The system is comprised of two components with the functions to collect, store, analyze and transmit data. The two components are a centralized storage computer at Cotton Incorporated and a set of on-site data-collecting computers. A set of computers installed at the remote site are called RDAC which stands for Remote Data Acquisition and Communication. RDAC collect and store HVI calibra-

tion data, perform some on-site simple analysis and transmit data to the central computer for detailed analysis. The on-site computer must be running Microsoft® Windows™ 3.1 in enhanced mode.

## MILLNet

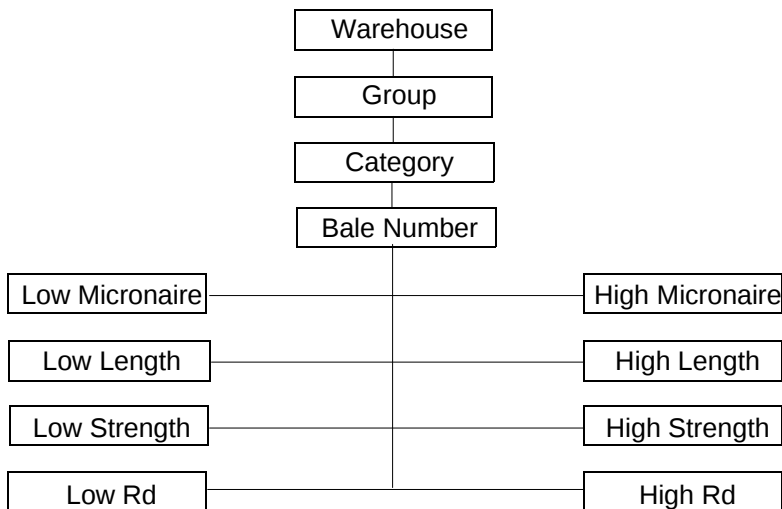
MILLNet is the most important component of the EFS® System. It is a program developed for use at the mills to manage contracts, to customize minmixes, to communicate with merchants/producers and to decide mixes. The ultimate objective is to meet the customer's specifications consistently and at the lowest cost for raw material. With the help of MILLNet, it is possible to determine how cotton deliveries match contract and consumption requirements; to analyze critical fiber properties during acquisition and mix selection; and to provide the optimum utilization of each property of cotton. Electronic data interchange, ANSI X12 data transfer, is supported by MILLNet. The program provides mills with a communication link to exchange cotton data electronically with merchants, cooperatives, etc., through a third party mailbox service. MILLNet handles ANSI X12 forms 856 (advanced tag list and shipping notice) and 863 (sample tag list and sample approval/reject list). In the mill, MILLNet is usually run under the supervi-

sion of a person in charge of cotton purchase or responsible for deciding mixes in the manufacturing/production department. Decisions for mixes are made on a bale-by-bale basis. It is possible to print reports from MILL-Net and also fax or send reports by electronic mail (E-mail).

The use of MILLNet has grown significantly since the initiation of its commercial scale adoption by the industry in 1982. In 1982, 43,500 tons of lint were processed on MILLNet; the number increased to 0.76 million tons in 1990. Currently, MILLNet is used by over 50 mills in the USA, Europe and the Far East. During 1994, over 1.96 million tons were processed on EFS®, and, during 1995, approximately 2.2 million tons will be handled using the EFS® System.

MILLNet helps the spinner, based on the HVI data, to accept or reject cotton for purchase. Once he has purchased cotton, he can store cotton in the warehouse so that bales are picked for mixing without having to move adjacent bales and delay mixing. At the warehouse, bales are generally grouped by area of origin and category of cotton based on limited important fiber characters. Each bale has a number allotted to it after going through bale tagging and testing at the mill. The number of groups and

categories depends on the cut-off limits established by a mill in the EFS® system using MILLNet. Although data may be available for many fiber characters, mills usually consider it important to decide mixing on the basis of micronaire, length, strength, color, trash and short fiber content. The flow chart will be something like the following:



Priorities may change depending upon the spinning system and end product, but the average value for the mix for any character and distribution from the mean value must remain the same for each mix and within mixes. Of course, the blending efficiency of the opening line also has an important role in making good mixes. Given the importance of fiber quality, cotton price, machinery type and performance, yarn count, twist and end product specifications are considerations in deciding mixes.

El-Mogazy (1995) has discussed in detail three different methods for picking bales for mixing, i.e., random picking, proportional weight category picking and optimum category picking. Random picking is close to traditional massive blending. In proportional weight category picking, the distribution of fiber characters is divided into a number of classes, as shown in the diagram, and bales are picked in quantities proportional to the class relative frequency. In the optimum category picking, bales are selected on the basis of optimization of factors contributing to blend uniformity taking into account category variance, picking cost and category inventory. El-Mogazy recommends using a proportional weight category picking method for normally distributed fiber characters, or, if fiber characters are distributed more widely, optimum category picking.

## **Electronic Data Interchange**

QRNet is a program meant to facilitate electronic data interchange (EDI) among participating mills, gins/producers and merchants in the cotton industry. All parties using the EFS® System should have an account with a third party electronic mailbox such as EDI\*EXPRESS™. However, QRNet is also available as a stand-alone program. At the Eighth Annual EFS® Conference, Cotton Incorporated introduced its own value added network service named CD~EDI for electronic communication of data. It is claimed that CD~EDI is an efficient and less expensive device compared with the third party mailbox service (Parham, 1995). It is also said that CD~EDI is reliable and secure to use, because password protected accounts allow users to have access to only those data files addressed to them.

## **Advantages of the EFS® System**

The EFS® System has also been applied in many countries outside the USA. Go (1994) from Litton Mills in the Philippines has compared the use of MILLNet with non-utilization of MILLNet. He reported that installation of

MILLNet at the mill reduced yarn breakage and improved fabric quality as follows:

| <b>Yarn/Fabric Performance</b>                        | <b>Without MILLNet</b> | <b>With MILLNet</b> |
|-------------------------------------------------------|------------------------|---------------------|
| Yarn Quality Evaluation<br>(Breaks per million yards) |                        |                     |
| Ball warping                                          | 0.46                   | 0.38                |
| Rebeaming                                             | 8.06                   | 5.20                |
| Sizing                                                | 0.36                   | 0.29                |
| Fabric Quality Evaluation                             |                        |                     |
| Quality level based on Int.<br>4-Point Demerit System | 75.0% pass             | 93.5% pass          |
| Shade variation (no. of shades)                       | 14                     | 4                   |

Information is not available on the cost of installation of the EFS® System in part at a gin/mill or all components. However, some advantages of the EFS® System are as follows:

- Purchase of required qualities of cotton to meet target specifications of end products at minimum cost.
- Best utilization of technological fiber properties of cotton.

- Spinning runs more smoothly and ultimately the cost of spinning is reduced.
- Improved uniformity of yarn and, thus, improved quality of fabric.
- Labor saving in warehousing.
- Ease of communication with producers/merchants. Communications among producers, ginner and spinners helps to identify factors affecting quality and thus improves quality in the next year.

**Note:** EFS® System software programs are furnished to licensed users by Cotton Incorporated, USA. The software is proprietary to Cotton Incorporated and strict copyrights apply. The EFS® System is constantly improving as new programs become available and understanding and measurement of fiber properties of cotton by HVI improves. For more information on the EFS® System, contact Mr. Charles H. Chewning, Jr., Vice President, Fiber Processing Research, Cotton Incorporated, 4505 Creedmoor Road, Raleigh, NC 27612, USA, phone: 919-782-6330, fax: 919-832-8003.

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# Where Do Yield Improvements Come From?

(This paper is based on the personal views of M. Rafiq Chaudhry, Head, Technical Information Section of the ICAC)

Cotton yields and quality have improved throughout the world, and the largest contributions are considered to have come from breeders. Lint yield in cotton is generally considered to be controlled by genes and breeders assemble desirable genes in the target variety. In the current article, a viewpoint contrary to the claims made by breeders is expressed. This viewpoint is based on the hypothesis that the cotton plant has an unlimited potential for yield, the expression of which depends on growing conditions. In order to understand the phenomenon of yield improvement in cotton, it is important to understand the botanical nature of the cotton plant and its effects on yield.

# Botanical Nature of the Cotton Plant

Cotton belongs to the family *Malvaceae* and genus *Gossypium*. Only four species of *Gossypium*, two diploid and two tetraploid, are grown on a commercial scale. All four cultivated species of cotton have complex morphology because they are perennials that have been adapted as annual plants. There are two hypotheses regarding the development of annual plants. It may be that heavy selection pressure for desirable genotypes with a shorter growing period resulted in the development of annual plants. Alternatively, annual plants, as a result of natural mutation, may have existed in the population and they were adopted for commercial cultivation. Whatever may be the origin of annual cotton, the cotton plant by nature never fruits itself to death. It has a tendency to grow as long as suitable conditions exist for growing. Growing points include the main axis and two types of branches: monopodial and sympodial, also called vegetative and fruiting branches, respectively. Some varieties might have only sympodial branches. The main axis and both types of branches are indeterminate in nature and the cotton plant can rightly be called pseudo-annual. The main stem is divided into nodes, internodal length being dependent on genetic

make-up and growing conditions. At each node, a leaf appears and, in the axil of a leaf, either a branch or a flower bud is formed. Monopodial and sympodial branches appear on the main stem in zigzag fashion and also behave like the main stem --- formation of leaves in a zigzag manner and also each leaf axil forming a branch/branches or a flower bud. The only difference is that sympodial branches never give rise to sub-branches and, once a sympodial branch appears on the main stem, there are no more chances of formation of monopodial branches.

The main stem and branches, being indeterminate in nature, will never cease growing unless they are confronted with internal or external limitations. One external limitation is sensitivity of the plant to photoperiodic conditions. But, the plant exerts its fullest promise to continue growing and forming leaves simultaneously followed by buds. Such a phenomenon is very prominent in cytoplasmic or genetic male sterile lines compared with their isogenic “B” lines. As soon as the plant enters into reproductive growth, partitioning of the dry weight is diverted toward fruit and vegetative growth is checked. Boll load increases with the age of the plant and ultimately, in interaction with the climatic conditions, vegetative growth comes to a stop. Certainly, this phenomenon occurs more quickly in fertile plants

than in sterile plants. However, if fertile plants are intentionally stopped from bearing flowers/bolls, they will grow taller, thus creating more fruiting points.

## **Yield and Yield Components in Cotton**

Different crops are grown to harvest different parts of the plant. Economic yield, which is determined by its value, varies from root to leaves, stem, flower, fruit and in many cases a portion of a flower or a fruiting part. Economic yield in cotton is lint, fibers on the seed, probably created by nature for seed protection and easy dispersal of seed. Many uncultivated species of cotton do not have lint on the seed and still belong to a group of fiber crops. The presence or absence of fibers on the seed coat is controlled by a single gene. Without going into details to show that fiber quality is even more important than quantity in cotton, the weight of fibers produced per unit area, which is equivalent to the universally recognized term called “yield,” will be discussed here.

In cotton, like many other crops, yield is comprised of a number of factors. However, economic yield in cotton can be improved for each boll, for each

plant or unit area. Because economic yield is generally measured in terms of unit area, the components of yield are usually considered to be:

- total number of plants per unit area
- number of bolls per plant
- boll weight (average seedcotton weight for seedcotton yield and lint weight for lint yield)

The number of plants depends on the seed rate used for planting and agronomic operations like thinning, hoeing, etc. It can easily be increased by using a good quality seed, higher seed rate, optimum planting conditions and agronomic care. The number of total bolls per plant can also be manipulated in the same variety from only a few to many-fold through agronomic operations, particularly plant spacing. Boll weight, which is an equally important component of yield, is itself based on at least four other parameters within the boll:

- number of locules per boll
- number of seeds per locule

- number of fibers per unit area on the seed or total number of fibers on the seed
- weight for each fiber (thickness, length)

The number of locules in American Upland varieties varies from four to five. There may be only three locules per boll, but such varieties are not grown commercially. Varieties with six locules are also not available and varieties with seven locules do not exist. An increase in the number of locules decreases the number of seeds per locule. Similarly, a higher number of seeds with shorter fibers may result in a lower economic yield.

The above-mentioned components of yield are so interdependent and influenced by the environment that it is not possible to base economic yield on these factors. They are good for assessing calculated yield, which may be very close to actual yield after harvest.

## **Is Yield Limited?**

If what has been said above about the botanical nature of the cotton plant is accepted, the total number of leaf positions on the plant should corre-

spond to the number of fruiting points less the number of branches. If some leaf axils are capable of producing two flower buds at the same time (twin bearing), theoretically, the total number of fruiting points may even exceed the total number of leaf positions on the plant. In practice, however, the number of bolls less the number of branches never corresponds to the number of leaf positions or the number of nodes. The percentage of productive bolls in the total number of fruiting positions has improved with selection pressure for short duration, heat tolerant genotypes. However, bolls still develop only on a small percentage of actual positions on the plant and that is why we have limited yield --- a small percentage of the actual potential carried by the plant. The plant has a huge yield potential, but it is suppressed due to internal and external constraints. In order to improve yield, it is necessary to identify constraints and eliminate them from the production system.

## **Identification of Constraints**

Every year at the ICAC Plenary Meetings, the Committee on Cotton Production Research conducts a Technical Seminar on a selected topic. The topic of the Technical Seminar held at the 52nd Plenary Meeting in Octo-

ber 1993 was “Yield Constraints in Cotton and Producing Quality Cotton under Rainfed Conditions.” Most of the papers presented in the seminar referred to factors affecting yield and not yield constraints. Yield constraints will show their effect only if all other inputs are provided, otherwise they will be mixed up with factors affecting yield. Finding a remedy to eliminate a constraint is probably easier than identifying a constraint. Constraints may also be resolved without identifying them.

Several constraints have been identified in the past and resolved. As a result, significant increases in yield have been achieved in many countries. Two major constraints which have received worldwide recognition are nutrient limitations in the soil and insect pressure on the plant. Synthetic fertilizers were developed to meet the nutrient requirements of the plant and yields improved. Later, insects were found suppressing yield. Insecticides were developed to protect the maximum fruiting positions on the plant and again yields improved. Because the adoption of synthetic fertilizers and insecticides has been very steady, yields have also improved gradually. If we take out these two inputs from production practices, yields will revert to lower levels.

Fertilizers and insecticides are broad spectrum constraints which apply to almost all cotton growing conditions. Constraints may be very localized for a particular set of agro-climatic conditions. Heat stress resulting in non-fertilization of flowers was a constraint in Pakistan; heat tolerant varieties were developed and yield improved. Similarly, low temperature could be a constraint under another set of agro-climatic conditions. It is probably already a constraint in Uzbekistan; if not now, it might become a limiting factor in Uzbekistan if the summer continues to shorten and become milder. In order to bring improvements in productivity, new constraints have to be identified and eliminated from the production systems. It seems that now is the time for physiologists/chemists to alter the plant's behavior. The cotton plant is unable to utilize all the carbohydrates formed during the process of photosynthesis and is thus called a C<sub>3</sub> plant. On the average the cotton plant photorespires 30% of its photosynthetic rate. The amount of carbohydrates which is released into the environment or burnt by the plant could best be utilized for growth. A big jump in yield improvement can be achieved by inhibiting the photorespiration behavior of the plant and converting it into a C<sub>4</sub> plant.

# Current Beliefs About Yield Improvement

According to a survey undertaken by the ICAC during 1994, breeders are the largest group of researchers among all disciplines working on cotton production research. Early maturity and changes in plant type are major achievements of breeders. Improving fiber quality has only been possible through breeding. Twenty-year data show that, in the USA, on the average, fiber length and strength have increased at the rate of 0.8 mm and 2.8 g/tex (Sasser, 1994), respectively, in ten years because of breeding for improvement in these characters. More improvement is required and can only be brought about through breeding. Breeders' contributions could be further accelerated if they had an option of picking and choosing genes of their choice for insertion into new genotypes. Now, from the successful development of transgenic cottons, it seems that optional addition or deletion of genes for improvement in specific characters is not far away.

Improvement in yield is the top most priority among breeding objectives and breeders have made significant contributions to improve productivity in cotton. Suitable parents are selected and crossed to obtain high yielding varieties. It is assumed that each parent contributes 50% to the develop-

ment of a new genotype called the  $F_1$  generation. Because reciprocal crosses are said to behave similarly,  $F_1$  generation seed is usually multiplied to grow  $F_2$  generation seed. Single plant selections are made from the 1st segregating generation based on good-looking, high yielding plants and other target priorities. The selected plants are screened for high yield and fiber quality. This process goes on through the  $F_6$  or  $F_7$  generation as a single plant selection or as a progeny row selection until it is confirmed that the selected plants are consistent in their morphological behavior. It is claimed that, by  $F_6$  or  $F_7$ , plants become homozygous, but there is no way to verify the claim. However, during this process, plants most suited to the growing conditions are inadvertently selected. At the end, it is claimed that a high yield variety has been developed through the accumulation of desirable genes. It is a generally accepted phenomenon that yield in cotton is a quantitative character controlled by many genes and the accumulation of more desirable alleles in one genotype enhances its genetic ability to yield more seedcotton. According to Meredith (1984), yield in cotton is a composite of many traits, each influenced by many genes and expression of each gene is modified by the expression of other genes. The approach followed to improve yield is empirical and breeders have no control over it.

Because it is not possible to determine which genes or their alleles will give you better combinations and because their locations are unknown, breeders cannot forecast any increase or decrease in genetic potential for yield. It is still believed that new high-yielding varieties emerge as a result of a better genetic make-up of the plant.

## **A New Concept of Yield Improvement**

As already stated above, the cotton plant, by way of its botanical nature, is capable of bearing a large number of bolls but is restricted due to internal and external limitations. Internal limitations could include an increase in the anti-auxin activities or short supply of carbohydrates, while external limitations are unsuitable climatic conditions. If these stresses can be avoided, the plant will grow and, consequently, develop more fruiting points. The number of fruiting points on the plant is again mainly determined by growing conditions. The cotton plant has a huge potential for yield, but how much of its potential is actually realized depends on agro-climatic conditions. Agronomists/breeders find the most suitable genotype for a given set of agro-climatic conditions and claim that they have improved genetic potential for yield in cotton. In fact, they determine the best combination of

yield components for a genotype for a given set of growing conditions. Afzal (1986) has summarized the phenomenon of yield improvement as follows:

- Yield can be improved by augmenting the plant's physiological well-being through adjustments in the environment by removing the constraints which are operating to reduce the inherent yield.

There is no dispute that breeders have produced yield improvement and they need to continue work along current lines. Presently, no other method is available to conventional breeders to improve yield in cotton. Improvements in productivity have occurred, but the genetic potential of the plant has not been changed. The only dispute is the basis for yield improvement.

## **How to Test the Hypothesis?**

Fortunately, it is possible to test the so-called “genetic superiority” of one genotype over another by growing them together under a similar set of conditions. Improvements brought for higher yield through the accumulation of desirable genes, if any, should stay in the genotype and express them-

selves whenever suitable conditions are provided. No new variety is approved for commercial cultivation unless, after many years of repeated testing, its better genetic potential to give higher yield has been proven. The margin over an existing variety may vary, but usually a 5% increase is considered satisfactory, although the actual average increase in yield per hectare in the USA in the last 20 years has been less than 3% per year (Sasser, 1994). Methods to test for genetic superiority are the following:

- In countries where cotton has been grown for many years and there are obsolete varieties grown before the introduction of synthetic fertilizers and insecticides, it is very easy to test the hypothesis. Simply plant the obsolete varieties and the presently grown commercial varieties under the old set of conditions --- no synthetic fertilizers and no insecticides. If they were irrigated in the olden days, irrigate them. For justifiable comparison, it is very important to create the old soil growing conditions, which may require more than one year. All requirements of the obsolete varieties should be followed properly. Minor increases, in any set of varieties, could be due to many other factors, but, if modern varieties are capable of showing the cumulative increase claimed over 50 years, genetic potential has really improved.

- It is also possible to compare obsolete varieties with the latest commercial varieties under modern cultivation practices. The objective here is to check the performance of the old varieties under conditions when they do not suffer from a lack of nutrients from the soil and insect damage. Because cotton production practices have changed drastically in the last three to four decades, care should be taken to avoid undue advantage to present commercial varieties. Present varieties are short stature and early in maturity, making the plant more responsive to higher doses of nitrogenous fertilizers. So, in the case of obsolete varieties, some adjustment in agronomic practices, particularly plant spacing, may be needed to generate reliable data.

(The author of this paper, editor of this journal, is himself a cotton breeder by training and was a practical breeder for over five years. He is grateful to the late Mr. Muhammad Afzal for the wisdom he shared with the author about yield in cotton.)

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# Some Facts About Whitefly

In the last two decades, whitefly has become a major pest of cotton in many countries, necessitating spraying, causing stickiness at the textile mill and resulting in production losses due to virus transmission. 1100 species of whiteflies have been identified in the world, but cotton is affected by only two species, *Bemisia tabaci* and *Bemisia argentifolii*, the latter of which, previously called biotype "B," has emerged recently. Some facts about whitefly species affecting cotton, collected from many published articles and reports, are reported here.

## Origin and Distribution

|                 |                                                                                                                                                             |
|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Common names    | Sweet potato whitefly, cotton whitefly, tobacco whitefly and cassava whitefly for biotype "A" and silver leaf whitefly or poinsettia strain for biotype "B" |
| Technical names | <i>Bemisia tabaci</i> (Gennadius) - biotype "A" <i>Bemisia argentifolii</i> - biotype "B"                                                                   |

|                    |                                                                                                                                                                                                                                                                                                      |
|--------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Original name      | <i>Bemisia tabaci</i> was first described as <i>Aleurodes tabaci</i> from tobacco in 1899.                                                                                                                                                                                                           |
| Area of origin     | Indian subcontinent is the center of origin, then it spread to Africa, Europe and the Americas by human transportation of plant material.                                                                                                                                                            |
| Recognized species | 1100 species                                                                                                                                                                                                                                                                                         |
| Synonyms           | <i>Aleurodes tabaci</i> , <i>A. inconspicua</i> , <i>Bemisia inconspicua</i> , <i>B. costa</i> , <i>B. limai</i> , <i>B. signata</i> , <i>B. babiliana</i> , <i>B. gossypiperda</i> , <i>B. hibisci</i> , <i>B. longispina</i> , <i>B. goldingi</i> , <i>B. nigeriensis</i> , <i>B. rhodesiansis</i> |
| Classification     | <i>Bemisia tabaci</i> belongs to the family and sub-family <i>Aleyrodidae</i> , order <i>Hemiptera</i> and sub-order <i>Homoptera</i> or in the sub-order <i>Sternorrhyncha</i> and order <i>Homoptera</i> . Morphological differences among species are not prominent.                              |

|                                               |                                                                                                                                                                                                                                                                                                                                                                                                  |
|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Geographical distribution of <i>B. tabaci</i> | <i>B. tabaci</i> is a pest of tropical and subtropical areas, but now it is also showing up in temperate climate conditions.                                                                                                                                                                                                                                                                     |
| Reporting countries                           | <i>Bemisia tabaci</i> is reported in over 90 countries in the world.                                                                                                                                                                                                                                                                                                                             |
| Pest status                                   | In India and Pakistan, it was not an important pest of cotton until the early 1980s. It is still not a serious pest in Uzbekistan, but the population is increasing. It is also not a pest of cotton in China (Mainland). In the USA, during the 1980s, whitefly was found causing no economic losses in cotton. An epidemic outbreak occurred in Arizona and California during the early 1980s. |

## Species

|                           |                                                                                                                                                                            |
|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Identification of species | Many species are similar in morphology and difficult to differentiate. However, the 4th instar (also termed as "pupal case") is commonly used for identification purposes. |
|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

|                                                          |                                                                                                                                                                                                                           |
|----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Biotypes or races                                        | Geographical isolation has given rise to various biotypes of <i>B. tabaci</i> which vary in their ability to utilize various hosts. 19 described species of <i>Bemisia</i> were at some time considered a single species. |
| Latest isolated species                                  | <i>B. argentifolii</i> , initially identified as a different biotype in the USA in 1986, is the latest species isolated from <i>B. tabaci</i> .                                                                           |
| Geographical distribution of <i>Bemisia argentifolii</i> | <i>B. argentifolii</i> is of paramount importance in the USA, Caribbean and Central America, but it now has also been recorded in Africa, the Arabian Peninsula, Europe, the Mediterranean Basin and Japan.               |
| Spreading of biotype "B"                                 | Biotype "B" did not originate independently in various countries. It is assumed that it was spread among countries and continents with physical movement of host plants like poinsettia.                                  |

"A and "B" differences      Electrophoretic studies showed that the two species differ from each other in their esterase banding pattern. Biotype "B" has an elevated esterase level. The two species also differ in DNA composition, pathogen transmission characteristics, honeydew production and egg production. Biotype "B" has a wider host range and better adaptability to temperate climate, it is more virulent and is also more resistant to insecticides, particularly pyrethroids, organophosphates and carbamates.

## Host Plants

|                      |                                                                                                                                                        |
|----------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| Change in morphology | Whitefly species have a high plasticity in their morphology. The morphology of <i>B. tabaci</i> changes significantly with a change in the host plant. |
| Alternate hosts      | Over 500 cultivated and wild species belonging to 74 families have been reported as hosts of whitefly.                                                 |

|                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Weed hosts                | In addition to many vegetables, flower plants and field crops grown during the winter season when cotton is not in the field, whitefly survives on weed plants. However, high population weed hosts also vary from country to country. Potential weed hosts for four important countries are Israel: <i>Lantana camera</i> , <i>Abutilon grandifolium</i> and <i>Ipomoea batatas</i> ; Sudan: <i>Ipomoea cordofana</i> ; Pakistan: <i>Sonchus</i> spp., <i>Euphorbia</i> spp. and <i>Convolvulus arvensis</i> ; USA: <i>Helianthus annuus</i> , <i>Convolvulus arvensis</i> and <i>Lactuca serriola</i> . |
| Affected crops            | Vegetables like tomato, cauliflower, potato, turnips, etc; fiber crops, staple and ornamental plants.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Types of losses in cotton | Losses are caused as a sucking insect, as a secreting insect and as a vector. Losses are qualitative as well as quantitative                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

## Feeding on Cotton

|                                    |                                                                                                                                                                                               |
|------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Most damaging stage                | Adult                                                                                                                                                                                         |
| Mode of action/<br>feeding         | Whitefly adults and nymphs feed on the undersurface of the leaves. They suck leaf sap and inject saliva. Leaf tissues are killed by piercing.                                                 |
| Feeding status                     | Most whitefly species are monophagous, but <i>B. tabaci</i> and <i>B. argentifolii</i> are polyphagous.                                                                                       |
| Symptoms on the<br>affected plants | General weakening of the plant with leaf shedding and reduced vegetative growth.                                                                                                              |
| Stickiness                         | Adults and all larval instars excrete copious amounts of honeydew on the leaves and open bolls which make the fibers sticky and also provide a medium for the growth of fiber staining fungi. |
| Physiological effects              | In heavily infested plants, the nitrogen index is increased after 65 days of planting. It has also been                                                                                       |

observed that total sugar contents are reduced and the phosphorous index rises in heavily infested leaves. These changes may have a significant effect on boll and lint development.

#### Economic losses

No records are available on direct losses caused only by whitefly. However, the losses which occurred in Sudan due to whitefly as a vector of viruses are famous. Now it seems that production losses in Pakistan in the range of over 800,000 tons of lint, due to leaf curl disease caused by whitefly-transmitted geminiviruses, have surpassed previous records.

## Life Cycle

#### Developmental stages

The life cycle is comprised of six developmental stages: Egg, three immature nymphal or larval instars, a fourth immature pupal stage with two often recognized entities and adult.

|                       |                                                                                                                                                                                                                                                                                    |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| No. of eggs/life span | 100-300 eggs                                                                                                                                                                                                                                                                       |
| Mating                | Newly emerged adults start their first mating from a few hours to 1-2 days after emergence. Pairing generally starts at 8:00 hours and may continue up to 16:00 hours. Males show aggressive behavior and actively seek females. In copula time is usually less than four minutes. |
| Pre-oviposition       | Under laboratory conditions, the pre-oviposition period ranges from 3.3 to 4.9 days at 28°C and 14°C, respectively. Under field conditions, pre-oviposition period varies from 1 to 8 days and may extend to 22 days at low temperatures of 14°C.                                  |
| Eggs                  | Egg laying is strongly influenced by temperature. Eggs are firmly embedded in the leaf tissue and vertically placed to the leaf surface on the underside of the leaves. They are yellowish-brown but turn brown prior to hatching.                                                 |

## Egg hatching

Maximum egg hatching usually occurs at temperatures between 25°C and 35°C. Temperatures below 25°C and above 35°C have a significant effect on percentage of hatching eggs. Eggs are oval and sub-elliptical in shape. They are tapering toward the distal end and are provided with a stalk on one side of the base which serves to attach the egg to the plant. Mean length and width of an egg is 0.211 mm and 0.96 mm, respectively. Mean stalk length is 0.024 mm. If leaves wither and die, the eggs collapse, even if they were about to hatch. Because eggs are usually inserted into the tissues of the host plants, relative humidity has almost no effect on viability of eggs.

## Larva

Larvae are comprised of three instars. The 1st instar, also called crawler, measures around 0.27 mm long and 0.15 mm in width. It is yellowish in color and usually lives for 2 to 6 days, depending upon the living conditions. Temperature has a

significant effect on longevity of the larval stage. Under lab conditions at 25°C, duration of the 1st instar was 2.8 days which was extended to 9.0 days at 14°C. The 1st instar has the highest mortality rate. The 2nd and 3rd instars are greenish-yellow in color. The 2nd instar larvae (0.37 mm long and 0.22 mm in width) are usually bigger in size compared with the 1st instar and, likewise, the 3rd instars measure longer (0.49 mm) and wider (0.3 mm) compared with 2nd instars. Life duration ranges from 1 to 5 days and 2 to 7 days, respectively, for 2nd instar and 3rd instar larvae. All instars have a waxy colorless coating. Under normal conditions of 25°C, three instar stages are completed in 7 days. A 6°C rise in the temperature delays completion of the larval stage by 6 days. Similarly, low temperatures also have a significant effect on larvae development.

## Pupae

Whitefly pupae are yellowish to light brown in color. At a temperature of 25°C, it takes 4-7 days to complete the pupal stage. A rise in temperature to 31°C delays adult formation by 1.5 days. Low temperatures show a similar effect. In general, a long-day photoperiod enhances completion of larval and pupal stages compared with a short-day photoperiod. The host crop also has a significant effect on the life duration of pupae. The pupae stage is generally shorter on cotton than on other host crops. Pupae carry a colorless, waxy coating and vary in size. In fact, sex can be distinguished from the size of the pupae. Females emerge from longer pupae and males from smaller pupae. Mean pupae length is 0.7 mm as against mean width of 0.38 mm.

## Adults

Adults are first whitish-yellow in color but, after a few hours of emergence, change to completely white due to deposition of wax on the body and

wings. From vertex to the tip of their wings, females measure 1.33 mm on average as against 1.15 mm for males. Adult females also live longer than males. However, mouth parts in both sexes are typical piercing and sucking types. The adult body is pale-yellow in color with two white wings. Adults remain near the pupal case for 10-20 minutes wait for their wings to dry before they start feeding on the cotton leaves.

|                      |                                                                                                                                                                       |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Male to female ratio | 1:1 to 1:6                                                                                                                                                            |
| Life span            | At 30°C, the life cycle is completed in 17 days but may extend to six weeks or more depending upon climatic conditions; longest in winter and shortest during summer. |
| Generations per year | In many countries, 11-15 generations are completed in one year.                                                                                                       |
| Parthenogenesis      | Parthenogenetic reproduction occurs with unfertile female eggs, producing only males.                                                                                 |

# Transmission of Diseases

|                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Commonly transmitted diseases | More than 70 diseases in cultivated plants and weeds are transmitted by four species of whitefly, but, in cotton, leaf crumple disease and leaf curl disease are the only important diseases.                                                                                                                                                                                                                                                                                                 |
| Virus vector                  | 19 types of viruses, most belonging to the family <i>Geminiviridae</i> , are transmitted by whitefly. <i>B. tabaci</i> , <i>Trialeurodes vaporariorum</i> , <i>T. abutiloneus</i> and <i>B. argentifolii</i> are known vectors of viruses, but, until the recognition of <i>B. argentifolii</i> as an independent species, <i>B. tabaci</i> was the most important virus vector and the only known vector of geminiviruses. Pathogens are transmitted more effectively by females than males. |
| Virus acquisition             | Late stage instars and adults can acquire viruses.                                                                                                                                                                                                                                                                                                                                                                                                                                            |

Virus transmission  
time

Most viruses can be transmitted after 24 hour acquisition access feeding and 48 hour inoculation access feeding.

Mechanism of virus  
transmission

The precise mechanism is not as yet known. Capsid protein is understood to be involved in insect transmission of viruses. Preliminary evidence shows that virion presumably passes through the stylet and midgut of the insect into its hindgut where it crosses the plasma membrane into the haemocoel by classical endocytosis. From there, it probably moves through the hemolymph and crosses the plasmalemma of the salivary gland into the accessory salivary gland, and then it is transmitted into the host plant through saliva injected by the whitefly while feeding.

## Control Measures

### Chemical Control

Chemical control is generally considered difficult because adults feed on the underside of the leaf. Organophosphates have been extensively used to control whitefly. Where whitefly is a virus vector, pyrethroids have been used for rapid knockdown of the vector. However, late season effects of pyrethroids have limited this option. Carbamates have not received any recognition as a measure to control whitefly.

### Resistance to insecticides

Whitefly has developed resistance to a group of chemicals including monocrotophos, dime-thoate and cypermethrine. Cross resistance has also been noticed in many countries.

### Non-conventional control

Botanical extracts such as azadirachtin from neem seed and glandular secretions from pieces of nicotiana are highly toxic to nymphs. Experi-

ments have shown that cotton seed oil and Neemark are effective in controlling whitefly adults.

#### Sex pheromones

The use of pheromones to control whitefly is not seen in the near future.

#### Host plant resistance

Low leaf-hair density and okra leaf shape have been very effective morphological characters in minimizing whitefly populations in cotton. Okra leaf shape provides better aeration, low humidity and comparatively high temperature conditions a microclimate undesirable for whitefly to multiply at a higher rate.

#### Parasites

All reported parasitoids of whitefly, with the exception of two, belong to *Aphelinidae* in the genera *Eretmocerus*, *Encarsia*, *Prospaltellea* and *Pteroptrix*. Important parasite species utilized in some countries include *Amitus bennetti*, *Amitus* spp. from the Caribbean, *Encarsia adrianae*, *E. brevivena*, *E. cibcensis*, *E. desantisi*, *E. deserti*, *E.*

*formosa*, *E. hispida*, *E. inaron*, *E. japonica*, *E. longifasciata*, *E. lutea*, *E. luteola*, *E. meritoria*, *E. mineoi*, *E. mohyuddini*, *E. nigricephala*, *E. partenopea*, *E. pergandiella*, *E. porteri*, *E. quaintancei*, *E. reticulata*, *E. strenua*, *E. transvena* and *Eretmocer**us corni*, *Eretmocer**us haldemani*, *Eretmocer**us mundus*, *Eretmocer**us* spp. uniparental and *Eretmocer**us* spp. biparental. In India, *Chrysoperla carnea* and *Serangium parcesetosum* are also important.

## Predators

Predators are not strongly attracted to whitefly. However, more than 20 species of predators have been recorded on whitefly. Most species belong to families *Chrysopidae*, *Coccinellidae*, *Miridae*, *Ceraphronidae* and *Phytoseiidae*. *Euseuis hibisci*, a phytoseiid, is capable of feeding and developing to the adult stage by consuming 4-5 whitefly eggs per day. Some other mite species said to have potential as a predator of whitefly include *Ceracochrysa*

*cubana*, *Chrysopodes collaris*, *Chrysoperla carnea*,  
*Chrysoperla rufilaris*, *Delphastus psillus*,  
*Deraeocoris pallidus*, *Jalysus*  
*spinosus*, *Macrolophus caliginosus*, *Nabis*  
*alternatus*, *Orius insidiosus*, *Orius tristicolor*,  
*Rinacola* spp. and *Spanangonicus* spp.

#### Pathogens

Fungi are the only pathogen so far reported on whitefly. Fungi are still not used in any country, but some fungi recorded on cotton whitefly and being researched include *Paecilomyces farinosus*, *P. fumosoroseus*, *Aschersonia aleyrodinis* and *Erynia radicans*.

#### Trap crop

Whitefly prefer eggplant and cucurbits for oviposition, but nowhere is trap cropping used to minimize the population of whitefly.

#### Agronomic control

Defoliation without concurrent control of whitefly can be used as a control strategy.

|                                |                                                                                                                                                                                                                           |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Breeding for resistance        | Hairy leaves are preferred by whitefly. But, where jassid <i>Amarasca devastans</i> is a major pest, it is not advisable to breed for glabrous leaves.                                                                    |
| Spacing and irrigation         | Apparently plant spacing and irrigation intervals show no effect on whitefly population. Numerically, irrigated vs. non-irrigated and frequently irrigated vs. less irrigated fields show higher populations of whitefly. |
| Sowing dates                   | A late sown crop usually shows a higher whitefly population.                                                                                                                                                              |
| pH effect                      | Whitefly prefer high pH leaves.                                                                                                                                                                                           |
| Favorable agronomic conditions | Increased use of nitrogen, diversification and intensification of the cropping system                                                                                                                                     |
| Pest position on the plant     | Adults are mobile on the plant, but long distance dispersal is wind dependent. Females prefer upper, younger leaves for oviposition. Thus, eggs are generally found on the upper leaves, larvae on the                    |

middle leaves and pupae on the bottom portion of the plant.

#### Trapping

Yellow sticky traps have been widely used to monitor whitefly adults. Light of different wavelengths has also been tried.

#### Sampling

Adults are usually not uniformly distributed on the plant, but adults are still counted to establish the threshold for spraying. The average number of live adults per leaf are counted to determine whether to spray the crop against this pest. 5-6 adults/leaf is the generally accepted threshold.

#### Prediction

It is possible to develop crop simulation models of growth of cotton and population dynamics of whitefly. However, drastic effects of weather conditions and agronomic factors on population development make it difficult to forecast the whitefly population for any particular year.

Species  
reaction

Among the cultivated species, *G. hirsutum* has shown a high susceptibility to whitefly. Desi cottons, *G. arboreum* and *G. herbaceum* are tolerant to whitefly, but they cannot easily be utilized in breeding programs for *G. hirsutum*.

## Other

Newsletter

A newsletter *Bemisia* dedicated to whitefly is jointly published by Dr. Dan Gerling of the Tel Aviv University, Israel, and Dr. Lance S. Osborne of the University of Florida, USA, according to need and available material.

# Short Notes

- Cottonseed oil is used mostly for cooking and frying purposes. It is the preferred oil of potato chip manufacturers because it produces unique, buttery-flavored potato chips. In many cotton producing countries, cottonseed oil is a major source of vegetable oil. However, with the growing trend of consuming less fat and, particularly, fewer free fatty acids, it is feared that cottonseed oil may lose its market against other oils. In the USA, according to the Food and Drug Administration (FDA), “low in saturated fat” products must contain less than one gram of saturated fat per one-ounce serving size of 28.4 grams, or say less than two grams in 50 grams of potato chips. On average, cottonseed oil contains 26-27% saturated fatty acids. Assuming a typical oil content of 36% in potato chips, it is estimated that each one-ounce serving contains an estimated 2.65 grams of fatty acids, thus potato chips do not meet the FDA's required minimum limit of one gram per serving. A paper presented by Mr. Monoj K. Gupta at the 1995 Oilseed Conference showed that “low fatty acid” claims can be made by using only four types of oils --- canola oil, low linolenic acid canola oil, high oleic sunflower oil and low linolenic acid, low

saturated fatty acid soybean oil. If the “low in saturated fat” claim is not an issue, corn oil can be used in potato chips. After light hydrogenation, regular canola, soybean and sunflower oils can be used to meet the FDA standard. However, there is a great deal of concern about trans-fatty acids and their nutritional implications. Corn oil is also an alternative for reducing saturated fat content without claims of meeting the low saturated fat standard. Chip manufacturers will quickly shift to low fatty acid oils if such oils become available at low cost and without sacrificing shelf life. (Source: Cottonseed Alternatives, *The Cotton Gin and Oil Mill Press*, Volume 96, No. 11, May 27, 1995).

- **Whitefly Sampling Method**

When to start spraying against any insect has an economic impact as it determines the total number of sprays per season and, ultimately, the cost of production per unit area and per kilogram of cotton. Just as spraying too early is undesirable for a number of reasons, spraying too late also results in losses in yield. When to start spraying against any insect or insects actually depends on the thresholds established by researchers. Normally, in many countries, in order to start spraying against whitefly, the number of whitefly adults/leaf are counted and, if the number exceeds the

established threshold, spraying is recommended. In countries where the whitefly is a major problem, spraying the crop is advised if the whitefly population exceeds 5-6 per leaf.

In the USA, where the whitefly problem has caused heavy losses to cotton in addition to vegetables and fruits, particularly in Arizona and California, a new method of sampling the whitefly population was tested for general application. The “leaf-turn” method was developed in Arizona and has been found useful for farmers. Important steps of the sampling procedure are as follows:

- The size of the sampling field should not be more than 32 hectares in a one variety field. The field should have uniform agronomic treatments with the same or close planting dates.
- Select a plant at least 10 rows into the field. Always try to select a representative plant from the field. The selected plant should not be too tall or too short; it should not be heavily or less infested compared with other plants in the field.

- Once a plant has been selected, select the fifth true leaf on the main stem node from the terminal. Carefully turn over the leaf to the underside and count the number of whiteflies. If the total number of whiteflies is three or more, this leaf is infested.
- Select the second plant at 3-4.5 meters away from the first selected plant and similarly count the number of whiteflies on the underside of the leaf. Sample 15 plants and then move to another site in the field and sample 15 more plants. Once 30 leaves have been sampled, calculate the percentage of infested leaves.
- Compare the percentage of infested leaves with the table below. If the percentage of infested leaves reaches/exceeds 57%, the crop needs to be sprayed.

**Whitefly Adults/Leaf****Percent Infested Leaves**

|    |    |
|----|----|
| 1  | 14 |
| 2  | 28 |
| 3  | 39 |
| 4  | 49 |
| 5  | 57 |
| 6  | 64 |
| 7  | 70 |
| 8  | 75 |
| 9  | 79 |
| 10 | 82 |

The table also indicates the average number of whitefly adults for a certain percentage of infested leaves. If 57% of the checked leaves have three or more whiteflies, there are, on average, 5 whiteflies per leaf which is the threshold used in many countries. The “turn-over” method is simpler to use as there is no need to count the actual number of whiteflies on each leaf which may be much higher under high infestation (*Cotton Grower*, Volume 31, No. 6, June 1995).

- **Cotton Contamination**

The International Textile Manufacturers Federation (ITMF) undertakes a

cotton contamination survey biennially. Spinning mills in various countries are asked to indicate absence (non-existence/insignificant) or presence (moderate and serious) of fiber or string levels of woven plastic, plastic film, jute/hessian and cotton. They are also asked for similar levels of organic matter (leaves, feathers, paper, leather), inorganic matter (sand/dust, rust and metal/wire) and oily substances/chemicals (grease/oil, rubber, stamp color and tar). In regard to stickiness and seed-coat fragments, the mills are asked to indicate only if they experienced stickiness in the last 12 months. Though the survey is comprised of an unequal number of participating mills and types of cotton used in each country, it gives an indication of improvement or deterioration since the last survey. 275 mills from 26 countries participated in the 1995 survey. In total, 1,542 samples belonging to 83 cotton descriptions were evaluated. Data for the last four years are as follows:

### ITMF Cotton Contamination Survey

| Year | Degree of Contamination        |          |         | Stickiness | Seed-coat<br>Fragments |
|------|--------------------------------|----------|---------|------------|------------------------|
|      | Non-existent/<br>insignificant | Moderate | Serious |            |                        |
|      | (%)                            |          |         |            |                        |
| 1989 | 86                             | 9        | 5       | 21         | NA                     |
| 1991 | 85                             | 11       | 4       | 27         | 34                     |
| 1993 | 85                             | 11       | 4       | 26         | 36                     |
| 1995 | 81                             | 13       | 6       | 20         | 39                     |

According to the 1995 survey, there is a 2 percentage point increase in the seriously and moderately contaminated levels of cotton; accordingly, there is a 4 percentage point decrease in the samples which were either free of any contamination or were only insignificantly contaminated with the 16 above mentioned contaminants. Jute/hessian fibers and strings are the most common source of serious contamination, followed by organic matter and sand/dust. On average for the 1,542 samples, 13% of the cotton had serious contamination with jute/hessian string. Moreover, 9% of the samples were moderately contaminated with jute fabric. 3% of the samples showed serious contamination from

stamp color. Tar and rubber are the least found foreign matter in cotton. The stickiness situation seems to have improved in the last two years as only 20% of the respondents complained about stickiness, as against 26% in 1991. Data since 1991 show that ginning quality has deteriorated, resulting in higher seed-coat fragments. The 1995 ITMF *Cotton Contamination Survey* can be obtained free of charge from the International Textile Manufacturers Federation, Am Schanzengraben 29, Postfach, CH - 8039 Zurich, Switzerland, phone: 41-1-2017080, fax: 41-1-2017134.