Discover Natural Fibres Initiative

THE ICAC RECORDER

International Cotton Advisory Committee

Technical Information Section

VOL. XXIX No. 1
MARCH 2011

Update on Cotton Production Research

Contents

Introduction

The first article in this issue is about cotton production in Mozambique. In Mozambique, cotton was planted on 125,000 hectares in 2009/10, which is only one third of the area planted to cotton in 1998/99 and in the early 1970s. The main reason for the drastic decline in area is low yields and no increases in yields for many years. Slight increases are not enough to compensate for the increases in the costs of production. Cotton also faces tough competition from sesame, which is priced almost double that of cotton and does not require the same level of technical skills as cotton. In Mozambique, cotton helps to alleviate poverty in terms of securing quality livelihoods, contributing to job creation, providing income to farmers and as a source of foreign exchange. In addition to the Cotton Institute of Mozambique and the Agriculture Research Institute of Mozambique at the government level, private sector cotton companies play a critical role in production, supply of inputs and purchase of seedcotton from farmers. Currently, 12 cotton companies are active in the country, and they have the responsibility to provide technical advice to cotton growers. Farmers do not have the choice of buying inputs from the open market. This article describes the cotton production system in Mozambique and also makes suggestions on how to improve the system.

The second article is an update on irrigation of cotton. Ten years ago, the Secretariat estimated that 55% of world cotton area was irrigated, and that 45% of cotton area depended on rainfall. The latest ICAC survey on the cost of production of cotton suggests that assured irrigation extended to 63% of the world cotton area accounting for 72% of world cotton production in 2009/10. Rainfed accounted for 37% of area and 28% of production. Irrigation facilities have been extended in Brazil and Turkey, and in many other countries irrigated area has expended. Sewage water (waste water) is a good source of nutrition and can also compensate for a shortage of water. A comparatively recent study done in Iran showed that the treated municipal water increased yields. Irrigation water is becoming expensive. Research in many countries shows that a little water stress may not only save water but can increase yields. The objective is to produce the most cotton from the least amount of water.

The third article is on mealybug and was contributed by Dr. Keshav R. Kranthi and his colleagues from India. An article entitled Mealybug: A New Threat to Cotton was published in the June 2008 issue of *THE ICAC RECORDER*. The article stated that 'Over the last three years, the mealybug has been appearing in the region and has already caused heavy losses in Pakistan. The mealybug is also spreading into India.' Since then the pest has gained strength and has become the most serious pest on cotton in India and Pakistan. The pest is also on the increase in China. *Phenacoccus solenopsis* (Tinsley), and the pink hibiscus mealybug, *Maconellicoccus hirsutum* (Green) have been found in India but P*henacoccus solenopsis* is the dominant species in India and Pakistan. In India, *P. solenopsis* species was found to infest 166 host plants belonging to 51 families comprising 78 weeds, 27 ornamental plant species, 19 tree species, 17 vegetables, 12 field crops, 8 fruit trees, and 5 spice crops. The pest is new on cotton, not only in India and Pakistan, but also throughout the world. There is not much published literature and technical information on the species found in India and Pakistan. High reproduction rates add to the difficulties of controlling the pest. The current article is focused on the management strategy for mealybug.

5th Meeting of the Asian Cotton Research and Development Network

The 5th Meeting of the Asian Cotton Research and Development Network was held in Lahore, Pakistan from February 23-25, 2011. The Department of Agriculture of the Punjab province hosted the meeting. Delegates from Azerbaijan, Bangladesh, Canada, China, India, Iran, Kazakhstan, Kyrgyzstan, Myanmar, Tajikistan, Thailand, Turkey, Turkmenistan, USA, Uzbekistan, FAO, CABI, ICAC and a large number of participants from Pakistan attended the meeting. Between 250-300 participants were present in all the sessions. Participation and support from the private sector, including seed companies and farmers from

The ICAC RECORDER (ISSN 1022-6303) is pulbished four times a year by the Secretariat of the International Cotton Advisory Committee, 1629 K Street, NW, Suite 702, Washington, DC 20006-1636, USA. Editor: M. Rafiq Chaudhry <rafiq@icac.org>. Subscription rate: $205.00 hard copy, $165.00 electronic version.

Pakistan, was very strong.

The Ayub Agriculture Research Institute, Faisalabad, of the Department of Agriculture, Punjab, made the arrangements for the meeting. ICAC, CABI-Pakistan and FAO Sub-Regional Office for Central Asia sponsored the meeting. Over 60 papers were presented in the meeting; The papers are available on the ICAC web page at <http://www.icac.org/tis/regional_networks/asian_network/asian_network.html>. The list of participants is also available. Dr. Noor-ul-Islam of Pakistan was elected Chairman of the Network. The next meeting will be held in three years.

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Delegates from many countries emphasized the need for an international research center on cotton. The ICAC will work with the Chairman to identify a host country for the next meeting and to encourage communications among researchers via the E-mail list hosted by the ICAC Secretariat.

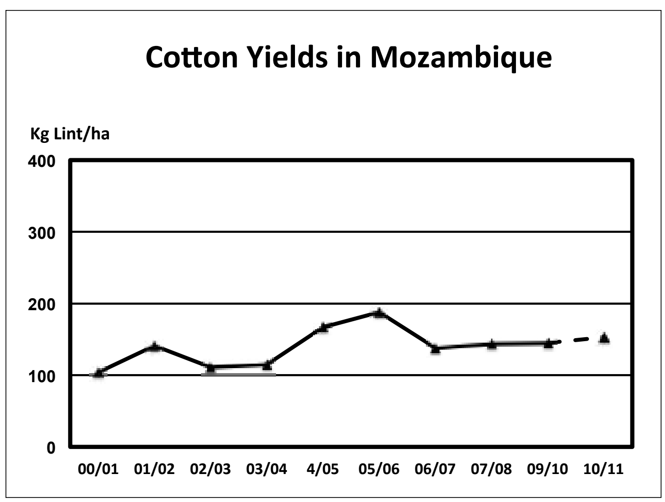
World Cotton Research Conference-5 (WCRC-5)

The World Cotton Research Conference-5 will be held in Mumbai, India from November 7-11, 2011. The Indian Society for Cotton Improvement and the Indian Council of Agricultural Research will host the meeting. Pre registration is now closed as the full registration package has become available. Early bird registration must be made by May 25, 2011. Online abstract submission is also valid by May 25. The full registration package includes information on outline of scientific program, hotel booking and pre & post conference tours. Full-length papers must be submitted to Session Coordinators by end of July 2011. The registration package can be visited online at <http://www.wcrc-5.com/index.html> or through the ICAC web page at <http://www.icac.org>.

Cotton Production Prospects in Mozambique

Mozambique has about 36 million hectares of arable land suitable for the cultivation of a variety of agricultural crops, fruits and vegetables. However, only about 4 million hectares are currently under cultivation. Over 95% of farmers are smallholders cultivating their land either manually or, to a limited extent, using animal traction. While land is available in abundance, expansion of the land area for effective uses is limited by many constraints, among which are: labor, suitable farming systems based on agroecological zones, shortage of draught power, irrigation water and infrastructure (roads, irrigation systems), technology and systems to provide support for agriculture such as banks (credit for agriculture is scarce). The area devoted to cotton is also limited by many of the factors mentioned above. According to the latest ICAC estimates, cotton was planted on 125,000 hectares in 2009/10, which is only one-third of the area planted to cotton in 1998/99 and during the early 1970s. Cotton area has varied dramatically over the years, dropping as low as 50,000 hectares during the late 1980s.

Cotton yields have also varied widely until about 10 years ago. Since 2000 the average cotton yield in Mozambique has stabilized around 160-180 kg of lint per hectare. The main reason for the fluctuation of cotton area is the minimum price fixed by the government for seedcotton vs. the market price of sesame, although some cotton companies pay above the approved price as a strategy to motivate farmers. Mozambique has concluded that a two-hectare cotton farm can be cost-effective if proper attention is given to cotton production technology. Sesame is a cash crop and competes against cotton for land and other inputs. Farmers prefer to focus their attention and inputs on sesame before turning to cotton. To ensure food security and to avoid the risk implicit in mono-cropping, farmers generally plant a mix of crops each year, using either sole cropping or intercropping systems. Inter-cropping is particularly common in the case of food crops. Rural families often farm several plots in different areas. Farmers have a tendency to quickly shift to sesame if they are not satisfied with cotton yields and the prices fixed by the government, and vice versa. Maize, cassava and cowpeas are



the main food crops. Together with rice, millet and groundnuts, food crops are grown on about 90% of the cultivated land in the country. Thus sesame and cotton compete against each other for about 400,000 hectares. An estimated 15% of the country's farmers grow cotton or sesame.

Cotton Production System in Mozambique

Cotton is grown in the central and northern parts of Mozambique. As many as 300,000 families may be involved in cotton production. The important players in the cotton sector are: the Cotton Institute of Mozambique, the Agriculture Research Institute of Mozambique and the cotton companies.

The Cotton Institute of Mozambique (IAM) – This institution plays a crucial role in cotton production and marketing in Mozambique. The sphere of competence of the IAM encompasses policy and regulation, cotton promotion, supervision, issuance of certificates to gins, liaison with ginning companies, cotton classification, and strengthening of cotton associations, etc. IAM is the only agency empowered to classify cotton. In Mozambique, cotton is still tested manually, and there are seven lint grades: I, II, III, IV, V, VI and lower than VI. All cotton graded below VI is considered to be of the poorest quality. Mozambique is in the process of moving to High Volume Instrument (HVI) classification and three Premier HVI machines have been purchased and are being installed, one each at three different locations. No bale of cotton can be sold without a certificate of origin carrying the following information: certificate number, bale number, year of harvest, name of exporter, gross and net weight of bale, ginning plant, company name, cotton variety, etc. This certificate is issued by IAM. Although it is in the ginner's interest to ensure that the ginning process is efficient and that there is no waste of cotton, IAM has the authority to take samples and verify ginning ratios and gin trash. Each and every bale of cotton produced in Mozambique must have a cotton seal. In sum, IAM serves as a nodal point for cotton at the national and international levels in Mozambique.

The Agriculture Research Institute of Mozambique (IIAM) – In 2004, the National Institute of Agronomic Research, the National Institute of Veterinary Research, the Animal Husbandry Institute, the Forest Experimental Center and the Agricultural Training Center were integrated to create the Agriculture Research Institute of Mozambique. IIAM operates under the Ministry of Agriculture and is engaged in applied as well as adaptive research on all aspects of agriculture, forestry, animal husbandry and veterinary sciences. The mission of IIAM is to enhance technology for sustainable development of agribusiness and food security in the country. It is organized into four directorates at the institution's headquarters and four decentralized Zonal Research Centers in the South, Center, Northeast and Northwest zones. The Namialo Research and Seed Multiplication Center for Cotton (CIMSAN), under the Northeast Zonal Research Center, is charged with research and pre-basic seed production of cotton. CIMSAN also does research on food crops, including beans, maize, sorghum, sesame and others.

Cotton Companies - Cotton Promotion System in Mozambique

Cotton in Mozambique is produced under the system commonly known as the Concessionaire System, and via a contract with the State, represented by the Government (Ministry of Agriculture), whereby private companies are entrusted with a given area (or territories) for a certain period of time (7 years). Cotton companies have the right to promote cotton production and are obliged to provide extension services and distribute inputs to farmers on a credit basis. In return, they have the exclusive right to purchase the seedcotton produced in that territory. The concessionaire system guaranties that farmers can produce cotton without having to pay up front for inputs, technical assistance or production tools such as sprayers, which are provided free of charge. Farmers have the additional assurance that their production will be sold free of the vagaries of international price dynamics or production constraints by local factories.

Nowadays, 12 private companies have cotton as their core business. (See table next page).

The cotton sector provides an invaluable contribution to poverty alleviation in terms of securing quality livelihoods, contributing to job creation, ensuring farm income and revenue, supporting private companies and benefiting the country as a whole through the contribution that cotton makes to the balance of payments by way of fiber exports.

Mozambique has various comparative advantages for cotton production in the region as a result of its agroecological adaptability and the existence of ports around the country located fairly close to ginning facilities. Productivity is very low. There are two key factors that determine the country's productivity, namely:

1. Climate: The cotton production system is mostly dry-land agriculture. Hence cotton is dependent on climate. Mozambique is subject to cyclical weather shocks resulting in long droughts alternating with severe flooding. However, normal weather accidents have also been known to have an impact on productivity.
2. Market: Among the variables that make up the formula used to set the minimum seedcotton price for the season, the most important are the international price and the exchange rate.

These two concerns are broadly discussed at the consultation fora of the cotton sub-sector. On the one hand, companies postpone reinvestment alleging lack of profits as a consequence of reduced volumes and quality. On the other hand, farmers complain that the companies are foisting their own losses onto them by manipulating the price of inputs, pesticides and the purchase price for seedcotton. Consequently, the fallout

Table 1: Cotton Companies in Mozambique 2009/10

Cotton Company	Active in the Province of	Approximate Area Covered (Ha)
PLEXUS	Cabo Delgado & Nampula	40,400
SAN / JFS	Niassa	13,200
SANAM	Nampula	28,200
SAMutuali	Nampula	5,700
OLAM Moçambique	Nampula	15,400
N. OPERADORES	Nampula	4,000
OLAM/Morrumbala	Zambezia & Tete	6,300
C.N.A.	Sofala & Manica	3,200
OLAM AVZ	Manica & Tete	1,200
Chipata Cotton Company	Sofala & Manica	700
ALGODÃO DE MOÇAMB.	Inhambane	500
C.A.F.A.	Gaza	600
Total		119,400

is a cascade situation wherein companies find themselves financially limited, which develops into a stumbling block preventing the provision of better services for farmers. Furthermore, these circumstances often result in companies having to close, creating a large gap in the structure of rural communities, with farmers losing their service provider and people losing their jobs.

At the end of the ginning season, which usually comes in the month of October, the government holds an annual cotton meeting to prepare the cotton plan for the following year and to determine the price to be paid to farmers. The government price for the 2009/10 season was MZM 8.10 (about US$0.27) per kg of seedcotton; the price was increased to MZM 10.00 (about US$0.31) for 2010/11.

Only 500 or so hectares are not planted through companies.

Research on Cotton

The Namialo Research and Seed Multiplication Center for Cotton (CIMSAN) has an area of 347 hectares, but only 30-40 hectares are usually cultivated for experimental purposes and seed multiplication. The center receives about 1,000 mm of rainfall annually, mainly between November and May. CIMSAN, located about a two-hour drive from the provincial capital of Nampula, provides optimum conditions for research on cotton. The newly created position of Coordinator of the National Cotton Research Program is also based at CIMSAN.

The technical staff comprises two breeders, a plant protection expert, and a general agriculture graduate supported by sufficient technicians and field staff. The center is not equipped with the farm machinery needed to cultivate all the land at its disposal. It has a gin for large cotton samples and a cold storage facility for germplasm. Unfortunately, fiber testing equipment is not available.

The cotton research program followed at CIMSAN comprises four main areas of research: plant breeding, plant protection, agronomy and soil sciences. Breeders have assigned a high priority to hairiness and are continuously vigilant of hairy leaf genotypes in the segregating populations. Efforts are also being made to improve the hairiness level of existing commercial varieties. Breeders are responsible for production of pre-basic seed and for maintaining the purity of commercially grown varieties.

Plant protection work is focused on strip intercropping to control *Helicoverpa* spp. and other insect pests, testing various seed coatings to control sucking insects at an early stage and to avoid seedling diseases, conducting weed management trials and evaluating insecticides already used by farmers.

The agronomic and soil science work is geared to the development of crop husbandry practices and the formulation of a production technology package for farmers. Other trials include studies of: the economic and insect control benefits of intercropping cowpeas and maize with cotton, mulching of cotton sticks for water and soil conservation, performing plant density trials for different soil types, and fertilizer trials.

The CIMSAN center needs additional farm machinery to be able to cultivate all its land for seed multiplication purposes. The center can produce additional quantities of basic seed and sell it to cotton companies or private seed companies, whenever they enter the market. The Government of Mozambique has plans to strengthen the technical capabilities of staff through local and international training programs.

The Polytechnic Institute of Higher Education, in Gaza, Chokwe, operating under the Ministry of Higher Education, also has limited trials on cotton research, albeit more of an academic nature. A national university, Eduardo Mondlane University (UEM), through its Faculty of Agronomy and Forestry Engineering (FAEF), also runs a limited research program on cotton.

Production Practices

Most cotton is produced in the northeast and central regions. The best time for planting cotton in the central region is mid-November, while planting in the northeast region begins about 10 days later. All sowing of seed is done manually, as is most weeding. On average, 25 kg of seed are used to plant a hectare of cotton. Sesame is more important as a competing crop in the central region. Competition from sesame comes in the form of higher prices, which are almost double those of cotton, while yields may be nearly equal. Insecticide use is similar for both crops. Inputs received from cotton companies are often applied to sesame.

Plant protection consumes the greater part of the attention and resources of cotton producers. Cotton is sprayed an average of five times a year. The number of sprays may vary from one production area to another for a number of reasons, including the decisions by the companies to provide greater or lesser amounts of insecticide. If a farmer sprays cotton five times a season, the first two sprays are usually made against sucking insects, such as aphids and jassids. The other three insecticide applications are made against bollworms, in particular against *Pectinophora gossypiella, Helicoverpa armigera* and the red or Sudan bollworm, *Diaparopsis watersi.* Most companies provide treated seeds, along with five foliar sprays of insecticides. A farmer has to pay an average of 80 MZM (US$2.5) for treated seed to plant one hectare. The first spray is applied 30 days after planting and the second spray 15 days later. Consequently, insecticide applications are usually completed in 90 days, irrespective of crop growth. Some companies advise spraying more than five times, in which case spraying may continue after 90 days. Calendar spraying is not only common but recommended by companies for better control, although educated growers prefer following economic threshold levels.

A pilot project on IPM benefited a number of farmers. Scouting was done by using a pegboard, a method that requires a lot of training and experience. Cotton companies are supposed to employ agronomists to disseminate technology, identify insects, etc., but companies are usually not very efficient at this task. CIMSAN runs trials on insecticides used by growers in order to check for efficacy. Nevertheless, ineffectiveness of insecticides is a common complaint among farmers. There may be many reasons for such complaints, including under-dosing, poor spraying, delayed spraying and a level of pest pressure far surpassing the economic threshold at the time of spraying the insecticides. One reason for such delays may be that it is common for 10-15 farmers to share a single insecticide sprayer. They are obliged to use the sprayer by turns, thus delaying insecticide applications while laying the blame on insecticide efficacy. A micro- ULV sprayer costs about US$60, but the tendency persists among growers to share sprayers. Researchers at CIMSAN are endeavoring to eliminate two sprays on cotton, but they have concluded that it is not possible to cut any of the last three sprays against bollworms. Consequently, the only option is to avoid the need for spraying against sucking insects. Although researchers are working in this direction, it seems extremely unlikely that they will achieve this target.

The use of fertilizer is recommended, but many farmers do not use it. In Mozambique, a single company, Agrifocus, imports all inputs; hence, companies buy fertilizers from Agrifocus. Herbicides are not used and diseases are also not a big problem. Limited fertilizer trials have recently been initiated in cotton growing areas.

Cotton picking starts in May. Cotton is picked by hand using family labor, although farmers may occasionally employ hired hands. Farmers pick cotton and bring it home for storage, but as the cotton is packed in bags, they separate it into first grade and second grade cotton. Farmers have to carry their cotton to the local ‘sale points’ and they usually carry the cotton bags by themselves, or with help from hired labor. Farmers usually start taking their cotton to the sale points in June. Different companies have different payment systems. Farmers may be paid right away in cash, or by check, or they may be asked to come back in few days to receive payment. Depending upon the supply, companies may even advance money to farmers as an incentive to hire labor in order to get the cotton to the sale points on time. Cotton picking starts early in the central region and, if prices are higher across the border in Zimbabwe, there is always a possibility that farmers may sell their cotton across the border to buyers in Zimbabwe. The reverse is also true, but in general, prices are always higher in areas close to the border with Zimbabwe. Poor logistics and the use of same means of transportation to carry other crops are the main reasons for the slow movement of cotton to the sale centers after picking.

Constraints and Needs

Farmers are able to express their concerns through the National Forum of Cotton Producers (FONPA) and farmers’ associations. Farmers raise their grievances at all levels. The following are some of the grievances that the government must address in order to improve cotton productivity in Mozambique:

- Farmers often complain that the price fixed for seedcotton by the government is too low. They perceive that the price favors cotton companies and not cotton producers. This, in turn, results in unhealthy relationships among the parties. This perception must be corrected.
- Farmers work hard to grow their crops successfully but they believe that cotton companies are not compensating them adequately for their hard work. When it comes to sharing the profits, farmers believe that cotton companies are making money at the cost of cutting into the profits of cotton farmers.
- All operations are done manually. There are a number of field operations that should be mechanized.
- Farmers do not have easy access to credit. There is a need to improve farmers’ access to inputs through rural credit schemes and the option of turning to an alternative input/

service provider.

- There is a need to place greater emphasis on cotton research in all disciplines; but particular attention must be devoted to the development of new varieties.
- There is no planting seed production system in Mozambique. The varieties developed by IIAM researchers may fail if they are not backed by a good planting seed production system. The important thing is not who produces the planting seed, the public sector or the private sector; the key factor is that the seed must be of known origin and certified in terms of purity and germination.
- Currently, the technical know-how comes from cotton companies which are supposed to employ cotton experts for the transfer of technology. However, no one knows with any certainty the degree to which the extension staff is proficient and trained in educating cotton growers. Assuming that the job is done efficiently, there is a need to improve the system. On the other hand, farmers must also have an option to buy the inputs of their choice and apply them according to their own needs. Farmers need to be inducted into the technology learning process.

Biotech Cotton in Mozambique

The cotton production system described above is dominated by plant protection measures, especially the use of insecticides. The fact that more than half to three quarters of the number of sprays are used against bollworms attests to the fact that biotech cotton having insect resistance could easily substitute for most insecticide use. The American bollworm *Helicoverpa armigera* is the dominant pest but, since the pink bollworm *Pectinophora gossypiella* and the red or Sudan bollworm *Diaparopsis watersi* also appear at the same time, a stacked gene bollworm resistant biotech cotton would be more economical to grow. The opportunity cost of not deploying biotech cotton in Mozambique will increase over time due to increases in the cost of insecticides and greater insect pressure year after year. It is also highly unlikely that cotton growers will be able to increase yields without efficient insect control. There is no doubt that biotech cotton provides better control of target insects than insecticide applications that might fail as a result of inappropriate timing, spray equipment, dosage, product selection and quality.

It is not easy to quantify anticipated increases in yields that biotech cotton might produce. In some countries, there was as much as an 80% increase in yield in five years. In others, there was almost no increase in yield. Instead there was a significant reduction of the cost of production, plus the attendant contribution to environmental safety. It stands to reason that Mozambique could benefit from biotech cotton. Evidence suggests that it might be possible for yields to increase, as cotton yields in Mozambique are among the lowest in the world and have not increased in many years. Benefits must be expressed in terms of monetary gains for farmers as a result of higher yields. Biotech cotton is profitable for farmers if the marginal rate of return on investing in biotech cotton is greater than or equal to 100% of the technology fee. Net income from biotech cotton will depend on the technology fee, which is not fixed, but depends on negotiations among technology providers and the national government. Such negotiations have already started, but they have not come to a conclusion yet.

The *ex ante* hypothesis is that there could be a significant increase in yields due to the adoption of biotech cotton, but it could also result in more stable yields. Consistent performance of cotton could boost farmers' morale and encourage them to pay as much attention to cotton as they do to sesame and food crops and this could prove to be another factor that would contribute to the successful cultivation of cotton. Expected yield benefits could set the stage for the social and economic welfare of about 300,000 households that are now, or could in the near future, be involved in the second most important cash crop of the country.

Data from India show that at the time when biotech cotton was introduced, in 2002/03, cotton was planted on 7.7 million hectares. Since then and up to the 2009/10 season, the international cotton price as expressed in the Cotlook A Index was far below the long-term average of 72 cents per pound of lint, except for the 2007/08 season when it was slightly over 72 cents per pound of lint. International prices did not perform well from 2002/03 to 2009/10, but the cotton area in India started to expand as of 2003/04. Cotton was planted on 10.3 million hectares in India in 2009/10 for a 35% increase in seven years. The cotton area in India is expected to increase to 11.0 million hectares in 2010/11, but that increase could also reflect the effects of higher prices.

Mozambique has a small-grower farming system with cotton growers that also grow sesame and maize. Both crops, but particularly sesame, have common insect pests with cotton, which may not require enforcement of refuge crop requirements in the biotech cotton area. If biotech cotton is commercialized in Mozambique, it will be as an area-wide crop managed by a specific cotton company. The question is: should biotech cotton be adopted through already adapted local varieties, or through Deltapine or varieties from other countries? This is something that IAM and IIAM will have to decide and advise the government accordingly. Pitoro (2004) undertook an economic analysis that provided an indication as to whether there is a basis for public sector investment or whether this should be a purely private sector activity. He observed that biotech cotton could only be economically feasible for farmers if their yields increased by at least 6% over conventional cotton. These estimates are based on hypothetical technology fees and hypothetical increases in yields. The fact is that the ultimate decision lies with the government and implementation by the cotton companies. Pitoro (2004) also observed that more research was needed to fully assess the economic, environmental, and social benefits and risks of biotech cotton, and the ICAC Secretariat believes this is still true. This study starts by fixing the yield of conventional cotton at 860 kg/ha of seedcotton and assesses the benefits of yield gains of 10%, 30% and 45%, combined with a reduction in average sprays of 3.5, all based on experiences in developing countries. It would seem, however, that the study overestimated the cost of technology. The argument that a high pressure of sucking pests, such as jassids and aphids, not controlled by Bt, could depress yields is not true because biotech cotton has to be sprayed against sucking insects in order to reap the full benefit of the technology.

One of the major factors for consideration is that biosafety regulations in Mozambique are still in their infancy. In 2001, Mozambique ratified the Cartagena Protocol on Biosafety and established an interinstitutional and multidisciplinary team called the National Biosafety Working Group. The main responsibilities assigned to the Group were to coordinate biosafety activities in the country, set up proper systems for regulatory and administrative issues, to develop a decision-making process based on risk assessment and management, and to create a mechanism for public participation in the process. It has been learned that the Group has submitted draft legislation governing the import of biotech plants. Thus the legal framework is in place for the commercialization of biotech cotton in Mozambique.

Joint CFC/EU/ICAC Project

The ICAC is currently implementing a project entitled 'Improving Cotton Production Efficiency in Small-Scale Farming Systems in East Africa through Better Vertical Integration of the Supply Chain'. The project is designed to improve farm income in Kenya and Mozambique. In Mozambique, farmers participating in the project will receive good quality seed from the Namialo Research and Seed Multiplication Center for Cotton and they will be encouraged to use optimum doses of fertilizers and insecticides. Farmer Field Schools have been established and the project staff has organized courses to train the trainers. The trainer staff was chosen from among the staff of the district agriculture departments, provincial departments of agriculture, IAM and the cotton companies that will be working with IAM to implement the project. The IAM staff, in collaboration with the Namialo Research and Seed Multiplication Center for Cotton, is taking the lead in educating growers in cotton production technology. Multiple demonstration plots have been laid out in Nampula and Safala provinces. Each demonstration covers an area of one hectare, half under traditional practices and half under the integrated crop management system devised by the project. CABI-Africa is managing the project, which will run for four years. Major funding has come from the European Union, facilitated by the Common Fund for Commodities. In addition to national governments, the Common Fund for Commodities has also contributed funds to the project. Farmers in the project will be taught through the use of demonstration plots and they will be encouraged by the trainers to use the recommended cotton production practices called 'Integrated Crop Management' in the project. The project is in the first year of implementation.

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Update on Irrigation of Cotton

Cotton is a drought-tolerant crop but its domestication as an annual crop -- planted at a given time of the year and harvested at a given time of the year -- has required regular irrigation if it is to produce optimum results. The basic drought-tolerant nature of the plant has been retained and the delta of water for cotton is about half of the requirement for rice and sugarcane, two major cotton crops competing in many parts of the world. The irrigated cotton area in the world is not concentrated is any one country or region. Irrigated cotton is grown along with rainfed cotton in the same country and even within the same region. However, there are a number of countries, and regions within countries, where cotton is grown only under assured water supply conditions.

In a reduced number of countries, rainwater is collected, stored and used to irrigate crops, including cotton. Australia is a perfect example. There, rain water is collected in manmade reservoirs and used to irrigate cotton. Almost a decade ago, about 55% of the world cotton area was irrigated and the remaining 45% depended on rainfall. The most recent ICAC estimates indicate that assured irrigation has extended to 63% of the world cotton area, which accounted for 72% of world cotton production in 2009/10. The remaining 37% of the world cotton area was cultivated under rainfed conditions and produced only 28% of global cotton. Irrigation facilities have experienced a significant extension in only a limited number of countries, such as Brazil and Turkey, while in others, the cotton that is grown on irrigated land is on the increase.

Water Availability

There is a discrete amount of water available on the planet. That amount can neither be increased nor decreased. According to Kandiah (1997), there are nearly 1.4 billion km^3 of water available on the planet. Most water is in seas and oceans, leaving only a fraction of the world's total water readily available for direct human use. Approximately 110,000 km^3 of precipitation fall on the earth every year. Most of it evaporates back into the atmosphere, is absorbed by plants or seeps underground into easily accessible deposits or hard to reach recesses. As the pressure to grow more food, feed and fiber crops increases the demand for fresh water in agriculture, its conversion into different states raises concerns as to its quality. Water may be available, but perhaps not with the desired quality. For example, brackish water may be unfit for irrigation due to its higher salt content.

According to the paper mentioned above, in 1940, total water use on earth was about 1,000 km^3. That figure doubled in 1960 and doubled again in 1990, reaching 4,130 km^3. There is no doubt that the trend has continued and by now total water use may have exceeded 6,000 km^3. Most of this water, close to 75%, is used in agriculture, about 20% in industry and the remainder, less than 10%, goes to the municipal water supply and other uses. In many countries, irrigation is subsidized and farmers either do not have to pay for irrigation water or they just pay for the maintenance of the irrigation systems that service their fields. These countries, which have large irrigation systems, also find it necessary to conserve water in order to improve cropping intensity and productivity per unit area. In Pakistan, for example, where over three million hectares of cotton are grown under assured irrigation conditions, cotton growers have shifted to ridge sowing (using raised beds where seed is planted on both sides of the bed with a row-to-row spacing of 76 centimeters). This practice was virtually unknown in the country in the 1990s. It is estimated that in 2009/10, 20-25% of the cotton area in the country was planted on ridges. Many other countries are improving irrigation methods in order to consume less water. Farmers must choose from different options: flood irrigation, ridge irrigation, various types of sprinkler irrigation systems, sub-surface or above-surface irrigation methods. They must also have a more precise assessment of irrigation needs in order to apply water at the most appropriate times. These issues, however, will not be discussed in this article.

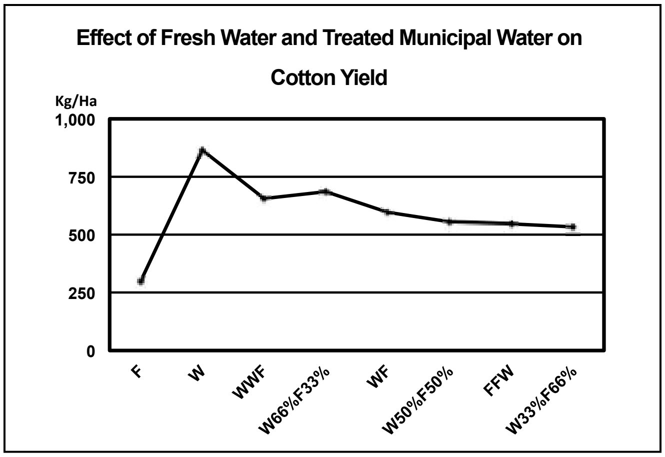
Use of Sewage Water for Irrigation

As discussed above, water is available on the planet in a finite quantity. The use of water for one purpose may make it unavailable for other purposes, and this is an obvious constraint. Population growth had led to increasing demands for water in the home and for sanitation. Sewage, or wastewater, is inadequate for direct use in agriculture. With the current emphasis on environmental health and attending water pollution issues, there is an increasing awareness of the need to use waste safely and beneficially. The runoff of residual water from fields after irrigation is often considered to be wastewater but in the present article, the term is used exclusively in reference to the liquid waste discharged from homes, commercial premises and industrial plants into individual disposal systems or municipal sewer systems. Thus the focus is on municipal water that may be treated and reused in agriculture. All sewage water must be treated before it is used in agriculture and it is not usually recommended for vegetables and fruit for social reasons. Municipal water was initially used on forestlands and later slowly extended to field crops. Treated municipal water is beneficial for agriculture for a number of reasons: (a) water shortages can be reduced; (b) large amounts of waste water can be disposed of in an environmentally sustainable way; (c) high-quality water resources can be earmarked for potable uses; (d) there are economic benefits in terms of additional nutrient supply and (e) the availability of additional water near population centers can broaden the variety of crops that may be grown by farmers (Biswas *et al*. 1999 and Jiménez-Cisneros 1995).

The effect/benefits of using treated waste water in agriculture can vary depending on a number of variables, such as: crop type, variety (tall or dwarf), soil type (clay loam, sandy, etc.), fertility status (highly fertile soil may not require any supplemental doses of fertilizers, whereas nutrient deficient soils would), as well as the actual need for irrigation. There is a great deal of literature available on the use of wastewater to irrigate cotton. The following is a report on a very recent study done by Baniani *et al*. (2011) in Iran. A medium tall (80-95 cm) cotton variety was planted on a fairly uniform clay loam non-agricultural soil (virgin) without salinity or drainage problems and with an average annual rainfall of 150 mm. Treatments consisted of a mix of fresh water and treated municipal water.

Table: Description of Irrigation Treatments

Treatments	Type of irrigation
F	Irrigated with freshwater
W	Irrigated with Treated Municipal Water (TMW)
WF	Irrigated with freshwater and TMW alternatively and continued with the same manner
WWF	Irrigated twice with TMW and one time with freshwater and continued with the same manner
FFW	Irrigated twice with freshwater and one time with TMW and continued with the same manner
W50%F50%	Irrigated with mixture of TMW and freshwater proportional 1:1 and continued with the same manner
W33%F66%	Irrigated with mixture of TMW and freshwater proportional 1:2 and continued with the same manner
W66%F33%	Irrigated with mixture of TMW and freshwater proportional 2:1 and continued with the same manner



Data were collected for many variables, including agronomic characters, such as plant height, internodal distance, number of bolls per m^2, boll weight, leaf area index, dry matter and dry leaf weight. Economic data were collected on seedcotton and lint yield, lint percentage, fiber length, length uniformity, elongation, strength and micronaire. Statistical analysis revealed significant differences among all agronomic characters; fiber quality features were affected but not dramatically. Irrigation of cotton with treated municipal water had a significant effect on cotton yield, plant height, internodal distance, number of bolls per m^2, boll weight, leaf area index, dry matter and dry leaf weight. Results showed that the greater the amount of treated municipal water applied, the greater the yield gains. Also there was no significant impact on yield attributable to treatment intervals or to treatment mixtures applied to the cotton plots. Use of treated municipal water caused no significant effect on fiber quality parameters, but cultivation of cotton in non-agricultural soil (vs. cultivated land) increased lint percentage and fiber strength, while lowering other fiber quality characteristics.

According to Braatz and Kandiah (online), in China, over 1.33 million ha, mainly croplands, are irrigated with wastewater. Mexico City's wastewater use scheme is the largest in the world (90,000 ha of irrigated land) and wastewater is utilized throughout the country in many cities. Land treatment with treated sewage effluent is also quite common in dry areas of the United States. For example, 7-8 % of the total volume of municipal wastewater produced in California is being used for agriculture, landscape irrigation (golf courses, lawns, roadside plantings, etc.) and ground water recharge. India also reported a significant area under sewage water application. In Israel, sewage water is cleaned and used on cotton, but banned from use on fruit and vegetables. It has been estimated that the nitrogen content of effluents averages some 20 mg/liter and the phosphorus content 7 mg/liter. Thus, assuming an average annual wastewater application rate of 8,000 m^3/ha, the total annual input would be 160 kg/ha of nitrogen and 56 kg/ha of phosphorus, enough to sustain cost-effective cotton yields. In Israel, where cotton is irrigated with sewage water, the problem is not boron deficiency but excess boron.

Wastewater needs to be treated before use. It is very important that the cost of treating wastewater not surpass the benefits of its use. The primary treatment process involves simple sedimentation in which organic and inorganic solids are allowed to settle so they can more readily be removed from the water. The treated water is good for the irrigation of trees, orchards, vineyards, fodder crops and some processed food crops. In industrialized countries, wastewater requires secondary treatment involving biological processes (i.e., metabolism by aerobic microorganisms, mainly bacteria) to remove the rest of the organic matter and suspended solids. The third treatment is more sophisticated and expensive and is used to eliminate specific constituents from the water. An additional disinfection treatment is required to purge it of viruses and pathogens.

Cost of Irrigation

According to the cost of production study published by ICAC in September 2010, the worldwide cost of irrigation to produce a kilogram of lint averaged US$0.10/ kg in 2009/10, i. e., less than the cost of all major operations (fertilizers, insect control, weed control, harvesting and ginning) except the purchase of planting seed. The same data also showed

Cost of Irrigation in Various Countries

Country	Cost/Ha (US$)	Cost/Kg Lint (US$)
Argentina, Santiago del Estero	28.58	0.04
Australia, Irrigated Upland	297.51	0.13
China (Mainland)	132.36	0.13
Egypt	49.11	0.06
Ethiopia, Afar Irrigated	25.65	0.03
India, North	60.47	0.07
India, Central (Irrigated)	77.73	0.10
India, South (Irrigated)	118.76	0.17
Iran	120.97	0.14
Israel	714.29	0.41
Kazakhstan, Irrigated	55.34	0.08
Mexico, Baja California	29.59	0.02
Pakistan, Punjab	141.18	0.20
Pakistan, Sindh	120.01	0.17
South Africa, Loskop Irrigated Scheme	215.38	0.13
South Africa, Taung - Northwest Irrigated	256.41	0.13
Sudan, Gezira (Irrigated-Long Staple Barakat)	45.11	0.10
Sudan, New Halfa (Irrigated Acala)	35.18	0.06
Syria, Government Irrigated Projects	330.64	0.24
Syria, Well Irrigation	1104.64	0.81
Turkey, National Average	291.76	0.17
Turkey, Southeast Anatolia	220.00	0.12
Turkey, Cukurova	174.00	0.10
Turkey, Aegean	480.80	0.33
USA, Fruitful Rim	90.39	0.13

that the cost of irrigation per kilogram of lint produced under irrigated conditions was US$0.15. The study did not take into consideration whether the cotton was irrigated by flooding or by any other irrigation method, or whether there was any subsidy for irrigation water. In most countries with large irrigation schemes, farmers do not have to pay for the irrigation water brought from rivers over long distances by water canals and channels. What the farmers in countries like Egypt, India, Pakistan, Sudan, and others pay for is exclusively the cost of maintaining those water channels, or a mere nominal price for the water itself.

The use of wastewater for irrigation could lower the cost of irrigation as well as improve soil fertility. According to FAO, the fertilizer value of the effluent is almost as important as water itself. Typical concentrations of nutrients in treated wastewater effluents from conventional sewage, as mentioned above, at an application rate of 5,000 m^3/ha/year, can potentially supply the nitrogen and much of the phosphorus and potassium normally required for most agricultural crops. Some intensively cultivated crops might require additional supplies of nutrients. In addition, other valuable micronutrients and organic matter contained in the effluent would provide additional benefits. For example, a city with a population of 500,000 and a water consumption of 120 liters/day/person produces about 48,000 m^3/day of wastewater. Assuming that 80% of the used water reaches the public sewerage system, this treated waste water, used in carefully controlled irrigation at a rate of 5,000 m^3/ha/year, could benefit some 3,500 hectares (see http://www.fao.org/DOCREP/005/Y3918E/y3918e10.htm).In addition to lowering the cost of production, some issues, like nutrient runoff, would be automatically minimized.

Irrigated vs. Rainfed Area

The most recent ICAC estimates indicate that cotton agriculture is extending irrigation services to a greater surface area, perhaps because of the pressure to earn more cash for food security. A good cash crop enables a farmer to buy inputs for his food crops on time and in sufficient quantities. Irrigated cotton definitely produces higher yields, although over-irrigation may ultimately trigger the law of diminishing returns. Only the lack of irrigation water and/or facilities can limit greater production of cotton under irrigated conditions. Approximately 65% of India's cotton is grown on dry lands and 35% on irrigated lands. In the northern zone, where technology adoption is more advanced, almost all cotton is grown under irrigated conditions and consistently higher yields are achieved. The irrigated area is much smaller in the southern zone where about 60% of the

Rainfed and Irrigated Cotton Area in Various Countries

Country	% Not Irrigted	% Irrigated	Irrigation Method			
			Flood	Furrow	Sprinkler	Drip
North America						
Mexico, Baja California						
USA, National Average	59	41		5		
South America						
Argentina, Northeast	100					
Argentina, Northwest	90	10	60	7	33	
Brazil, Central West/Cerrado	98	2	100			
Colombia, Coastal Region	97	3	100			
Colombia, Interior Region	15	85		77	23	
Paraguay, National Average	99	1			100	
Peru				99	1	
Australia						
Australia	10	90		85	4	1
Asia						
Bangladesh, *G. arboreum*	100					
Bangladesh, *G. hirsutum*	75	25	5			
China (Mainland)	< 10	> 90	90	5	2	3
India, North	< 1	99				
India, Central	77	23				
India, South	60	40				
Iran, Ardabil		100	2	98		
Iran, Fars		100	50-52			5-10
Iran, East & Central		100	58			1
Iran, North	5-10	90-95	60-65	20-30	5-10	1
Israel, National Average		100			20	80
Kazakhstan, National Average	100					
Myanmar	96	4		100		
Pakistan, Punjab		100	70	30		
Pakistan, Sindh		100	75	25		
Philippines	100					
Syria		100	73	23	< 1	3
Thailand	100					
Turkey, Aegean		100	60	40		
Turkey, Mediterranean		100	20	80		
Turkey, Southeast Anatolia		100	40	60		
Vietnam	95	5		100		
West Africa						
Burkina Faso	100					
Cameroon	100					
Chad	100					
Côte d'Ivoire	100					
Mali	100					
Togo	100					
Africa						
Egypt, National Average		100		99	< 1	
Ethiopia	55	45	9	91		
Kenya	95	< 5				
Madagascar, Northwest	100					
Madagascar, Southwest	98			2		
Mozambique	95	< 5				
Nigeria, National Average	100					
Sudan, Gezira		100		100		
Tanzania	100					
Uganda	100					
Zambia, National Average						
Zimbabwe, National Average						
Europe						
Greece	4	96				
Spain	8	92		57	25	19

cotton land does not have assured water supply. The central zone is the largest cotton-growing region in India, but only 23% of its total cotton area is irrigated. Egypt, Pakistan, Syria and Sudan may be the only countries where cotton is grown exclusively on irrigated land. The reason may be that in these countries it is not economically viable to produce cotton under rainfed conditions. Therefore, they are obliged to choose between growing irrigated cotton or growing no cotton at all.

Production in most countries is limited by drought coupled with lack of irrigation. It is hard to imagine cotton production in an area where there is no rain during the cotton-growing season. On the other hand, literature from the US reports that in a season with normal rain fall in the country's southeast region, irrigation may or may not improve the economic yield of cotton, depending on energy costs and yield potential. Nuti *et al.* (2010) applied irrigation at four proportions of the full rate recommended by 'Irrigator Pro for Cotton', i.e., 100, 66, 33, and 0%. With the 100% treatment rate, water was supplied at the recommended time for the full yield potential. The objective was to determine the cost effectiveness and water use efficiency of irrigation at different irrigation rates and over a given number of years. The total amount of water applied (rainfall + irrigation) ranged between 22.0 and 34.3 inches (56-87 centimeters) over eight years. The non- irrigated yields were subtracted from the irrigated yields in each respective replication. The value of the cotton produced at each irrigation level over the non-irrigated was expressed in terms of the value of lint per inch of water applied. The experiments concluded that irrigation provided a profit in 7 of the 8 years of the study. Reduced irrigation rates produced the highest return per unit of water applied, but simply decreasing the irrigation level does not maximize efficiency; yield limiting stress must be avoided if optimum yields are to be obtained. Although 100% irrigation is not the most efficient irrigation level, it often provided the greatest economic return.

Water Use Efficiency: Lessons from Texas

During its 69th Plenary Meeting held in Lubbock, Texas, on September 20-25, 2010, the ICAC organized a Round Table discussion on water use efficiency in order to benefit from the experience garnered in Texas. In his statement to the Round Table, Dr. Jim Bordovsky, Senior Research Scientist and Agricultural Engineer, with Texas AgriLife Research, in Lubbock/Halfway, Texas, USA, explained that 60% of the water consumed in 2007 in Texas was used to irrigate crops, 26% went to municipal use, 9% to manufacturing, 2% to livestock use and less than 5% to all other uses. In Texas, over 2.1 million hectares, devoted to various crops, are irrigated. In 2008, 31% of the cotton area in Texas was cultivated under irrigated conditions. The state's irrigated area began to expand early in the 1940s, but over the last three decades, there has been no additional expansion of the area with assured irrigation. Furthermore, increases in population have brought about further limitations in water supply. The presentation offered three options to deal with irrigation water shortages.

- Developing and implementing more efficient water delivery systems to farms;
- Improving management and performance of irrigation systems;
- Reducing "non-water" production limits.

While the first two options have always attracted the attention of researchers and farmers, improving the ability of plants to produce higher yields, even at reduced water supply levels, is a comparatively new line of research that is being explored by biotechnologists. Water use efficiency may be improved through better delivery and water management systems, i.e., reducing seepage losses in channels by lining them or by using closed conduits; lowering evaporation by avoiding mid-day irrigation; using under-canopy rather than overhead sprinklers; avoiding over-irrigation; planting and harvesting crops at optimal times, and irrigating frequently using just the right amount of water to stave off water stress.

The main target of growers and researchers has been to cultivate a greater area using the same amount of water in absolute terms and without sacrificing the yield or the quality of the crop. Traditional approaches to the development of drought-tolerant crops, however, have not lived up to expectations. In a comparative test of three irrigation methods carried out in Texas, sub-surface drip irrigation produced greater yields than both "Low Energy Precision Application" (LEPA) and low elevation spraying. Moving from spray irrigation to LEPA irrigation results in a 10% increase in water use efficiency and moving from LEPA irrigation to sub-surface drip irrigation achieves an additional 10% increase in water use efficiency. But, given its high installation costs, sub-surface irrigation is the least used system in Texas. About half of the irrigated land in Texas receives water by spray systems while the other half receives it by furrow, LEPA and sub-surface irrigation.

The Texas Commission on Environmental Quality monitors groundwater quality and the Texas Water Development Board monitors water supplies. The Round Table noted that in Australia, water quality issues are primarily due to surface runoff. The need to improve water use efficiency has been highlighted and growers are more vigilant about pesticide management in order to prevent water pollution. In Australia, where water use conditions are, in a way, stricter than in most countries, nutrient runoff from drylands poses a greater pollution problem. The Round Table concluded that a city/farm partnership could successfully expand water use efficiency.

Conclusions

World average yield for 2009/10 under rainfed conditions amounted to only 66% of irrigated yields. Thus the elimination of irrigation would require 39.7 million hectares to produce the 21.8 million tons of lint obtained in 2009/10. It is simply not possible to divert an additional 10 million hectares from competing crops to dedicate them to cotton cultivation. The target must be to produce the greatest quantity of cotton with the least amount of water. The work done in various countries has shown that a little water stress may not only save water, but can actually increase yields. Thanks to the extensive research done on irrigation methods, together with the lessons learned from using water efficiently, significant progress has been made toward producing many more kilograms of cotton with the same quantity of water used 3-4 decades ago.

In most countries, an average of as little as 50-60 hectare centimeters (24 acre inches) of applied water is currently enough to produce a normal crop. Cotton's share of irrigation water use in the world is no more than its share of world arable land. A lot of work has been done on water conservation irrigation methods. The trend must continue and, hopefully, drought-tolerant biotech cotton and fertilizer-efficient biotech cotton, if and when they are developed and commercialized, will further minimize cotton's need for irrigation water. But, at the same time, two things require priority attention: how to minimize water loss before water reaches the farm, and how to make more extensive use of wastewater.

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Package of Practices for Managing Mealybug on Cotton

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Introduction

Mealybugs (Hemiptera: Pseudococcidae) are sap sucking insect pests that cause severe economic damage to a wide range of plant species, including several vegetable, horticultural and field crops. Infested plants show symptoms of distorted and bushy shoots; crinkled, twisted and bunchy leaves and stunted plants that dry completely in severe cases. Late season infestations during the reproductive crop stage resulted in reduced plant vigor and early crop senescence. Historically, mealybugs were never considered as pests of economic significance on cotton in India and rest of the world. Isolated reports indicated the occurrence of the pink hibiscus mealybug, *Maconellicoccus hirsutus* on the native 'desi' species, *Gossypium arboreum* (Linn.) in 1980 in Punjab and on *Gossypium herbaceum* (Linn.) during 2000 in Gujarat. The mealybug species *Phenacoccus solenopsis* was first reported to occur on American cotton *Gossypium hirsutum* in 1991, and later reported to cause severe economic damage to American cotton in India and Pakistan from 2005, China in 2009 and Australia in 2010. It was estimated that the mealybug *Phenacoccus solenopsi*s had destroyed 34,000 tons of cotton each in India and Pakistan during 2007. Infestation levels have decreased lately, due to the establishment of a newly identified parasitoid *Aenasius bambawalei* in India and Pakistan.

Status of Mealybugs on Cotton

- The solenopsis mealybug, *Phenacoccus solenopsis* (Tinsley), and the pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green) was found to infest cotton plants from India, Pakistan and several other countries.
- The solenopsis mealybug, *P. solenopsis* was found to be the predominant mealybug species, comprising 95% of the samples examined from 47 locations representing 9 cotton growing states of India. Prior to 2005, it was reported to occur in India, but it now appears to be widespread on cotton in almost all cotton-growing states of the country. It is considered to be an exotic species that

has its origin in the USA.

- Papaya mealybug *Paracoccus marginatus* Williams and Ganara de willink also infests cotton and was found to be a sporadic but potential pest in the South Zone.

The solenopsis mealybug, *P. solenopsis* is a polyphagous pest, with a wide host range. It establishes and spreads more easily than many other insect species because of the following factors.:

- The mealybug *P. solenopsis* was found to infest 166 host plants belonging to 51 families comprising 78 weeds, 27 ornamental plant species, 19 tree species, 17 vegetables, 12 field crops, 8 fruit trees, and 5 spice crops in India, thus far.
- The mealybug species *P. solenopsis* are parthenogenetic (they do not require a male for reproduction) with ovo-viviparity (lay eggs and crawlers) and have a high reproductive rate. Each female lays 400 eggs/crawlers.
- Have immense potential to emerge as a major pest, thereby causing severe economic damage to a wide range of crops and pose a grave threat to agriculture in the introduced country.
- The bugs possess a waxy coating on the dorsal side that protects them from insecticides and natural mortality factors.
- Have the ability to hide in the soil cracks and crevices, and corner regions of plants.
- The crawlers spread through wind, water, irrigation, rains, floods, ants, animals, sprays, man, birds, raw cotton and fuzzy seeds.
- *P. solenopsis* has a short life cycle with 12 generations in a year.
- The mealybugs are sessile insect pests and infest only a few plants if left undisturbed.
- The mealybug species *P. solenopsis* cannot easily survive on young plants and infestation generally intensifies during the late stage of the crop. Plants that are on the verge of senescing or under wilt or drought stress are prone to infestation.

Management

Management strategies have been devised based on the following basic information:

- Pigeon pea, maize and bajra are the least preferred by the mealybugs.
- Mealybugs survive on weeds during and after each season.
- *Aenasius bambawale*i is the most effective parasitoid.
- The predatory beetles *Cryptolaemus montrouzieri, Brumus suturalis* and *Scymnus* spp. are prominent in the ecosystems of India and Pakistan.
- The entomopathogenic fungi, *Metarrhizium anisopliae, Beauveria bassiana, Verticillium lecanii* and *Fusarium pallidoroseum* are effective in infecting mealybugs.
- Botanical mixtures containing neem oil, citrus peel extracts and fish oil rosin were found to be effective in controlling the mealybugs.
- The insect growth regulator, Buprofezin is effective in control. Insecticides such as Malathion and Acephate, which are considered by the WHO as only slightly hazardous (WHO III category), can be used as soil applications near the root zone.
- All the populations collected in India were highly homogenous, indicating scant genetic diversity in India.

Recommendations

Mealybug crawlers spread through human interventions such as spraying, irrigations and frequent movement through the infected area, etc. Therefore avoid disturbing mealybug-affected plants. It is important to remember that young cotton plants can overcome mealybugs, and it is better not to resort to chemical sprays on young plants that have slight infestation. It has been observed that mealybugs were unable to establish colonies on cotton during early vegetative and peak vegetative stages. It is only in rare cases, which is generally possible on a few susceptible genotypes, that mealybugs colonize plants during the vegetative stage.

All over the country, several parasitoids (predominantly *Aenasius bambawalei*) and coccinellid beetle predators are found to keep mealybug populations under control, thereby preventing spread and damage. Insecticides such as profenophos, chlorpyriphos, monocrotophos, etc. which are being commonly used for mealybug control, destroy the parasitoids and predators and can result in mealybug outbreaks. Therefore, insecticide applications should be avoided until peak boll formation stage, so as to allow establishment of the parasitoid and predator complex in the ecosystem. Eco-friendly insecticides such as neem oil based botanicals and the insect growth regulator buprofezin can be used if necessary in the initial stages so as to keep mealybugs under check while causing minimum disturbance to the ecosystem.

However, during the peak boll formation stage, mealybugs can establish colonies but are initially restricted to a few plants along the border rows, adjacent to the source of infestation. Thus they can be effectively managed through early detection and initiation of interventions to control early stages of infestation. If timely scouting and appropriate control measures are not initiated, cotton is likely to be severely damaged.

Insecticides should not be applied all over the field to manage mealybugs. Such a practice disrupts the ecosystem and does not allow naturally occurring parasitoids and predators to establish natural control. Therefore, the following practices are advised:

- Locate infested plants with more than one twig infested completely with mealybug colonies.

- Do not allow physical contact with the infested plant. Do not disturb the plant vigorously. If possible, the affected twig can be gently detached from the plant, collected in bags and taken far away from fields to be destroyed by burning.
- If at least two infested plants have at least one stem completely colonized with mealybugs, in more than 50 plants randomly sampled per hectare, chemical control measures may be initiated. Insecticide application should start first on the neighboring plants and then as spot application near the root zone, at the base of the plant, and on the infested parts.

PACKAGE OF PRACTICES FOR MANAGING MEALYBUG ON COTTON

What to do	When to do	Why to do	How to do	What not to do	Why not to do
Cultural Practices					
Early crop termination	Immediately after last picking and between two cropping seasons	To prevent continuous food supply and shelter for multiplication and carry-over of mealybugs	Removal of cotton crop from the fields immediately after the last picking and maintenance of host free period	Ratoon cropping or allowing the cotton crop to continue to stand in the field after final harvest	Ratoon crop offers food and shelter for mealybugs and provides inoculum for next season
Destruction of cotton stalks	After final picking is over	Destruction of cotton stalks following harvest reduces the shelter and food supply to mealybug and carry-over to next season	The dry cotton stalks should be pulled out of the fields or shredded and burnt off *in situ* before ploughing the field	Stacking of cotton stalks in or nearby areas of the fields	Mealybug populations survive on stalks and pass on to the next season
Clean cultivation: Destroy alternate weed hosts growing on field bunds, water channels and wastelands in the area	During the crop season and off-season	Weeds especially congress grass *Parthenium* and *Xanthium* are the most suitable hosts for mealybugs and assist them to survive and spread on the adjacent crop	Biological- inoculative release of *Zygogramma bicolorata.* @500-1000 beetles /ha on parthenium. Spray weedicide+insecticide on bunds	Do not throw infested plants into irrigation canals. Do not spray only weedicides	Mealybugs spread through water. If weeds are destroyed, mealybugs move to the adjacent crop
Use acid-delinted seeds for sowing	At the time of sowing /planting	Delinted seeds do not carry any infective stages of the mealybug	Delinting should be done with sulfuric acid, washed with water, neutralized with lime and dried under shade	Using fuzzy seeds for sowing	Fuzzy seeds may harbor infective stages of mealybug, especially crawlers
Select varieties/ hybrids approved by research agencies	Before planting and procurement of seed material	Approved varieties/ hybrids are tested before release in particular zone for their tolerance to pest and other abiotic factors	Consult the research institutes located in the area while making a choice of genotypes	Use of unapproved varieties	Unapproved cultivars may be susceptible to mealybugs
Grow pigeon pea, bajra or maize as border crop wherever possible	At the time of planting	These crops offer least support for the growth & multiplication of mealybugs. Border rows act as barrier crop that prevent mealybug infestation from border weeds	Growing two rows of densely planted pigeon pea or maize or bajra around the cotton field and also if possible as intercrop of 1- 2 rows after 5-6 rows of cotton	Avoid growing malvaceous and solanaceous crops near the cotton fields	Malvaceous and solanaceous crops are good hosts for mealybugs. They serve as shelter and spread mealybug infestation
Regular monitoring of the pest	After the sowing of cotton crop	The pest is initially restricted to a few plants along the border rows, adjacent to the source of infestation	The pest can be effectively managed through early detection and initiation of interventions to manage early stages of infestation	Do not allow free movement of labor/ animals in infested fields	Mealybugs spread through water, air, human, animal farm implements etc.

What to do	When to do	Why to do	How to do	What not to do	Why not to do
Botanical and Biological Control					
Neem seed kernel extract (NSKE 5%) 50ml/l + Neem oil 5ml/l + detergent powder 1gm/l can be sprayed as spot application on infested stalks only	Initial stage of infestation. When 2 infested plants are observed to have at least one stem completely colonized with mealybugs in more than 20 plants per acre	Spot application restricts the spread of mealybugs. These formulations are less harmful to natural enemies and thus help in conserving ecosystem. The parasitoid *Aenasius bambawalei* is highly susceptible to chemical pesticide sprays	Spray on the crop adjacent to the infested plants and at the base of the infested plants without disturbing the mealybug colonies	Do not use chemical insecticides at early stage of crop	Use of insecticides disrupts native predators and parasitoids
Fish oil rosin liquid 10ml mixed with neem10ml/l and citrus peel extracts or Karanj oil 10ml /l may be sprayed					
Use of *Cryptolaemus montrouzieri* adults /grub@ 10 per infested plants wherever available	Inoculative releases of the ladybug beetle, prior to the cotton season, on weeds and perennial trees harboring mealybug colonies, and also on infested cotton plants	The predator *Cryptolaemus montrouzieri* (Mulsant), occurs in the cotton ecosystems and inoculative releases can destroy P. *solenopsis*.effectively	Release the adult beetle during morning or evening hours to avoid direct exposure to hot sunlight		
Spray biopesticides viz., *Verticillium lecanii* (Potency 2 X 10^8 C.F.U /gm) 10gm/l and *Beauveria bassiana* (Potency 10^8 spores/ml), 10ml/l	Initial infestation during August- October i.e high humid months coinciding with vegetative growth phase of crop	The formulations disrupt growth and multiplication of mealybugs by causing disease without harming other natural enemies and the environment	Spray of biopesticides formulations during morning / evening hours on infested crop area	Do not use pathogen (*Verticillium lecanii* and *Beauveria bassiana*) formulations when humidity is low	Fungal spores germinate and cause disease in the insect when optimum relative humidity (>60%) conditions prevail
Chemical Control					
Spray less hazardous insecticides (WHO Cat III), such as Acephate, 75 SP 1gm/l, Malathion 50 EC 2ml/l, Buprofezin 25 SC1ml/l	When at least 2 infested plants have at least one stem completely colonized with mealybugs) in about 20 plants per acre (0.4 ha)	WHO class III (Slightly hazardous) – Acephate, Malathion and WHO Class IV (Unlikely hazardous) – Buprofezin 25 % SC1ml/l cause less harm to the environment	Spray the chemicals first on plants around infested plants and then as spot application at the infested plants	Avoid use of insecticides with high eco-toxicity such as methyl parathion, (classified by the World Health Organization as WHO 1a: extremely hazardous), dichlorvos methomyl, triazophos metasystox and monocrotophos, (WHO 1b: highly hazardous)	Insecticides with high ecotoxicity should be avoided since they are not only ecologically hazardous, but also detrimental to predators & parasitoid wasps that control mealybugs and other insect pests. WHO1a and WHO1b insecticides are generally misused in developing countries
As the last option, spray moderately hazardous insecticides (WHO Cat II): Quinalphos 25 EC 5.0 ml/l, Chlorpyriphos 20 EC 3.0 ml/l, Profenophos 50 EC 5.0 ml, Thiodicarb 75 WP 5.0 gm/l		WHO class II (Moderately hazardous) – Quinalphosl, Chlorpyriphos, Profenophos, Thiodicarb cause comparatively less harm to the environment.as compared to the WHO Category 1 insecticides			

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TECHNOLOGIES FOR PROSPERITY

Registration for the World Cotton Research Conference-5 to be held from November 7-11, 2011 in Mumbai, India is now open. All information is available at http://www.wcrc-5.com/ and can also be accessed from the ICAC web page at http://www.icac.org/.

Early bird registration:	May 25, 2011
Submission of abstracts:	May 25, 2011
Acceptance and notification:	June 15, 2011
Receipt of full-length paper:	July 31, 2011

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