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

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Introduction

Australian cotton yields have been either the world's highest or second only to those in Israel during the last two decades. Australia's average yield includes about 125,000 rainfed hectares (30% of total area), while Israel's total area is smaller (25-30,000 hectares) and all cotton is irrigated, two-thirds by drip irrigation and the rest by various types of sprinkler systems. The average rainfed yield in Australia is higher than the world's average yield, and the average irrigated yield is more than double the world's average. The Technical Information Section of the ICAC invited Dr. Greg A. Constable of Australia to write an article for the *ICAC RECORDER* on achieving high yields in Australia. According to Dr. Constable, the development of high-yielding varieties, proper soil management, including the avoidance of soil compaction, appropriate pest control and suitable weather conditions are responsible for such high yields. 45% of the contribution to high yields has come from breeding high yielding varieties, 25% from soil-nutrition-irrigation management, 20% from insect control and 10% from disease management. More details on the contributing factors to high yields in Australia are given in the first article.

The term integrated pest management is almost 40 years old and became popular because of the success of an FAO IPM program on rice in Asia. In cotton, the cost of complications from excessive use of insecticides motivates researchers and farmers to think of IPM. Now, IPM is more commonly associated with cotton than any other crop. Even though IPM is still not fully implemented in many countries, the significance of a multi-dimensional approach to pest control in cotton has increased tremendously in the last few years. Most programs are now directed toward distancing from chemical-based farming practices to a more sustainable approach. IPM is often mistaken to mean the elimination of pesticides, which may be true for some production conditions but untrue for others. Many issues regarding IPM, including international efforts, are discussed in the second article.

The 4th general meeting of the Interregional Cooperative Research Network on Cotton for the Mediterranean and Middle East Regions was held in Turkey from September 20-24, 2000, sponsored by ICAC, FAO and the University of Çukurova, Turkey. A report summarizing the highlights of the meeting is included in this issue of *THE RECORDER*.

The Technical Information Section of the ICAC has updated the database on "Current Research Projects in Cotton," and a published report is available. The report has four main sections: structure of research; complete addresses of institutes/organizations working on cotton in 45 countries; research projects in all production research disciplines, along with key researchers responsible for the projects; and email addresses of all researchers. The database is also available on the ICAC web page in a searchable form, and access to the database is free.

Meetings/Conferences

The World Cotton Research Conference–3 (WCRC–3) will be held in Cape Town, South Africa from March 10-15, 2003. The WCRC–3 will be held under the auspices of Cotton South Africa and the Agricultural Research Council of South Africa. Cotton South Africa is the apex body on cotton production,

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marketing, ginning, classing, fiber and textile technology, and quality control. Cotton SA also represents the government of South Africa in the International Cotton Advisory Committee. However, research on cotton is undertaken at the Institute for Industrial Crops of the Agricultural Research Council, which will host the Conference. More information in the form of a brochure for preliminary registration is available from the ICAC Secretariat and also on the ICAC web page at http://www.icac.org/ under meetings.

The ICAC, with major funding from the Common Fund for Commodities, is sponsoring the project "Improvement of the Marketability of Cotton Produced in Zones Affected by Stickiness–CFC/ICAC11." The Sudan Cotton Company, the Agriculture Research Cooperative of Sudan, CIRAD of France and the Textile Institute of France worked together on this project. The project has developed reliable methods to separate sticky from non-sticky cotton and to determine threshold levels for spinning sticky cotton by mixing it with non-sticky cotton under varying environmental conditions. The project is near completion, and the final workshop for the dissemination of results from the project will be held in France from February 5-7, 2001. More information on the workshop is available on the ICAC web page at http://www.icac.org/ under meetings.

The Beltwide Cotton Conferences of the National Cotton Council of America will be held in Anaheim, California from January 9-13, 2001. The theme of the Conferences will be "Possibilities, Progress, Promise." The booklet containing information on registration, hotel reservation and travel has been mailed by the National Cotton Council to previous attendees and is also available on line at www.cotton.org/beltwide. Information can also be obtained from the following address.

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The Components of High Yields in Australia

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Introduction

Using photosynthesis rates and season length, Baker and Hesketh (1969) calculated yield potential of cotton to be over 4,000 kg lint/ha. This yield is yet to be achieved, but in Australia we have documented instances of large fields with nearly 3,000 kg lint/ha, large farms which average more than 2,250 kg lint/ha and a national average which can exceed 1,700 kg lint /ha in some seasons.

High yields can give a low cost of production per unit of lint. Despite relatively high costs for insect control, weed control, planting seed and ginning, Australia had total costs of US$1.20 per kg lint in 1990/91, lower than all other countries surveyed except Argentina and Paraguay (Anon 1992).

The national yield average in Australia over the past five years has been in excess of 1,500 kg lint/ha, about 2.5 times the world average and only exceeded by Israel in other cotton producing countries (Anon, 1999). The yield trend in Australia in the past 30 years (Figure 1) clearly shows fluctuations between seasons that are more or less favorable, as well as the average increase of 23 kg/ha/year over that time. Meredith (1991) showed a similar increase in lower yield levels for the U.S., but the data showed a plateau in yield in the last 15 years. The Australian data shows that the trend continues and can easily be achieved, particularly in lower-yielding irrigated fields, correcting factors that have reduced their yield.

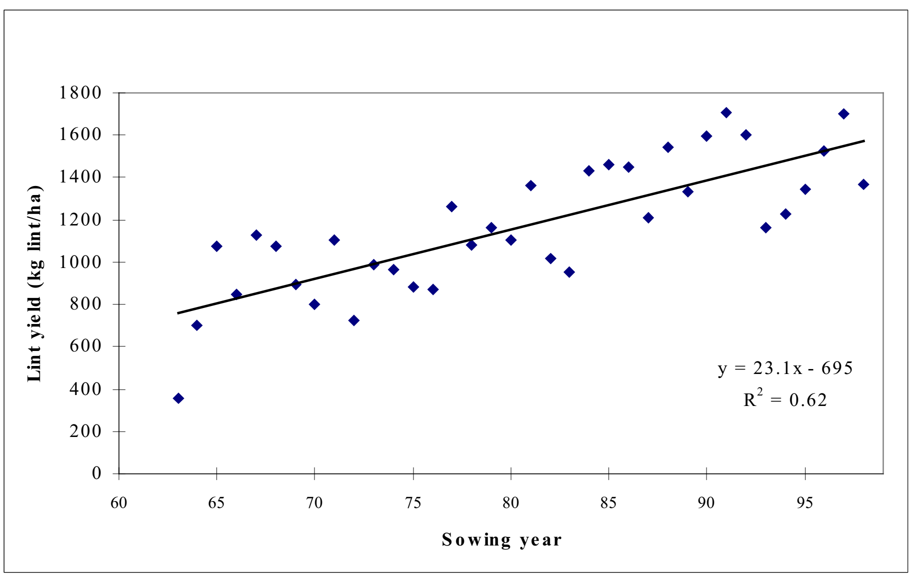

Figure 1. Average yield of the Australian cotton industry since 1963

Cotton is grown in Australia on a belt running north-south on the western side of the mountain range, about 200 km from the eastern coast of the states of NSW and Queensland (Figure 2). The total area is now in excess of 500,000 ha. There are about 5,000 ha of *G. barbadense* Pima cotton grown in the western areas of NSW. All other cotton is *G. hirsutum* upland cotton of medium to high fiber quality. About 80% of the crop is furrow irrigated from water gathered from dams upstream on rivers which run west and south from the mountain range. Irrigation water is regulated by state authorities and the irrigation allocation of about 6 megaliters/ha is varied according to the water supply held in the dams. Long droughts can be a severe production impediment. Most irrigated cotton farms also have on-farm storage dams for recirculating runoff from irrigation and rain. About 20% of the crop is raingrown which on average achieves less than half the yield of irrigated cotton.

The four central production valleys of the Darling Downs, McIntyre, Gwydir and Namoi account for more than two-thirds of production and have similar climate and soil types. Data presented in the following sections will use these locations as examples of typical production areas in Australia. Northern areas are warmer and wetter, while southern areas are cooler in spring and autumn as well as being drier in summer.

History

Only very small areas of cotton were grown in the years following the beginning of European settlement in 1788. Significant cotton was grown in Australia in response to a greater demand in the world market during the U.S. Civil War and when the boll weevil curtailed U.S. production. Once full-scale production in the U.S. was resumed, cotton growing in Australia contracted to a very small scale in Queensland. Production resumed in the early 1960s when high-input irrigated cotton growing commenced in three states, NSW, Queensland and Western Australia, in response to the construction of irrigation schemes.

Components of Yield and Progress

Yield is a consequence of many factors that make up the cropping system. The good yields in Australia can be attributed to favorable soil and climate, new well-adapted varieties and good management, which is encouraged and rewarded by the incentive of high gross margins. Variety development, improved management and information transfer have been assisted by well-coordinated research, partly funded by a levy from growers on each bale. A good network of cotton extension specialists is involved, with notable decision support initiatives such as SOILpak (McKenzie, 1998) and CottonLOGIC (Deutscher and Plummer, 1998) being produced. In more recent years, all major research and extension providers have been given federal funding to encourage collaboration in a Cotton Cooperative Research Centre. This concept has significantly enhanced the research, extension and education capacity for cotton related issues and will have major benefits in training the next generation of research and extension personnel. Cotton growers actively participate in research planning.

Another important component of a successful and vibrant industry is a progressive attitude from being a relatively new industry grown from a few pioneering and experienced irrigated cotton farmers from the U.S. who moved to Australia in the early 1960s. A classic example of the open attitude is the rapid adoption of okra leaf varieties in the mid-1980s (Thomson, 1994). This type of cotton has a different look and cotton farmers in other countries have been reluctant to adopt okra leaf.

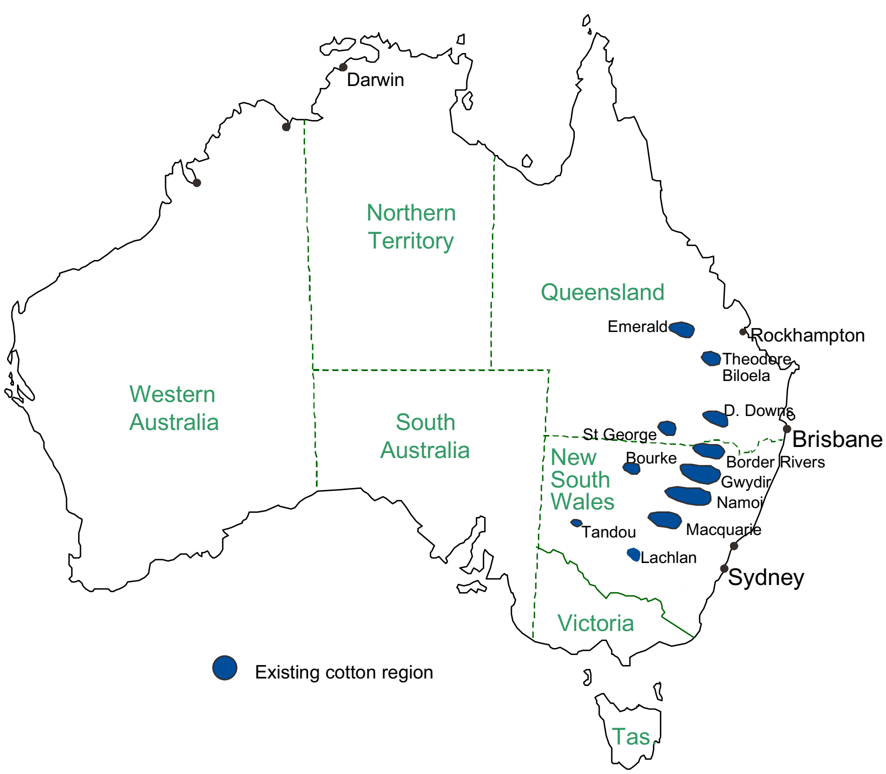

Figure 2. Major cotton producing regions in Australia.

The Australian cotton industry is highly mechanized, although some hand weed control is still practiced illustrating the low tolerance of weeds and their associated problems. The use of modules instead of trailers was quickly adopted, as well as large equipment such as eight to twelve row planters, cultivation equipment, and four-row pickers. All gins are high capacity.

The following sections detail the factors that have contributed mostly to the high and increasing cotton yields in Australia. The relative contribution of each factor will vary according to the season and circumstances, but it is most important to recognize that progress has been due to a combination of factors, rather than to any one in particular. All cropping practices have been evolving over the past 40 years, with the last 25 years in particular producing very significant changes in management to increase productivity and sustainability. For example, it is felt that soil structure has actually improved in the past 20 years. A suggested allocation of the relative magnitude of different factors contributing to cotton yield increase in the past 25 years is shown in Figure 3. Although these values are approximate, they illustrate the magnitude where data below have measured the contribution of new varieties to the increase, but it is not possible to accurately measure the relative contribution of other factors.

Variety

Breeding and variety evaluation programs have been part of cotton research in Australia for many years. Dedicated breeding in central Queensland was being done more than 70 years ago; other programs have been present in northern Western Australia and south and north NSW. By the mid 1970s, most breeding programs had been reduced or centralized at Narrabri, where CSIRO under Dr. Norm Thomson had initiated a new breeding program to develop full season varieties for the main cotton growing areas. Initially the program concentrated on improving tolerance to *Helicoverpa* - okra leaf varieties originated from this initiative. As time progressed, improved fiber quality (particularly strength), disease resistance (particularly bacterial blight and verticillium wilt) and regional adaptation (such as early maturity) became important breeding objectives. There are about eight major conventional and three transgenic CSIRO cotton varieties sold in Australia by Cotton Seed Distributors. A joint venture, between Cotton Seed Distributors international arm and Aventis, has CSIRO varieties also being sold internationally under the FiberMax name.

U.S. varieties were exclusively grown during the 1960s and 1970s, particularly Deltapine Smoothleaf, Deltapine 16 and Deltapine 61. CSIRO varieties with disease and insect tolerance and improved fiber quality became available from the early 1980s and by 1994 were being grown on more than 90% of the crop area, the remainder being Deltapine 90. Deltapine established a breeding program in Australia in 1991 and uses CSIRO germplasm for new variety development.

The CSIRO cotton breeding program runs a series of advanced line trials in 13 different locations in Australia each season. The series includes two varieties grown in the 1970s (Deltapine 16 and Namcala). This data set enables an accurate analysis of yield progress with obsolete varieties and a comparison of new genotypes with those standards.

Over the last 25 years, the lint yield of the two standard varieties (Deltapine 16 and Namcala) has increased by 13 kg/ha/year (regression of yield through time, data not shown). The increase represents progress with crop management which is detailed in the following sections, but when compared with the average increase by the industry in Figure 1, it shows that management has contributed about 55% of the yield progress through that time period, indicating that variety has contributed 45% of the progress.

Since 1983, the yield of new genotypes has increased by 1.86% per year when compared with the standard varieties. The increase is another measure of the progress with plant breeding and represents the combination of yield potential with adaptation to local soil types and climate and with resistance to diseases such as bacterial blight, verticillium wilt and alternaria, and with some tolerance to insect pests in okra leaf varieties. The improved fiber properties enable ready export marketing, the destination for more than 90% of production.

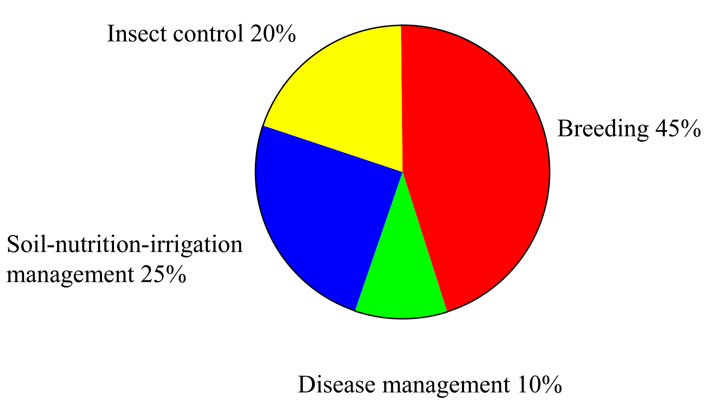

Figure 3. A suggested relative contribution of some important factors contributing to the increase in cotton yields in Australia in the past 20 years.

Soil Management

The most common soil type used for cotton production in Australia is an alkaline heavy clay. The soil is sometimes sodic at depth but it is naturally fertile. All locations receive nitrogen fertilizer at rates up to 200 kgN/ha, depending on cropping history; about half the fields receive phosphate at rates up to about 20 kgP/ha; and less than a quarter of fields receive potassium at rates up to 80 kgK/ha. Foliar fertilizer including low rates of zinc (less than 200 gZn/ha) is applied to about a quarter of fields, in recognition of the low availability of zinc in alkaline soils. Fertilizer management is very good, with little evidence of any nutrient deficiency constraining yield (Constable *et al*., 1988; Constable *et al.*, 1992). There is increasing awareness of the need to reduce mining of nutrients and more growers are replacing removed nutrients as fertilizer, regardless of response to that fertilizer.

Another feature of the high clay is the high water holding capacity—up to 195 mm total available water in the root zone (Chan and Hodgson, 1981). This characteristic is an advantage in extending irrigation intervals.

The disadvantage of heavy textured soils is susceptibility to waterlogging and to soil compaction. Yield reductions from waterlogging directly and from nitrogen and iron uptake inhibition have been documented (Constable and Hearn, 1981; Hodgson and Chan, 1982). Management of fertilizer, irrigation design and scheduling, to avoid these problems, has been researched (Hodgson, 1982; Hearn and Constable, 1984; Hodgson and MacLeod, 1987) and adopted by growers.

Soil compaction will occur if wet soils are cultivated or trafficked while they are wet (Daniells, 1989; McGarry, 1990). The solution is to avoid these circumstances, with standard practice now for minimum tillage on permanent beds; restoration of compaction relies on rotation with cereals to dry and crack the soil (Daniells, 1989; Constable *et al.*, 1992). The average crop rotation in cotton systems is two years cotton followed by one year of wheat. This rotation has soil structure, soil fertility and disease benefits. Improvements in soil structure also benefit irrigation scheduling and water use efficiency.

The SOILpak manual (McKenzie, 1998) was produced from research and extension to promote good soil management via improved soil structure and fertility.

Insect Management

The most significant insect pest in Australia is the *Helicoverpa* bollworm complex (Evenson and Basinski, 1973; Hearn and Fitt, 1992). There are two species: *H. punctigera* and *H. armigera*, with the latter being the greatest problem in terms of developing resistance to synthetic pesticides (Forrester *et al.*, 1993). These species are numerous in all regions every season. The cotton industry in the Ord region of north-Western Australia failed because of large numbers of resistant *H. armigera* up to 1974, when 34 insecticide sprays were required (Hearn, 1975). Under heavy *Helicoverpa* pressure, it is not uncommon for unsprayed experiments to have near-zero yield.

Currently, the most conventional cotton in Australia is sprayed for *Helicoverpa* species about ten times, with another two sprays for other pests such as spider mites (*Tetranychus urticae*), thrips (*Thrips tabaci* and *Frankliniella schultzei*), mirids (*Creontiades dilutus*), aphids (*Aphis gossypii*) and tip borer (*Crocidosema plebiana*). Mites can be a significant pest (Wilson, 1993), but the others are irregular in occurrence (Evenson and Basinski, 1973).

Control of multiple pests and large numbers of potentially resistant *H. armigera* can be difficult. Research and extension programs have emphasized an Integrated Pest Management (IPM) approach (Brook *et al.*, 1992) with chemical group rotation, biological control, resistant varieties, cultural control and the use of damage thresholds. Adoption of chemicals and varieties has been very good, but discipline with damage thresholds has been disappointing. Incentives for change have come from environmental problems, including contamination of stock and waterways. By the year 2000, the imposition of restrictions on some chemicals and the establishment of the Best Management Practice program industry will see most growers adopting more elements of IPM. The computer decision support package, CottonLOGIC (Deutscher and Plummer, 1998) has been created to assist with recording and integrating information for IPM decisions.

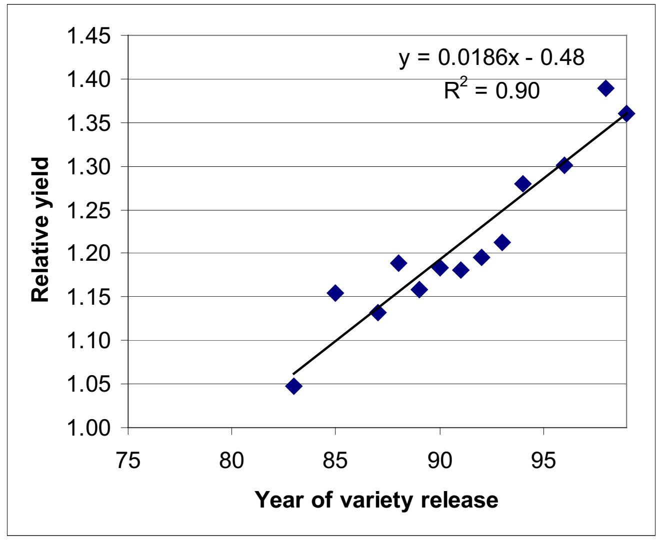

Figure 4. Yield improvement of released CSIRO cultivars according to their year of commercial release. Relative yield is the yield of each cultivar as a ratio with obsolete control cultivars (Deltapine 16 and Namcala). Pooled data for up to 13 locations.

Transgenic cotton expressing Monsanto's Cry1Ac Bt gene (trade name Ingard) has been grown in Australia since 1996, available in both CSIRO and Deltapine germplasm. This technology has led to a halving of insecticides required for *Helicoverpa* control (Constable *et al.*, 1998). Resistance management practices imposed by regulatory authorities have limited this technology to 30% of crop area until two gene varieties are available in about 2003.

Disease Management

A number of significant diseases are present in Australia. Bacterial blight (*Xanthomonas campestris* pv *malvacearum*), verticillium wilt (*Verticillium dahliae*) and other pathogens are most likely endemic to Australia and reside in weeds in low density. Black root rot (*Thielaviopsis basicola*), alternaria leaf spot (*Alternaria macrospora*) and a new strain of fusarium wilt (*Fusarium oxysporum* fsp *vasinfectum*, Kochman 1995) are also significant and cause expanding problems in at least some production areas every season.

Both varietal resistance and cultural control such as crop rotation have managed these diseases. The combination of those factors has led to bacterial blight essentially being eliminated by resistant varieties, and verticillium wilt being considerably reduced in incidence by varietal resistance and crop rotation with cereals (Reid *et al.*, 1999).

Climate

Two aspects of climate in the Australian cotton belt are positive for optimizing cotton yield: temperature and rainfall pattern. Summer temperatures in the majority of production areas average 33/19^{o}C maximum and minimum. This temperature range is near optimum for cotton growth keeping most of the day within the range for high photosynthesis (El-Sharkawy and Hesketh, 1964; Ludwig *et al*., 1965; Downton and Slatyer, 1972; Burke *et al*., 1990) and being low enough during the night to limit dark respiration (Hesketh *et al*., 1980). Early soil preparation and good seedbeds ensure adequate germination and seedling development during spring when temperatures are lower. Management of the crop for earliness will have fiber development complete before temperatures fall in autumn.

Rain is very erratic in Australia, with considerable extremes from droughts to floods in the cotton belt. The month of April is the driest on average and the time when peak harvest occurs. Temperatures are still high in April for good drying conditions if rain does occur, so problems with rain reducing yield and fiber quality at harvest are infrequent.

Summary

This paper has specified the factors most likely involved in contributing to high yields of cotton in Australia. There are human factors as part of a young and vibrant industry responding to attractive gross margins. Direct factors that cannot be controlled and which are very important include an optimum temperature and rainfall pattern, and a soil type with high fertility and water holding capacity. Management factors that exploit the good conditions, and which are continually being improved to produce higher yields, include new varieties, soil management (affecting soil structure, soil fertility and water use efficiency) as well as disease and pest control. These factors make up a package that gives a national average yield in excess of 1,500 kg lint/ha, with an increase of 23 kg lint/ha/year. These increases can be sustained.

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Integrated Pest Management in Cotton

What Is Integrated Pest Management (IPM)?

The term "Integrated Pest Management" was coined over four decades ago and is now the most widely used catchword in agriculture production, particularly in cotton and rice. IPM can be defined in many ways. According to the Food and Agriculture Organization of the United Nations, IPM is "a broad based ecological approach to pest control utilizing a variety of control technologies compatible in a pest management system." IPM is a durable, environmentally and economically justifiable pest control system whereby damage caused by insects, diseases and weeds is prevented through the use of natural factors and, if needed, supplemented with appropriate chemical control measures. IPM can also be defined as a system that controls pests and contributes to long-term sustainability by combining judicious use of biological, cultural, physical and chemical tools in a way that minimizes the risks of pesticides to human health and the environment. The significance of IPM has increased in recent years and is now accepted as the best approach to pest control in terms of long-term sustainability of cotton production, environment protection, human safety and sound profitability.

Why IPM?

Insecticides were adopted at different times in different countries. Pesticide use on cotton started in the USA long before it started in many other countries. Cotton researchers discovered in the 1950s that insects were developing resistance to pesticides due to repeated exposure. Researchers were alerted to develop strategies that relied more on natural mortality factors. The need for IPM increased as other effects of pesticides, and particularly of insecticides, became known and the cost of pest control operations exceeded economical levels due to increases in the number of sprays required every year. One of the first successful approaches was the concept of economic threshold levels to replace calendar spraying. The concept works and is still one of the most popular recommendations in insecticide control. Nevertheless, thresholds cannot stop the consequences of insecticides. It can be rightly claimed that IPM is a response to the failure of many chemical pesticides to provide long-term solutions to pest problems.

Why Were Insecticides Adopted?

Crops have been grown since time immemorial, first under natural conditions and then under cultivated and supervised growing conditions. Insect pests existed on crops long before they became a threat to yield and quality. Insect pressure built up slowly, and intensive cropping is probably a major factor responsible for the faster multiplication of insects. Over-wintering has become easy and the continuation of insect generations year after year has become more feasible. Insects have learned to live under hardship conditions and they explore a variety of alternate host plants in the absence of a primary host. When insecticides were still not available, insect pressure increased, and losses due to insect damage exceeded economical limits, researchers were bound to look for artificial means of controlling insects. Researchers' efforts, in a struggle to fight insects, received a great impetus from some international events. Once the chemical control of insects was confirmed, insecticides were not only aggressively promoted but quickly adopted. There could be many more claims on why insecticides were adopted so quickly, but following are the two most important reasons that convinced farmers throughout the world to use insecticides and make them a regular component of production practices:

- Insecticides were shown to be the most effective. There were, and still are, many means of controlling insects but none of them was comparable to the effectiveness of insecticides. When an insecticide was sprayed, results became visible in the shortest possible time. And, if insecticides were sprayed in the recommended dose and the right way, the effect was always positive.
- The economic benefit of insecticide use was much higher compared to the cost of insecticides at the beginning. Regardless of how effective insecticides were, if the cost-benefit ratio had not been good, farmers would never have adopted them. Extremely high benefits—in terms of higher yields—compared to the cost of the product, including application, convinced farmers to go for insecticides.

Does IPM Mean Elimination of Insecticides?

IPM has become so popular that everybody claims to apply it. Pesticide companies encourage IPM to increase sustained use of pesticides while others, particularly researchers and extension workers, promote IPM to minimize dependence on pesticides. IPM is also often mistaken as an alternative technology against insecticides and misunderstood as altogether the elimination of pesticides. In IPM, the emphasis on reducing pesticide use increased as pesticide costs increased beyond economic limits. Although the target could be the elimination of insecticides, it might not be possible to do so everywhere. So, at this stage the IPM approach has the primary objective of minimizing pesticide use without sacrificing yield and quality, which is possible through the integration of various other approaches for pest control.

What Was Ignored in a Haste to Adopt Insecticides?

Many aspects of insecticide use were ignored in an effort to utilize an efficient and cost-effective method for controlling insects and minimizing losses in yields. If the negative aspects were not ignored, at least they were not properly analyzed and understood. Had the negative impacts been foreseen, the adoption of insecticides would have been more cautious, which would have prolonged their use. The following implications of insecticide use were overlooked:

- Currently, one of the most important concerns of farmers is the development of resistance to insecticides. If not ignored, it was not anticipated that insects would develop resistance to this extent. Fortunately, not all insects have an aptitude to develop resistance, as have some of the most notorious insects like whitefly and the bollworm *Helicoverpa armigera*. Because resistance has multifarious implications, it has been taken more seriously in insecticide use than in other pesticides. The cotton industry has learned lessons from the experience with insecticides, which are evident from similar concerns raised with respect to Bt cotton, even in the first year of its large-scale commercial production in Australia and the USA. Transgenic cotton toxic to bollworms is in its fifth year of production, and resistance to the Bt gene has not yet been observed but is still a concern.
- Once an insect develops resistance to a group of chemicals, chances are it may also automatically develop resistance to another group of chemicals. Not only was resistance not anticipated, but farmers and researchers were not prepared to face cross-resistance problems. Early warnings of cross-resistance were not enough to properly study and manage the problem in most countries.
- Insecticide use extended beyond expectations. The rate of adoption was fast and, in spite of the pesticide industry's vigorous programs to extend insecticide use through qualified staff, demand surpassed plans for its strict implementation. Pesticide companies realized the need for direct training of farmers in pesticide handling and use, and undertook extensive training programs in most countries.
- One of the important components of the pesticide industry, particularly with respect to quality, has been distribution through dealerships. This weak link and its effects seem to have been skipped at the time of introducing insecticides in many countries.
- Pesticide use was new in agriculture and it was not anticipated that it could have serious effects on the pest complex. Many conclusions—like early-stage use of pyrethroids could enhance the chances of late season mite attack—were drawn. In countries where a number of sucking pests affected the crop at an early stage, effective control of one sucking pest year after year changed the status of pests. A major sucking pest lost its significance and a minor sucking pest became a major pest among the sucking complex. Similar changes have happened in bollworms, and the cotton bollworm *Helicoverpa armigera* has emerged as the number one pest on cotton in the world.
- High insecticide use turned cotton into a more technical crop compared with other field crops. When to spray, how to spray and what to spray became the most important questions in the cotton production system.
- Breeding for high yield and improved fiber quality served as a focal point in cotton development. According to studies undertaken by the ICAC, there are about 253 production research institutes working on cotton in the world, and almost every one has a program to develop new varieties. Breeding is still the most researched area in cotton but insecticide use has definitely shifted the emphasis toward entomology and converted cotton production into a pesticide-dominated management practice.
- Insecticide use introduces drastic changes in the agronomic requirements of cotton plants. Higher boll retention on plants

enhanced the need for different nutrients. Shorter stature varieties have been developed and plant efficiency has improved from 30% to close to 70% in many countries. The share of input use going to seed and lint production has increased relative to vegetative mass.

- Insecticides were initially used for effective control of insects for higher productivity. Though not properly assessed in terms of what level of which bollworm/sucking pest would result in how many yellow spots or how much stickiness, an effective bollworm control would reduce yellow spots and improve the grade of cotton. Higher grade means higher price.

What Are the Components of IPM?

IPM is a multidimensional approach that consists of cultural, agronomic, regulatory and many other components. Each component has to be applied in order to achieve the maximum benefit from an IPM system. In broad terms the components of IPM are:

Cultural Control

Cultural control, also called physical control, is comprised of operations undertaken by the farmer to produce conditions unfavorable for pests to survive or multiply. Monoculture is common in cotton, and a simple example of cultural control is a crop rotation that interrupts the normal life cycle of a pest by changing the environment to one in which the pest cannot flourish. It is a strategy that requires changes to accommodate non-pest sharing crops in the production system without serious economic implications. Another form of physical control is the "mating disruption" technique involving the use of sex pheromones, which are chemicals similar to the ones produced by female insects to attract males for mating. Scientists have been able to analyze the chemistry of sex pheromones in many insects and reproduce them synthetically for use in commercial fields. When pheromones are placed in the field, males are strongly attracted and get confused, resulting in mating disruption. Less mating means a lower population. The other formulation of such a technique is the production and release of sterile moths, which has proved very successful in the control of the pink bollworm *Pectinophora gossypiella*. Similar techniques could be found for other pests, but the importance of traditional cultural methods like uniform planting, weed-free and clean fields, optimum plant nourishment, and longer host-free periods, cannot be ignored.

Biological Control

Biological control of insect pests existed even before chemical control was invented. The fundamental principle of biological control is that every pest has natural enemies-predators, parasites or pathogens—and introducing or encouraging such enemies can control the population of the target pest. There are three approaches to biological control:

- Research has established that some major and most damaging cotton insect pests have natural enemies. Production practices that minimize the destruction of beneficial insects are required. Production practices including the minimum use of insecticides and appropriate insecticide timing can encourage the multiplication of beneficials. A detailed article on an approach developed in Australia to improve the beneficial-to-pest ratio was published in the June 2000 issue of *THE ICAC RECORDER*.
- If natural enemies do not exist in one set of production practices, there are possibilities to import and establish biological agents. But it is very important that all aspects of such introductions be properly considered and analyzed. There is a possibility that a beneficial may be effective against the target pest but could also affect other beneficials already working in the system. Nowadays, biologists are required to carry out extensive research, before a control organism is released, to find out whether it will attack species other than the pest species.
- Even if the population of a beneficial is too low to be effective against the target pest and the production practices followed do not help to establish a desirable relationship level, the effectiveness of a particular beneficial can be increased through mass production in the laboratory and release in the field as and when required. The biological control system followed in Uzbekistan uses this technique and is one of the most successful programs in cotton. The parasitoid *Trichogramma pintoi*, and to a lesser extend *Bracon herbetor,* are reared in bio-factories and systematically released in cotton fields every year. The moth-catch-data in pheromone traps are used to decide whether or not the *Helicoverpa armigera* and *Agrotis* populations have reached the threshold level for egg parasitoid release. The augmentation program has proved its worth in Uzbekistan, and the average number of insecticide sprays on cotton is only 1-2 per season. A number of whitefly control agents are also known to exist in many countries but it has been established that they are only effective at high population levels of the target pest. A wasp, *Catolaccus grandis,* was found to be very effective against the Mexican boll weevil *Anthonomus grandis,* but economical rearing methods are not available. Trichogramma seems to be the most widely used biological control agent in cotton producing countries.

Host Plant Resistance

Certain morphological plant features can serve as a hindrance to the easy multiplication of pests. Enough literature is available on the usefulness of special characters and their side effects, if any, on the productivity and quality of cotton. Genetic control of desirable features has been established and they can be easily incorporated into the desired cultivars. Some of these special characters provide a strong defense, while others may be only helpful in minimizing the multiplication of pests. Leaf hairiness is a well-established plant character that offers strong resistance to jassid *Amrasca devastans,* a feature that has been successfully utilized in many countries. But the problem lies in the impact of such features on the multiplication of other insects. While leaf hairiness, in the form of dense and longer hairs, serves as a great annoyance for jassid, it helps the whitefly to establish better. Nectariless leaves, frego bracts and okra leaf shape, though utilized in many countries, cannot be used as a replacement for insecticides, but they certainly help to minimize insecticide use. However, such characters must be used cautiously so that they do not become a favoring factor for other pests.

Chemical Control

Chemical control of insect pests through pesticides is an integral part of IPM, at least until an efficient replacement is discovered. Problems have been created not by the use of pesticides, but by their misuse. The wise use of pesticides requires sound knowledge of the biology and ecology of target insects and a thorough understanding of the agroecosystem. It is also important to know which is the most suitable chemical to be applied, when it should be applied and how it should be applied. Finding the most vulnerable stage of the insect life-cycle to be attacked, developing new pesticides and insect growth regulators, and other developments could augment the chemical control process. The key to chemical control is its use in a way that complements rather than hinders other elements in the IPM strategy.

What Are the Objectives of IPM?

The chemical control approach is designed to hit insects hard and provide immediate relief to the crop from damage. The IPM approach is a balanced utilization of cultural, biological, genetic and chemical methods to control insects. Such an approach should not be at the cost of farmers' profit and risk to the environment. Thus, the objectives are:

- ✓ Maintain yield
- ✓ Reduce cost of production and improve profitability
- ✓ Do not rely on single control strategy
- ✓ Utilize control methods safe to the environment
- ✓ Minimize pesticide use
- ✓ Enhance the sustainability of growing cotton

What Is the Role of Bt Cotton in IPM?

Bt cotton could be a very successful element of an integrated control strategy. Under the components discussed above, utilization of the Bt gene to avoid spraying against bollworms now, and maybe against a variety of insects in the near future, would fall under the category of host-plant resistance. In the case of special morphological characters, a natural occurrence of a particular feature is utilized, while in Bt cotton the same effect is created through artificial manipulation of genetic material. Bt cotton can be even more important for the successful implementation of an IPM program because the effect of the Bt gene is stronger than the naturally-occurring special characters. However, it is understood that the successive use of the Bt gene or any other built-in genes is going to affect the pest complex for years. If a particular pest is suppressed for years, a minor pest may become major and new pests may also appear on cotton. Under such circumstances, Bt cotton may cause a significant impact on future strategies in the implementation of IPM.

What Is "100% Area" Under IPM?

Some countries have plans to successively increase area under IPM. IPM does not work like an off and on switch, either you have it or you do not have it. It is not a package of formulated strict actions either, to be implemented on a percentage basis as a replacement of some other technological package. Unlike insecticides, herbicides, insect pheromones, etc., IPM is not a commodity that one can buy in a shop and start implementing. It is quite possible that even if IPM is implemented, insecticides would still be used on a regular basis. Under such conditions, the objective would be no increase in pesticide use. This is particularly true for production conditions where insecticide/pesticide use is still low. On the other hand, the strict application of IPM techniques could also eliminate the need for insecticide use. Thus, a number of factors will determine the impact of IPM in reducing the role of pesticides in cotton production. IPM comprises so many insect control measures other than chemicals that it is hard to say it is not implemented on a specific area or that it is 100% implemented on another area.

Can There Be One IPM Program for Many Countries?

IPM programs will vary depending upon the pest complex and agroclimatic conditions, but it is certain that an area-based IPM program has higher success than a farm-based program. IPM recommendations are based on many factors including varieties, planting time, weather, and even target yields and farmers' know-how. Fundamental principles will remain the same, but no two IPM programs are identical. Generic recommendations have to be adjusted according to growing conditions in a particular country or even according to different areas within countries. Adjustments may also be required from one season to another depending upon deviations from normal pest behavior.

What Are the Main Benefits of IPM?

Conventional chemical-based production practices are perceived as low risk because pesticides provide assured control and lower the chances of variations in yields and product quality, which are very important for cotton. But once IPM practices are established, the risks of insect damage are also reduced. In the long run, the following benefits are expected from IPM:

- ✓ More efficient use of inputs, particularly pesticides

- ✓ Reduced health hazards
- ✓ Reduced pollution of ground and surface water and the environment
- ✓ Less danger to biodiversity loss
- ✓ Improved sustainability of farming practices
- ✓ Lower chances of creating complicated problems like development of resistance to insecticides
- ✓ Improved profitability of cotton production by lowering costs and maintaining yields

How Can Governments Affect IPM Programs?

Government programs can have tremendous effects on the successful implementation of IPM programs. Even if cotton production is 100% in the private sector, governments can influence the fate of IPM programs in two major areas: policy incentives and regulations. Governments can provide subsidies to pesticides, as most did at the beginning of pesticide adoption, or they can encourage or ban imports of specific products. Governments can also allow free imports of generic pesticides and require strict quality-control monitoring. Regarding regulations, governments can enforce laws to grow specific varieties in specific areas (zoning), can force farmers to clear fields and destroy sticks by certain dates, can have specific cotton-free periods, and many other regulations including those related to handling, storage, disposal, processing and marketing of cotton, which help in the establishment of a long-term pest control strategy.

What Is the Future of IPM?

Pest control is a continuing struggle. Though pests have been eliminated in some countries—one of the best examples is the elimination of the boll weevil from the Southeast and other parts in the U.S.—total eradication of a pest is not very common. The chances of eliminating a pest of native origin are even lower compared to introductions like the Mexican boll weevil in the USA. This is true for other categories of pests, including weeds. Thus, control against insect pests is a long-term struggle that is going to intensify with complications in pest patterns.

The consequences of heavy reliance on chemical control are becoming more evident in cotton producing countries throughout the world. New research efforts are more aggressively looking for ways to control pests without relying heavily on pesticide use. The importance of a knowledge-based multi-dimensional approach has been acknowledged and IPM has been accepted as a promising approach. The current trend shows that more people and countries will adopt IPM, and the role of IPM in the cotton production system will increase. The role of farmers in diagnosing pest problems and the development of solutions will also increase.

What Are the International Efforts on IPM?

The Food and Agriculture Organization of the United Nations has made numerous efforts to popularize IPM in cotton. In addition to presentations and advocacy at various international meetings, FAO has organized a number of international events on this issue in the recent past.

The IPM program of FAO, started in rice in 1982, proved very successful in South and South-East Asia. The Farmers Field School concept was developed, and the FAO later encouraged many countries to try it on cotton and other crops. In February 1991, FAO organized a Regional Workshop on Integrated Pest Management in Cotton in Pakistan. One of the recommendations from this workshop was to develop and implement national IPM programs and formulate a regional project on IPM in cotton (Report on the FAO-PCCC Regional Workshop on Integrated Pest Management in Cotton, Pakistan Central Cotton Committee, Karachi, Pakistan). More recently, the FAO Regional Office for Asia and the Pacific started a project, "Integrated Pest Management for Cotton in Asia," which will be executed in Bangladesh, China (Mainland), India, Pakistan, the Philippines and Vietnam, with financial help from the European Community. The Farmers Field School approach will be followed and national IPM programs will be strengthened in five years.

The ICAC has always promoted safe and sustainable control methods against pests. So far, the ICAC has sponsored eight projects for funding from the Common Fund for Commodities. While one project, approved as a Fast Track project, will study the extent of resistance to insecticides by the cotton bollworm in project countries, four out of seven other projects are directly related to the IPM approach in twelve countries. The projects are

- Integrated Pest Management for Cotton (Egypt, Ethiopia, Israel and Zimbabwe)
- Integrated Pest Management of the Cotton Boll Weevil in Argentina, Brazil and Paraguay
- Genome Characterization of Whitefly-Transmitted Geminiviruses of Cotton and Development of Virus-Resistant Plants Through Genetic Engineering and Conventional Breeding (Pakistan, UK and USA)
- Sustainable Control of the Cotton Bollworm *Helicoverpa armigera* in Small-Scale Cotton Production Systems (China (Mainland), India, Pakistan and UK)

Fourth Meeting of the Inter-regional Cooperative Research Network on Cotton for the Mediterranean and Middle East Regions

Adana, Turkey, September 20-24, 2000

The 4th Interregional Cooperative Research Network on Cotton for the Mediterranean and Middle East Regions has ten working groups: Breeding and Genetics (WG-1), Variety Trials (WG-2), Growth Regulators (WG-3), Nutrition (WG-4), Plant Growth Modeling (WG-5), Water Management (WG-6), Integrated Pest Management (WG-7), Fiber Technology (WG-8), Biotechnology (WG-9) and Economy (WG-10). Each working group has its own chairman, and the General Coordinator of the Network coordinates overall activities. A joint workshop and meeting of all working groups was held in Adana, Turkey, from September 20-24, 2000. The major objectives were to exchange information on subjects related to cotton within and among the working groups and to plan future activities. The Cotton Research and Application Center of the University of Çukurova, Adana, Turkey, hosted the meeting. The Food and Agriculture Organization of the United Nations, ICAC, the University of Çukurova, the Cotton Research and Applications Center, the Adana Exchange, the Sanliurfa Exchange, Adana's Chamber of Commerce and some private companies sponsored the meeting. Delegates from Bulgaria, Greece, Iran, Israel, Italy, Japan, Sudan, Syria, Turkey, the USA, Uzbekistan, CIRAD-CA of France, FAO and ICAC attended the meeting. A list of participants is enclosed.

The program consisted of country reports, a review of activities by the working group chairs, technical papers from various countries and activity plans until the next meeting of the Network. Over 70 papers and reports on all disciplines of production research, and some papers related to production economics, were presented in three days. Highlights of the meeting are reported here.

The country reports provided interesting information about numerous countries, including: 90% of irrigation water for cotton is from recycled water in Israel; licenses from the government are required to grow cotton in Syria; a major shift in cotton production among regions is occurring in Turkey; the development of extremely short duration varieties in Uzbekistan; efforts are underway to promote cotton cultivation in the South of Italy; and efforts continue to separate sticky from non-sticky cotton in Sudan.

Researchers in Greece studied out-crossing using glandless cotton and red leaf color for two years and concluded that natural crossing decreased as the distance between the varieties planted increased. Mean out-crossing in the adjacent rows between glandless vs glanded and green vs red leaf color was the same. Out-crossing under Greek conditions even in plants grown in adjacent rows was less than 5%. Lower out-crossing under current production practices was correlated to insecticide use. A paper from Turkey concluded that out-crossing varied in different regions in Turkey and was as high as 13.3% in some cases. Discussion diverted to the flying distance of insects carrying pollen grains, time for which the pollen grains remain viable, and receptivity of the ovules. However, it was concluded that it was safe to grow two varieties even for seed purposes at a distance more than 10 meters in Greece, but in Turkey it requires longer distances.

Survival and performance of any good variety depends on the seed production system. A good variety may not be able to remain under commercial production if it is not backed by good quality seed production. At least two papers, one each from Turkey and Greece, narrated the seed certification and registration systems in these countries. The seed production system in Turkey requires expansion for meeting the needs of all cotton farmers for certified seed, while in Greece all farmers use certified good quality seed and it is all delinted. The seed production system on scientific lines is almost 50 years old in Turkey and the Seed Control and Certification Center of the Ministry of Agriculture is responsible for the implementation of certification standards. Any variety that has been bred/improved in Turkey or developed outside can be registered in Turkey. For commercial production in Greece, the company/enterprise has to have a license for seed multiplication, and only seed varieties that are included in the national or European Community catalogue can be produced. The company that multiplies seed of any variety has to submit a control and certification form with all the information on the variety. The Hellenic Cotton Board oversees the quality control aspect through field inspection and monitoring at various stages of seed processing, storage and distribution. In order to include a new variety on the national catalogue, it has to be properly defined for its distinctiveness, uniformity and stability. The variety is evaluated for its yield performance, agronomic characteristics and utilization value and it has to be tested for two years, and sometimes three years.

Turkey is on the verge of adopting machine picking. The main reason is cost. Work is being done related to suitable plant types for machine picking, the effects of machine picking on agronomic needs, and fiber quality. Machine picking resulted in 11-16% loss in yield as against 2-7% in the case of handpicking. Trash content in machine picked cotton ranged from 10-14% in different varieties. It was concluded from the replicated trials that there is no urgent need for a change in the varieties planted in Turkey, and the varieties currently grown can be machine picked. However, there is a need to study the changes in cultural practices and other agronomic requirements of the plant as a prerequisite for mechanical picking. It is estimated that about 10 picking machines have already been imported into Turkey.

Genetic engineering, and the cultivation of Bt varieties in particular, came under discussion many times. The Bt cotton variety trials conducted in Israel showed 5-37% increases in yields, a savings of up to 50% in pest control costs and early maturity, representing an economic advantage of US$300-700/ha (10-20% of total production costs/ha) under Israeli conditions. Israel still does not have the regulatory requirements completed to plant Bt cotton on a commercial scale, but it was concluded that some production areas in Israel are suitable for Bt cotton. Greece has established a protocol for developing cotton resistant to *Verticillium dahliae*. During 1999/00, cotton represented 9% of genetically engineered crops grown in the world. In the USA, transgenic cotton area increased to 72% of the total cotton area in 2000/01 as against 60% in the previous season. Concerns were expressed not only about the development of resistance to the toxin by the target bollworms in Bt varieties, but also that the elimination of sprays against sucking insects, which were controlled in an effort to control bollworms, could enhance the sucking pest population. Such a change in pest pressure could result in long term changes in pest control in cotton in some countries.

Many other issues related to commercial cultivation of transgenic cottons were discussed in the meeting, including the impacts on the environment, out-crossing between pure and transgenic varieties, utilization of this technology for quality improvement, availability of this technology for other countries, and regulatory requirements for large scale production. Uzbekistan is trying to develop its own transgenic varieties having early maturity, high oil percentage, high ginning outturn, resistance to pathogens and better fiber quality. Uzbekistan maintains a huge germplasm collection from all over the world and has used it effectively in developing genotypes of specific interest. *G. hirsutum* has been crossed with the diploid species *G. trilobum, G. sturtii* and *G. raimondii* for developing amphidiploids having a complex of desired characteristics. By using non-traditional approaches, *G. barbadense* varieties with four and five locks have been developed.

Control of insect pests remained a major issue for discussion. In the Çukurova region of Turkey, insect pressure has increased and, consequently, area is going down. Whitefly has become a serious pest with losses that sometimes go up to 67%, and the pink bollworm is already causing damage to yield. Biological control is not popular in Turkey but it is realized that poor planting seed quality could be a reason for the high pink bollworm population year after year. Turkey has started an IPM program in four areas with the objective of minimizing insecticide use. In Israel, monitoring of the pest situation is undertaken on a weekly basis throughout the cotton-growing season. Reports on the pest population are received at the Israeli Cotton Production and Marketing Board Ltd. every Tuesday, and guidelines are issued to all concerned on Wednesdays for taking the necessary control measures. In Israel, the "Insecticide Use Policy" is very strict and insecticides for farmers are purchased by the Board, to assure a lower price and good quality, as it is the bulk purchase that reduces the cost. The implementation of IPM on a wider scale has reduced pesticide use significantly in Israel. In 1986, the average number of sprays per season was 16, which was reduced to eight sprays in 1990 and only to five sprays in 1999. In Syria, farmers cannot spray insecticides until they get permission by experts from the government. The program has been very successful and insecticide use on cotton is the lowest in the world in Syria, with only 3-4% of the cotton area being sprayed not more than twice per season.

Cotton contamination is one of the major issues of concern to the textile industry. According to the ICAC, about one third of the total cotton produced in the world is baled in cotton cloth, 21% in jute bags and 24% in polypropylene. Only a few countries wrap in plastic, and polypropylene is a major contaminant. Although expensive, it is recommended to use cotton cloth for wrapping cotton bales. Stickiness is a problem but at least it has not increased in the last few years. Sudan has a stickiness problem from whitefly resulting in the whole cotton production being discounted, though the problem may be related only to a percentage of the whole. Sudan has developed a protocol to isolate sticky cotton from non-sticky cotton in collaboration with CIRAD-CA's Cotton Program. The project was sponsored by the ICAC with major funding coming from the Common Fund for Commodities. The project is near completion, and a workshop will be held from February 5-7, 2001 in France for disseminating the project findings. Sudan and CIRAD invited all members of the Network to the workshop.

The whitefly population is increasing in many parts of the world, worsening the stickiness problem. Even though stickiness is not a problem in Iran, work presented at the meeting showed that sticky and non-sticky cotton from the same area varied in fiber length, lint percentage, length uniformity, strength and elongation most of the time. Stickiness was tested on H2SD. In Turkey, Çukurova is the region worst affected. In 1993 almost one-third of production in Çukurova had some level of stickiness. Discussions on fiber quality raised the point that though fiber quality is measured and quantified in terms of fiber length, strength, maturity, etc., production regions have an additional effect on yarn quality. Some regions may measure the same quality but cotton produced in one of the regions may always have an additional advantage in spinning and this is the reason that cotton in Turkey is classed by region instead of varieties, as is the case in some other countries.

Breeding of Pima types in Israel has shown that most fiber quality characters can be assumed to be uncorrelated. The correlation coefficient between fiber strength and length and between length and length uniformity was 0.74 and 0.84, but it is still possible to improve these characters independently of each other. The correlation coefficient between different quality characters measured on conventional equipment came out to be different from the HVI measurements. Though the conclusion referred to Pima cotton, the recommendation not to use HVI for testing breeding material was a surprise.

The cotton plant sheds fruit everywhere in the world, but among the countries participating in the Network, shedding is the number one problem in Syria. Though the categorization of the problem could be related to minimum insect pressure, high day and night temperatures result in excessive shedding in Syria. The last date to plant cotton in Syria is mid-May, and flowering occurs at extremely high temperatures, sometimes exceeding 45°C for daytime highs. Thermotoxicity results in shedding of small buds, flowers and even small bolls. Breeders have developed heat tolerant varieties, but it is still a challenge for researchers to prevent shedding as much as possible to increase yields.

Future Activities

The working group on breeding will collect information on breeding methodologies followed in various countries and try to formulate a common procedure to be followed and distribute it among researchers participating in the working group. The group also decided to keep track of the published material, and any paper that could be of use will be reproduced and distributed among the members. The group will also prepare a project outline and try to establish a website for the network.

The working group dealing with variety trials decided to continue common variety trials in the network countries but with new varieties. Each country must have preliminary variety trials before submitting them to the working group. In total, 12-16 varieties will be tested in the trials in about 10 participating countries. A protocol will be prepared and sent to all participating countries so that the same methodology is applied in all countries and the same data are recorded on all varieties. Individual countries can record additional data on trials or on a particular variety but only uniform data will be brought to the meeting and discussed. The trials will be conducted for two years. The working groups on variety trials and plant growth modeling will work to have at least one variety studied for its fruiting and growth pattern. All trials will be conducted in the major cotton producing areas and under conventional practices followed by the majority of the growers in the area. The participating countries will provide seed to each country directly and preferably by the end of February. The working group realized that verticillium wilt is a common disease in the countries of the Network and a stronger strategy against this menace is needed. If possible, scientists in the participating countries will visit trials in various countries. The chair of the working group will prepare a directory of researchers and circulate it among members of the group.

The working group on growth regulators will prepare a new protocol including new products, and trials will be conducted in Bulgaria, Greece, Iran, Syria, Turkey and the USA for three years. The same physiological measurements will be recorded in all countries, but countries have a choice to include additional data. The directory of researchers working on growth regulators will be updated.

The working group on nutrition will continue its focus on varieties x fertilizer interaction studies including foliar fertilization.

A limited number of researchers participated in the activities of the plant growth modeling studies so one of the group's challenges is to increase its membership. Recording data on a daily basis and modeling plant growth is laborious; however, the group will continue its emphasis on the source and sink relationship.

The working group on water management has not been active and a new chairman was elected who will prepare a work plan to be followed by members and revive activities.

Future activities of the integrated pest management group will increase its focus on weed control, which has become a more serious pest and usually receives less attention in the IPM package. Information will be collected from participating countries working on common problems and a directory of researchers working on various aspects of IPM, including insecticide resistance management will be published. The group realized that there is a need to enhance research in IPM and decided that IPM will be applied as an interdisciplinary approach involving researchers from various other working groups.

In the field of fiber technology, activities will be enhanced to exchange information on how to use specific equipment, including calibration, for improving measurement of fiber quality characteristics. The working group will explore some funding particularly from the EU for joint efforts. The exchange of information through email will be enhanced. The group also considered focusing presentations on a particular topic in the next meeting of the Network.

The working group on the economics of cotton decided to update its membership and enhance its activities for providing updates on the current activities/achievements in this field. The group realized that there is a need to redefine the objectives and targets which must include issues like analysis and assessment of income of cotton producers and economic analysis of cotton production systems. The working group will introduce itself to more researchers and will also try to organize a symposium on a particular topic. Members of the group from Turkey agreed to host such a symposium. It was recommended that the possibilities of getting the support of the European Forum for Agricultural Research and the Association of Agricultural Research Institutions for the Near East and North Africa (AARINENA) be explored. They have identified cotton as one of the four crops for their priority collaborative projects. The working group will study the cotton sectors and their policies in various countries.

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